that science lacks — a tried and tested way of observing and altering, through careful attention to meditation, the subjective workings of the mind. Neuroscientists can show how the practices used by meditators result in physiological changes in the brain, but as several of the Dharamsala conference participants attest in the book, neuroscience does not yet have the tools to explore the various states of consciousness they experience. Buddhism seems to offer a kind of science of introspection.

As a research exercise, the East–West discourse on consciousness sounds harmonious, but at a deep level, it is anything but. Both Luisi and Lopez identify this as an area of great conceptual divergence. Whereas cognitive science's best guess is that consciousness is an emergent property of neuronal organization, Buddhists see it at some pure subtle level as not contingent on matter at all, but deriving instead from "a previous continuum of consciousness" — the Dalai Lama's words — that transcends death and has neither beginning nor end. That is hard to test. Furthermore, it seems impossible for anyone to grasp such Buddhist notions of consciousness without experiencing them, because there is no way yet of quantifying them — and that means years of meditation. As Chu says in *Mind and Life*: "It's like a physicist explaining electromagnetic waves to someone who doesn't know mathematics."

"Buddhism seems to offer a kind of science of introspection."

Despite this, Luisi's depiction leaves you with the impression that if cognitive scientists and Buddhists can learn a little more of each other's language, they might be on to something. Consciousness aside, the book is stimulating whatever your field or expertise, because it is likely to offer a way of looking at the world that you had not tried. Readers will also get a short, sharp primer into the nature of fundamental particles and the origins of life, and the philosophy behind Buddhist ethics. Lopez's book, by contrast, is more likely to excite those seeking an in-depth analysis of Buddhism's historical relationship with science. He purports to offer a 'guide for the perplexed' — presumably those who are perplexed that the two disciplines should be compatible at all. His scholarly treatment should provide succour, yet he gets off to a sticky start by pondering what it means to group the words 'Buddhism' and 'science' in the same phrase, concluding that it depends on "what one means by Buddhism, what one means by Science, and, not insignificantly, what one means by and". It would take more than a week in Dharamsala to unpack that one. ■

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Seeing is behaving

Living Control Systems III: The Fact of Control
by William T. Powers
Benchmark Publications: 2008. 250 pp.

The field of behavioural science, combining psychology, sociology and neuroscience, has diversified over the past century such that there is a desperate need for an integrative theory. William T. Powers, medical physicist and engineer, proposes that 'control' is the unifying process. *Living Control Systems III* is the latest in an influential but contentious series of works in which Powers presents his theory of perceptual control and illustrates its explanatory power.

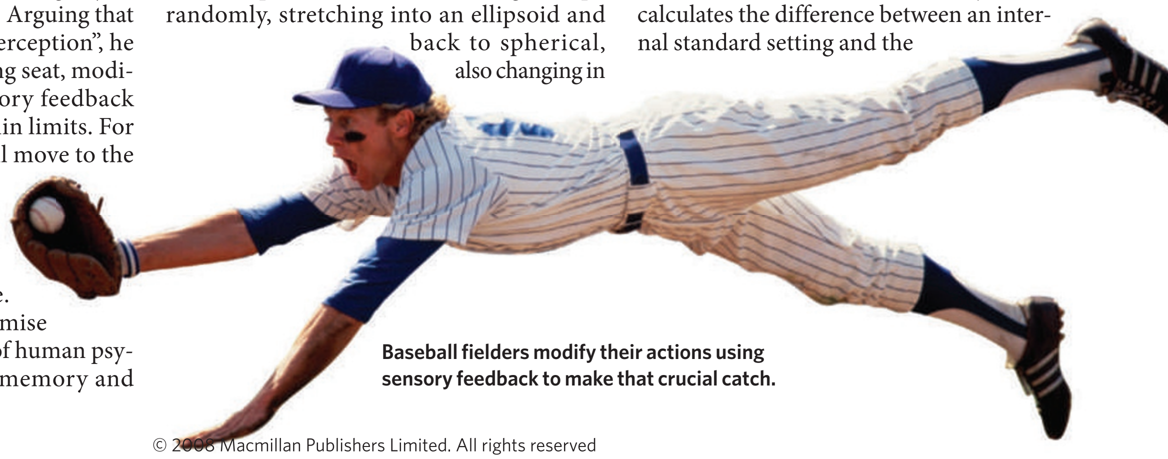
Powers innovatively applies the principles of 'control engineering' — as used in devices such as amplifiers and cruise-control systems — to the management of perceptual variables, such as our ability to track a moving object or maintain a sense of comfort. Arguing that "behaviour is the control of perception", he puts the organism in the driving seat, modifying its action through sensory feedback to control its experiences within limits. For example, a baseball fielder will move to the optimum position to catch a ball by maintaining an image of the ball moving at a constant velocity, relative to the playing field, on the retina of his eye. Powers builds on his basic premise to account for the complexity of human psychology, including learning, memory and skill acquisition, through the operation of multilevel hierarchies of control systems.

Recent developments within computing allow Powers to bring his theory to life. The book is organized around an accompanying compact disc containing 13 computer simulations of perceptual control. They span from the tracking of moving targets and the simulation of balance, to three-dimensional models of arm coordination and the emergence of crowd behaviour. Powers uses a combination of common sense reasoning, philosophical argument and mathematical models to make his case. Throughout, the style is engaging yet authoritative.

"Behaviour is the control of perception and not a learned response."

After setting the historical context, Powers turns to the interactive computer demonstrations. A sphere on the screen changes shape randomly, stretching into an ellipsoid and back to spherical, also changing in placement and projected angle. The viewer is asked to control the shape, location or the orientation of the figure by moving the computer mouse, the movement of which is recorded and plotted. The graph makes it clear that the user's behaviour exactly opposes the random changes in the sphere's perceived properties. The more that the computer tries to squash its shape, the more the user moves the mouse to return it to a spherical form. According to Powers, this shows that behaviour is controlling perception and is not a learned response to the environment. By contrast, most traditional theories explain behaviour as the result of a learned association between a stimulus and a response; for example, as a rat might be conditioned to press a lever for a food reward. Such theories, Powers proposes, do not provide an adequate explanation of behaviour.

The basic unit of control is the negative feedback loop. This is a mathematical system that calculates the difference between an internal standard setting and the



D. MADISON/GETTY IMAGES

Baseball fielders modify their actions using sensory feedback to make that crucial catch.

perception of that same quantity, and uses this difference to drive the behaviour that reduces the discrepancy. A newly hatched duckling, for instance, would have a setting for how near it needs to be to its parent. When the parent is further away, the difference drives the duckling's behaviour, perhaps making it run, to restore the error to zero. According to Powers, this continuous process of perception, comparison and action goes on in many systems simultaneously within any living animal.

Because these adjustments involve many systems, conflict between them is common. An animal might need to regulate its proximity to safety and an optimum level of novelty or stimulation in its environment, for instance. But going closer to novel environments can take the animal further from the safety of its lair. Powers proposes that two systems in conflict have their set points determined by a higher level system. In order for the conflict to cease, these settings need to change. He suggests that a random, trial-and-error change in these settings takes place until they no longer cause conflict — a process known as reorganization. An example is the mechanism by which the bacterium *Escherichia coli* heads towards increasing levels of certain chemicals in a surrounding fluid, known as chemotaxis.

Living Control Systems III is an interactive tutorial rather than a coffee-table introduction, and occasionally, but not crucially, demands mathematical knowledge. Increasingly, academic textbooks are becoming more electronic and interactive. But this book's dual format is inconvenient: it would be easier to absorb the material if it was fully electronic. The computer demonstrations are powerful, and the novice reader may get a good grasp of the theory simply by skipping to the penultimate chapter to experiment with a range of novel displays of perceptual control.

Perceptual control theory has spawned a diverse range of applications within psychotherapy, education and artificial intelligence over the past 50 years. It has been lauded by Carl Rogers, the creator of person-centred counselling; Thomas Kuhn, the philosopher of science; and self-regulation theorists such as Charles Carver. Yet it has still to be accepted within psychology, perhaps because it requires psychologists to accept the same level of precision as in physics, biology and engineering. Whether this animated third volume will prompt that leap is an open question, but it succeeds in being a sophisticated yet colourful demonstration of a contentious theory. ■

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Change begins at home

Climate Change: The Threat to Life and a New Energy Future
American Museum of Natural History, New York City
Until 16 August 2009

A thin red line snakes along a wall, rising from below knee level to a height of three metres. The long glowing tube plots global carbon dioxide concentrations from the year 1600 — when the world's population was less than 600 million, goods were transported by wheelbarrow and horse-drawn vehicles, and the estimated atmospheric CO_2 concentration was 274 parts per million — until the year 2000. By that time, the world's population had reached more than 6 billion, aeroplanes were plying the skies, and atmospheric CO_2 had topped 369 parts per million. Today, that concentration is at more than 385 parts per million, a level not seen on Earth for at least 800,000 years. Earth is also hotter now than at any time in the past four centuries.

With this grand flourish, the American Museum of Natural History in New York opens its new climate-change exhibition, which runs until August 2009. With displays, interactive videos and dioramas, *Climate Change* clearly and comprehensively provides the facts on global warming. It dispels doubts about the reality of the crisis — of which there are still plenty among the American public.

The exhibition stresses that humans are responsible for the recent rise in CO_2, and that this is linked to a 0.8 °C increase in average global temperatures in the past 100 years. A video installation explains how greenhouse gases such as CO_2 trap heat, and shows how global temperatures and atmospheric CO_2 are rising in tandem. A small model of a coal-powered steam engine, invented by Thomas Newcomen in 1712, ties the rise in CO_2 to the start of the Industrial Revolution. A giant, jagged, one-tonne slab of coal reminds us that this dirty fuel, the burning of which generates nearly twice as much CO_2 as natural gas, still provides 40% of the world's electrical energy.

The effects of climate change are already obvious: longer, drier droughts in the south-western United States and the North African Sahel, spring arriving earlier, warmer seas that kill coral — a bleached and lifeless model reef sits in one corner — and shrinking Arctic sea ice. This last consequence has forced polar bears to spend more time on land, and a diorama depicts a stuffed polar bear foraging for food on a pile of snow-sprinkled rubbish — plastic bottles, a discarded television set, a doorless refrigerator. If that sad scene spurs its viewers to change their lifestyles, then the curators suggest plenty of ways to do so. Touch-screen videos invite visitors to click on their current car and see how much carbon it emits. Drive 99 kilometres in a sports utility vehicle every day, and in a year it will cough out more than 14,000 kilograms of CO_2 — enough to fill up two-and-a-half hot-air balloons. The same daily distance in a hybrid-fuel economy car will pump out one-third of that amount.

Many other options are offered for combating climate change: ditch the car and take public transport; avoid bottled water; switch to energy-saving light bulbs; line-dry clothes; fly less; install low-flow showers; pay for wind power; plant trees and shrubs. The exhibition also considers broader solutions such as carbon capture and storage; wind power — already supplying Denmark with more than 20% of its electricity; hydropower; geothermal and solar energy. More than 25,000 solar panels are now sold every year in Kenya, where they are used to power television sets and recharge mobile-phone batteries.

D. FINNIN/AMNH

Rising seas may threaten cities such as New York.

A final wall display invites visitors to write or draw their own solutions on postcards. "We need nuclear energy" is followed by "Windmills and solar power, not nuclear — until we have a plan for nuclear waste". Another exhorts us to "Promote science education — Study Nature!". But my favourite card offers one simple word: "Vote". ■

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