BOOKS & ARTS

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A robust approach

The functional overlap between different components protects biological systems.

Robustness and Evolvability in Living Systems
by Andreas Wagner
Princeton University Press: 2005. 408 pp. $49.50, £32.50

Eörs Szathmáry

When sitting on an aeroplane, we obviously hope that it won't crash. A tacit assumption behind this wish is that our biological system isn't about to crash either. It so happens that these systems share several features. Both have specific parts that serve certain functions. The plane was designed by engineers, who were in turn designed by evolution through natural selection. Both systems seem robust and yet fragile, but how can we reconcile these two seemingly opposing features? One answer is that they are robust and fragile to different perturbations, being particularly robust to perturbations that are common in their 'niche'. Another answer is that robustness can be in a trade-off with other features, such as price and reproduction rate.

In his book *Robustness and Evolvability in Living Systems*, Andreas Wagner deals with some hot issues of current biology. As well as the terms in the title, the main keywords are 'neutral spaces', 'redundancy' and 'networks' — all of them highly fashionable, no doubt. But fashions fade, and usually a fraction of the original claims remain robust.

The robustness in biological systems is a consequence of their complexity. Many biologists are suspicious of ideas and models in the field of complexity, but I would encourage them to set their suspicions aside and read this book. Wagner's treatise is more than good biology; it is also very interesting biology. The picture is painted by talented hands. Wagner surveys many relevant examples, from the genetic code to organismal design, taking in properties of ribonucleic acids and proteins, the fascinating robustness of metabolic pathways and networks, the inelegant but robust genetic networks in development, and the many developmental pathways that can lead to essentially the same adult form. The level of detail is adequate in most cases and the questions and explanations are lucid. The mathematical treatments are relatively easy to follow and deliver real insight.

One of the book's chief merits is that the author knows a lot about many levels of biological organization, something that can't often be said for the 'complexologists'. Many erroneous claims about, and faulty models of, various biological networks have sprung from a lack of knowledge about the complexity of biological phenomena.

If I have a favourite aspect of the book, it is the meticulous yet insightful analysis of neutral spaces and their relevance for the main themes of the book. Structures in biology can be envisaged as being embedded in a suitable 'space'. Protein-sequence space, for example, is multidimensional and discrete, as polypeptides are made up of a whole number of amino acids. There are 20 amino acids, so if the length of a polypeptide is, say, 100, then any given polypeptide chain has 1,900 (that is, 100×19) nearest 'neighbours', all of which differ by only one amino acid from the reference sequence. Many of these neighbours have the same biological function, because altering

one amino acid has little effect. But some proteins much farther away in this space (that is, with many different amino acids), may also have the same function. If you imagine that the space at all these 'neutral variants' is shaded, then the shaded areas make up the original protein's 'neutral space' and indicate the organism's robustness.

My only grumble is that I would have used the word 'domain', as the neutral region is a subregion of the whole protein space, but I hope no great confusion will arise. The author shows clearly that although neutral-space analysis supports old principles of population genetics in several cases, sometimes it does not. Consider, for example, the limited validity of the Haldane–Muller principle, which states that the mutational load depends only on the mutation rate. Mean fitness is found to depend on the robustness of the population, which is actually a function of the structure of the neutral space.

I would like to know more about how the nervous system fits into the framework of Wagner's book. We know from studies ranging from the synapse to cell shape and functional neuroanatomy, for example, that at different scales a great many parts of the brain can have essentially the same function, in line with Wagner's analysis of 'distributed robustness'. But I realize that even the best story must end somewhere and leave space for future ones. ■

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Psychology in the real world?

World As Laboratory: Experiments with Mice, Mazes, and Men
by Rebecca Lemov
Hill & Wang: 2005. 304 pp. $30

Steve Blinkhorn

The modern world was created by egg-headed, white-coated scientists working in laboratories, surrounded by complex equipment and inventing ever more ingenious gadgets. That at least is the popular myth of intentional or intelligent design, and there is some truth in it: after all, the laser began as a laboratory curiosity firmly rooted in hard science, but now delivers entertainment to the masses.

Other technologies, arising from theories long since discredited and from scientists whose claims to white-coat status now seem tenuous, have moulded our world more than we realize. What's more, there were shadowy and sometimes sinister sponsors at work promoting and channelling developments that are now ubiquitous and inescapable in Western culture. These are techniques intended to shape behaviour, attitudes and thinking, arising principally from experimental psychology. And they are dangerous. That is the message I take from *World As Laboratory*, an anthropologist's view of twentieth-century psychological, behavioural and social science.

Rebecca Lemov's avowed focus is on the transfer of laboratory findings to the real world, and on the treatment of the real world as if it were some kind of laboratory. She finds manifest and manifold flaws in this enterprise, which she calls variously "human engineering" and "the American experiment". Her topics range from Jacques Loeb's experiments on tropisms, Elton Mayo's Hawthorne studies and Clark Hull's work on learning in rats, to the American administration of Pacific islands after the Second World War, brainwashing in Korea and subsequent work by the CIA, Stanley Milgram's obedience experiments and the Stanford prison experiment.

Much of Lemov's attention is given to the Yale Institute of Human Relations and the Rockefeller funding sources that supported it. Indeed, the extent to which Rockefeller money bankrolled laboratory psychology and allowed favoured schools of thought to flourish in the 1930s without a care for tomorrow, while most of the world was coping with the Great Depression, was news to me.

"A secret history that's not really a secret any more" is how the dustjacket puff characterizes Lemov's story. Unfortunately it's not really a history either. Her theme encompasses the whole of experimental, social and differential psychology, and more besides, but there is a great deal of selective focus in the tale she tells. The narrative veers from revealing new perspective to radical misconception, with some startling clangers on the way, and great chunks missing. A couple of howlers: on the use of electric shocks in experiments on rats, "the current ranged in intensity from 3.3 amperes to 7.6 volts"; on the use of a tape recorder in the 1950s, the tape was "running at the standard rate of seven and a half feet per second". There is also a bizarre misreading of history: rat researchers' accomplishments apparently "included the intelligence test, the SAT, the opinion survey, the early poll, the projective test…" (although the development of none of these is described at all). A huge omission, but for a passing reference, is operant conditioning and the work of B. F. Skinner. Such flaws undermine one's confidence in the author's sure-footedness on topics where one has to trust the detail of her account.

On a second reading, it becomes clear where the problem lies: Lemov has failed to get under the skin and into the minds of the characters who populate her narrative, and she has too selective and episodic a view of how psychology and related disciplines developed. It is as if she got her perspective from the sorts of stories that get into newspapers and failed to notice that they are but the tips of icebergs. Whether it is in the potted biographies or her account of laboratory methods, she comes to describe but stays only to scoff. The prevailing tone is one of uncritical pre-modern ethnography: look at this strange tribe and the weird things they got up to.

Empirical psychology arose and developed in contradistinction to prevailing views of the nature of mind, and grasped at emerging technologies both for theoretical models (hydraulic systems, the telephone exchange, the computer) and for laboratory tools. It is not necessary to agree with the theories, be sympathetic to the characters concerned or share their moral standpoint to make sense of what happened. Schools of thought flourished and then failed as their limitations were made manifest, but some left behind effective technical methods that can be used for good or ill, regardless of their theoretical origins.

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High hopes: in the 1950s researchers tried to manipulate behaviour by altering our view of the world.