not new: it was proposed in the 1960s by Konrad Zuse and Ed Fredkin, and revived more recently by Stephen Wolfram. However, unlike his predecessors, Lloyd stresses the quantum nature of computation. This distinction is important because, to the best of our knowledge, it seems impossible to simulate the evolution of a quantum system in an efficient way on a classical computer.

A classical computer simulation of quantum evolution typically involves an exponential slowdown in time. This is because the amount of classical information needed to describe the evolving quantum state is exponentially larger than that needed to describe the corresponding classical system with similar accuracy. However, instead of viewing this intractability as an obstacle, today we regard it as an opportunity — if that much computation is needed to work out what will happen in a quantum multi-particle interference experiment, then the very act of setting up such an experiment and measuring the outcome is equivalent to performing a complex computation. Since Richard Feynman and David Deutsch pointed out this opportunity in the 1980s, the hunt has been on for interesting things for quantum computers to do, and at the same time, for the scientific and technological advances that could allow us to build quantum computers. The field is flourishing, and Lloyd provides a good popular introduction to the subject. However, he does not stop at the level of building quantum computers, he takes on the biggest quantum computer there is — the Universe.

The Universe is a quantum computer, and quantum mechanics supplies the Universe with 'monkeys' in the form of ubiquitous random quantum fluctuations — the same fluctuations that provided the seeds of galaxy formation and of all that followed. The Universe has pockets of complex behaviour because, Lloyd claims, the monkeys have been working very hard. He estimates that the visible Universe, programmed by quantum fluctuations, has performed about 10^{122} operations on 10^{92} quantum bits. No wonder we are here!

I think this is a delightful book, but some parts are patchy and many details are brushed under the carpet. For example, anyone trying to work out numerical estimates of the physical limits to computation or the computational capacity of the Universe is much better off consulting Lloyd's original paper on the subject (see *Nature* **406,** 1047–1054; 2000). It is clear that Lloyd has forsaken accuracy for snappiness in several places, but then this is a popular exposition.

Seth Lloyd is a good storyteller, but is the story convincing? Well, I was convinced, but when I tried a nice line from the book — "programmed by quanta, physics gave rise to chemistry and then to life, programmed by mutation and recombination, life gave rise to Shakespeare, programmed by experience and imagination, Shakespeare gave rise to *Hamlet*" — on a colleague of mine, an English literature fellow, he only shook his head in disbelief and walked away. ■

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Cover story

Skin: A Natural History
by Nina G. Jablonski
University of California Press: 2006.
290 pp. $24.95, £15.95

John Galloway

Biology is a historical science. Ask a 'why?' question about biology, as Nina Jablonski keeps doing in her book *Skin*, and you invite an evolutionary answer. She also tells us everything we might want to know about skin; perhaps more than some people want to know. She then goes on to take informed guesses as to why skin is the way it is and, by implication, why it is not like something else. Skin's appearance, its form and function, questions of how and why it works, and sometimes doesn't, have been thrashed out over a billion or so years at — to borrow her words — the "negotiating table of evolution".

For Alexander Pope, the "proper study of mankind" may have been "man", but Jablonski, as befits a modern biologist, thinks otherwise. Understanding starts, and possibly finishes, with comparisons, between humans and our biological relatives and neighbours, both near and not-so-near. We may share virtually all our genes with chimpanzees, but those we don't share are responsible for a lot of differences, reproductive, linguistic and cognitive. Skin genes, for example, which are responsible among other things for colour, body hair and the number of sweat glands, may well explain why chimps are still confined to African jungles, whereas we, their closest relatives, have already been to the Moon.

Skin is not just about biology, but also the way we live. Our skin is the visible, immediate personal territory where biology most obviously gives way to culture. Jablonski quotes Franz Kafka, who had the right idea, viewing the skin as "not only a garment but also a straitjacket and fate". People go to a lot of trouble and expense to alter their appearance and change their fate. From war-paint and cosmetics to tanning, bleaching, tattooing, ritual scarring, botox, body piercing and 'nipping and tucking', there is someone making money out of it. And it does not necessarily have to stop just because someone is dead, as some enterprising Ancient Egyptian undertaker realized.

The skin's characteristics have been thrashed out at "the negotiating table of evolution".

Some forms of personal make-over and disguise teach a salutory lesson: that culture comes at a biological price, paid from the genetic legacy bequeathed you by evolution. You are, let's say for the sake of argument, a fair-skinned northern European. But it has become the thing to show off a nice tan (Jablonski fingers fashionista Coco Chanel as the perpetrator of this particular vanity), and that means lying about without clothes in hot sun in latitudes rather nearer the Equator. The trouble is, the reason you are fair is a good historical one, indeed a matter of life and death for your ancestors in the Europe of 50,000 or so years ago. And that fact has implications for modern day Sun-worshippers, some of whom discover that mortality still starts with the skin.

At the core of Jablonski's theme is the skin's ability to multi-task: it protects, controls temperature, senses the world around you, and shows people how you really feel, as opposed to what you choose to tell them. But skin is also a chemical factory, fuelled in part by solar radiation. It manufactures vitamin D, without which you can neither extract calcium from your diet nor incorporate it in your bones — posing something of a challenge to survival. Here's an evolutionary conundrum. Ultraviolet light, which damages DNA directly and also destroys the folic acid essential for its synthesis, is, ironically, the energy source needed to make vitamin D. In equatorial Africa, our ancestral home, evolution engineered a nice compromise that allowed humans to leave the sheltering forest canopy and begin global colonization. Melanins that absorb ultraviolet

afforded enough protection for the DNA, but left scope for the necessary production of vitamin D. When our dark-skinned ancestors started to migrate to the rest of the world, they first colonized regions that also had the strong sunlight to which their skin was already well adapted.

But dark skin was not adapted to the lower intensity of sunlight in northern Europe. It was simply over-protected, leading to problems producing vitamin D. Jablonski argues that Europe could only have been colonized in the wake of a genetic mutation that altered both the nature and the distribution of melanins in skin, producing fair skin with a tendency for freckles. The European climate selected for a gene that might well have been lethal back in equatorial Africa. Evolutionary negotiation achieved a new compromise.

These historical events have reverberated down the years, from biological prehistory into human documented history. On the one hand there have been rocketing frequencies of skin cancers in fair-skinned people exposed to too much sun; on the other, rickets became a problem in both the white-skinned populations of sun-deprived, smoke-polluted industrial Britain, and the later, darker-skinned immigrants to a postindustrial but still relatively unsunny northern Europe. These issues hint at the medical truth that any deep understanding of our ideas of 'wellness' and 'illness' is only likely to come from the central concepts of evolutionary theory: reproductive fitness and adaptation. It is amazing that medicine does not make much more use of evolutionary ideas. It is surely a sea change that is long overdue. ■

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SCIENCE IN CULTURE

Chart toppers

An exhibition explores the diverse ways of putting data on the map.

Martin Kemp

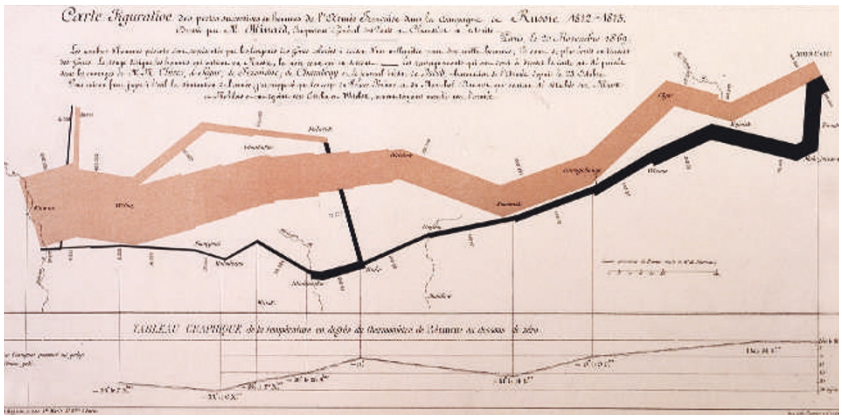
It was often said that geography was about maps, and history about chaps. But there are virtually no sets of data — about chaps or anything else — that cannot be mapped, although sometimes a visually appealing map can hide as much as it reveals. This is the message of the exhibition 'Places and Spaces: Mapping Science' (http://scimaps.org/exhibit/nyscience/), which can be seen at the New York Hall of Science until 25 February, after which it will tour the United States, Japan and Europe.

Curated by Katy Börner and Julie Smith of Indiana University, the exhibition contains a judicious selection of early and modern maps that lay out in various ways how historic cultures have charted the configuration of the Earth and the heavens. There are also specialist maps showing, for example, the distribution of telegraphic linkages, exports and poverty. The charts of scientific papers and patents by region are especially revealing, the latter showing the globe grotesquely morphed by 'fat' zones of high innovative activity.

Relationships between 'chaps' are also mapped, with networks of scientists and citations to the fore. Scientific disciplines are laid out according to their apparent relationships, and historical episodes are charted over time and space, most notably the discovery of DNA. Internet activity is plotted both architecturally and dynamically.

As the entities in the charts become more conceptual, the challenges become more complex and ultimately intractable. One set of juxtapositions in two dimensions necessarily precludes others that may be equally valid. An attempt to devise a two-dimensional distribution of geographical terms ends up by separating space in its political dimension from urban planning, which cannot be right.

The non-topographical mapping seems distinctively modern. But one of the most effective statistical maps is also the earliest in the exhibition. In 1869, the retired French engineer Charles Joseph Minard produced a remarkable map of Napoleon's catastrophic invasion of Russia. It has hardly been surpassed for visual efficacy, and was acclaimed by the pioneer of 'cinematographic' photography, Etienne-Jules Marey, for its "brutal eloquence".



E. R. TUFTE, GRAPHICS PRESS

Decline and fall: Charles Joseph Minard mapped French losses in Napoleon's invasion of Russia.

The basis of Minard's map (shown here) is a straightforward chart of the territory traversed by the French army in the winter of 1812–13, from Kowno (Kaunas) on the left to Moscow on the right. The width of the tinted strip represents the number of soldiers in the French army as it progresses eastwards. The plot doesn't thicken — quite the reverse in fact, beginning with a rearguard of 33,000 men branching off to remain at Polotsk. A series of abrupt falls then brings the company of 422,000 down to 100,000 by the time they reach Moscow.

The black line represents the retreating body of soldiers after they had sacked the Russian capital. The diminishing band is temporarily boosted from 20,000 to 50,000 as the rearguard rejoins, but at the River Berezina a Russian attack triggers a shambles. A stark black step graphically records the extent of the disaster.

Even more remarkably, Minard also charts one of the causal factors, the severe drop of temperature, on the army's return march during November and early December. By 6 December it had reached –30 °C and the army had been scythed down to a tiny rump of just 12,000 men.

Minard's map is both a vivid graphic and a tool for analysis, and forms the basis for further questions, such as the onset of infections, food deprivation, failure of equipment, and shortage of ammunition. Minard's map lays down a series of challenges in lucidity, functionality and potentiality that few since have fully met.

All this was accomplished by Minard after the age of 70. His last act was to publish the Napoleonic map in juxtaposition to one showing the Roman emperor Hadrian's disastrous losses on his return trip across the Alps from his northern expedition. It was designed to demonstrate the enduring human cost of war.

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