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I'm a Surfer

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* A Life Decoded: My Genome: My Life by Craig Venter

Until fairly recently, you did not choose a scientific career with the idea of getting rich. After the end of World War Two, American academic scientists started out on about $2000 a year – the rough equivalent of $17,000 these days – while few full professors at the peak of their careers commanded as much as $10,000. The American scientist, a writer in Science magazine observed in 1953,

> is not properly concerned with hours of work, wages, fame or fortune. For him an adequate salary is one that provides decent living without frills or furbelows. No true scientist wants more, for possessions distract him from doing his beloved work. He is content with an Austin instead of a Packard; with a table model TV set instead of a console; with factory rather than tailor-made suits. . . . To boil it down, he is primarily interested in what he can do for science, not in what science can do for him.

Around the same time, a US senator asked Karl Compton, a physicist and president of MIT: 'Do you believe this is a correct statement, that probably of all the professions in the world, the scientist is least interested in monetary gain?' Compton agreed: 'I don't know of any other group that has less interest in monetary gain.'

In fact, the enormous wealth thrown at American science from early in the Cold War was already beginning to erode these sensibilities. In the 1950s, it was increasingly said that the scientist uninterested in material rewards ought to become an extinct species. Americans respected occupations according to a money metric and it was, therefore, a disservice to the dignity of the scientific profession for a researcher to settle for a cheap car. The Science piece elicited a quick response: 'The plumber who owns the new Packard and the salesman who owns the new Buick can only look with pity upon their learned neighbour, the professor, who can hardly afford to

keep up his Austin.' The labourer was worthy of his hire, and if that labour was reckoned to contribute to national power, social welfare and commercial profit, why shouldn't scientists be richly rewarded? Why shouldn't they do science in order to secure such rewards?

It was physicists who first experienced a bump in their salaries and, for a few of them, an entrée to the corridors of government and corporate power. And while many scientific disciplines enjoyed Cold War largesse, those few commentators who fretted about the effects on knowledge of ties to wealth and power both expected and hoped that the life sciences would remain forever unaffected by such things: calm and quiet disciplinary spaces where traditional scientific virtues might continue to flourish. By the mid-1970s, these hopes had been proved wrong. In standard genealogies, the biotech industry was created in 1976 'over a couple of beers' at a bar, in a conversation between Robert Swanson, a 29-year-old venture capitalist, and Herbert Boyer, a biochemist at the University of California, San Francisco. Working with the Stanford geneticist Stanley Cohen, Boyer had helped to develop some elegant recombinant DNA technologies which immediately suggested enormous value to the pharmaceutical industry.

As was normal at the time, intellectual property rights were assigned to the universities, from the licensing of which Stanford and the University of California eventually derived about $200 million before the patents expired in 1997. Swanson saw vast commercial potential in these technologies and, although Cohen was unwilling to leave academia, he and Boyer developed a business plan, put in $500 each of their own money, secured $100,000 in seed capital from the Palo Alto venture capital firm Kleiner Perkins, and incorporated a company, known as Genentech, whose current market capitalisation of $85.1 billion makes it the biggest biotech company in the world. Boyer became rich and Cohen comfortably well-off. And this sort of spinning-out of science from universities to entrepreneurial companies established new possibilities for biomedical scientists: new ways of making large sums of money; new institutional forms for doing science; a new practical and moral texture for the scientific life.

So some members of the generation of life scientists who came of age in the period that ran from the 1960s to the early 1980s experienced seismic shifts in the material and institutional

possibilities of a scientific life. At the start of their careers, the monetary rewards flowing from a research and teaching career were modest, but, sometime afterwards, opportunities emerged to earn much more. If vast wealth was what you wanted, it was still a far better bet to go into law or investment banking, but if the cards fell in the right way, it wouldn't be a Buick you were driving but a Bentley.

Craig Venter's career – he was born in 1946 – tracks these historical changes. The route he followed to a scientific vocation was as personally circuitous as it was structurally perspicuous. An adolescent bored with school, he muddled part of the way through a California community college, becoming a surf bum – 'I was a surfer in high school, I was a surfer in Vietnam, and I'm still a surfer' – before serving as a navy medical corpsman in Vietnam, where he was a serious disciplinary problem, and where he learned to despise bureaucracies. Afterwards, he surfed and he drifted. But by 2000 the surf bum was standing at Bill Clinton's side as the president announced success in the race to sequence the whole human genome, all three billion nucleotides. He was celebrated as one of the authors of the 'Book of Life' and Time put him on its list of the hundred top 'men and women whose power, talent or moral example is transforming the world'. And he is arguably the most famous living scientist, taking over the role once occupied by Albert Einstein. Unlike the much loved Einstein, however, Venter is aggressive, arrogant and ruthlessly competitive. He's probably far more admired outside the community of his scientific peers than he is inside it. (Eight years ago, a New Yorker profile started with a remark made by a scientist who understandably wanted to remain nameless: 'Craig Venter is an asshole.')

When Venter began his scientific career in the mid-1970s, he was a biochemist working on how cells respond to adrenaline. This was painstaking basic science. Venter's account of an ingenious experiment designed to show how adrenaline affects the heart is one of the few genuinely evocative passages in A Life Decoded, but this wasn't an area you'd go into with high expectations of curing sick people, and none at all of saving the planet, changing fundamental human values or making a lot of money. He did this kind of work for about ten years at a university-linked cancer research institute before accepting an offer from the National Institute of Neurological Disorders and Stroke (NINDS), a division of

the vast National Institutes of Health (NIH). At NINDS, Venter's research agenda was about to take a turn which fundamentally changed both the institutional circumstances and financial possibilities of his science. Interest in the function and structure of the adrenaline receptor protein led to interest in the gene that coded for it. The body didn't have many molecules of this protein, and so you more or less had to do genetics to work with it. If you had control of the gene that coded for the protein, you could then, in principle, make as much of the protein as you liked. So the move into sequencing genes was a natural extension of Venter's concern with traditional biological questions about physiological function: questions he was about to set aside in favour of a research agenda driven largely by technological possibilities.

From the mid-1970s, Frederick Sanger at Cambridge and Walter Gilbert at Harvard had developed ways of working out the nucleotide sequence of particular genes – 'reading their code' – and at NINDS Venter adapted those methods, slow and laborious as they then were, to determine the sequence of the adrenaline neurotransmitter receptor gene. It took him about ten years to do that one gene, at a time when it was believed there might be as many as 100,000 genes in the human genome. (It is now thought that there are only about 25,000.) To learn more about genes of this sort, Venter wanted to sequence the equivalent genes of other species, but the prospect of repeating that 'unbelievable grind' was dismal. The adrenaline receptor gene sequence was published in 1987, the year the name 'genomics' was given to the effort to sequence and map organisms' genetic make-up. Venter realised that he was about to enter a very different scientific world, one with different work rhythms, different capital requirements and different financial consequences.

What changed everything was new technology. Just after he published the sequence of the adrenaline gene, Venter read a paper by Leroy Hood that announced a radical new advance in the techniques of DNA sequencing. Hood and his colleagues had invented a machine that used fluorescent dyes, a laser-reading system, a photomultiplier detecting tube and computer recording to provide an automated direct read-out of the genetic code, 'transforming the analog world of biology into the digital world of the microchip'. Venter grasped the possibilities immediately: if you could automate sequencing, there were no limits to what genomics

might achieve. The Model 370A DNA Sequencing System cost $110,000; and when the NIH baulked at the expense, Venter dipped into a grant he still held from the Pentagon to finance its purchase. The machine arrived at the NINDS laboratory in 1987, and Venter remembers thinking: 'This was my future in a crate.'

The relationship between machine and user wasn't passive – Venter had to do a lot to get the ABI sequencer to produce reliable data – and within months he was publishing the first mechanically produced gene sequences. Venter got angry when Hood described the ABI machine as a Ford 'Model A' and said that he really wanted to produce a Ferrari. The production of genomic knowledge needed quickly to become Fordist, and Venter was a man in a hurry: 'I just wanted to get on with it.' He gave the receptor work over to his wife, then working in another part of the NIH, and rebranded himself as a full-throttle, state of the art mechanical sequencer: 'We were going to turn biology upside down.' The revolution had come and it was a revolution in the techniques of knowledge production. Giving a journalist a tour around his sequencing facility in 1999, Venter announced:

> This is the most futuristic manufacturing plant on the planet right now. You're seeing Henry Ford's first assembly plant. What don't you see? People, right? There are three people working in this room. A year ago, this work would have taken one thousand to two thousand scientists.

When biology fully entered the Age of Mechanical Production, we would know it all. Right now, 'My view of biology is "We don't know shit."'

Sequencing the whole human genome was now a theoretical possibility, but it was radically uncertain how it could or should be done, how long it would take, how much it would cost, who would pay for it and why. The fundamental question of whether the whole genome should be sequenced was debated for a while, but once the race was on, the goal defined the game. Only 3 per cent of human genetic material has a functional role in coding for protein. The residual 97 per cent Venter dismisses as 'regulatory regions, DNA fossils, the rusting hulks of old genes, repetitious sequences' and 'mysterious stretches of who-knows-what'. An alternative to sequencing the whole genome would have been, therefore, to

sequence only the bits of DNA that actually code for protein. For a while, a decision didn't have to be taken. Over the next few years, Venter was sequencing genes at an astounding rate: by 1990, his group was finding between twenty and sixty new human genes a day, and by 1992 he published a paper identifying 2375 human brain genes alone. He had developed radical new techniques that allowed him rapidly, if inelegantly, to find the gene-bits of the human genome, and then, using ever improving and ever more expensive automated machines, to churn out their sequences as they were found.

It's the genes that interest physicians and pharmaceutical companies, and it's not easy to say why someone who believed that 97 per cent of the human genome was 'mysterious stretches of who-knows-what' would want to sequence the whole thing. A rising tide of technological enthusiasm is one possibility. You might take on the human genome in the same spirit Mallory climbed Everest; its 'thereness' constituting a notable scientific landmark – 'the biggest prize in biology'. Sequencing the whole genome was sexier than sequencing a bunch of genes. But one shouldn't dismiss the role of corporate sequencing machine-makers, politicians and bureaucratic patrons such as the US Department of Energy, looking for new uses for the super-computer capacity that had traditionally been used to design and simulate the testing of nuclear weapons. (The ABI Prism 3700 machines that were eventually used to sequence the human genome cost $300,000: Venter alone bought hundreds of them and so did his rivals in the public genome effort. In 1999, the top-of-the-line computer at Venter's shop was rated as the world's fastest civilian machine.)

Sequencing lots of genes wasn't cheap science, but sequencing the entire human genome was going to be vastly expensive, certainly the most expensive biological project ever undertaken. As the idea began to surface and be taken seriously in the late 1980s, there were comparisons with other expensive technological projects whose scientific and practical justifications were problematic and whose costs distorted scientific research across a broad spectrum: the Apollo Moon landing programme ($25 billion in contemporary dollars), the Superconducting Supercollider particle accelerator (budgeted at $12 billion and cancelled by Congress in 1993), the International Space Station (possibly as much as $48 billion in US contributions alone). Things that cost a lot of money are inherently

political; they involve bureaucracies; the logic they follow sometimes has little to do with the intellectual agendas and priorities of existing scientific disciplines. The bill to the US taxpayer of the NIH-led project was about $2.7 billion, and the UK Wellcome Trust committed about $317 million. Impatient with the bureaucratic obstructionism of the public project, 'a pointless, annoying and frustrating distraction' from 'getting on' with the science, Venter became increasingly tempted by the possibility of leaving the NIH and striking out on his own. He needed many more sequencing machines; more powerful computers and software; more space; more speed; more people. And all of these meant that he needed more freedom of action and much more money.

New organisational and economic possibilities for doing genomics opened up in a serious way in 1992, when a wealthy handbag manufacturer and private investor named Frederic Bourke – subsequently indicted by the federal government for attempting to corrupt Azerbaijani politicians in an oil scam – floated the idea of backing Venter in an elaborately funded new genomics company in Seattle. Venter was reluctant: despite all the annoyance of dealing with federal bureaucracies, he feared for his autonomy. But Bourke persisted. He asked Venter to join him and a few associates on his island retreat off the coast of Maine. The guests made up a configuration of scientific knowledge, political power and private capital that would have been unimaginable to life scientists even twenty years earlier: the leading genomic scientists, all with strong ties to entrepreneurial companies; the Democratic Senate majority leader, George Mitchell; the two heads of the Senate budget committee, James Sasser and Paul Sarbanes; and, as an apparent afterthought, one of Bourke's summer neighbours, David Rockefeller. Getting wind of the commercial initiative, the NIH offered Venter more power, more autonomy and even more money, and in the UK the Wellcome responded similarly in support of the Medical Research Council's sequencing work. By this time, Venter had got rid of his major irritant at the NIH, the abrasive James Watson, and was batting away multi-million-dollar offers to join already established biotech companies. 'Science,' Venter says, 'was ultimately more important to me than money' – but he was beginning to formulate an imaginative idea for having his cake and eating it too.

Why not get the capitalists to fund twinned organisations: a Venter-headed non-profit basic research institute that would offer its discoveries for a fixed period to an allied for-profit company that would transform the concepts into drugs; a company in which, incidentally, Venter would own significant equity? The venture capitalist Wally Steinberg went for it, though his associates, shocked at the challenge to accepted business models, 'looked as if they were about to faint', and, after a handshake on the deal in June 1992, Venter prepared to leave the NIH. 'I didn't want to run a company, I wanted to keep doing basic research,' he insisted, but the venture capitalist offered him a research budget of $70 million over ten years, and it was an offer he couldn't refuse.

Venter is a hugely ingenious scientist, but his greatest originality has probably been in the design of new arrangements for doing genomic research and new ways of situating that research in the force field between science and capital: the scientific experiments are made possible by practical experiments in the sociology of organisations. The non-profit bit was called the Institute for Genomic Research (TIGR), paired with a commercial biotech company, Human Genome Sciences (HGS), that was meant to take ownership of TIGR's intellectual property and turn it into commercial drugs. Then, in 1998, the instrument-maker Perkin Elmer laid out $300 million for Venter to found a commercial organisation, Celera Genomics, set up specifically to win the race against the NIH-Wellcome public initiative to sequence the whole genome. Venter was convinced that he could do the genome a lot faster and a lot cheaper if only he didn't have to deal with the dead hand of government or academic bureaucracies. If you want free, unconstrained and risk-taking science, then you more or less need to do it in, or with the support of, the commercial sector. Science and capital have a relationship as vital as it is sometimes uneasy. So sublimely convinced was Venter of the organisational and technical superiority of his private enterprise that at a joint meeting of public and private scientists he proposed that he should go after the human genome while the public initiative did the mouse genome. The public scientists were outraged. 'I almost punched him in the fucking mouth,' one of them recalled. 'Craig,' James Watson announced, 'wanted to own the human genome the way Hitler wanted to own the world.'

To his critics, who accused him in the mid and late 1990s of corrupting the very idea of free and open science, Venter pointed out that it was the NIH's technology transfer office that had first insisted on taking out patents on his discoveries while he was still with the government lab; that his intellectual and emotional allegiance was to the non-profit bits of his organisational environment; that the 'business model' of the commercial bit was not meant to 'own' the genome but to market packaged genomic information, notably to big pharmaceutical companies, so turning Celera Genomics into the 'Bloomberg of biology'. (On that, Venter turned out to be mainly right. Despite predictions of a lucrative genomic 'land-rush', only a few patents on human genes turned out to be worth very much – one notable exception being Myriad Genetics Inc's development of diagnostics from their patents on breast and ovarian cancer genes. The stock prices of companies that aggressively assembled human gene patent portfolios aren't doing very well, and promises that the medical-industrial complex would have a solid genomic foundation have yet to be fulfilled.)

To Venter the question wasn't whether genomics should have a commercial arm, but rather what business model best suited it. Commercial goals of some kind had to be achieved if genomic knowledge was going to cure sick people and extend life. Bioscience needed capital as much as capital needed bioscience. If you want to do this sort of science, you need this sort and source of money; if you want drugs and diagnostic tools to be developed, you need to become part of the capitalist nexus. When, in 2004, BusinessWeek celebrated Venter as one of America's 'Great Innovators', they elected to pose him wearing a white lab coat on one side and a businessman's jacket on the other, an admired chimera of scientific knowledge and capitalist entrepreneurship.

Venter grew rich through these manoeuvres. In November 1993, he had over 700,000 shares in HGS, worth $9.2 million and rising fast. During the last days of the high-tech bubble in early 2000, he accounted himself the world's first 'biotech billionaire'. And he now had the toys befitting his station as alpha-male entrepreneur. Trading up over the years from humble sailing boats, he was deep in negotiations to buy a $15 million racing yacht. On 14 March 2000, Bill Clinton celebrated 'the scientific breakthrough of the century – perhaps of all time' and announced an agreement with

Tony Blair stipulating the essential openness of scientific knowledge:

> We have a profound responsibility to ensure that the life-saving benefits of any cutting-edge research are available to all human beings . . . Our genome, the book in which all human life is written, belongs to every member of the human race . . . As scientists race to decipher our genetic alphabet, we need to think now about the future and see clearly that in science and technology the future lies in openness.

Whereupon Celera's share-price fell off a cliff: the first and only time that pronouncements about the social relations of science have moved the stock-market. Asked by a Wall Street Journal reporter how he felt, Venter bluntly replied 'poorer' – to be precise, $300 million poorer. Worse was to come. Ousted from Celera in 2002, Venter was just days short of taking up a large chunk of his stock-options and was obliged to sell his shares at less than advantageous prices.

That's one version of Venter – 'the poster boy for the commercialisation of research', selling science to the highest bidder – but he prefers another version. A Life Decoded tells a very different story, one in which scientific practices and the environment for doing science are radically novel but the motives are deeply traditional. When Celera Genomics was founded in 1998, Venter gave TIGR half his 10 per cent stake in the new company – then worth $150 million – as an endowment, 'so that one day I could return to do the research I wanted to do for the rest of my life'. Throughout his involvement with HGS, Venter was in conflict with the for-profit company over its business model: HGS wanted aggressive patenting and relatively strict secrecy policies; TIGR wanted the quick release of genomic data. His sacking from Celera Genomics followed a similar pattern, as Venter constantly sniped at the CEO's unrealistic and wrong-headed conviction that you could make huge amounts of money from owning lots of gene sequences, as opposed to selling processed and packaged information about them. The CEO, Venter said, 'did not buy into or understand this science crap', but it was science that Venter thought the firm was and ought to be doing.

The pattern continues: returns from Venter's equity in the profit-making enterprises have been folded into the non-profit J. Craig Venter Institute (JCVI), which receives funding from the environmentally conscious Gordon and Betty Moore Foundation (its money derives from the microchip giant Intel) and the US Department of Energy. JCVI hit the front pages recently by taking significant steps towards the fabrication of the world's first synthetic organism: Venter and his colleagues took 'cassettes' of commercially available DNA and fabricated the almost complete genome of the tiny microbial parasite Mycoplasma genitalium. All you now have to do to create 'artificial life' is to stick that DNA into a 'cellular shell' and let the genomic software 'boot up', taking over the organism's vital functions. They expect this to happen within the year. The man who, it's said, first read the Book of Life now means to begin writing a new one.

In the meantime, JCVI scientists continue to analyse the fruits of Venter's two-year-long combined eco and ego-trip round the world on his lavishly equipped yacht, Sorcerer II, a trip Venter compared in significance to Darwin's voyage on the Beagle. The purpose: to sequence not any particular newly discovered marine micro-organisms but, in effect, the whole of the world's oceans, with the idea of finding new genes that can solve the energy and climate change crises: genes, for example, that you can pop into a microbe of your choice to make abundant hydrogen to fuel cars. Already JCVI scientists have discovered millions of new genes, and Venter has published huge amounts of this material in the open-access, peer-reviewed Public Library of Science, the same place where, several months ago, he published the first diploid genome of an individual human being – unsurprisingly, his own. And so, if you want to know who Craig Venter really is, you can go to http://biology.plosjournals.org/archive/1545-7885/5/10/supinfo/10.1371_journal.pbio. 0050254.sd001.pdf and see him genetically naked, the ultimate collapse of scientific author into scientific object. As one JCVI colleague insisted, this unprecedented act of self-disclosure shouldn't be seen as rampant egoism but as a deeply moral act, running 'the risk of divulging intimate personal details, including any current and future genetic markers for disease', and done 'to stimulate efforts to develop cheaper sequencing technology and usher in a new era of individualised genomic medicine'.

But the non-profit JCVI has its commercial twin, too: Synthetic Genomics Inc, a privately held company founded with $15 million of a Mexican entrepreneur's cash that is using genomic engineering to custom-design microbes to produce biofuels, promising 'a clean energy future through genomics'. The president of the company was parachuted in from the Department of Energy, one of Venter's long-standing patrons, and, as it becomes profitable, so Synthetic Genomics funds research at the non-profit JCVI. (Sequencing the human genome sometimes seems simpler than working out the organisational networks of late modern bioscience.) Is it science, is it humanitarianism, is it moral transformation, is it a new twist on old forms of corporate capitalism? Venter insists it's all of these: 'We are on a crusade as much as it is an economic goal . . . This is one of those crusades that only works if it becomes really profitable.'

If Craig Venter is the iconic scientist of the early 21st century, what conception of science does he embody? Belligerent, innovative, ambitious and entrepreneurial, he is an emblem of the radical changes in American scientific life, and especially in the lives of biomedical scientists, over the past thirty years or so. The intense relationship between biomedical science and capital is substantially new, and so is the texture of much scientific practice in the area, including the pace of work, the funds required to do the work, the instrumental production and processing of inconceivably large amounts of scientific information, and the institutional configurations in which biomedical science now happens. At the same time, Venter expresses sentiments about science that could scarcely be more traditional, even romantic. A ruggedly freebooting individualist, contemptuous of authority and of bureaucracy, he revives an old conception of scientific independence and integrity in an age when the bureaucracies that allegedly block the advance of science are as much academic and non-profit as they are commercial. When academic bureaucracies are said to protect intellectual orthodoxies, when cumbersome and politicised government bureaucracies harbour cults of personality, and when corporate bureaucracies build on business models that stultify both science and commercial growth, the only person you can trust is an edgy hybrid of self-confessed 'bad boy' and self-advertised humanitarian who thinks he has a spoon long enough to sup with all the institutional devils and sacrifice his integrity to none. The imaginative development of new institutional forms appropriate to

the new science, the new economy, and a newly emerging moral order is made to depend on a unique individual. Later this year, when ‘boot up’ inevitably happens, he will – according to some conceptions of the thing – have created life. If you trust Craig Venter, he will, like his predecessor in the life-creating business, see that it is good.

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