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Life, DNA and the model

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Abstract. This paper argues that the 1953 double-helix solution to the problem of DNA structure was understood, at the time, as a blow within a fiercely fought dispute over the material nature of life. The paper examines the debates, between those for whom life was a purely material phenomenon and religious people for whom it had a spiritual significance, that were waged from the aftermath of the First World War to the 1960s. It looks at the developing arguments of early promoters of molecular biology, including J.D. Bernal, his pupil Max Perutz and his pupil Francis Crick, on the one side, and of the so-called 'Inkling' cluster of writers including C.S. Lewis and J.R.R. Tolkien, on the other. This debate was conducted through polemical works, journalism, and science fiction and through the Festival of Britain and can be followed through the commentary of Jacob Bronowski. The paper concludes with the model of the double helix now at the Science Museum, which can be considered an archaeological relic of a battle in a war which is still being fought.

A plaque mounted on the wall of the Eagle pub, close to the former building of the Cavendish Laboratory in Cambridge, commemorates the moment on 28 February 1953 when Francis Crick made his entrance, proclaiming that he and Watson had 'found the Secret of Life'.[1] The thesis of this paper is that Crick's enthusiastic boast should be taken seriously. The 'secret of life' was not just an eternal and timeless question. It was also an urgent and particular issue for the deeply fractured intellectual elites of scientists and literary intellectuals of early Cold War Britain. Many scientists favoured strictly materialist and antireligious interpretations of life; contesting these were writers for whom life had an essentially spiritual dimension. The model of DNA's structure now in the Science Museum can therefore be seen as a relic of a major cultural confrontation, and not just a statement about an important molecule.

This paper is a work of synthesis which attempts to join two established historical discourses. The paper begins with a summary of the discussions of vitalism and

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1 The prime source for this anecdote is James Watson, *The Double Helix*, London: Weidenfeld and Nicholson, 1968, p. 197. However, Crick also referred to having found the 'basic copying mechanism by which life comes from life' in a letter to his son. See Francis Crick to Michael Crick, 19 March 1953, Box 2, Folder 24, Francis Crick Personal papers, MSS660, Mandeville Library, UCSD. Quoted by permission.

materialism that took place between the First World War and the 1950s. To that debate, this paper links the broad discussions about the cultural objectives of molecular biology that were coincident with the early days of modern DNA science, and shows how, through the arguments of people such as Crick himself and of Jacob Bronowski, perceptions of molecular biology were intimately bound into the longer-term disputes over vitalism. Finally it suggests that this understanding of molecular biology as part of the public sphere, even in its youth, helps us read the large model of DNA built in 1953 which, reconstructed, sits in the Science Museum today.

As Frank Turner and Peter Bowler have shown, in the early twentieth century the debates between science and religion in Britain had taken a new turn.[2] Previous arguments over evolution gave way to a renewal of the ancient debate over materialism and vitalism which acquired new significance in the wake of the Great War.[3] Religious believers mourning their dead were comforted by thoughts of meaning, of life eternal and of self-sacrifice. To others, the emergence of the Soviet Union gave hope for a new age, a new economy and a new culture here on earth. European societies, then, were sharply divided between conservatives with strong religious views and modernizers keen to disenchant the world.[4] For both groups the questions of life and matter were far from abstract.

The newly sharp edge to this issue can be seen in the different tones of the Gifford lectures on science and religion presented by the leading Conservative politician Arthur Balfour in 1914 and, again, in 1922. The publication of the post-war lectures, unlike their predecessors, was prefaced by a 'prologue'. This introduction reflected on the changing times, the revolution caused by the war, the dominance of technology in everyday life and the wonderful findings of science. A former prime minister and recent

2 Frank M. Turner, 'The Victorian conflict between science and religion: a professional dimension', *Isis* (1978) 69, pp. 356–376; Peter Bowler, *Reconciling Science and Religion: The Debate in Early-Twentieth-Century Britain*, Chicago: University of Chicago Press, 2001.

3 On the complex growth of spiritualism see Jennifer Hazelgrove, *Spiritualism and British Society between the Wars*, Manchester: Manchester University Press, 2000. This book provides insight into the complex democratizing factors behind widespread interest in spiritualism and the sense of life being irreducible to material reality.

4 Of course there is a century-old concern. See Robert J. Richards, *The Romantic Conception of Life: Science and Philosophy in the Age of Goethe*, Chicago: Chicago University Press, 2002. As early as 1838, Mill had distinguished between the 'conservative' views of Coleridge and the 'progressive' views of Jeremy Bentham. All Englishmen, he contended, could be associated with the philosophy of one or the other. See John Stuart Mill, 'Bentham', *London and Westminster Review* (August 1839) 29, pp. 467–506; and *idem*, 'Coleridge', *London and Westminster Review* (March 1840) 33, pp. 257–302. Mill's categories were echoed and analysed by Karl Mannheim, who explored the disenchantment of the world in his 1927 essay 'Das conservative Denken' (which appropriately appeared in English in 1953, 'Conservative Thought', in P. Kecskemeti (ed.), *Essays on Sociology and Social Psychology: By Karl Mannheim*, London: Routledge and Kegan Paul, 1953, pp. 74–164) and in his very well-known 1929 *Ideologie und Utopie*, which had been translated in 1936. Karl Mannheim, *Ideology and Utopia*, London: Routledge, 1936. Mannheim contrasted the attitudes of two generations and mindsets. He contrasted the rationalists, looking forward ideologically to a bright future, with conservatives who harked back to a utopian past. On spiritualism before the First World War and the reaction against the disenchantment of the world see Alex Owen, *The Place of Enchantment: British Occultism and the Culture of the Modern*, Chicago: University of Chicago Press, 2004. For the interwar period see Hazelgrove, op. cit. (3).

negotiator of the Versailles treaty, Balfour was concerned not so much by doctrinal disputes over such matters as the age of the Earth as by competition for the hearts of his audience. He introduced his readers to the thought 'that some part at least of the alleged "conflict between Theology and Science" is not a collision of doctrine, but a rivalry of appeal; and that so far as Science, or rather scientific Naturalism, is concerned, the strength of that appeal is largely modern'.[5]

Balfour's elegant turn of phrase belied the intensity of the divides then appearing in Britain and expressed in a fierce and widespread debate over vitalism. In contrast to the belief in a special spark of life espoused by religious communities, typically, the biochemical community had advanced materialist interpretations. Thus the meeting, in 1928, of the British Association for the Advancement of Science had been dominated by talk of new findings that might challenge the concept of an immaterial soul. So public was the debate, and so excited were the scientists, that the London *Times* could report the failure to reach resolution itself as 'news': 'Science and life. Ancient mystery unresolved'.[6] More hopefully, on 28 September, the *New York Times* reported on the British Association meeting: 'England stirred by theories on life'.[7] Two days later, the science editor Waldemar Kaempffert devoted more than a double-page spread to an article which began, 'What is life? Can we create it in the laboratory?'. Biochemist F.G. Donnan was quoted as predicting on the basis of recent discoveries that the synthesis of living cells was coming nearer. The next year, the London *Times* report of the meeting, held in South Africa, also focused on discussions of the nature of life.[8] Biochemists had come to be associated with materialism.

At a time when the physics of the very small and the very fast was turning out to be rather different from the physics of everyday scales, 'materialism' was not necessarily to be equated with a 'reductionism' that would reduce biology to chemistry and physics. Many scientists believed that the very complexity of biological systems created unique contexts for the operation of scientific laws. Roger Smith, looking at the work of Sherrington and Julian Huxley, has shown how scientists reflecting on the complexity of life took part in a broader intellectual discourse: each, in his own way, saw a special quality in life arising from its complexity, even though they were materialists. Even Schrödinger's *What Is Life* of 1944 has been shown by Robert Olby to reflect the vision of a non-reductionist physicist who expected to find novel laws ruling the formation of life.[9]

5 Arthur James Balfour, *Theism and Thought: A Study in Familiar Beliefs*. London: Hodder and Stoughton, 1923, pp. 3–4.

6 'Science and life. Ancient mystery unresolved. Professor Evans on research', *The Times*, 11 September 1928.

7 'England stirred by theories on life', *New York Times*, 13 September 1928.

8 'The nature of life. Scientists' discussion at The Cape', *The Times*, 26 July 1929.

9 Roger Smith, 'Biology and values in interwar Britain: C.S. Sherrington, Julian Huxley and the vision of progress', *Past and Present* (2003) 178, pp. 210–242; Robert Olby, 'Schrödinger's problem: What is life?', *Journal of the History of Biology* (1971) 4, pp. 119–148. Olby argues that in fact Crick and Watson were not influenced by Schrödinger's philosophical approach. Kenneth Schaffner has argued that even their findings are not necessarily reductionist. Kenneth Schaffner, 'The Watson–Crick model and reductionism', *British Journal for the Philosophy of Science* (1969) 20, pp. 325–348. See also Hilde Hein, 'The endurance of the

At the same time, there were many people, such as Balfour, for whom any materialist mindset, with its denial of the divine presence, was itself to be condemned. Attitudes to science in student circles provide an interesting guide to wider debates amidst their peers. Debates in the Oxford Union, for example, were indeed used to indicate the climate of opinion at the time, and the famous 1932 decision not to fight for 'king and country' has been much cited as an indicator of a wider mood of pacifism.[10]

Patterns of undergraduate journalism and debate also provide an indicator of the tension within the educated classes between those for whom science's achievements were to be celebrated and those for whom they seemed a darkening threat. Jacob Bronowski, a literary mathematics student, co-founded and edited in November 1928 an undergraduate magazine with the positive title *Experiment*. The first issue contained just one article on science, titled 'Biochemistry'.[11] Other supporters of the magazine were the future film-makers Humphrey Jennings and Basil Wright, while the cover was designed by Misha Black, later to be a most distinguished industrial designer but then known as the younger brother of the treasurer, mathematician Max Black.[12] These people would work together for a generation.

In competition with *Experiment*, a more arty magazine, *Venture*, was established the same month. Its founders – student and actor Michael Redgrave and his friend Robin Fedden, with the collaboration of the art historian Anthony Blunt – would be as distinguished as the competition. Julian Bell, an undergraduate student of English, son of Vanessa Bell and nephew of Virginia Woolf, was closely associated with *Venture* and he also spoke in support of a motion at the Cambridge Union on 'The sciences are destroying the arts'.[13] Although that motion was heavily defeated, Bell himself had spoken eloquently. He dismissed businessmen as 'the waste-product' of science. Within a few years he would be dead. Killed fighting for the Republicans in Spain, he would not have a chance to make his own name. Nonetheless the talent and future distinction of many of his contemporaries should dissuade us from dismissing their arguments on grounds of their youth.

It was not only within the ancient universities that concerns over the claims of science were raised. The analyst of science fiction Mark Hillegas has discerned a 'broad cultural movement which, gaining momentum in the twenties and thirties, turned

mechanism–vitalism controversy', *Journal of the History of Biology* (1972) 5, pp. 159–188; John Beatty, 'Evolutionary anti-reductionism: historical reflections', *Biology and Philosophy* (1990) 5, pp. 199–210.

10 The debate in the Oxford Union in 1933, which carried the motion that 'this house would in no circumstances fight for King and country', is a well-known example. On the meaning of this debate see Martin Creadel, 'The "King and country" debate, 1933: student politics, pacifism and the dictators', *Historical Journal* (1979) 22, pp. 397–422. The historian A.J.P. Taylor cited the debate as an indicator of national mood in his classic *English History 1914–1945*, Oxford: Clarendon Press, 1965, p. 362.

11 J.O. Giršavičius, 'Biochemistry', *Experiment* (November 1928) 1, pp. 34–37.

12 Jason Harding, 'Experiment in Cambridge: a manifesto of young England', *Cambridge Quarterly* (1998) 27, pp. 287–309. Also see Kate Price, 'Finite but unbounded: *Experiment* magazine Cambridge, England, 1928–33', *Jacket* (December 2002) 20, available at http://jacketmagazine.com/20/price-expe.html, consulted 1 December 2008.

13 See 'The Union Society', *Cambridge Review* (2 November 1928) 50(1223), pp. 94–95. For *Venture*, see the account of Bell's life in Peter Stansky and William Abrahams, *Journey to the Frontier*, Chicago: Chicago University Press, 1966.

from dreams of reason, progress, science and the perfectibility of man to tradition and the doctrine of original sin'.[14] Famously, the Bishop of Ripon argued in 1927 that science was moving so quickly that a 'science holiday' was called for, to allow reflection and social response.[15] In his examination of the debate in early twentieth-century Britain over whether science and religion could be reconciled, Peter Bowler shows in detail how the debate over the validity of any non-scientific views came to be polarized in the late 1930s.[16] Behind strictly local factors was an increasingly fractious global political context, with the competing attractions of the Soviet Union and Nazi Germany expressed in such conflicts as opposing views over the Spanish Civil War. This debate reflected such tensions, the internal dynamics of the debate and also the acerbic leadership of such potent writers as Hillaire Belloc and G.K. Chesterton on the religious side and, opposing, an outspoken cohort of public scientists.

The reductionist biologists

A generation of scientists younger than J.S. Haldane were beginning to assert themselves in the 1930s. Several were hard-nosed reductionist materialists, for whom the idea of an organism being different from a chemical was vitalistic claptrap.[17] In the early years they were led by J.S. Haldane's son, John Burdon Sanderson (JBS), who had reacted against his father's holism. A man who had particularly enjoyed fighting in the recently concluded First World War, 'JBS' began 'Daedalus', his 1923 reflection on the potential of science, with the evocation of a 1915 battle. The main protagonists seemed to be the big guns rather than men: 'One would rather choose those huge substantive oily black masses which are so much more conspicuous, and suppose that the men are in reality their servants, and playing an inglorious, subordinate, and fatal part in the combat.'[18]

In 'Daedalus' Haldane dismissed opponents as looking at innovators as heretics. He enthused about the possibility of biological innovations, such as ectogenesis – which he was sure would be considered 'blasphemy'. Famously this inspired the riposte of his friend Julian Huxley's brother Aldous – the novel *Brave New World*. As another member of the 'visible college' of left-wing scientists, Haldane's friend the embryologist Joseph Needham pointed out in a review that Huxley had got the biology right.[19]

14 Mark Hillegas, 'Introduction', in *idem* (ed.), *Shadows of Imagination: The Fantasies of C.S. Lewis, J.R.R. Tolkien, and Charles Williams*, Carbondale: Southern Illinois University Press, 1979, pp. xii–xix, xvii.

15 'British Association. Bishop of Ripon's address. Science and religion', *The Times*, 5 September 1927. See Carroll Pursell, '"A savage struck by lightning": the idea of a research moratorium, 1927–37', *Lex et Scientia* (1974) 10, pp. 146–158.

16 Bowler, op. cit. (2).

17 On this group see Gary Werskey, *The Visible College*, London: Allen Lane, 1978. It is striking that while Werskey cites the scepticism over reductionism of two members of his group, Needham and Hogben, both move away from experimental biology and neither comes to be involved in molecular biology.

18 J.B.S. Haldane, 'Daedalus, or science and the future, a paper read to the Heretics, Cambridge, on February 4th, 1923'. The lecture was published as *Daedalus*, London: Kegan Paul, 1924.

19 Joseph Needham, 'Notes on the way', *Time and Tide* (10 September 1932) 12, pp. 970–972.

J.B.S. Haldane would be converted to communism during the 1930s, like many other biochemists for whom the science of socialism and biology were identical.

In the pantheon of materialist biologists, J.B.S. Haldane was, in turn, closely associated with his younger contemporary, the crystallographer known generally as 'Sage', John Desmond Bernal. The historian and philosopher Stephen Toulmin expressed Bernal's influence thus in an article in the *New York Review of Books*:

> In the 1930s, indeed, Bernal became for a while a major intellectual influence. Though it was the poets of the Popular Front era (Auden, Spender, Day Lewis) who took the public eye, the real focus of radical thought in the Britain of the time was among the scientists of Cambridge, and the man at the center of it all was J.D. Bernal.[20]

A young man in the 1920s, and too young himself to fight in the First World War, in 1929 Bernal published his heretical work *The World, the Flesh and the Devil*. The words of the title knowingly chosen by this lapsed Catholic were drawn from the list of potential sources of evil specified by the Counter-Reformation Council of Trent. For Bernal, the list served as provocative headings for the challenges posed by science. He even reflected on a future when man would transcend this Earth and escape to the stars. Humanity would be freed too of the limitations of the natural materials from which we are made; it is incidentally ironic that Bernal's wife Eileen was a close friend and correspondent of that arch-opponent of scientism, Julian Bell, the two allied in their love of the biochemist Antoinette Pirie, hatred of fascism and passion for correspondence. They could, however, not agree on Eileen's materialism and fervent Marxism.[21]

Bernal's disdain for religion did not make him an enemy of art or of aesthetics.[22] It did resonate, however, with a scorn for belief in the immaterial. Bernal was fond of quoting Engels that life was the mode of existence of albumen. He inspired his followers in the search for a chemical basis for living processes. Max Perutz, first director of Cambridge's Laboratory of Molecular Biology and Francis Crick's doctoral supervisor, would recall his first encounter with Bernal, his own supervisor-to-be: 'I asked him: "How can I solve the secret of life?" He replied: "The secret of life lies in the structure of proteins, and X-ray crystallography is the only way to solve it."'[23] In the same year as this conversation, 1936, Bernal emphasized his materialist interpretation in an article for the Marxian journal *Science and Society*: 'The practical scientists of today are learning to manipulate life as a whole and in parts very much as their predecessors of a hundred years ago were manipulating chemical substances. Life has ceased to be a mystery and has become a utility.'[24]

20 Stephen Toulmin, 'Progressive man', *New York Review of Books* (March 1966) 6, p. 20.

21 There is an extensive correspondence between Julian Bell and Eileen Bernal in the Archives Centre, King's College, Cambridge, see PP/JHB/2. See, for instance, Eileen Bernal to Julian Bell, 7 July 1936. Cited with permission.

22 On Bernal's artistic friends, particularly Barbara Hepworth, see Andrew Brown, *J.D. Bernal: The Sage of Science*, Oxford: Oxford University Press, pp. 153–154. A mural sketched by Picasso on Bernal's wall now hangs over the entrance of the Wellcome Collection.

23 Max Perutz, 'Co-chairman's remarks: before the double helix', *Gene* (1993) 135, pp. 9–13, 9; see Georgina Ferry, *Max Perutz and the Secret of Life*, London: Chatto and Windus, 2007, pp. 26–39.

24 J.D. Bernal 'Dialectical materialism and modern science', *Science and Society* (1937) 2, pp. 58–66.

Bernal, more than any other single individual, inspired a British school of what would come to be called 'molecular biology'. At the same time an American school fostered by the Rockefeller Foundation was exploring how biological processes could be understood at the molecular scale. Between these two different but complementary networks, there were a number of historic meetings. For instance, in 1938 the Rockefeller foundation organized a meeting in the Danish town of Kampenborg on molecular biology. There were four British participants: Bernal, Conrad Waddington, Cyril Darlington and William Astbury. After the Second World War, the first three would all write fiery books about the nature of life.[25] The influence of each of these men through their writings and their students was considerable. Reflecting on the discipline as a whole, Fuerst has argued in a finely wrought 1982 article that the molecular biology which emerged in the post-war era rested on a reductionist belief system.[26]

The humanist response

An answer to Bernal and his protégés was hurled back by Oxford 'Christian humanists' who had been scarred by the experience of the First World War and interpreted the nature of evil during the Second World War. The title 'humanism' was bitterly contested at the time. The name by itself was used by those such as the atheist philosopher Bertrand Russell for whom man rather than any God was the source of morality.[27] But another group also claimed the title 'the Christian humanists'. For them the needs and qualities of man should be the measure of nature, not the other way around.[28] Balfour had concluded his 1922 lectures with the reflection that humanism could not be divorced from theism. From the 1920s, the views of such writers were deeply coloured by recent wartime experience. The anglo-Catholic T.S. Eliot penned *The Waste Land*. The Roman Catholic J.R.R. Tolkien vividly described the terrifying warrior half-visible 'ringwraiths' said to be based on the ghostly images of men half alive returning to their trenches from an assault.[29]

25 J.D. Bernal, *The Physical Basis of Life*, London: Routledge, 1951; Cyril Darlington, *The Facts of Life*, London: Allen & Unwin, 1953; Conrad Waddington, *The Nature of Life*, London: Allen & Unwin, 1961. On the difference between the American and British schools see the comments of John Kendrew, 'How molecular biology got started', *Scientific American* (1967) 216, pp. 141–143.

26 John A. Fuerst, 'The role of reductionism in the development of molecular biology: peripheral or central?', *Social Studies of Science* (1982) 12, pp. 241–278. See also the references in note 9.

27 On Russell see Philip Ironside, *The Social and Political Thought of Bertrand Russell*, Cambridge: Cambridge University Press, 1996. Ironside (on p. 44) points out how in the philosophy of Russell, 'Desire and emancipation take on the function of sin and salvation'.

28 On the Christian humanists see Lee Oser, *The Return of Christian Humanism: Chesterton, Eliot, Tolkien, and the Romance of History*, New York: University of Missouri, 2007. For a critical review of this book which explores Oser's concept of religious humanism see Anthony Kenny, 'Too good to last', *Essays in Criticism* (2009) 59, pp. 91–98. Interestingly, while Oser does not deal with C.S. Lewis in detail, Kenny suggests that he might have been a more appropriate case study than Tolkien. For the relation of Coleridge to religion see J. Robert Barth, *Coleridge and Christian Doctrine*, Cambridge: Cambridge University Press, 1987.

29 John Garth, *Tolkien and the Great War: The Threshold of Middle-Earth*, London: HarperCollins, 2003.

Such writers as Tolkien, and his friend and Oxford colleague C.S. Lewis, were the legitimate descendents of the poet and philosopher Samuel Taylor Coleridge, both in the quality and impact of their writing and in their theistic interpretation of life. Their visions transcended the bounds of their own time, casting back to a more attractive medieval world and making claims on the future. At the beginning of the twenty-first century, the thunderous responses of Tolkien and Lewis to the challenge of the modern technocrats still resonate.[30]

There is a huge literature analysing the work of both Lewis and Tolkien. Its scale and scholarship assert the significance of their works to other intellectuals and their serious intent behind what might seem to be fantasy.[31] These two writers were linked by vocation, by friendship and by shared experience of the Great War and of the suffering it had inflicted. While neither writer was against science per se, both were suspicious of its claims and of the impacts of applied science. So while Lewis was impressed by the possibilities of the literary genre pioneered by H.G. Wells, he was also very wary of the Wellsian technocratic philosophy.[32] In a 1954 letter, Lewis explained that *That Hideous Strength* was about 'Grace against Nature and Nature against Anti-Nature (modern industrialism, scientism and totalitarian politics)'.[33] Tolkien too was appalled by the same three demons. The *Nature* editor Henry Gee has worked hard to demonstrate that he was not 'against' knowledge per se, but certainly *The Lord of the Rings* is very much a romantic reaction against modern industrial life.[34] Intertwined within its tales of daring and adventure are portraits of evil and polluted industrial worlds, and speeches articulating a wicked materialism expressed by the evil wizard Saruman.

Meeting in the *Eagle and Child* pub in the centre of Oxford, the friends – J.R.R. Tolkien, C.S. Lewis, Warren Lewis (the brother of C.S.) and Charles Williams – together with such followers and students as Roger Lancelyn Green, took the name 'the Inklings'. From the 1930s to the early 1950s this loose cabal discussed literature and retaliation against the forces of scientism.[35]

30 Amazon reports that sales of *The Lord of the Rings* by Tolkien have exceeded 150 million copies worldwide, and the films based on the book are among the most expensive and most successful ever made. The seven Narnia books of C.S. Lewis have sold 85 million copies, according to the BBC.

31 On Lewis see Bruce L. Edwards (ed.), *C.S. Lewis: Lifework and Legacy*, 4 vols., Westport: Praeger, 2007. On Tolkien see Patrick Curry, *Defending Middle-Earth: Tolkien, Myth and Modernity*, New York: Houghton Mifflin Harcourt, 2004.

32 On Lewis's attitude to Wells see David Downing, 'Rehabilitating H.G. Wells: C.S. Lewis's *Out of the Silent Planet*', in Edwards, op. cit. (31), vol. 2, pp. 13–34.

33 Roger Lancelyn Green and Walter Hooper, *C.S. Lewis: A Biography*, London: Collins, 1974, p. 179.

34 Henry Gee, *The Science of Middle Earth*, London: Souvenir, 2005.

35 On the status of the Inklings as a group see David Bratman, 'Gifted amateurs: C.S. Lewis and the Inklings', in Edwards, op. cit. (31), vol. 4, pp. 279–320. For the opposition between the Inklings and the biological materialists see Mark B. Adams, 'The quest for immortality: visions and presentiments in science and literature', in Stephen Garrard Post and Robert H. Binstock (eds), *The Fountain of Youth*, Oxford: Oxford University Press, 2004, pp. 38–71. See also *idem*, 'Last judgement: the visionary biology of J.B.S. Haldane', *Journal of the History of Biology* (2000) 33, pp. 457–491.

Lewis addressed himself, explicitly, to the reductionist materialist challenge raised by Bernal and Haldane. In 1943 he presented the Riddell lectures at Durham on the subject of the 'Abolition of man'. In this study of values and education he put his argument that 'what we call Man's power over Nature turns out to be a power exercised by some men over other Men with Nature as its instrument'.[36] Lewis also expressed his views about the reduction of humanity to Nature in a more popular genre. His science fantasy books and particularly *That Hideous Strength* of 1945 were a direct response to Bernal's vision of man escaping the planet. Even the more apparently child-oriented books in the Narnia series have recently been interpreted in terms of Lewis's preference for a medieval world view.[37]

That Hideous Strength tells the story of naive scientists associated with an organization called 'N.I.C.E.', the National Institute of Coordinated Experiments, who allow themselves to be manipulated by evil power-hungry men.[38] A Bernalian figure is given the words 'If Science is really given a free hand it can now take over the human race and re-condition it: make man a really efficient animal'. Miraculously, N.I.C.E. is destroyed by Merlin reborn, supported by lovers of trees and flowers, and real and lovable animals. In case this book is seen wrongly as a piece of whimsy, the sceptic is pointed to the more obviously scholarly *The Abolition of Man*, which made the same points: by removing meaning, science has left the way open for evil. As Bowler points out, Lewis's image of Weston, the liberal scientist converted into the devil in *Perelandra* (preceding *That Hideous Strength* in Lewis's trilogy), is an iconic image of 'the changed relationship of science and religion in the Britain of the 1940s'.[39]

The scientists recognized the attack. In the new communist literary magazine the *Modern Quarterly*, J.B.S. Haldane reviewed Lewis's science fiction, accusing the writer of 'pandering to moral escapism by diverting his readers from the great moral problems of the day'.[40] Nonetheless, the *Modern Quarterly* was quite happy to focus upon the origins of life as a major issue. An article on the topic published just a few months after the end of Second World War, in spring 1946, had evoked so many responses that there was a special discussion of it in the autumn edition.

The 1950s debate

The polarization between materialists and deists that had been so evident before the war survived well into the 1950s. The Oxford Inklings continued their meetings, publishing their best-known works: Lewis's *Chronicles of Narnia* were published between 1950 and 1956, while Tolkien's *The Lord of the Rings* appeared between 1954 and 1955.

36 C.S. Lewis, *The Abolition of Man*, Oxford: Oxford University Press, 1943, pp. 54–55.

37 Michael Ward, *Planet Narnia: The Seven Heavens in the Imagination of C.S. Lewis*, Oxford: Oxford University Press, 2008.

38 On the possible inspirations for Lewis's image of N.I.C.E. and indeed of the nearby town of Belbury see Joseph Pearce, *C.S. Lewis and the Catholic Church*, San Francisco: Ignatius Press, 2003, p. 93.

39 Bowler, op. cit. (2), p. 403.

40 J.B.S. Haldane, '"Auld Hornie", F.R.S.', *Modern Quarterly* (1946) NS 1, pp. 32–40.

Their competitors continued to be persons who mixed science, left-wing politics and materialist antireligious views.

Science's ambitions were made visible in the culture of the 1951 Festival of Britain, symbolized by the soaring Skylon and by the Dome of Discovery. Becky Conekin, the design historian, has suggested that the exhibition was intended from its first conception to integrate the arts and science.[41] But in so far as it did, this integration was on science's terms. Several of the most influential figures in its conception had been involved in the pre-war Cambridge magazine *Experiment*. Misha Black, a founding editor, was a key designer; Humphrey Jennings and Basil Wright made films for the Festival; and Jacob Bronowski wrote the text of the science exhibit.

Conekin has suggested that the Festival represented a Labour Party vision of 'new Britain'. To this, she opposes the Conservative vision of what was sometimes called, evoking England's defiance of Philip II of Spain and, later, the name of the new Queen, 'the new Elizabethans'. Certainly the Conservatives loathed the Festival of Britain and arranged for its demolition as soon as they came to power. Moreover, as Conekin points out, such promoters of the 'new Elizabethan' image as the journalist and author Sir Philip Gibbs would express a lyrical love of old England and a dislike of modernism and bureaucracy.[42]

By contrast to the imagery of 'deep England' conjured by Gibbs, the dominant designs of the Festival of Britain were derived from crystallography. Electron-density maps of insulin exemplified the new aesthetic. The question of 'life' was also addressed. Max Perutz, pupil of Bernal and supervisor of Crick, was responsible for a section of the exhibition, labelled alternatively 'Problems of life – structure of proteins' or 'Physical and chemical approach to life', displayed in the science annexe, in the new western extension to the Science Museum, South Kensington. It featured a large mural commissioned from the modernist but Romantic artist Peter Ibbetson, forthrightly entitled *The Problem of Life* in the catalogue to an exhibition dedicated to Ibbetson's work held at London Little Gallery in 1949. Ibbetson's inspirations were identified as William Blake and Gerald Manley Hopkins.[43] The combination of his Romantic style with a materialist message was particularly powerful. Perutz's script explained that 'scientists find it useful to leave out the idea of vital force and to think of a cell as a complex system of chemical, mechanical and electrical devices, a kind of clockwork of great complexity'.[44] This high-profile and, at that time, unusual intervention by a scientist into the public sphere

41 Becky Conekin, *The Autobiography of a Nation: The 1951 Festival of Britain*, Manchester: Manchester University Press, 2003. On the designs see Leslie Jackson, *From Atoms to Patterns: Crystal Structure Designs from the Festival of Britain*, Shepton Beauchamp: Richard Dennis, 2008. Perhaps the very last gathering representing this community was the centenary memorial meeting for J.B.S. Haldane, held at the Science Museum 10–11 April 1992. Attendees included Professor Patricia Clarke and Haldane's sister Naomi Mitchison.

42 Conekin, op. cit. (41), p. 227; and see Sir Phillip Gibbs, *The New Elizabethans*, London: Hutchinson, 1953. Also see Robert Hewison, *Culture and Consensus*, London: Methuen, 1995, pp. 66–67.

43 See 'Peter Ibbetson', published to accompany an exhibition held at Little Gallery, London, 4–30 April 1949. Blake was, of course, also a hero for Bronowski, who had written a biography, *William Blake: A Man without a Mask*, London: Secker & Warburg, 1944.

44 Max Perutz, 'Molecular aspects of living processes', WORK 25/23, National Archives UK.

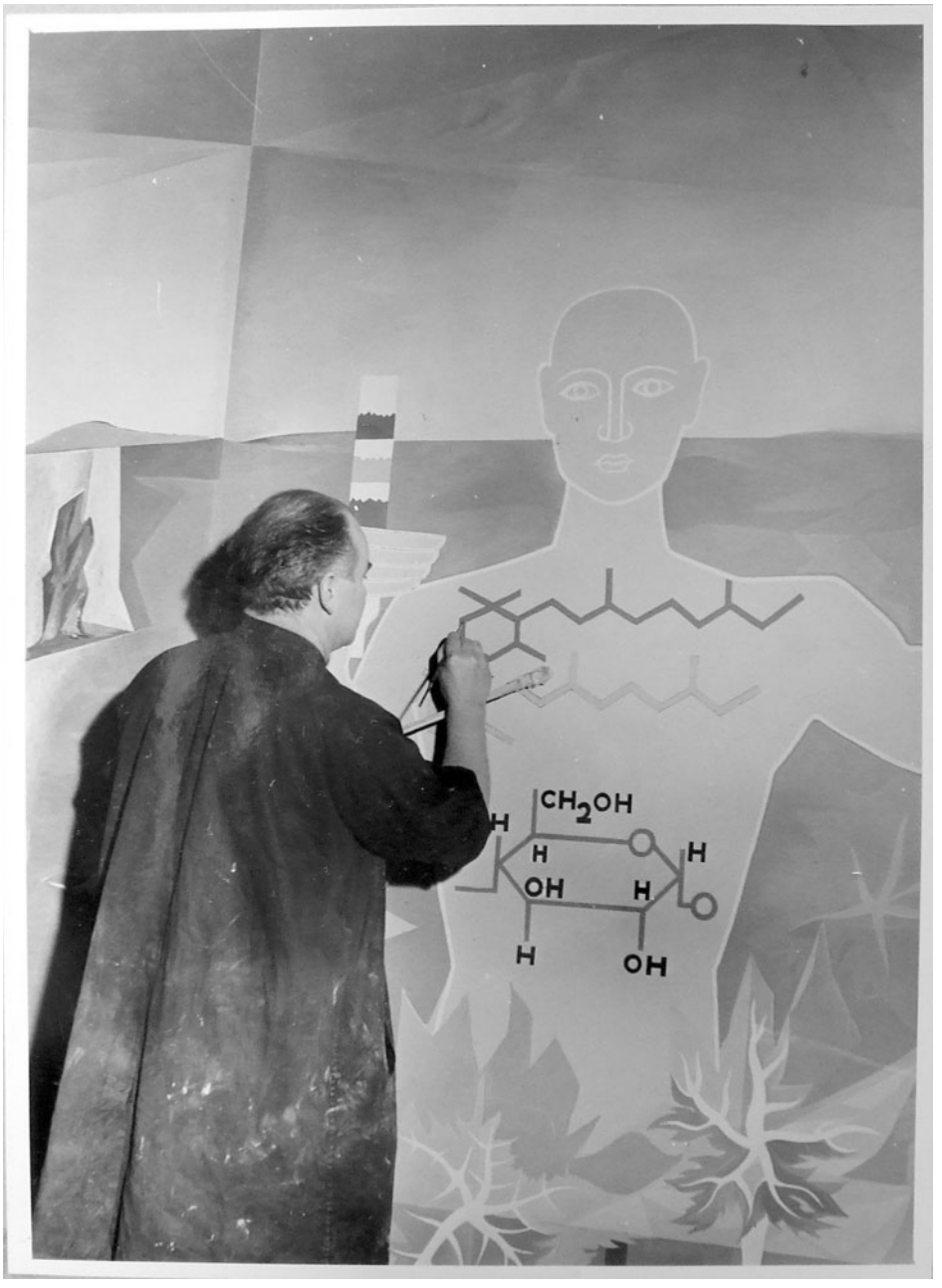

Figure 1. Peter Ibbetson working on *The Problem of Life* mural at the 1951 Exhibition of Science, Festival of Britain at South Kensington. Courtesy: National Archives UK.

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highlights for us the authenticity of Perutz's later autobiographical memories of his early interest in the scientific challenge of life.

At the same time as they were ideologically opposed, writers and scientists were socially and geographically intermingled. The close relationship between Eileen Bernal and Julian Bell shows just how intimate were the members of the two groups. When C.S. Lewis published his science fantasy *Perelandra*, he was challenged by the science enthusiast Arthur C. Clarke and a correspondence and meeting ensued.[45] Aldous Huxley, the dystopian novelist, was the brother of biologist Julian Huxley, close collaborator of 'JBS' Haldane. His pre-war *Brave New World* was widely seen as having continuing relevance in the 1950s. In 1956 the *Sunday Times* printed three long articles by the novelist himself reflecting on how *Brave New World* looked a quarter of a century on.[46] Naturally, such close interactions within Britain's intellectual elite made its members all the more aware of the challenge posed by the other side. It led to instant irritated responses such as Haldane's published response to Lewis and indeed to an unpublished reprise by Lewis. This was the atmosphere in which words and symbols such as 'soul' and 'protein' and soon 'DNA' would become ideological weapons.

This section, and the last, have suggested that for thirty years the views of British intellectuals about life had been deeply polarized. There were those who believed that understanding should begin with the human being, 'holistically' understood, an ethical, an aesthetic and a spiritual being. By contrast there were those who believed that this was sentimental rubbish and that living beings could be understood at the molecular level. Before the war, the division was most evident as a political split between the communist left and the religious right. As the Festival of Britain had shown, the divide continued. Perutz's treatment of life in the festival demonstrated its ferocity even without the previously vehement political overtones.

Francis Crick, Bronowski and the two cultures

There was little doubt from which direction both Francis Crick and James Watson approached religion. Watson has frequently expressed his scepticism.[47] I shall, however, focus on Crick, whose intellectual trajectory through English life from the late 1940s to the 1960s would clearly locate the significance of the double helix and of molecular

45 Haldane appeared at the Socratic Society and Lewis at the British Interplanetary Society. C.S. Lewis also engaged in debate with Arthur C. Clarke in an Oxford pub in 1944, an encounter described by Francis Spufford, *The Backroom Boys*, London: Faber, 2003, p. 9. See also Ryder W. Miller (ed.), *From Narnia to a Space Odyssey: The War of Letters between Arthur C. Clarke and C.S. Lewis*, New York: I Books, 2005.

46 See the *Sunday Times* (London), 27 May 1956, 3 June 1956, 10 June 1956. Famously the last of these articles emphasizing the continuing potential of new chemical sources of happiness and the potential replacement of alcohol prompted the board of the Distillers company to look seriously at the potential of Thalidomide.

47 See, for instance, the essays included in J.D. Watson and Walter Gratzer, *A Passion for DNA: Genes, Genomes, and Society*, Oxford: Oxford University Press, 2000.

biology more broadly.[48] He would later remember his intellectual trajectory as he plotted his future:

> Quickly I narrowed down my interests to two main areas: the borderline between the living and the nonliving, and the workings of the brain. Further introspection showed me that what these two subjects had in common was that they touched on problems which, in many circles, seemed beyond the power of science to explain. Obviously a disbelief in religious dogma was a very deep part of my nature.[49]

Crick's first hope on entering academic science after a wartime career in magnetic and acoustic firing mechanisms for mines was to study with Bernal. However, he was directed by his advisers towards Cambridge, where he ended up as the pupil of Bernal's student Max Perutz. Crick was too young, perhaps, to enter into a direct conflict with Lewis and Tolkien. However, as we have seen, the nature of life had already been defined as the critical point in the conflict between Christian humanists, for whom the secret would ever remain a mystery, and advocates of science, for whom decoding the 'secret' was an exciting challenge. I therefore argue that Crick's boastful cry as he entered the Eagle – that he and Watson had 'found the Secret of Life' – should not be seen merely as the proud claim of stealing victory from the establishment competitor Linus Pauling, who – as Pnina Abir-Am has shown – had already defined the issue of decoding the units of heredity in terms of the secret of life.[50]

It is too simple to interpret Crick's expression merely as the whoop of joy of a young man who had beaten an elder. His autobiographical reminiscences, his lineage as a pupil of Perutz and self-confessed grand-pupil of Bernal, and his own ongoing assault on humanists suggest that he was well aware of the cultural current in which he swam. Robert Olby, Crick's biographer, reports a May 1953 interview he gave to the journalist Peter Richie Calder, which appeared on the front page of the liberally oriented *News Chronicle* newspaper under the title 'Why you are you. Nearer the secret of life'.[51]

Crick's combative views on molecular biology and religion were expressed in a BBC World Service broadcast in 1960. This talk, given just a few years after the decoding of the double helix, was a strong denunciation of people who wanted to see something special about living beings. It began with a disparaging swipe at a young woman he had met at a dinner party who emphasized that she did not eat living things. He then explains, 'It's the aim of the modern science of molecular biology to explain living things in terms of atoms and molecules and their interactions; that is in

48 For Francis Crick the standard reference is Robert Olby, *Francis Crick: Hunter of Life's Secrets*, Cold Spring Harbor: Cold Spring Harbor Laboratory Press, 2009. Olby emphasizes Crick's dislike of the institutional strength of the Church.

49 Francis Crick, *What Mad Pursuit: A Personal View of Scientific Discovery*, New York: Basic Books, 1990, p. 17.

50 Pnina Abir-Am, 'The discourse of physical power and biological knowledge in the 1930s: a reappraisal of the Rockefeller Foundation's "policy" in molecular biology', *Social Studies of Science* (1982) 12, pp. 341–382. See 'Chemists unravel protein's secrets', *New York Times*, 5 September 1951.

51 Olby, op. cit. (48), p. 194.

terms of physics and chemistry.' As an afterthought the typed text was amended in pen to read,

> It now seems very probable that the understanding of living things in terms of atoms and molecules will be essentially complete before the Royal Society celebrates its next centenary, and with that understanding man's whole view of himself – of his nature and of his place in the universe – will be radically changed. And a good thing too, considering all the superstition which still permeates our whole society.[52]

Crick expanded on his views at greater length in a 1966 lecture series published as *Of Molecules and Men*.[53] His lectures were a vehement assault on vitalism (the series itself was entitled 'Is vitalism dead?'). He re-emphasized points which have been repeated throughout this paper. In a letter to Conrad Waddington, who had attended the pre-war Kampenborg conference and had produced his own book entitled *The Nature of Life* in 1961, he expressed his total agreement on the issue of vitalism.

Crick went further, however. In *Of Molecules and Men* he located himself in the newly rearticulated conflict between the arts and the sciences: the two cultures. This is, of course, symbolized by the work of C.P. Snow; however, the intervention of Jacob Bronowski shows that the issues were rather deeper than the debates between Snow and Leavis might suggest. In *Of Molecules and Men*, Crick was certainly happy to endorse Snow's 'two-cultures' argument, but complained,

> The mistake he [Snow] made in my view was to underestimate the difference between them. The old, or literary culture, which was based originally on Christian values, is clearly dying, whereas the new culture, the scientific one based on scientific values, is still in the early stage of development, although it is growing with great rapidity.[54]

This distinctively future-orientedness of science had, as we have seen, been debated for a generation; it was also coming to a head in late 1950s Britain. As Guy Ortolano has recently reminded us, there was then an attempt to introduce the modernism of science not just into cultural but also into political discourse. Labour party leader Hugh Gaitskell convened the so-called 'Gaitskell group' of left-leaning scientists including Bernal, C.P. Snow, Patrick Blackett and Jacob Bronowski.[55] At this critical moment in the Cold War, scientists were associated with socialism and the future. It was in this environment that Snow had pushed the issue onto the public stage with his 1959 Rede Lecture on 'The two cultures'. If scientists for Snow 'have the future in their bones, then the traditional culture responds by wishing the future did not

52 Crick, *Living Matter*, broadcast on the BBC World Service, 15 November 1960, PP/CR1/H2/39 Special Collection, Wellcome Library. I am grateful to the Wellcome Library for permission to quote this passage.

53 Francis Crick, *Of Molecules and Men*, Amherst: Prometheus Books, 2004; first published 1966. For the correspondence with Waddington see Crick to Waddington, PP/CR1/I2/6/5, see online http://profiles.nlm.nih.gov/SC/B/B/L/T/.

54 Crick, *Of Molecules and Men*, op. cit. (53), p. 93.

55 Guy Ortolano, *The Two Cultures Controversy: Science, Literature and Cultural Politics in Postwar Britain*, Cambridge: Cambridge University Press, 2009.

exist'.[56] The proximity of this view to Crick's later expression was matched by a telling change in the second edition of Snow's *Two Cultures*, published in 1964. There, in identifying the critical masterpiece of science of which every citizen should be familiar, he replaced the second law of thermodynamics cited in the first edition by an understanding of DNA. Snow wrote, 'This branch of science is likely to affect the way in which men think of themselves more profoundly than any scientific advance since Darwin's – and probably more so than Darwin's.'[57] Both Crick and Snow were founding fellows of Cambridge's new scientific college Churchill College in 1958, and a typescript of the second edition of Snow's *Two Cultures* is to be found in the Crick papers.[58]

Snow's argument famously met with vehement opposition. Critique and author were jointly condemned, and indeed abused, by the Cambridge English don F.R. Leavis. He saw Snow's argument entirely in terms of academic disciplines, the misplaced assault of the scientists upon the humanists, and the incompetence of Snow as an author purporting to be able effortlessly to turn his hand to novels. At a time of university expansion and contested ground this reading would strike home. Yet the argument was more fundamental than a mere conflict between disciplines for resources.

The high cultural stakes were highlighted by the approach taken by mathematician, intellectual and Gaitskell group member Jacob Bronowski. In 1962 Bronowski authored a play, 'The abacus and the rose', explicitly on the model of Galileo's *Dialogue on the Two World Systems*, a classic counterposing of the ancient geocentric Aristotelian system against the modern heliocentric model in which man's habitation had been decentred. This ambitious vision of the clash of civilizations was first broadcast on the BBC's Third Programme. Bronowski attempted to show the contrast between the anthropocentric world view of the humanists and the perspective of the scientist. It attracted considerable attention and the dialogue was published with considerable prominence in the American magazine *The Nation* two years later, and subsequently incorporated with the second edition of Bronowski's *Science and Human Values*.[59]

There was no doubt in Snow's mind about the significance of this essay. He complimented Bronowski for what he saw as a homage to his argument, writing,

> It is a tremendous support. It was gallant and generous of you to weigh in like this, and I shall never forget it. It was a pure chance that you didn't have to bear the major weight of this controversy – as I have repeatedly said both in public and in private. If that had been the case,

56 C.P. Snow, *The Two Cultures*, 2nd edn, Cambridge: Cambridge University Press, 1993; first published 1964, p. 11.

57 Snow, op. cit. (56), p. 74.

58 The manuscript copy is to be found in the Crick papers at the Wellcome Foundation, PP/CR1/9/20.

59 This was broadcast on 16 November 1962 and published in *The Nation* two years later. See Jacob Bronowski, 'The abacus and the rose, a dialogue after Galileo', *The Nation*, 4 January 1964. This essay is treated in a piece published on the Web by Timothy Sandefur, at http://sandefur.typepad.com/freespace/2009/05/the-two-cultures-and-the-abacus-and-the-rose.html, consulted July 2009. There Sandefur suggests that the character of the host was based on C.P. Snow and that of Harping on F.R. Leavis. His piece agrees with my own assessment that Potts is clearly based on Crick.

> I hope I should have behaved as handsomely as you have done. It means more to me than I can easily say.[60]

The dialogue is cast as a dinnertime debate between a scientist (Potts) and an English don with a senior civil servant as the genial, if slightly dim, host. For Bronowski, the tension between the modern English don and the molecular biologist was the modern equivalent of Galileo's struggle with the Church. He describes his scientific protagonist Potts as

> a little smug, because success came young, and slow to see that there really are other points of view (and interests) than that of the molecular biologist – not yet forty-five, lacking the critical gift of the other two, his sense of mission as sharply positive, as theirs is negative, Irish voice smouldering with idealism.

Bronowski's character ends with a definition of a molecular biologist almost identical in wording to the one given by Crick himself in the 1960 BBC World Service broadcast:[61] 'He is a man who unravels the secrets of life by using the tools of physics. He shows – we have shown – that the structures of biology become intelligible when we treat them, not as strings of mysteries, but as strings of molecules.' There is no need to intuit a parallel with Crick: there is a copy of the *Nation* article itself in the Crick papers. The Irish accent, of course, did not relate to Crick, but may rather have indicated Bernal.[62]

Harping, Potts's opponent in Bronowski's play, is one of the Angry Young Men whose philosophy also resembles that of the school of D.H. Lawrence.[63] Bronowski describes him as displaying a 'puritan anger, but bitter because he feels helpless in a changing time – about thirty-five, Reader in English at Southampton, say, Midland voice of preacher with cutting edge'.

The debate between the two men hinges on the nature of beauty. To the scientist Potts, a sunset was in itself beautiful. On the other hand, Harping argues that the discoveries and observations of scientists are banal and without depth while he and his colleagues are concerned with the deeper expressions of the human spirit. Here, Bronowski had not in fact made a novel point, even in terms of his own biography. He was harking back to a debate aired in the very first issue of his youthful publication *Experiment*.[64] Before that it had been explored in *The Riddle of the Universe* by the German Darwinist, materialist and founder of the philosophy of monism Ernst Haeckel. In Germany, this work had

60 Snow to Bronowski, 10 December 1962, folder 15, box 70, MS coll 173, Bronowski papers, University of Toronto Library.

61 Compare Crick's formulation in his *Living Matter* broadcast in 1960 quoted above almost in the same terms.

62 I am grateful to Jon Agar for this insight.

63 I am grateful to Professor Deborah Cameron for the possible association of Harping with some aspects of D.H. Lawrence's philosophy. It may also be mentioned that Lawrence was also a favourite writer of Leavis himself.

64 See William Hare (Lord Ennismore), 'Beauty: a problem and an attitude to life', *Experiment* (November 1928) 1, pp. 5–10; (February 1929) 2, pp. 2–6. In Hare's description of his 'aesthetic' approach to beauty as empirical and psychological, and in contrast to the 'practical-sensuous, the moral, the religious, and the scientific attitudes', one may look fruitfully for roots of Bronowski's own attitudes.

been seen as a bible for those with a materialist world view, and even in Britain it was widely known. J.B.S. Haldane had been inspired by it as a boy and later described himself as a monist. Haeckel described the issue of beauty as the point of 'strongest opposition' between Christianity and his 'religion' of monism.[65] He distinguished between the *naturalistic* (Haeckel's emphasis) century of the present and the past *anthropistic* centuries dominated by Christianity.[66] This distinction between past and present, earlier evoked by Balfour, of course, was exactly that being made by Bronowski on behalf of Crick, and a few years later by Francis Crick himself in *Of Molecules and Men*.

The argument in this section has not been dependent on a close psychological reading of Francis Crick. Nor have I attempted to interpret an ambition to solve a scientific puzzle in terms of culture. Rather this section has suggested that attitudes to life were polarized at the time. Crick was well aware of the polarization and located himself clearly with respect to it. Although his documents from the early 1950s are rather sparse even in 1953, we have evidence of the interpretation of the double-helix decoding in terms of life: Watson's evidence of his whoop of joy, the letter to his son and the Ritchie Calder article. From 1960 onwards the evidence is indeed stronger: the BBC broadcast and his own Danz lectures. Most interestingly the Bronowski play locates molecular biology within the debate over the centrality of the human experience.

The model

Crick's confident assertion that he could now show his solution to the riddle of life had been precipitated by the successful building of the model of DNA and the explanation of its replication. He and Jim Watson had managed to build a small model which explained the crystallographic evidence of Rosalind Franklin, received via Maurice Wilkins. Shortly after this first model, Crick and Watson built other models. One, in particular, was as large as a man. This was seen by a Rockefeller Foundation official in April 1953 and exhibited at a Cavendish Laboratory open day a few months later. The model assured viewers of the elegance and hence the likely 'truth' of the young men's scientific interpretation.[67] From a strictly analytical point of view, its great scale of construction was extravagant, unconventional and unnecessary. As a rhetorical device in such an

65 Ernst Haeckel, *The Riddle of the Universe at the Close of the Nineteenth Century*, tr. John Maccabe, New York: Harper, 1905, p. 338. For an insight into Haeckel's aesthetics I am grateful for the opportunity to have heard a paper by Bernhard Kleeberg, 'Evolutionary monism and aesthetics', presented at the The Monist Century: 1845–1945 colloquium at Queens University Belfast, 2–3 October 2009. I am grateful to Professor Kleeberg for permission to cite his article. Also see Bernhard Kleeberg, 'God-Nature progressing: natural theology in German monism', *Science in Context* (2007) 20, pp. 537–569. On the influence of Haeckel on art nouveau see Paul Greenhalgh (ed.), *Art Nouveau*, London: V&A, 2000.

66 Haeckel, op. cit. (65), p. 343. We may reflect on why the immigrant Polish Jew still with a foreign accent but with a very wide and cosmopolitan knowledge may have decided not to cite Haeckel's German work in a broadcast less than fifteen years after the end of the Second World War.

67 In his book *The Double Helix*, op. cit. (1), Watson described Maurice Wilkins's encounter with the model. The encounter of Rosalind Franklin memorably portrayed in the BBC dramatization does not seem to

Figure 2. Watson and Crick with their DNA model. Courtesy: A. Barrington Brown/Science Photo Library.

environment as a Cavendish open day, however, it was powerful and communicative. Even at the moment of its creation the model was seen as having a public as well as a strictly scientific value.

The next step in the model's entry into the public arena was taken in May 1953. An undergraduate aspiring journalist hoping to sell a story to *Time* magazine asked his friend, a young freelance Cambridge photographer called Anthony Barrington Brown, to photograph it together with Crick and Watson. Although at the time Barrington Brown felt he had signally failed to get them to stand portentously, he had nonetheless

have happened. Watson recounts how Wilkins told her about the proposed structure which she then checked against her data.

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created a now iconic image.[68] After Watson used two of his shots in *The Double Helix* of 1968, they came to be widely reproduced. We can see Crick and Watson standing, proudly – if not portentously – with the model, and in the background, mounted on the wall, the diagrammatic structure published in their *Nature* article.

As interest moved on, the sculptural model came to be treated as ephemeral. It began to break apart and was subsequently dismantled. Nonetheless the majority of its pieces were kept, at first by Cambridge molecular biologist John Kendrew and then by the chemist Herman Watson, who took them when he moved to the Chemistry Department of Bristol University. The Science Museum curator Anne Newmark discovered these surviving pieces in Bristol, and in 1976 Farooq Hussain, a student at King's College, reassembled the existing pieces to re-create a portion of the large model. He added substitute side chains to replace those missing, but like a careful archaeologist left it clear which pieces were original and which substitutions.[69]

Re-created, the model was deposited in London's Science Museum, where it is identified as one of the most important of all the exhibits.[70] It has been compared by the art historian Martin Kemp to the *Mona Lisa* and to an ancient Greek vase in its impact on the viewer, its careful reconstruction and its cultural importance, describing it as a 'treasured cultural icon'.[71] Chadarevian, in reflecting on the significance of the relic in her account of the reconstruction of the model, suggests that relics 'are not just tokens of great deeds, but actively contribute to the creation and public celebration of those deeds'.[72] The use of words such as 'relic' and 'icon' emphasizes Kemp's point that, like Leonardo's *Mona Lisa*, the DNA double helix is a 'super-image' with a meaning far beyond the narrow band of professional interpreters. Both 'speak to audiences far beyond their respective specialist worlds, and both carry a vast baggage of associations'.[73]

By the 1980s, in an era of biotechnology, the question 'what is life?' again had a particular resonance, and displays and broadcasts were used to focus public attention on the issue and on particular resolutions. In that way it may seem to have been presented in the 1980s as a medieval relic of some ancient saint's bones was deployed to wage a contemporary dynastic conflict. As I have argued elsewhere, that is a legitimate and powerful role of the museum exhibit.[74] There is often the assumption that these powers are acquired by accident long subsequent to their construction, and that

68 See the account by Anthony Barrington-Brown himself, 'How I came to take their photograph', at http://www.thednastore.com/dnastuff/picture1.html, accessed 19 October 2008. See also Soraya de Chadarevian, 'The making of an icon', *Science* (11 April 2003) 300(3617), pp. 255–257.

69 The most detailed and authoritative account of the building and rebuilding of the model has been provided by Soraya de Chadarevian, 'Relics, replicas and commemorations', *Endeavour* (2003) 27, pp. 75–79.

70 The model was, for instance, included in the museum's list of ten seminal objects, released for the 2009 centenary.

71 For the comparison with the *Mona Lisa* and a reconstructed Greek pot see Martin Kemp, 'The *Mona Lisa* of modern science', *Nature* (January 2003) 421, pp. 416–420. The process of reconstruction is recounted by its progenitor Farooq Hussain on his website, http://www.farooqhussain.org/projects/doublehelixmodel/document_view, consulted 1 December 2008.

72 Chadarevian, op. cit. (69), p. 78.

73 Kemp, op. cit. (71), p. 416.

74 Robert Bud, 'Science, meaning and myth in the museum', *Public Understanding of Science* (1995) 4, pp. 1–16.

Figure 3. The DNA model at the Science Museum: a sword from the field of battle. Courtesy: SSPL/Science Museum.

they were not anticipated by their originators. However, it is the argument of this paper that the symbolic power was – in its significance, if not in its ultimate strength – indeed intended. It was built as a weapon in the debates of the public world. Chadarevian points

out how, according to the 1987 BBC adaptation of Watson's book, 'the double helix' is 'the "secret of life" made visible'. The suggestion here is that this reading was intended even in 1953. The model can therefore be compared with the archaeological remains of a battle. Just as a sword recovered from a field is a forceful reminder of a bloody conflict, so the model is a relic of a particular critical moment in an enduring dispute.

International comparisons

The particular constellation of skills and interests arrayed in Cambridge in 1953 was unique.[75] Crystallographic expertise, an interest in modelling and contacts with both Chargaff and Rosalind Franklin came together just there, and that alone would explain why DNA could be decoded in Cambridge. It is my core argument that, on top of this concatenation of technical skills and network linkages, Britain's cultural–political tensions at that moment gave a distinctive and high significance to the problem. Historically, equivalents had certainly existed. Engels's dialectical materialism had been influential on the left across Europe and not just on Bernal in Britain.[76] Among scientists, the philosophy of materialism had been most coherently and influentially expressed by Haeckel through monism. Subsequently, however, during the early twentieth century, in Germany the uses of monism had themselves evolved. The Nazis had drawn upon a racial interpretation of monism while left-wing materialists had been murdered or had fled.[77]

Even in the United States, from where Watson had come and with which the British community had close links, it took different forms. There, the German immigrant Jacques Loeb had promoted a philosophy close to that of monism.[78] The ground of debate between religion and science was, however, defined by the 1925 Scopes trial

75 See Lily Kay, *The Molecular Vision of Life: Caltech, the Rockefeller Foundation, and the Rise of the New Biology*, Oxford: Oxford University Press, 1993. It was even after the horrors of the Holocaust that Pauling suggested that anybody found to have the inherited sickle cell anaemia trait should be tattooed. Also see Pnina Abir-Am, 'Molecular biology in the context of British, French and American cultures', *International Social Science Journal* (2001) 53, pp. 187–99. Abir-Am's portrait of post-war France provides a parallel with the geographically claustrophobic but politically polarized nature of British intellectual life in which the double helix was formulated. However, the politics of existentialism created a rather different set of concerns. See also Bruno Strasser, 'Institutionalizing molecular biology in post-war Europe: a comparative study', *Studies in History and Philosophy of Science Part C: Studies in History and Philosophy of Biological Sciences* (2002) 33, pp. 515–546.

76 See Igor Polianski, 'Between Hegel and Haeckel: monism and dialectical materialism in the Soviet Union and East Germany', presented at The Monist Century, 1845–1945. Cited with permission.

77 See Ute Deichmann, *Flüchten, Mitmachen, Vergessen: Chemiker und Biochemiker in der NS-Zeit*, Weinheim: Wiley, 2001.

78 Hainer Fangerau, 'From Mephistopheles to Isaiah: Jacques Loeb, technical biology and war', *Social Studies of Science* (2009) 29, pp. 229–256, see particularly 235–236. I am grateful to Professor Fangerau for bringing this article to my attention. On the influence of Loeb's ideas in the United States see Philip J. Pauly, *Controlling Life: Jacques Loeb and the Engineering Ideal in Biology*, Oxford: Oxford University Press, 1987. I am delighted to have had the opportunity to discuss the issues in this article with Professor Pauly at the 2007 meeting of the International Society for the History, Philosophy and Social Studies of Biology shortly before his untimely death. It is to him I owe the realization of the difference between the US and British expressions of tension between science and religion.

over the teaching of evolution. Human evolution, and its management, provided the touchstone of materialism. Over evolution one sees vehement argument, but at the time molecular genetics did not provide exactly the same focus of religious disagreement.

A provocative parallel between the Cambridge achievement and American science was offered within a few months of the decoding of the double helix. In Chicago, Stanley Miller, a student of the distinguished chemist Harold Urey, announced the synthesis of the building blocks of life in the May issue of *Science*, just eight weeks after the Crick and Watson paper.[79] A means by which life could have originated through strictly material means had been proposed in the 1920s and 1930s, separately by J.B.S. Haldane and the Soviet scientist Alexander Oparin.[80] At the time their hypotheses were merely speculative, but following Urey's suggestion Miller had created amino acids by passing a spark through a mixture of carbon dioxide, nitrogen and hydrogen. Since amino acids were the building blocks of proteins it seemed that here was a mechanism for life to evolve without divine intervention. This paper was cited fifty-one times in its first ten years (as measured by the ISI) – a very considerable number, if less than the Crick and Watson total of 471 over the same period.[81] This work concentrated on proteins and amino acids rather than on nucleic acids, but like Crick and Watson's near simultaneous paper, it seemed to give support to a materialist interpretation of life.

Urey himself was a cosmopolitan politically aware chemist who had campaigned for world government and been a supporter of Republican Spain in the 1930s. At the time of his announcement he had recently defended the Rosenbergs in the *New York Times*. Urey was, however, no Marxist materialist. Nor did his finding become contentious in the United States.

Although issues over science and religion have turned, in the United States, time and time again, on the status of evolution and of divine creation of man rather than of 'life' itself, they did become intertwined with the issues raised by DNA through the 'man-playing-God' debate. This has been tracked by the sociologist John Evans, who has mapped and followed in detail the disputes over eugenics, test-tube babies and theology.[82] The period begins for him with a paper by the British psychiatrist and geneticist Lionel Penrose, who claimed that classical genetics was giving way to a detailed biochemical interpretation. As Evans has shown, from the mid-1960s the question whether molecular biologists were 'playing God' became a major theme in the

79 S.L. Miller, 'A production of amino acids under possible primitive earth conditions', *Science* (15 May 1953) 117(3046), pp. 528–529. It is interesting to note that one of the three references in this article was to work by Bernal.

80 Iris Fry, 'The origins of research into the origins of life', *Endeavour* (2006) 30, pp. 24–28; and *idem*, *The Emergence of Life on Earth: A Historical and Scientific Overview*, New Brunswick: Rutgers University Press, 2000.

81 Of the 7,853 papers published in *Science* between 1945 and 1954, Miller's paper was the fifth most highly cited up to October 2009 as measured by ISI's 'World of Knowledge'. The links between the work of Muller, Oparin and Haldane and Watson and Crick are ably described by Antonio Lazeano, 'What is life? A brief historical overview', *Chemistry and Biodiversity* (2008) 5, pp. 1–15.

82 John H. Evans, *Playing God? Human Genetic Engineering and the Rationalization of Public Bioethical Debate*, Chicago: University of Chicago Press, 2002.

emerging discipline of bioethics. By 1969 Albert Rosenfeld, in his book *Second Genesis*, could predict 'Coming: the control of life'.[83] Above all, the phrase was made popular by the 1977 book by Howard and Rifkin, *Who Shall Play God?*.[84]

Conclusion

In recent years the debate between Tory and technocrat over the secret of life has been as vigorous as ever.[85] In Britain, Prince Charles has kept alive the Inklings' spirit at the centre of the nation's establishment. On the other hand, Richard Dawkins has played a role that has evoked the image of a latter-day Crick, moving between explaining the centrality of DNA and denouncing theism.[86] This paper has suggested that such disagreement should not be seen as new. It is a continuation of a century of argument since the experience of the Great War and the rise of Marxism – over the nature of life and the status of scientific reductionism.

Science has continued to play an important role in this debate over the nature of humanity. The Human Genome Project has built on the nematode worm sequencing project which in its turn is a development of a 1963 idea of Crick's to describe the *E. coli* cell in its entirety.[87] As a recent report on so-called synthetic biology points out, 'One of the core ideas in synthetic biology is the notion of creating "artificial life". This claim has simultaneously provoked fears about scientists "playing God" and raises deeper philosophical and religious concerns about the nature of life itself and the process of creation.'[88] On 26 March 2008, the *Independent* newspaper asked in bold type on its front page, 'Is this a clump of cells or a living being with a soul?'[89]

This paper has endeavoured to show that it is not just in recent years that such debates over the nature of life have been linked to molecular biology. 'Monism' provides a continuing strand. I have shown that at the time of the announcement of the double-helix structure of DNA, the long-running debates over vitalism on the one hand, and over the explanatory potential of a molecular interpretation of life on the other, were still

83 Albert Rosenfeld, *The Second Genesis: The Coming Control of Life*, Englewood Cliffs: Vintage Books, 1969.

84 See Diane Paul, 'Genetic engineering and eugenics: the uses of history', *Pittsburgh Workshop in the History and Philosophy of Biology*, Pittsburgh, PA; 2–17 March 2002, published at http://philsci-archive.pitt.edu/archive/00000852/00/Chapter_1.pdf, accessed 27 January 2009; Ted Peters, *Playing God? Genetic Determinism and Human Freedom*, London: Routledge, 1996.

85 On the links between the 1950s and the 1980s see Meredith Veldman, *Fantasy, the Bomb, and the Greening of Britain: Romantic Protest, 1945–1980*, Cambridge: Cambridge University Press, 1994. On the two-cultures debate see D. Graham Burnett, 'A view from the bridge: the two cultures debate, its legacy, and the history', *Daedalus* (1999) 128, pp. 193–218.

86 See Richard Dawkins, *The God Delusion*, London: Bantam Press, 2006. See also Madeleine Bunting, 'Why the intelligent design lobby thanks God for Richard Dawkins', *The Guardian*, 27 March 2006.

87 Soraya de Chadarevian, 'Of worms and programmes: *Caenorhabditis elegans* and the study of development', *Studies in History and Philosophy of Science Part C: Studies in History and Philosophy of Biological and Biomedical Sciences* (1998) 29, pp. 81–105.

88 Andrew Balmer and Paul Martin, 'Synthetic biology: social and ethical challenges', an independent review commissioned by the Biotechnology and Biological Sciences Research Council (BBSRC), May 2008.

89 'Is this a clump of cells or a living being with a soul?', *The Independent*, 26 March 2008.

alive. Crick, certainly, endeavoured to use these debates to frame the cultural meaning of DNA even in its early years. The physical model of the double helix now in the Science Museum can therefore be seen as a relic of a peculiarly creative moment in a debate in the public sphere over the significance of life. Today, engagement with the model can still provoke viewers to reflect on their own attitudes to the secrets of life, and the meaning of science.