

J D Bernal and the replication of the genetic material – hindsight on foresight

The 1931 International Congress for the History of Science held in London is famous for the sudden appearance of a powerful group from the USSR, led by Nikolai Bukharin (1888–1938). Their papers were rapidly published as a book (later reprinted) because there was almost no place for them in the time-table. These papers stimulated much interest in the social function of science and in the current philosophical outlook of the new communist state, especially as it was a time of great world economic and social unrest. However, the main business of the congress was elsewhere, and the Soviet intervention was nominally a sideshow, although it excited the main publicity. It enabled J D Bernal to meet Nikolai Bukharin and Boris Hessen with important consequences for attitudes to the role of science in society¹.

The papers read at the congress were not systematically published.

J B S Haldane, already in 1923, in a lecture, “Daedalus or Science and the Future”, given in Cambridge to “The Heretics”², had declared boldly that biology had become the centre of scientific interest. Biology was to be divested of mystical, religious and vitalistic principles and was henceforth to be investigated by materialist scientific methods.

For Bernal, as Marx and Engels, not the most romantic people, wrote about Francis Bacon: “Matter smiled at man with poetic sensuous brightness”. The study of the arrangements of atoms was going to reveal the secrets of life, the universe and all that. Science had the power to liberate mankind from poverty, ignorance and hunger if only it could be applied properly.

For this 1931 congress Bernal prepared a paper which transmitted the seeds of the revolution in molecular biology, which was beginning mostly in Cambridge. Bernal had solved a number of amino-acid structures and was starting on sterols and his friend W F Astbury in Leeds had started on the fibrous proteins³. The paper is now available only as a four-page typescript (probably typed by Eileen Bernal) in the Bernal Archive at Cambridge University Library. Normally Bernal’s lecture notes consisted of three or four words scrawled on the back of an envelope but there had been a call, prior to the congress, for preliminary papers. From the report of the somewhat chaotic proceedings of the meeting (published in several numbers of *Archeion* in 1932) it seems that Bernal did not have the chance to make his intervention at the appropriate session on vitalism, materialism and life. However, he attended closely to the new Marxist outlook on the development of science propounded by the Soviet group.

Joseph Needham in his paper on “Historical and Contemporary Relationships of Physical and Biological Sciences” followed J S Haldane (J B S Haldane’s father), who while disclaiming vitalism, believed that there were principles special to life and included this comment on J S Haldane’s views:

“But here he neglects a figure who is always very much neglected in these discussions, namely, the crystallographer, who stands in some obscurity between the physicist on one hand and the biologist on the other” [*Archeion*, 14, p. 509, (1932)]. This happened to be literally the case and Bernal’s paper went unread. However, the typescript contained a very remarkable statement about the hereditary material, preceding Schrödinger’s “*What is Life?*” by some 13 years.

Needham’s later book “*Order and Life*” (1936) was expressly dedicated to the members of the Cambridge Theoretical Biology Club⁴ which was the epicentre for the eruption of modern molecular biology. It embodied many of the ideas of the group, notably Bernal’s stress on liquid crystals, dense assemblies of large molecules with labile order. The first novel of C P Snow (who was in Cambridge at that time), “*The Search*” (1934), communicates the excitement of the period and, in the character Constantine, provides a sketch of Bernal.

The Theoretical Biology Club was based around the Biochemical Laboratory of Gowland Hopkins, in which Joseph Needham also played a leading part emphasising embryology and morphogenesis. In 1932 Needham proposed to the Rockefeller Foundation, through Warren Weaver, the establishment of an Institute of Physico-Chemical Morphology. This was not funded, but in February 1945, before returning to Birkbeck after the war, Bernal produced a plan “to set up a research centre for the study of the structure and properties of large molecules by all available physical and chemical methods” which was based on the thinking of the Cambridge club and was the charter for the Birkbeck Laboratory set-up in 21–22 Torrington Square, London.

Bernal himself wrote later (1967) “It is characteristic of science that the full explanations are often seized in their essence by the percipient scientist long in advance of any possible proof” (*The Origin of Life*, 1967, p. 251).

This typescript seems to describe one of Bernal’s most prescient visions. He sought to show how modern physics is actually leading to the solution of fundamental biological problems. Quantum mechanics brings insight to biochemical processes and X-ray crystallography allows direct study of the structures of organic materials, as Needham intimated to the meeting. From the physical point of view the two chief problems of life are that of activity e.g. muscle contraction or nerve conduction, and growth, involving the building up of organized elements in the cell or in reproduction. He emphasized process as well as structure. We now quote from Bernal’s 1931 typescript:

“We are beginning to grasp the chemical and physical nature of the protein molecule”⁵ . . .

“The facts of genetics demand, as JBS Haldane has pointed out, that, at some stage in mitosis, the individual molecules in a chromosome must be exactly duplicated. A complete molecule can be duplicated in three ways. If it is solid and 3-D only a supernatural agency, a divine copyist, can, entering its inner complexity, reproduce it in detail. If we prefer a natural solution, we must imagine the molecule stretched out either in a plane or along a line. In either case the simpler constituent molecules have only to arrange themselves one by one on their identical partners in the original molecule, and then become linked to each other by the absorption of suitable quanta from radiation or from second order collisions. That such autocatalysis is possible is indicated by recent work in Russia and America, where the regular atomic arrays of metallic catalysts are shown to operate like laceworker’s frames⁶ on which simple organic molecules settle to be joined into larger aggregates.

A 2-D reproduction of this kind is impossible, owing to the fact that the constituent amino acids in nature are not symmetrical, but exist in right or left hand forms. 2-D reproduction would lead to mirror image molecules, which are not found in nature. There remains then only 1-D reproduction. At the moment of reproduction, but not necessarily at any other time, the molecule of the protein must be imagined as a pseudo-linear, associating itself, element by element, with identical groups, related by an axis⁷ instead of a plane of symmetry, and thus preserving only right – or only left-handed symmetry. This hypothesis is clearly indicated by Astbury’s explanation of Svedberg’s numbers. Svedberg has established that most natural proteins consist of M. Wt. 34,000 or multiples 2, 3, or 6 times that number. This gives us the confidence to treat all protein molecules, regardless of their complex constitution, as belonging to one natural species.”

“It is impossible to claim these that these ideas are anything but preliminary guesses, but they have the advantage of being susceptible to experimental test”. (*International Congress of the History of Science*, June–July 1931 A4-7 Box 22 of the Bernal papers.)

Bernal’s later involvement with the alpha helix of proteins (1948) and the double helix of DNA (1953) was slight. He accepted immediately that Watson, Crick, Wilkins, Gosling, Franklin and Pauling were correct. In the early 1950s, Crick reasoned that if a gene specified the correct sequence of amino acids for a protein, ‘the protein would fold itself up correctly into a unique three-dimensional structure’. With this assumption, the problem of the 3-D replication of protein structure was reduced to a 1-D puzzle. When Crick was shown excerpts from Bernal’s 1931 paper in 2001, he commented: ‘How perceptive of Sage (Bernal’s universal soubriquet). I myself did not consider the 2-D case. But of course I knew a lot more about proteins than they knew in 1931’. In part he knew more, because Bernal and Dorothy Crowfoot had shown in 1934 that proteins had a structure with every atom in its proper place. Life had a material structure and would be explicable.

Notes and References

- ¹Bernal's subsequent relations with Bukharin and Hessen remain enigmatic. Both Bukharin and Hessen were executed in the purges of 1936–1938 which began with the murder of S M Kirov in 1934 at a time when Bernal happened to be visiting the Soviet Union and they became “non-persons” in the USSR. After the 1931 meeting Bernal had written an article on X-ray crystallography for Bukharin's journal SORENA. Bernal's book “*The Social Function of Science*” was never translated into Russian, although it did not mention names, but it is suggested that his views served to perpetuate Bukharin's ideas on the planning of science. J G Crowther may have also been a link. It was a complex and murky period.
- ²“Singing my song of deicides” (last words of Haldane's paper; but who was the author of this poem?).
- ³Like the Pope with the Treaty of Tordesillas which divided the New World between the Spanish and the Portuguese, Bernal and Asbury divided the new world of proteins between themselves, Bernal taking the globular proteins and Astbury the fibrous.
- ⁴Apart from Needham himself, they included J H Woodger, C H Waddington, Max Black, Dorothy Wrinch, J D Bernal, Dorothy Needham, E Witschi (?). Others less closely associated with the group were: E S Russell, G C Robson, N F Mott, L L Whyte, and A A Ritchie.
- ⁵It was then believed that the genetic material was altogether protein.
- ⁶It is possible that Bernal really meant “embroidery frames” where a regular lattice of fabric, stretched flat by clamping rings, is embroidered with a pattern of cross stitches. perhaps this was the idea later articulated in Bernal's views on the origin of life as the mechanism by which oranic molecules might become concentrated and associated on the surface of clay.
- ⁷A two-fold axis would not be suitable for association of copies of the same molecule because complementary cavities and protuberances must fit together. A screw-axis might serve. In the double helix the complementarity is purine-pyrimidine and not identity.

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