Molecular biology in the context of British, French, and American cultures

Pnina Geraldine Abir-Am[1]

Introduction

Molecular biology, or the study of biological problems at the macro/molecular level (as opposed to other levels of biological order, such as the organismic, or the cellular), is a quintessential twentieth century science. As a new, integrative, inter-disciplinary, and international mega-discipline with a far-reaching and ever-growing impact on society, molecular biology unfolded historically in three major phases, each phase being primarily influenced by one of the exact sciences: chemistry, physics, mathematics (Abir-Am 1992/3, 1997, De Chadarevian and Kamminga 1998, Morange 1998).

For the first third of the twentieth century, and to some extent until the end of World War II, chemistry was the major disciplinary influence on molecular biology. Both powerful and feared as a result of its remarkable performance in World War I in the industrial production of munitions and nutrition on a national scale, most notably in Great Britain and Germany, chemistry supplied biology with a research methodology that had previously proved hugely successful in organic chemistry. It also defined the problematics of the structure, function and metabolic reactions of biological compounds, most notably the versatile enzymes and other proteins, as hegemonic (Fruton 1972, Holmes 1991, 1993, Kohler 1982, Kornberg 1989). This phase in the molecularisation of biology is better known under the name of 'biochemistry'. This term was favoured in Great Britain; variations such as 'physiological chemistry' or 'biological chemistry' were also used respectively in Germany and the United States; France used both *biochimie* and *chimie biologique*. The isolation of many enzymes and the discovery of pathways of intermediary metabolism were the most notable achievements of this phase.

Pnina G. Abir-Am is a Scholar-in-residence, Rockerfeller Archive Center at the Rockerfeller University and a visiting scholar in the Department for the History of Science at Harvard University. Email: abiramp@rockerfeller.edu or pgabir@-fas.harvard.edu She also coordinates a project on the public understanding of science by theatrical means, in cooperation with the Science Teaching Department at the Hebrew University of Jerusalem. Her most recent publication is *Commemorative Practices in Science: Historical Perspectives on the Politics of Collective Memory,* edited with Clark A. Elliott, 1999.

In a similar manner, during the middle third of the twentieth century, but especially from the end of World War II to the late 1960s, physics superseded chemistry as a hegemonic source of research methodology and scientific problem areas. Physical technologies, most notably X-ray crystallography, transformed the structure-function problematic, which had previously focused on the physiological and biochemical versatility of proteins, into one focused on the ability of nucleic acids to code for biological information. The discovery of the structure of DNA in the early 1950s, the operon model of genetic regulation and the genetic code in the early 1960s, were among the most notable achievements of this phase (Judson 1979, Olby 1974, Sarkar 1998).

Finally, in the last third of the twentieth century, especially following the moratorium on

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research in genetic engineering and biotechnology, declared at the Asilomar conference in 1975, computer science and applied mathematics and bio-computing superseded physics in defining the frontier of molecular biology. In this phase, which extends to the present, a leading research methodology focused on software technologies and automated large scale databases. It transformed the informational problematic, which had previously been focused on the unique ability of nucleic acids to code for proteins, into a combined structural-functional problematic focused on the mapping of the whole genome of exemplary organisms, including humans, the sequencing of genes, and most recently, structural genomics or the predictive design of drugs based on the shape of proteins. At the same time it built on the functional genomics that had formed the initial phase of the Human Genome project and had reached a 'final draft' in mid-2000. The discovery of genes for several hereditary diseases in the 1980s and 1990s and the manufacturing of genetically engineered drugs such as insulin, were among the most notable achievements of this phase, better known as applied molecular biology, or as biotechnology (Rabinow 1999, Wright 1994).

Given these phases in the growth of molecular biology, the question remains what role, if any, national culture may also have played in the rise of molecular biology from marginal research projects in the 1930s to the status of a leading discipline in the twenty-first century? Historiographical research since the mid-1980s suggests that three countries played a major role in the rise of molecular biology, with each country acting as a scientific vanguard in a different decade. Great Britain sustained the early discourse in molecular biology in the 1930s; the United States joined with new research programmes in the 1940s, and France emerged in the 1950s as the theoretical synthesiser of the mostly structural British contribution and the largely informational American effort (Abir-Am 1992 on the British phase; Abir-Am 1998 on the American phase; Abir-Am 1999 and Morange 1998 on the French phase; including comparisons with the American phase).

This article explores how each national culture influenced the rise of molecular biology. The impact of national culture upon this new discipline was mediated in each country by research schools or transient social formations revolving around leading scientists who came to embody both the scientific legacy of each school and the values of the national culture in which a particular school had emerged (Abir-Am 1992/3, 1997, 1999). These research schools had initially pursued innovative but marginal research strategies on the fringes of established disciplinary science, but eventually were able to seize favourable interdisciplinary trends in science policy both before and after World War II, eventually rising to prominence in their respective national scientific communities.

For example, we consider the role of British culture in the early rise of molecular biology in Great Britain in the 1930s. We seek to explain why American culture was particularly suitable to sustain new disciplines such as molecular biology during the 1940s. And we highlight the role of French culture as conducive to exceptional accomplishments in molecular biology in France during the 1950s. We also inquire whether such distinctive periods of influence of a national culture on molecular biology are still possible in the context of profound globalisation since the 1990s.

The question also arises whether the influence of a national culture upon a new science came mainly from its political culture, or whether it also emanated from the culture, or rather subculture, of intellectuals, especially the public intellectuals? If so, how did the public intellectuals in general, and the scientists, especially the molecular biologists among them, define themselves in these three countries in terms of key public issues in the twentieth century. Examples of these issues are the rise of state communism in the 1920s, the rise of state fascism in the 1930s, the great intellectual migration since the 1930s; World War II; the Cold War, especially during the 1950s; the race and gender liberation movements in the 1960s; the May '68 rebellion by students and workers; the Third World's rise to the status of a major international actor, especially with the Vietnam War and the Cultural revolution in China; and finally, the globalisation that is still under way.

In addition to the impact of political culture the institutional culture of science in each country, was influential in forming the future leaders and members of research schools in molecular biology. In Great Britain, the distinctive culture of the ancient universities, and of specific colleges and laboratories within them, had a definite influence on the founders of molecular biology. In France, or rather Paris, the contrasting cultures of the *sorbonnards* and the *pasteuriens* intersected in the rise of molecular biology. In the United States, regional cultures played a certain role, especially institutions that reflected regional specificities, such as the mid-Atlantic, mid-Western, and Pacific ones.

Certain discoveries appear to have been dependent on a specific cultural context as they were not likely to have been made elsewhere, e.g. the solution of the first protein structures by X-ray crystallography in Great Britain, the discovery of lysogeny in France, and the biochemical decoding of the genetic code in the United States. In contrast, other discoveries appear to have required a transnational, and hence transcultural, context. The interaction of the British, French, and American cultures in the making of major discoveries in molecular biology must also be accounted for. Thus, the double helix was a British–American collaboration; the *pa-ja-ma* experiment and the theory of allostery were French–American collaborations; while messenger-RNA was a French–British–American collaboration.

British culture and the rise of molecular biology in the 1930s

The pioneering role of British culture in triggering the rise of molecular biology in the 1930s had three aspects: (a) the *political*, or the fact that a national unity government in the early 1930s signalled a considerable range of new political options; (b) the *ideological*, or the fact that scientists played a prominent role in taking socialist, communist, and anti-fascist stances, thus acquiring the cultural authority of public intellectuals; (c) the *institutional*, or the fact that leading laboratories with an international reputation, most notably the Cavendish for physics, the Dunn for biochemistry, and the Molteno for biology and parasitology, all at Cambridge University, as well as smaller laboratories at other universities, most notably Leeds and Oxford, attracted and accommodated gifted would-be molecular biologists as well as investments by American philanthropic foundations.

Political culture and science policy in the last days of the British Empire

The political culture in Great Britain in the 1930s proved inspiring for innovative scientists in molecular biology, since it provided a favourable atmosphere for seeking solutions to social, economic, and scientific problems. The economic crisis of 1929, which led to the Great Depression, brought about the collapse of the gold standard, hunger marches, 'social unrest' and the falling of the Second Labour Government. Eventually, a National Unity government was established, signalling new opportunities in the domestic, social, and political life of a country that also served as the hub of a large Empire. Despite its great losses in human lives during World War I, Great Britain emerged as the major winner, especially since the country itself did not suffer from destruction and its Empire only grew larger with colonial possessions of the defeated countries. This advantageous position was further accentuated by the fact that the United States, which emerged from World War I as the greatest creditor, refrained from exercising an active role in Europe due to its isolationist ideology.

However, the rise of fascism in Central Europe and later in Spain, soon turned the political attention to foreign affairs and to issues of rearmament. Once again, a wide political spectrum of options were debated, ranging from the reception of refugees from Central Europe, participation in the Spanish Civil War, and overt crises in foreign policy, most notably the Munich conference in November 1938. In this politically charged decade, the political culture swung from appeasement to rearmament while bringing the seriousness of the political situation home to all. Such global causes mobilised a great part of the population, with scientists being particularly active in contributing their share in both defence and nutrition for the civilian population.

This vibrant political culture, so receptive of participation by various types of politically sensitive scientists, is well illustrated in the life and career of J. Desmond Bernal, 1901–1971, the founder of the British school of molecular biology, as well as a prominent spokesman for Communist-inspired or led organisations such as the Association of Scientific Workers (Abir-Am 1992, Hodgkin 1980, Swann & Apprahamian 1999). He pursued his career in both Cambridge and London. After graduating from Cambridge University in 1923, Bernal spent a crucial part of his career there in the period 1927–1937 as a lecturer and then Director of the Structural Crystallography Laboratory (transferred from Mineralogy to the Cavendish Laboratory of Physics). In London he served as research assistant of Sir William Henry Bragg (1860–1943) at the Royal Institution from 1923–1927 and was from 1938 Professor of Physics at Birkbeck College. Bernal undertook innovative studies of the structure of biological compounds, ranging from sterols to proteins, viruses, and nucleic acids, all key research objects of molecular biology. The first ever protein X-ray photo, which he took in 1934, is considered to be the start of molecular biology in Britain (Abir-Am 1992).

Following almost two decades of innovative research in X-ray crystallography, instrumentation, and molecular biology, Bernal turned his attention increasingly to social and political issues, with a flair for utopian projects in both science and society. His masterpiece *The Social Function of Science*, published in January 1939, articulated his ongoing concern with the greater role that science could play in a society willing to benefit from its capacity to bring about social progress. At the time, in the dramatic aftermath of the Soviet presentations at the Second International Congress for History of Science held in London in 1931 (Abir-Am 1985, Swann & Apprahamian 1999), Bernal believed that Marxism was the only social and political ideology that recognised the crucial role of science in society. Together with other leftist British scientists he often visited the Soviet Union, regarded as the only country implementing the Marxist ideology.

The wide latitude of British political culture enabled Bernal, among other scientist colleagues of similar persuasion, upon the outbreak of World War II, to become a scientific adviser to the Home Ministry. There he used his expertise, acquired initially as part of pro-rearmament activism on behalf of the Association of Scientific Workers, in measuring the impact of bombing damage on buildings. In 1943, Bernal became scientific adviser to the Chief of Combined Operations, Lord Mountbatten of Burma, and played a role in using science for studying the Normandy beaches where the Allied landing was planned for D-Day, among various other operations considered or put into effect during the war (Swann and Apprahamian 1999).

Only in the late 1940s did the combined effect of the Cold War and the British Society for Freedom of Science, established by John Baker and Michael Polanyi, manage to isolate Bernal and prevent him from playing a role in British science. Then, he and some of his colleagues, most notably his former student and Nobel laureate Dorothy Hodgkin (1910–1994), came to play a major role in sustaining East–West scientific contacts, viewed as a bridge to world peace, with many visits to the Soviet Union (where Bernal received the Lenin Prize in 1953 and became close to Nikita Khruschev), China, Vietnam, but also to Europe and the United States (they were denied visas in the early 1950s but were later given visas to participate in scientific congresses in North America).

The ideological subculture of scientists as antifascist public intellectuals

Another aspect of British culture that was conducive to the rise of inter-disciplinary fields such as molecular biology was the role of scientists as anti-fascist public intellectuals, most notably in the arena of aid to displaced academics from Nazi Germany. Even conservative figures such as Lord Rutherford, the Director of the Cavendish Laboratory, chaired the Aid Committee for the Defence of Learning. This stance further encouraged scientist refugees to stay in Great Britain, including future Nobel laureates in the biomolecular sciences such as Hans Krebs and Max Perutz. This mattered for the future of molecular biology, since with the departure of Bernal from Cambridge University in 1938, and until 1947, when the MRC established at the Cavendish Laboratory a small unit for the 'molecular structure of biological compounds', Perutz, an Austrian research student who became a refugee in 1938 with the annexation of Austria, but whose work on the structure of haemoglobin, or the 'molecular lung', became one of the paradigms of molecular biology, remained the only person active in molecular biology. Perutz's success in making protein X-ray crystallography appeal to the new Cavendish Professor, Sir Lawrence Bragg, ensured the future of molecular biology at Cambridge.

The institutional culture of science in Great Britain in the 1930s

The favourable climate for molecular biology in Great Britain in the 1930s also depended on several laboratories of international renown, which attracted talent, local as well as foreign, and support from private foundations, both British and American. The Rockefeller Foundation's new investment strategy after its reorganisation in the period 1928–1932 (Abir-Am 1982, 2000) emphasised not only excellence as it had in the 1920s, but mainly the transfer of physico-chemical techniques to biology. Hence, projects at the Dunn Institute of Biochemistry or at the Molteno Institute for Biology and Parasitology, both at Cambridge University, received priority with Rockefeller Foundation investments. A similar priority was given to biomolecular projects at the Universities of Leeds and Oxford.

This institutional infrastructure facilitated the recruitment of research assistants and new equipment, thus participating in a fluid growth of the scientific labour force and its instruments of production. While the Dunn Institute of Biochemistry received support from local and American philanthropy, from the MRC, and from the University, the Cavendish had support from DSIR and the University, as well as industry such as I.C.I. Similarly, the Molteno Institute of Biology received support from local and American philanthropy, as well as from the University.

The scientific subculture of each laboratory proved conducive to the rise of molecular biology, especially since the inter-disciplinary outlook of directors such as the Nobel laureates Frederic Gowland Hopkins, PRS, at the Dunn Institute since World War I, Sir Lawrence Bragg at the Cavendish since 1938, and David Keilin at the Molteno Institute, also since World War I, provided not only temporary accommodation of the early would-be molecular biologists in these laboratories during the 1930s but also led to their joining forces in obtaining government sponsorship in 1947. The gentlemen's culture of the time ensured that a meeting at the Atheneum Club between Bragg (acting at the suggestion of Keilin who was active on many committees of scientific institutions and as adviser to governmental departments) and Sir Edward Mellanby, the MRC Secretary, was sufficient to put a new unit in place.

This act was followed, on a larger scale and with greater bureaucratic procedure, by their respective successors, Max Perutz and Sir Harold Himsworth who expanded the 1947 unit into a large laboratory, to be called the MRC Laboratory of Molecular biology throughout the 1950s. In 1962 the Queen inaugurated this laboratory shortly before three of its members, Perutz, John Kendrew (1916–1997), and Francis Crick (1917–) received the Nobel prize, the first such prize for work in molecular biology, for solving the first structures of proteins and nucleic acids.

Work in molecular biology also began in the 1930s at the University of Leeds in the laboratory of the physicist William T. Astbury (1898–1961) who specialised in the X-ray crystallography and electron microscopy of fibrous proteins and nucleic acids (Abir-Am 1982, Olby 1974); in the laboratory of the chemist Dorothy Crowfoot Hodgkin (1910–1994) at Oxford University, especially on proteins and sterols; as well as the Mathematical Institute at Oxford University where the mathematician Dorothy Wrinch (1894–1976) developed the first theory of protein structure, a theory that focused the international discourse on molecular biology in the 1930s (Abir-Am 1987a,b).

The latitude provided by the British political culture in the 1930s, the ideological culture of anti-fascist mobilisation by public intellectuals including many scientists, and the specific subcultures of leading laboratories in biochemistry, physics, biology, chemistry, and mathematics, were key elements in producing a cultural context conducive to the rise of molecular biology in Britain in the 1930s, and to the

A construction of plastic tubes representing the human cell, in an international scientific conference of 1959. Keystone

retention of a leading position into the early 1960s.

With the outbreak of World War II, scientific research in molecular biology was severely curtailed in Great Britain as Bernal, the leading figure in the field, was mobilised for the duration of the war while his laboratory at Birkbeck College was bombed and rendered inoperative during the Battle of Britain. His students, research associates, and equipment were transferred to Dorothy Hodgkin's laboratory at Oxford University, in a countryside safe from war hostilities, where, however, war exigencies required that the major research effort be put into the solution of the structure of penicillin. This bioorganic compound had great medical relevance and its solution became a landmark in the acceptance of X-ray crystallography by organic chemists, but it did not involve work at the macromolecular level that was to become the hallmark of molecular biology. Work pertaining to proteins and viruses was limited to completing prewar projects such as a doctoral thesis on the structure of lactoglobulin, one of the proteins first examined by Bernal and his associates in the late 1930s, and an unfinished paper on the structure of the tobacco mosaic virus, also started by Bernal and his associates in the mid-1930s (Abir-Am 1992).

Work on protein X-ray crystallography at Cambridge University was also curtailed due to the internment of Max Perutz as an enemy alien, and his later recruitment for the war effort. Bernal's laboratory in London was rebuilt after the war and reopened in 1948; Hodgkin's laboratory grew modestly but steadily, while new units for the study of biomolecular structures were opened at King's College, London and in the Cavendish Laboratory at Cambridge – the latter two becoming the sites for the discovery of the structure of DNA and of the first proteins, for which the first Nobel prizes for molecular biology were awarded in 1962. But the most rapid growth of molecular biology in the 1940s took place in the US. The context of American culture sustained forms of molecular biology different from the protein X-ray crystallography that gave birth to this discipline in Great Britain in the 1930s. These forms came to be associated with quantum chemistry on the one hand, and with phage genetics on the other hand.

American culture and molecular biology in the 1940s

Much as in the case of British culture's impact on molecular biology in the 1930s, American culture in the 1940s can be viewed as having three dimensions: the political culture at large of an emerging superpower and its derivative science policy, including the establishment of the National Science Foundation (hereafter NSF); the ideological subculture of public intellectuals, especially scientists among them; and the institutional culture of science at a time of great restructuring, due to prominent uses of science in strategic and civilian projects during and after the war.

Political culture and science policy of the United States, the first nuclear superpower

American scientists such as Irving Langmuir, Max Bergmann, Linus Pauling, Carl Niemann, and David Harker, participated in the discourse on molecular biology in the 1930s, especially as it centred on the first theory of protein structure. While they agreed with the British scientists that protein structure was the most important problem to solve, some of the Americans, most notably Pauling and Niemann, disagreed with the British approach of doing this experimentally, the so-called 'direct method' championed by Bernal and his associates, which aspired to solve all the reflections in the diffraction patterns of proteins obtained by X-ray crystallography. They also disagreed with the theoretical and mathematical approach advocated by the British mathematician Wrinch which emphasised the role of symmetry and geometry in structural solutions. Instead, they favoured an 'indirect method' based on quantum chemistry considerations for solving the structure of the amino acids, the building blocks of proteins, as well as the links between them.

Though such work began in the late 1930s, it greatly expanded in the 1940s, due to Pauling's success in obtaining large-scale governmental, industrial, and philanthropic support for the presumed medical applications of such work, especially in the domain of artificial antibodies. Though this project was poorly rated by a panel of experts at the end of World War II, its large-scale resources enabled Pauling to advance work on protein structure, eventually discovering in the late 1940s the alpha-helix, or a type of three-dimensional structure occurring in many proteins. Pauling's triumph, published in 1951 while replacing previous models of protein structure published in 1950 by the British team of Bragg, Perutz, and Kendrew, signalled the efficiency of American culture in sustaining innovative science in the 1940s in a manner reminiscent of the large-scale conquest of the western frontier, so typical of American culture.

Whether during World War II, when the scale of Pauling's immunochemical research intensified as a war-related project; or after the war, when the incipient Cold War led to large-scale support of science by the US, then basking in its unique status as the first nuclear superpower, molecular biology became one of the great beneficiaries of American science policy. Pauling sought and obtained research grants in the range of a million dollars. Reflecting America's new position as the nuclear vanguard of the world, this science policy was part and parcel of a political culture that regarded science-based global strategy and power, as exemplified by the atomic bomb, as a cornerstone of its domestic and international politics (Abir-Am 1992/3, 1997). Molecular biology, often referred to as biophysics, became attractive to physicists not only as a new arena to colonise with physical technologies, but also as a result of its capacity to 'redeem' the sins of physicists in detonating the atomic bombs by putting their skills into the service of saving lives (Judson 1979, Rasmussen 1997).

However, American political culture had another dimension that proved crucial for the rise of molecular biology in the US. This pertained to America's ability to integrate scientist refugees rapidly. Indeed, yet another approach to molecular biology in the US, an approach focused on the study of phage genetics, was made possible by a partnership during the war between two recent refugees from Italy and Germany respectively, Salvador Luria and Max Delbruck, two American scientists, Alfred Hershey and Thomas Anderson, and an *emigré* scientist, Milislav Demerec. During World War II, these five joined forces to collaborate on phage genetics, while laying the foundations to the so-called Phage Group. This informal group greatly expanded after 1945 when active recruitment of both American and *emigré* scientists began via summer schools at the Cold Spring Harbor Laboratory in Long Island, New York (Abir-Am 1998, 1999).

The ideological inspiration of American scientists as public intellectuals

In addition to the favourable political culture of the 1940s, whether expressed directly in science policy currency, or indirectly via speedy integrative opportunities for refugee and *emigré* scientists, the rise of molecular biology in the US further benefited from the association of its scientists with a variety of public causes that supplied an important ideological aura of social conscience. For example, Leo Szilard, an architect of the Manhattan Project who switched to molecular biology after the war, was among the founders of the Bulletin of Atomic Scientists and the Division for Social Responsibility of Scientists of the American Association for the Advancement of Science (AAAS), and often spoke against the use of the atomic bomb. At the same time, Szilard served as a governmental adviser in the then science-dependent Department of Defense, the Office for Naval Research, and numerous other related bodies, all grappling with the new need for science policy. However, in New York City the confinement of the persona of the public intellectual to literary and artistic figures, meant that American scientists began fulfilling the role of public intellectual only during the McCarthy era, when their own freedom was impaired by a strong, anti-communist ideological witch-hunt.

Indeed, molecular biology in the US was hurt by the ideological obsession of US government during the McCarthy era. Visas were denied to scientists suspected of leftist inclinations, most notably those who took a public stance against the oath requirements at the time, which forced faculty members to swear that they were not communists. In the same vein, the denial of visas to Salvador Luria and Linus Pauling to attend scientific meetings in Great Britain in the early 1950s, prevented them from learning new scientific information concerning the role and structure of DNA, with the effect that both missed key advances. Similarly, the denial of US visas to leading British molecular biologists, most notably J. D. Bernal and Dorothy C. Hodgkin, and to the French Jacques Monod, also a leading figure in molecular biology, prevented mutually useful scientific exchanges from taking place.

The institutional culture of American biomolecular science in the 1940s

The rise of molecular biology in the US in the 1940s also built on concrete institutional cultures, most notably the Cold Spring Harbor Laboratory on Long Island, New York where the initial collaboration between the founders of the Phage Group took place in the relaxed atmosphere of a regional inter-university laboratory resembling the informality of marine biological stations, while servicing the dual needs for science and leisure of the Greater mid-Atlantic community. This is also the institution that helped recruit the new generation of disciples in phage genetics in the post-1945 era. A more thorough survey of pertinent scientific institutions for the rise of molecular biology in the US, especially on the West Coast and in the mid-West (most notably the Chicago triangle) or the institutional clusters in Northern and Southern California, is beyond the scope of this paper (Abir-Am 1998).

To summarise, the rise of molecular biology in the US in the 1940s, whether in the form of structural chemistry expanding into biology as in the alpha-helix discovery; or in the form of phage genetics, as in the Hershey–Chase experiment on the respective roles of proteins and DNA in phage multiplication and Benzer's work on the gene's fine structure, benefited from three cultural factors. These were a political culture reflecting the emergence of the US as the only nuclear superpower; an ideological culture reflecting the public role of molecular biologists in combating communist phobia; and an institutional culture of fluidity, especially the informality and hospitality of a key institution, the Cold Spring Harbor Laboratory. This convergence increasingly gave the American scientists an edge, that increased in the post-Sputnik period, with the effect that after the late 1960s, the majority of Nobel prizes in molecular biology were given to American scientists.

Nevertheless, between 1962 when four out of five Nobel prizes in molecular biology went to British scientists and 1968, when American predominance began to be felt in this field, the French prominence also needs to be accounted for. In 1965 all three Nobel prizes in molecular biology went to French scientists. The following section explores how the French cultural context may have assisted molecular biology to rise to prominence in France during the 1950s.

French culture and molecular biology in the 1950s

As British and American examples, the impact of French culture on molecular biology in France in the 1950s can be viewed as having three dimensions. First, there was the political culture of an unstable Fourth Republic struggling with various colonial crises amidst relative domestic prosperity due to the Marshall Plan and the GATT agreement. Although unable to implement its own innovative thinking in science policy, the Republic at least left latitude for entrepreneurial scientists to seek funding elsewhere, usually with American foundations or governmental agencies. Second, the ideological subculture of public intellectuals, prominent as it had always been in France ever since the Dreyfus Affair and Emile Zola's manifesto *J'accuse* in 1898, attracted scientists including molecular biologists. Last, the institutional culture of science, especially the glorious tradition of the Pasteur Institute, enabled molecular biology to grow outside the rigid universities, which were reformed only in the aftermath of the May 1968 events.

French molecular biologists and their foreign colleagues trace the beginning of molecular biology in France to 1921, the year when the most senior among the three French Nobel prize-winners in 1965, Andre Lwoff (1902–1994), arrived at the Pasteur Institute in Paris where he eventually established a department of Microbial Physiology – the unit in which molecular biology first developed in France. But the inter-war period in France is historically important only as a chapter in Lwoff's biography, including in particular his loose collaboration with Jacques Monod beginning in the 1930s. Major steps toward the rise of molecular biology as a discipline were taken after World War II, when Lwoff was able, due to the creation of a governmental body for the support of research, the CNRS (Conseil National pour la Recherche Scientifique) to accept key staff in his laboratory on a permanent basis. Jacques Monod (1910–1976) was appointed as Chef de Laboratoire in 1945; the M.D.s Elie Wolman (1917–) and Francois Jacob (1920–) came as Lwoff's Ph.D. students in 1947 and 1950 respectively, and many other French and foreign scientists flocked to Lwoff's laboratory in the same period (Abir-Am 1999, Lwoff & Ullmann 1979).

Indeed, Lwoff's discovery of lysogeny in 1950 provided the French group with its first major achievement, heralding more than a decade of incredibly outstanding work, culminating with the operon model of genetic regulation of protein expression, a major theoretical edifice of molecular biology (Abir-Am 1998, 1999, Morange 1998). How did the French political culture of the time, the ideological subculture of the French public intellectual, and the institutional culture of the Pasteur Institute, interact so as to sustain the creativity of the French school of molecular biology?

Political culture and the science policy of an unstable Fourth Republic

The political culture of the Fourth Republic, lasting from 1945 to 1959 when Charles De

Gaulle became President of the Fifth Republic inaugurating a stable regime for the rest of the century and beyond, revolved around chronic governmental instability, largely though not entirely due to disasters in foreign and colonial affairs, most notably in Indochina and North Africa. On the domestic front, the incomplete judiciary handling of collaboration with the Nazi occupier during the Vichy regime left many subjects out of the public discourse, and a pretence that everyone was in the Resistance continued to prevail until the late 1980s. With the onset of the Cold War, France began to dismiss communists (who made up the majority of the Resistance) from high state positions. For example, the Nobel laureate Frederic Joliot-Curie, son-in-law of the legendary Marie Curie, was dismissed from the position of High Commissioner of Atomic Energy in 1950. A 'red scare' was also evident in the dealings of French scientists with American philanthropic foundations in the early 1950s, with the latter suspecting that the CNRS itself was vulnerable to communist control (Abir-Am 2000).

At the same time, this period produced remarkable statesmen (Pierre Mendes-France, Maurice Schuman, Jean Monet) as well as an impressive democratic process. As far as science policy is concerned, it displayed a progressive concern with upgrading the French scientific infrastructure, as evident from the Colloque de Caen, a conference of governmental figures and science advisers who pronounced on a series of proposals for reforms in the science and technology base of France. While this progressive concern with the role of science in modernising the country led to expanding the CNRS, governmental instability made it difficult to implement long range or large-scale reforms.

However, this volatile context encouraged an entrepreneurial behaviour of scientists vis-à-vis foreign sources of funding, which in practice meant the American governmental agencies in life and biomedical sciences, the NSF (National Science Foundation) and the NIH (National Institutes of Health), as well as private foundations based in the US, most notably the Rockefeller Foundation and the National Foundation for Infantile Paralysis. American funding led in its turn to upgrading the equipment in French laboratories, as well as to accepting many American scientists as visitors to the Pasteur Institute. The large network of collaborative contacts in the US maintained by the leaders of the French school of molecular biology further provided them with numerous invitations to lecture there, thus being able to keep informed of the fast moving scientific frontier.

This situation was very beneficial for the French school of molecular biology whose work came to be well known in the US. The great reception of French discoveries throughout the 1950s, especially in the US, paved the way to the triple Nobel prize to French molecular biologists in 1965, the first such prize to be awarded to French scientists in 30 years. In addition to the indirect incentives that the French political culture provided during the 1950s in encouraging strong contacts with American science and scientists, the rise of molecular biology was also influenced by the ideological subculture of the French public intellectuals at the time.

The ideological subculture of French scientists as public intellectuals

The main opportunity for French scientists to step into the much-cherished role of public intellectuals came in 1948 with the Lysenko Affair. The denouncing of classical genetics by Lysenko and his backers in the Soviet Communist Party forced French scientists to take sides. While some staunch Stalinists sided with the pro-Lysenko group, which included communists loyal to the Soviet Union, other scientists, including Jacques Monod, articulated in public and in newspapers their disagreement with the intervention of the Soviet Communist Party into science in general, and genetics in particular.

Yet another opportunity for taking a stance as a public intellectual came in 1952 when Monod, among most other French scientists, protested the death sentence given in the US to the Rosenbergs, who were convicted of espionage for the Soviet Union. Both Monod and Lwoff favoured Camus' side in his debate with Sartre, thus suggesting that the scientists' ideological preference differed from that of philosophers and literary intellectuals who had habitually identified with Sartre and de Beauvoir's brand of socialist existentialism and political activism, against both Camus and Raymond Aron's liberalism. The participation of several molecular biologists in the Colloque de Caen further attested to their willingness to shape civic discourse on the place of science in society. Yet another cultural aspect affecting the rise of molecular biology in France pertains to the institutional culture of the Pasteur Institute, a private institution established with public donations, yet considered a national treasure.

The institutional culture of science: the Pasteur Institute's special legacy

The special status of the Pasteur Institute, as independent of state bureaucracy and capable of generating its own revenue through an arm of serum and vaccine production, explains the relative degree of freedom available to its scientists, especially in seeking foreign funds. In addition to the prestige of the Institute as the legacy of a legendary figure who proved a saviour for his country on several occasions in matters of public health and key industries (beer, wine, silk) this status provided molecular biologists with a much-needed flexibility that was missing from the more bureaucratic governmental laboratories and universities.

Still, by the mid-1960s they revolted against the concentration of decision power in the hands of a few directors close to Pasteur's family and trained as medical doctors, while writing a new constitution for the Institute. Most interestingly, with the ascent of Monod and Wollman as Director and Associate Director in the early 1970s, the formerly marginal molecular biologists came to run the Pasteur Institute ever since, changing its public face from an institution with a predominantly medical orientation and monopoly holder in producing vaccines, to one best known as a major research institute of international renown. The desire to transform the Pasteur Institute from a centre of applied science to one of basic science inspired much of the *gai savoir* during the 1950s, with an atmosphere invariably recalled as conducive to creativity, collegiality, and innovation.

Conclusions

This article suggests that British, American, and French cultures successively modulated the rise of molecular biology in the period 1930–1960. This has been ascribed to political culture and its derivative science policy, the ideological appeal of scientists as public intellectuals, and the institutional (i.e., both social and material) culture that prevailed in sites where molecular biology flourished. With the process of scientific globalisation beginning in the 1960s (Abir-Am 1992/3, 1997), the role of culture, whether national, political, ideological, or institutional in its dual, social and material dimensions, in stimulating scientific innovation, has become more difficult to assess. This is illustrated by the establishment of the European Molecular Biology Laboratory (EMBL), which was contemplated in the early 1960s and became operational in the mid-1970s. This is a supranational facility based neither in Britain nor France, the two countries that pioneered molecular biology in Europe, but in Heidelberg, Germany.

Though the cosmopolitan institutional culture of international laboratories such as CERN or EMBL is instrumental in stimulating scientific exchange and collaboration beyond national, political, or linguistic and cultural barriers, it still remains a matter of conjecture whether the stimulating cultural contexts that formerly sustained the diversified legacy of this increasingly influential discipline will totally disappear. A new equilibrium is yet to emerge between the linguistically sustained cultural context of science and the emerging multiculturalism of large-scale political formations that are increasingly appealing to the political sensibilities of the twenty-first century. This will be played out at levels other than that of the nation state, for example the region, the institution, or the supranational laboratory.

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References

ABIR-AM, P. G. 1982. "The discourse on physical power and biological knowledge in the 1930s: A reappraisal of the Rockefeller Foundation's 'policy' in molecular biology", *Social Studies of Science,* 12: 341–382.

ABIR-AM, P. G. 1985. "Recasting the disciplinary order in science: A deconstruction of rhetoric on 'biology and physics' at two International Congresses in 1931", *Humanity and Society,* 9 (November 1985), 388–427.

ABIR-AM, P. G. 1987a. The Biotheoretical Gathering, transdisciplinary authority and the incipient legitimation of molecular biology in the 1930s", *History of Science*, 25: 1–70.

ABIR-AM, P. G. 1987b. "Synergy or clash: Disciplinary and marital strategies in the career of the mathematical biologist Dorothy M. Wrinch' in P. G. Abir-Am & D. Outram (Eds), 1987. *1989. Uneasy careers and intimate lives, Women in Science, 1789–1979*. New Brunswick N.J. and London: Rutgers University Press, pp. 338–394.

ABIR-AM, P. G. 1992. "A historical ethnography of a scientific anniversary in molecular biology: The first protein X-ray photo (1984, 1934)", *Social Epistemology,* vol. 6, 1992, 323–354; 363–364; 371–372; 380–387.

ABIR-AM, P. G. 1992/3. "From multi-disciplinary collaboration to transnational objectivity: International space as constitutive of molecular biology, 1930–1970", in E. Crawford, T. Shinn & S. Sorlin (Eds), *Denationalizing Science: The International Context of Scientific Practice*. Dordrecht: Kluwer Academic Publishers, pp. 153–186.

ABIR-AM, P. G. 1997. "The molecular revolution in 20th Century biology: Three eras of post-war transdisciplinary stability" in J. Krige and D. Pestre (Eds), *Science in the 20th Century.* London: Harwood, pp. 495–520.

ABIR-AM, P. G. 1998 (Ed.) *La Mise en Memoire de la Science: Pour une Ethnographie Historique des Rites Commemoratifs*. Paris: Editions des Archives Contemporaines/ Gordon & Breach Publishers.

ABIR-AM, P. G. 1999. "The First American and French Commemorations in Molecular Biology: From Collective Memory to Comparative History", in Abir-Am P. G. and C. A. Elliott (Eds), *Commemorative Practices in Science: Historical Perspectives on the Politics of Collective Memory.* Chicago: Chicago University Press, pp. 324–370.

ABIR-AM, P. G. 2000. "The Rockefeller Foundation and Refugee Biologists: European and American Careers of Leading RF Grantees from England, France, Germany, and Italy" in G. Gemelli (Ed.), *The "Unacceptables". American Foundations and Refugee Scholars between the Two World Wars*. Brussels: Presses Interuniversitaires Europeenes, pp. 217–240.

DE CHADAREVIAN, S. & H. KAMMINGA (Eds) 1998. *Molecularizing Biology and Medicine, 1910s–1970s*. London: Gordon and Breach.

FRUTON, J. S. 1972. *Molecules and Life*. New Haven: Yale University Press.

HODGKIN, D., 1980. "J. D. Bernal, 1901–1971", *Biographical Memoirs of Fellows of the Royal Society,* 1–80.

HOLMES, F. L. 1991 (vol. 1) and 1993 (vol. 2). *Hans Krebs and the Fine Structure of Discovery*. Cambridge, MA: Harvard University Press.

JUDSON, H. F. 1979. (republished 1993). *The Eighth Day of Creation, The Makers of the Revolution in Biology*. New York: Simon and Schuster.

KOHLER, R. E., JR. 1982. *The Rise of Biochemistry: The Making of a Biomedical Discipline.* New York: Cambridge University Press.

KORNBERG, A. 1989. *For the Love of Enzymes*. Cambridge, MA: Harvard University Press.

LWOFF, A. & A. ULLMANN (Eds), 1979. *Origins of Molecular Biology. A Tribute to Jacques Monod*. New York: Academic Press.

Morange, M. 1998. *A History of Molecular Biology*. Cambridge, MA: Harvard University Press.

Olby, R. C. 1974 (republished 1994). *The Path to the Double Helix*. London: Macmillan.

Rabinow, P. 1999. *French DNA*. Chicago: University of Chicago Press.

Rasmussen, N. 1997. "The mid-century biophysics bubble: Hiroshima and the biological revolution in America, revisted". *History of Science*, 35: 245–296.

Sarkar, S. 1998. *Genetics and Reductionism*. New York: Cambridge University Press.

Swann, B. & F. Apprahamian (Eds), 1999. *J. D. Bernal: A Life in Science and Politics*. London: Verso.

Wright, S. 1994. *Molecular Politics*. Chicago: University of Chicago Press.