



Institutionalizing molecular biology in post-war Europe: a comparative study

Bruno J. Strasser

*Institute for the History of Medicine and Health, University of Geneva, CH-1211 Geneva 4,
Switzerland*

Abstract

The intellectual origins of molecular biology are usually traced back to the 1930s. By contrast, molecular biology acquired a social reality only around 1960. To understand how it came to designate a community of researchers and a professional identity, I examine the creation of the first institutes of molecular biology, which took place around 1960, in four European countries: Germany, the United Kingdom, France, and Switzerland. This paper shows how the creation of these institutes was linked to the results of post-war economic reconstruction. Then, it compares how the promoters of these different institutional projects delimited the goals of their discipline, reflected on its history, and suggested how research should be organised. I show how they carefully positioned their new discipline within the emerging national science policy discourse of the 1950s, and aligned it with the current vision of scientific modernity. In particular, I discuss how they articulated the meaning of molecular biology with respect to five common themes: the role of physics in the atomic age, the relations between fundamental research and medical applications, the ‘Americanisation’ of scientific research, the value of science in the reconstruction of national identities, and the drive towards interdisciplinary research. This paper thus demonstrates that beyond the local and national accounts there is a European history of molecular biology.

© 2002 Elsevier Science Ltd. All rights reserved.

Keywords: Molecular biology; Post-war Europe; Institutional history; Reconstruction; Americanisation; Atomic age

E-mail address: bruno.strasser@medecine.unige.ch (B.J. Strasser).

1. Introduction

In September 1963, 25 scientists from Europe, the United States, and Israel met in Ravello (Italy), where they decided to set up a European Molecular Biology Organisation (EMBO). They elected a provisional executive committee composed of researchers from very different scientific backgrounds: crystallography (Max Perutz and John Kendrew from the United Kingdom), microbiology (François Jacob from France and Ole Maaløe from Denmark), biochemistry (Hans Friedrich-Freksa and Adolf Butenandt from Germany), biophysics (Edouard Kellenberger from Switzerland, Charles Sadron from France and Arne Engström from Sweden), physical chemistry (Alphonso Liquori from Italy and Ephraim Katchalski from Israel), embryology (Jean Brachet from Belgium) and genetics (Adriano Buzzati-Traverso from Italy).¹ In the following months, they invited 140 other prominent scientists to join the organisation.

A decade earlier, however, most of these researchers had not known each other, and were hardly interested in each other's work. They had identified themselves, not with molecular biology, but with the speciality in which they had acquired their training. According to John Kendrew, in the 1940s and 1950s, phage geneticists and crystallographers for example, were 'almost entirely isolated from each other' (Kendrew, 1967, p. 141). In 1963, both communities considered their research to be at the centre of a new field called molecular biology.

It was only shortly before the foundation of EMBO that the term 'molecular biology' acquired its social reality and began to be used in Europe and in the United States to identify a field of research, a professional identity, and the research institutions associated with it. The *Journal of Molecular Biology*, for example, was founded in 1959 under the leadership of John Kendrew. Between 1957 and 1962, several of these future EMBO members designed large scale projects that were addressed to national funding agencies, in order to create institutions devoted to their new field in Germany, Britain, France, Italy, Switzerland, and Belgium. In the sense that they led to the creation of the first institutes of molecular biology in their respective countries, these various projects were demonstrably successful in contributing to the establishment of the field.

The institutional history of recent scientific fields is usually framed within a local or national perspective, and historians of science have now, generally speaking, moved away from 'top-down' master narratives to more confined accounts. The history of molecular biology is no exception, as can be seen, for example, in Lily Kay's masterly study of the 'molecular vision of life' at the California Institute of Technology (Kay, 1993). Similarly, the rise of molecular biology in Europe has recently been studied through two of its key institutions, the Pasteur Institute in Paris and the Medical Research Council laboratory in Cambridge (Gaudillière, 1993; Gaudilli-

¹ J. Kendrew, 'Summary of the proceedings of a meeting held at Ravello on September 16 & 17, 1963 to discuss European Co-operation in Fundamental Biology', 29 October 1963, EMBO Archives, Heidelberg, Germany.

ère 2002; de Chadarevian, 1994; de Chadarevian, 2002). In these studies, local factors—such as personal networks and particular organisational configurations—play a crucial role in the institutionalisation process, along with national factors, such as national research traditions, academic systems, science policy, and the war legacies. The very different national war-time experiences, for example, were shown to affect profoundly the development of molecular biology in the post-war period (Gaudillière 2002; de Chadarevian 2002; Deichmann, this issue). In the United States, and to a lesser extent in Europe, the Rockefeller foundation played an essential role in fostering the development of molecular biology. Thus, through their focus on local dynamics, these studies also address more global trends.

One might wonder, however, whether these more global trends could not profitably be identified by bringing different local stories, despite their contingent aspects, into a common perspective. In particular, could not the creation in Europe around 1960 of different new institutes for molecular biology be brought into a common framework extending beyond the national portrayals, since the promoters of these institutes, unlike their American counterparts, confronted comparable political, economic and cultural forces specifically related to the post-war European situation? Thus, could the European post-war context, rather than the very diverse national wartime experiences, provide a useful framework to compare these different cases? Could this shared framework highlight connections between the different cases and common factors not apparent in the national or local stories?² Since the promoters of these different institutes defined the meaning of molecular biology in their local context, would the comparison of these cases not permit a better understanding of the broad meaning that molecular biology had acquired at that time, at least in Europe?

In order to answer these questions, this paper proceeds via a ‘bottom-up’ approach. It re-examines and compares the institutionalisation of molecular biology in four local contexts that have been studied previously: Cologne (Germany), Cambridge (United Kingdom), Paris (France), and Geneva (Switzerland), and focuses more specifically on four projects that were submitted to national funding agencies for the purpose of creating new institutions devoted to molecular biology. As one would expect, a comparison between these four documents reveals the many differences arising from the various local and national contexts, but also the striking similarities consequent upon the post-war European situation. This comparison proceeds in two steps. First, it examines how molecular biology was construed, and second, how this new field was legitimised and acquired its broader meaning.

Focusing only on these institutional plans would, of course, be insufficient to draw meaningful comparisons between the four cases. I have relied therefore on broader archival work as well as on the detailed histories that can be found in the work of Soraya de Chadarevian on Cambridge (de Chadarevian 2002; de Chadarevian, 1996; de Chadarevian, 1994), Jean-Paul Gaudillière on France (Gaudillière 2002; Gaudilli-

² For a similar perspective, see Abir-Am (2001).

ère 1993; Gaudillière 1994, Chs. 1–2), Ute Deichmann on Cologne (Deichmann, 1996, Ch. 7) and my own on Geneva (Strasser, 2002a).³

Two main reasons have led to the choice of these four cases. Firstly, they include the two major players in the development of molecular biology in Europe, namely the Medical Research Council research group in Cambridge and the Pasteur Institute group in Paris, as well as two somewhat more peripheral groups.⁴ Secondly, each case documents the creation of the first institute of molecular biology in its respective national context.⁵

2. Local contexts

The German document was the first to be issued, on 20 November 1957. On that day, Joseph Straub, a professor of botany at Cologne University, addressed a long letter to the Deutsche Forschungsgemeinschaft (DFG), the main state agency supporting German research.⁶ Straub requested DM 2.5 million in order to found a ‘modern institute of genetics’ in the proximity of the university, comprising of five professorial chairs.⁷ One of these chairs was to be held for at least the first two years, by Max Delbrück, a German-born physicist who had emigrated to the United States in 1937 (Fischer & Lipson, 1988) and had become a major figure in phage genetics (he received the Nobel Prize in 1968) (Fig. 1). Genetic research was almost completely non-existent in the University of Cologne and, according to Straub, it would have been ‘almost impossible to find someone in Germany to hold the chair of genetics’.⁸ Delbrück was, from the start, closely associated with the development of the project for an institute of genetics in Cologne. The project was successful in that it led to the inauguration of the planned institute in 1962.

The British document had a similar aim to that of the German project. Francis Crick and Max Perutz, working as molecular geneticist and crystallographer respectively at the Medical Research Council Unit for Molecular Biology in Cambridge (a name the unit had acquired in 1957), proposed ‘setting up a large laboratory for

³ See also for France, Polanco (1990), and for Germany, Fischer and Lipson (1988, pp. 260–271).

⁴ Other cases could have been included, in particular the Italian International Laboratory of Genetics and Biophysics in Naples (Capocci & Corbellini, this issue) and the Belgian Department of molecular biology at the Free University of Brussels. However, the only comparable plans (in their aim and time-frame) that could be found, were the four projects discussed here.

⁵ In Germany, however, the renaming in 1960 of Alfred Gierer’s laboratory ‘molekularbiologische Abteilung’ at the Max Planck Institut für Virusforschung in Tübingen preceded the inauguration of the Cologne Institute (Anonymous, 1961).

⁶ J. Straub to the Deutsche Forschungsgemeinschaft, 20 November 1957, Delbrück papers, folder 21.5, Caltech Archives, Pasadena, United States. ‘German Plan’ hereafter.

⁷ The German document is the only one that does not explicitly mention ‘molecular biology’, but refers to it as ‘modern genetics’. This report can, however, be compared with the others, since it mainly described microbial genetic research under this label, which was understood as belonging to the field of molecular biology in the other reports.

⁸ ‘German Plan’, p. 8.



Fig. 1. Max Debrück and some members of the Phage group at Caltech in 1949. From left to right, Jean Weigle, Seymour Benzer, Elie Wollman, Max Delbrück, and Gunther Stent. Photograph by Ross Madden from Black Star. Courtesy of the Caltech Archives.

Molecular Biology' that would constitute a significant extension to the existing unit.⁹ They addressed their proposal to the Medical Research Council (MRC) on April 11th 1958. Most of the researchers at the MRC unit were investigating the structure of macromolecules. Max Perutz and John Kendrew, for example, were using x-ray crystallography for the study of the structure of haemoglobin and myoglobin (Fig. 2). Five years earlier, Francis Crick and James Watson had presented their double helix model for DNA, based on data obtained by the same technology. Hugh Huxley was studying muscle filaments by electron microscopy and Sydney Brenner had just started to work on bacteriophage genetics. The main change, in terms of the kind of research to be carried out, was the addition of a protein chemistry group headed

⁹ F. H. C. Crick and M. F. Perutz, 'The Case for a Laboratory of Molecular Biology', 11 April 1958, MRC 58/303, Public Record Office, Kew, Surrey, England. 'British Plan: The Case' hereafter. The document was accompanied by a 23 page overview of 'Recent Advances in Molecular biology', signed by Max Perutz, M. F. Perutz, 'Recent Advances in Molecular Biology', 2 April 1958, MRC 58/303, Public Record Office. Hereafter, 'British Plan: Recent Advances'.



Fig. 2. John Kendrew (left) and Max Perutz looking at a haemoglobin protein model in Cambridge, 1965. Courtesy of the Medical Research Council Laboratory of Molecular Biology.

by Frederic Sanger, who was then in the biochemistry department of the University of Cambridge (de Chadarevian, 1996). The proposal led, in 1962, to the inauguration of a new laboratory in a modern four-storey building (de Chadarevian, 1994). The approval for the report from the MRC was almost immediate, whereas the university authorities were more reluctant to accept the new laboratory (Perutz, 1987, p. 41). The same year, Max Perutz, John Kendrew, and Francis Crick, all from the laboratory, were awarded the Nobel Prize.

The French project was much larger in scope than the two previously mentioned. The Comité Français de Biologie Moléculaire signed a proposal addressed on March 8th 1960 to the new ministry of science, the Délégation Générale à la Recherche Scientifique et Technique (DGRST). The Committee aimed at doubling, within five years, the numbers of researchers in the field of molecular biology in France. This result was to be attained through the creation of new institutes, the training of young researchers, and the support of existing research groups. The Committee was composed of twelve leading scientists, five of whom were from the Pasteur Institute in Paris. Jacques Monod, who headed a biochemistry group there, wrote the first draft of the report (Fig. 3). Together with André Lwoff, who participated in the elaboration of the report and headed the microbial physiology laboratory at the Pasteur Institute and François Jacob, his collaborator, they received the Nobel Prize in 1965. The



Fig. 3. Jacques Monod in his biochemistry laboratory at the Pasteur Institute manipulating bacterial cultures, Paris 1965. Copyright Pasteur Institute Archives.

disciplinary backgrounds of the committee members were predominantly those of physical chemistry, microbiology, physiological genetics and biochemistry (Gaudillière, 1991).¹⁰ This broad project took many years for its realisation and led to the creation—often faced by strong resistance from the university and the Pasteur Institute—of several institutes of molecular biology in Paris and elsewhere, as well as to the recruitment of a number of new researchers (Polanco, 1990, p. 89).

The Swiss document was inspired by the French document, but its aim bore a greater resemblance to that of the British document. On 2 June 1962, biophysicists

¹⁰ Comité Français de Biologie Moléculaire, 'Rapport général sur la situation présente et l'action à envisager dans le domaine de la biologie moléculaire', March 1960, Fonds Monod, Mon.Ins.02., Service des Archives de l'Institut Pasteur, Paris, France. Hereafter, 'French Plan'. The proposal was accompanied by two appendices, one on recent developments in molecular biology in foreign countries, and another on the main research groups working in this field in France. For the French case, see Gaudillière (1991), chapter 2. For the Ephrussi group, not discussed here, see Burian and Gayon (1990); and on the fate of genetics in France and its link to molecular genetics, see Burian and Gayon (1999).

Edouard Kellenberger and biochemist Alfred Tissières presented a project to the Canton of Geneva political authorities and the Swiss National Science Foundation (FNRS). This proposed the foundation of an Institute of Molecular Biology in the University of Geneva, comprising the already existing biophysics laboratory (directed by Kellenberger) and a yet to be created biochemistry laboratory (directed by Tissières). The project required a 150% increase in the annual budget of the laboratory, as well as over a million Swiss francs for the equipment, and 2000 m² of laboratory space in a building to be constructed.¹¹ The researchers working in the existing biophysics laboratory (founded by the physicist turned biologist Jean Weigle) were predominately interested in electron microscopy and phage genetics (Fig. 4). Werner Arber, for example, was investigating the host range variations of bacteriophage, a work that earned him the Nobel Prize in 1978 for the discovery of restriction enzymes. Like the British plan, the main change envisaged for the new institute was the addition of a biochemistry group. The local political authorities and the Swiss National Science Foundation approved the project in 1962 and 1963 respectively (Strasser, 2002a).

These four documents have at least one common feature: they are all dated around 1960 and have led to the creation of the first institutions devoted to molecular biology in their respective countries. How can this simultaneity be explained? In each local context, institutionalising molecular biology involved obtaining considerable grants from the national funding agencies. Indeed, constructing new buildings to accommodate laboratories, buying expensive instruments and hiring a large number of researchers required sums that were far larger than those that local institutions could normally envisage, without even taking account of the possible resistance from the established disciplines.¹²

In the post-war period, the budgets, corrected for inflation, of the four funding agencies that began to support molecular biology, show the similar pattern of an unprecedented increase from the second half of the 1950s (Fig. 5). Between 1952 and 1962, the budget of the FNRS rose eight-fold, the DFG six-fold, the CNRS five-fold, and the MRC three-fold. These rises increased the financial means available to the funding agencies and thus allowed them to support new and larger research projects, such as those proposed by the molecular biologists. The institutionalisation of molecular biology in Naples (1963) and Brussels (1965) confirms this view since here too it was made possible by the new funding possibilities. Both cases, in fact, relied on large grants provided by the newly created European Atomic Energy Agency (EURATOM), which covered 30% and 40% respectively of the total expenditures.¹³

The increased budgets of the national funding agencies can be attributed to specific

¹¹ E. Kellenberger, 'Création d'un Institut de Biologie Moléculaire, Mémoire A', 12 January 1962, hereafter, 'Swiss Plan A'; and A. Tissières and E. Kellenberger, 'Institut de Biologie Moléculaire, Mémoire D', 2 June 1962, 'Swiss Plan D' hereafter, Archives of the University of Geneva, Geneva, Switzerland.

¹² For Britain in the 1960s, see Abir-Am (1992).

¹³ For Naples, see Capocci and Corbellini (this issue); for Brussels, see Errera (1997), p. 24.

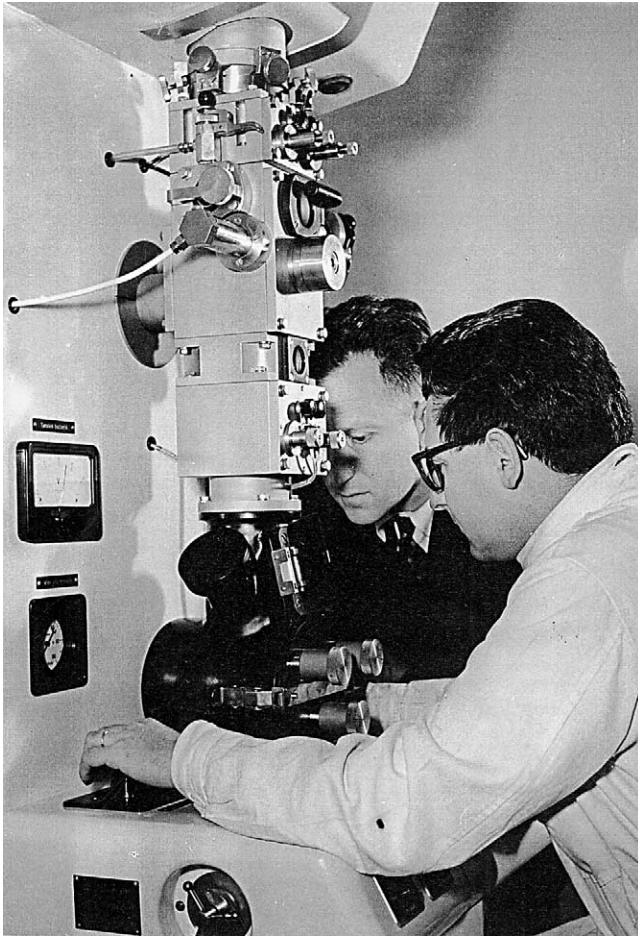


Fig. 4. Edward Kellenberger with the Swiss electron microscope, Geneva 1950. Copyright Keystone/Photopress-Archive.

science policy decisions taken by national governments, such as the creation of special funding programmes. Above all, however, it reflected the increased prosperity of the national economies (Strasser, 2002b, Ch. 9), resulting from the different national reconstruction programmes (Ellwood, 1992). Since the institutionalisation of molecular biology in the four countries studied here relied on the new prosperity of the national funding agencies, this offers a partial explanation for its occurrence in the different European countries at approximately the same time. This explanation is only partial because it does not clarify why this money was spent on molecular biology specifically. Thus, in a following section, I will show how the promoters of molecular biology were able to seize this favourable economic opportunity in order to gain financial support for their new field.

This increased funding of science, linked to European recovery, thus parallels a

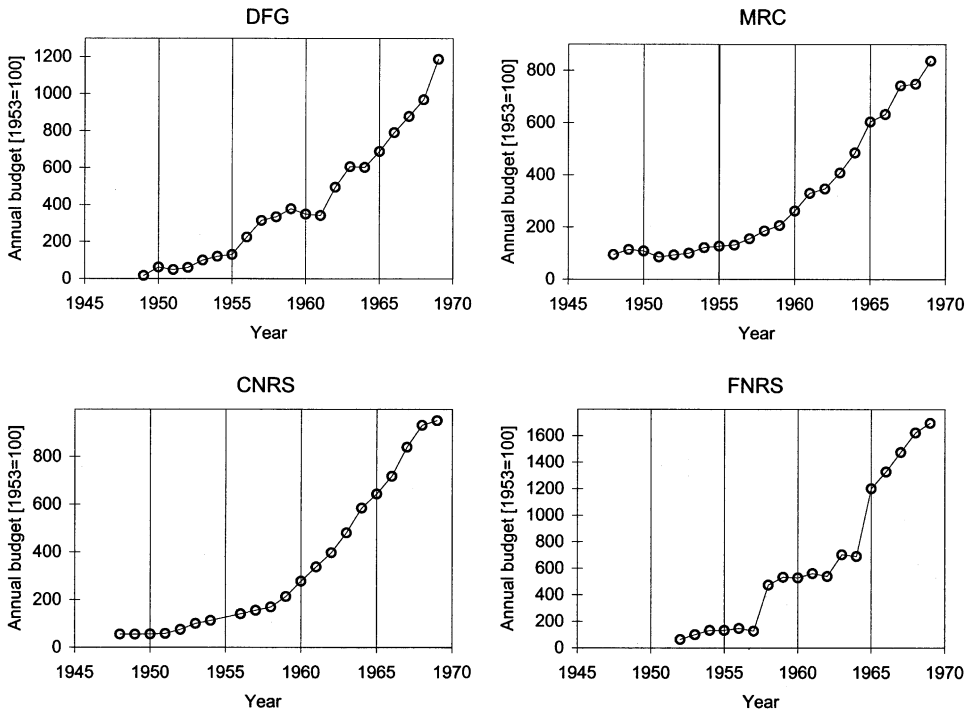


Fig. 5. Annual budget of the four funding agencies supporting molecular biology in Germany, the United Kingdom, France and Switzerland: respectively, the Deutsche Forschungsgemeinschaft (DFG), the Medical Research Council (MRC), the Centre National de la Recherche Scientifique (CNRS) and the Fonds National de la Recherche Scientifique (FNRS).¹⁴

similar increase in the United States, where it was associated with the ‘post-Sputnik race’ (Geiger, 1997). Indeed, the budget of two major federal patrons of molecular biology in the United States, the National Science Foundation and the National Institutes of Health, skyrocketed after 1957 and only terminated in late 1960 when the Vietnam war attracted money away from domestic priorities (Wright, 1994, pp. 21–25; Appel, 2000, p. 69). One important difference distinguishing the United States from the European countries, with the possible exception of Great Britain, remains: in the late 1950s, the funding of science had already been flourishing in the United States for more than a decade immediately following the end of World War II, whereas in Europe it was just beginning to rise significantly.

¹⁴ Data from the annual reports of each agency (Deutsche Forschungsgemeinschaft, multiple years); Landsborough Thomson (1973), p. 205; Centre National de la Recherche Scientifique (multiple years); Fonds National Suisse de la Recherche Scientifique (multiple years), corrected by national wholesale price deflator (Flora, 1983). For the French case, one should add the special program in favour of molecular biology, funded by the DGRST, which lasted ten years, beginning in 1960.

3. Defining molecular biology, its history and its social organisation

I now wish to take a closer look at the way in which the authors of the four documents defined the new field that they wished to institutionalise. In their proposals, they delimited the goals of their discipline, reflected on its history and suggested how research should be organised. In previous years, these authors had not identified themselves with molecular biology, but with disciplines such as biophysics, genetics, microbiology, or biochemistry. They therefore elaborated definitions of molecular biology that could encompass these different traditions within a common framework, in order to present it as a new, coherent and innovative field. A comparison of the four plans reveals that each definition was adapted to a local political agenda, but also revolved around a shared idea: the aim of molecular biology is to explain biological functions in terms of macromolecular structures.

Each of these different definitions of molecular biology had a very local dimension. The British report, for example, began by affirming that the ‘basic phenomena of living matter [should be] understood in terms of the interaction between molecules of known structures’.¹⁵ Such a definition placed the x-ray crystallography work of Perutz and Kendrew to the forefront. For the French authors, molecular biology came about through the convergence of two disciplines: genetics and biochemistry—genetics being understood as microbial (molecular) genetics, not classical genetics, and biochemistry, as enzymology or protein chemistry, not as the study of general metabolic pathways.¹⁶ Such a definition was neatly tailored to the situation of the Pasteurian groups, where the research teams of André Lwoff and Jacques Monod were strong representatives of each approach. Since the author of the Swiss document was directing a biophysics laboratory, he did not forget to add biophysics as one of the founding disciplines of molecular biology. Interestingly enough, biochemistry was not mentioned in the German document as a field participating in ‘modern genetics’, perhaps because of Max Delbrück’s disdain of biochemists (Kay, 1993, pp. 250–252).

Molecular biology, however, also assumed a shared meaning in the different reports. For the British authors, ‘The main object of setting up a large laboratory for Molecular Biology is to provide a focus in this country where structure and function . . . can be studied from a new unified point of view’.¹⁷ In a similar vein, for the authors of the French report, molecular biology was best characterised by its focus on the ‘problem of specificity of structure and action’.¹⁸ In the German document, ‘modern genetics’ was intended to explain how genes define the ‘morphology and function’ of their end products. The authors of the Swiss report were perhaps more explicit than the others in their appeal to a fundamental complementarity in

¹⁵ ‘British Plan: The Case’, p. 2.

¹⁶ An overview of the appendix listing the research groups that were involved in molecular biology in France confirms this interpretation. ‘French Plan’, Appendix.

¹⁷ ‘British Plan: The Case’, p. 2.

¹⁸ ‘French Plan’, p. 1, my own translation, as with all the following quotes from French, German and Swiss documents.

nature between molecular structure and function when they wrote that ‘the term molecular biology was created to indicate that its subject is to explain the biological function of certain macromolecules by the knowledge of their structure at the molecular level’.¹⁹ In addition, all the authors seemed to agree that molecular biologists were interested in only two classes of molecules: proteins and nucleic acids.

This common idea of a structure–function relationship entailed not only epistemological but also political consequences, especially in relation to the stability of the new discipline and its social structure. As the anthropologist Mary Douglas pointed out,

before it can perform its entropy-reducing work, the incipient institution needs some stabilising principle to stop its premature demise. That stabilising principle is the naturalisation of social classifications. There needs to be an analogy enabling the formal structure of a crucial set of social relations to be found in the physical world, in the supernatural, in eternity or anywhere else—as long as it cannot be seen purely as a socially contrived arrangement²⁰ (Douglas, 1986, p. 48).

It was precisely this structure–function relationship that the promoters of molecular biology took as an analogy in the natural world to stabilise the ‘socially contrived arrangement’ of their new discipline. Each research group derived from this idea whatever counted as relevant problems, methods and objectives, and which researchers therefore had to be included or left out of the new institution.

How did the authors of the different reports come to agree that the defining feature of their discipline was the explanatory relationship between molecular structures and functions? During the 1950s, several new biological facts were established that revealed crucial links between some of the different molecular approaches used to study biological problems. In particular, the demonstration in 1957 by Vernon Ingram in Cambridge that the mutation causing sickle cell anaemia resulted in a single amino acid change in the haemoglobin chain, confirmed the idea that genes specified the amino acid sequence of proteins (de Chadarevian, 1996; Strasser, 1999). Concurrently, different experimental approaches converged towards the idea that the amino acid sequence alone determined the three dimensional structure of proteins, and therefore their function (Strasser, 2001). These views, which became popular as the ‘Central Dogma’, a catchphrase coined by Francis Crick in 1957 (Crick, 1958), made it clear that genetics, protein biochemistry, enzymology, and crystallography could be complementary approaches for understanding the same problem, namely, protein synthesis. Research groups that had lived in relative isolation from one another (phage geneticists, crystallographers, and biochemists, for example) began to realise

¹⁹ ‘Swiss Plan D’, p. 2. ‘Structure’, however, meant something different in Geneva, compared with Cambridge. Whereas in Cambridge it referred essentially to x-ray crystallography, in Geneva it designated electron microscopy, one of the main research lines of the group.

²⁰ Mary Douglas is using the word ‘institutions’ in a broad sense here as ‘legitimised social grouping’, (Douglas, 1986, p. 46).

the full relevance of each other's work (Kendrew, 1967, 1970; Crick, 1980). The structure–function slogan aptly illustrated this interdisciplinary collaboration.

This particular definition of molecular biology excluded much biological research that was carried out at the molecular level. Photosynthesis research, for example, which was, as Doris Zallen has shown, once part of the broad definition of molecular biology in the 1940s (Zallen, 1996), was not included in the new disciplinary configuration of the 1960s since it borrowed more from physiological modes of thought than from a complementarity between structures and functions. Similarly, research in embryology was funded by the Rockefeller Foundation under the heading 'molecular biology' from 1938 (The Rockefeller Foundation, 1938), whereas twenty years later, the British authors stated explicitly that molecular biologists did not work in such fields as 'embryology, ecology, animal behaviour, the higher nervous system etc.'²¹

In all four cases, defining molecular biology as a trans-disciplinary field that included parts of genetics, biochemistry, microbiology, and biophysics, and borrowed methods from other disciplines (such as physical chemistry or immunology), posed a real challenge to the traditional social order of institutionalised life science based on the nature of the object being studied (animals, plants, humans). This was particularly true where molecular biology was to be introduced into a university.²² According to Delbrück in 1956, the Cologne report hoped to accomplish something that 'neither Lwoff [in Paris], nor Maaløe [in Copenhagen], nor Hayes [in London] have been able to accomplish, namely to carry modern biology right into a university set-up'.²³ Indeed, creating a department for molecular biology in a University meant 'breaking down the organisational deadlock in which biology finds itself all over the world, with Caltech [Delbrück's home institution] almost an unique exception'. The deadlock arose from 'the fact that departments of botany and zoology were created long ago, and that their creation and perpetuation has stunted the growth of genetics, biochemistry, microbiology, physiology etc. in the academic institutions'.²⁴ Indeed, molecular biology could be defined neither by the object it was studying—as in the main disciplines of biology (botany, zoology, and anthropology)—nor by the methods that were being used, since the latter came from various disciplines. The appeal, therefore, of the structure–function slogan served, under the cover of an epistemic programme, as an organising principle for the new discipline. As expressed by Pnina Abir-Am, the conception of scientific order was 'pluralistic, participatory and transdisciplinary' (Abir-Am, 1992, p. 171).

It is thus hardly surprising that, with the exception of Geneva, the development of molecular biology in post-war Europe began in research institutions, such as the Max-Planck Institutes in Germany, the MRC laboratory in Cambridge, and the Past-

²¹ 'British Plan: The Case' p. 2.

²² The difficult relationships between the MRC Molecular Biology Research Unit and the University of Cambridge (Perutz, 1987, p. 41), or between the Pasteurian group and the Parisian universities, show the resistance from academia towards the introduction of new transdisciplinary research space (Gaudillière, 1991, Ch. 2).

²³ M. Delbrück to G. Beadle, 6 September 1956, Delbrück papers, folder 2.10, Caltech Archives.

²⁴ M. Delbrück to G. Beadle, 6.9.1956, Delbrück papers, folder 2.10, Caltech Archives.

our Institute in Paris, rather than in the universities.²⁵ In all cases, its institutionalisation necessitated a resort to funding sources administered by a centralised agency (DFG in Germany, MRC in Britain, DGRST in France, and FNRS in Switzerland). In this way, the promoters of molecular biology could bypass the traditional university allocation mechanisms, which, unlike the American presidential scheme, were very much under the control of faculty members, and therefore conservative in respect to new emerging fields.²⁶

The production of the different reports was an ideal moment for a reflection on the short history of the field. All four documents, in fact, devote considerable space to the issue. This exercise was not purely academic since history, however short, was the primary source of legitimacy for the new discipline. Comparison of the four documents reveals two strategic lines of argument.

In the first place, the authors of each report tried to cast their own research tradition in a constitutive role for a ‘new biology’. The German and the British reports in particular attempted to draw somewhat far-fetched historical connections with respected national scientists.²⁷ According to Max Perutz, for example, the history of molecular biology could be traced back to an eminent British figure: ‘25 years ago Sir Frederick Gowland Hopkins created the scientific climate in which our research on the chemical structure and spatial architecture of proteins was begun’.²⁸ It is only, however, ‘during the past six years [that] Molecular Biology [has] changed from a subject of speculation and uncertainty to an exact science’.²⁹ Since the document was dated 1958, this meant that the transformation of the discipline had started in 1953, i.e. the year that Watson and Crick, working in Cambridge, published their double helix model of DNA. This transformation of molecular biology was primarily brought about, according to Perutz, by ‘powerful methods of x-ray analysis’—the principal technique used in his own laboratory.

The second strategy argument common to all four reports was the establishment of a claim that their respective countries suffered from a ‘historical backwardness’, a supposed delay compared with the ‘normal’ historical development of the life sciences. This strategy made it possible to advocate the necessity of ‘catching up’ by supporting the various proposals made in the reports (Deichmann, this issue; Santesmases, this issue). This discourse of scientific backwardness was well in tune with current ideas about the ongoing process of modernisation, i.e. the reform of political institutions and economic structures taking place in the post-war years (Gottweis, 1998, pp. 50–76). The fact that ‘normal’ essentially meant ‘American’,

²⁵ An exception was noted by a *Science* reporter (Walsh, 1968). This exception is further discussed in Strasser (2002a).

²⁶ This difference, among others, is used by Harwood to explain the ‘national styles’ in genetics in Germany and in the United States during the inter-war period (Harwood, 1987).

²⁷ These historical claims, which attributed an essential role in the origins of molecular biology to a particular discipline, provoked heated controversy among scientists in the 1960s, when several disciplines attempted to appropriate the scientific authority, social prestige and economic power of molecular biology (Abir-Am, 1985; Abir-Am, 1992).

²⁸ ‘British Plan: Recent Advances’, p. 1.

²⁹ ‘British Plan: Recent Advances’, p. 13.

and that the development of science in Europe for some reason necessarily had to follow the American path, never received consideration.

After reflecting on the goals and history of the field, the authors of the four reports discussed how it should be organised. All reports acknowledged that a molecular biology group had to be constituted by bringing together various ‘specialists’. According to the British report, ‘specialists’ were the ‘main body of workers’ in the field. There was, nevertheless, also a ‘small, but increasing group of first class workers who understand the subject as a whole’.³⁰ Max Delbrück was cited as an example of such a person, together with others whose work was described in the proposal (i.e. that of Perutz, Crick, Kendrew, and Sanger).

The French report adopted a similar approach, by calling upon the ‘union’ of researchers trained in different disciplines to ‘resolve the fundamental problems of molecular biology’.³¹ According to the authors: ‘More than any discipline, molecular biology requires that the direct collaboration between researchers coming from the most different backgrounds be prepared, organised, and realised’.³² In a similar vein, the Swiss report noted that: ‘A good centre for molecular biology is always composed of a team of researchers having a common interest but different training and specialisation’.³³ The German report also appealed for a multidisciplinary institute.

Apart from in Germany, no particular desire was expressed for the teaching of molecular biology as a body of knowledge at undergraduate level. This fact derived from the way in which the field was construed in the first place. Since it was envisaged as an organised body of specialists, there was no real need for these specialists to understand the problems in their wider perspective. All that was needed was a practical acquaintance with the different methods used to solve these problems, and this could only be acquired through research practice.

Accordingly, molecular biology was to be the object of a managerial strategy. A few enlightened molecular biologists were to coordinate and organise a multidisciplinary team of research ‘specialists’, understood as being scientists who had mastered a specific technique. The kind of questions to be answered and the methods to be used to this effect were to be formulated by an organising ‘elite’. Its authority did not derive from its technical virtuosity in one specific field, but rather from its ability to make the results of the different specialists relevant to the ‘fundamental problems of life’.³⁴ This way of organising research was the exact counterpart of the manner in which America and Britain had mobilised science during the war, i.e. managerial, problem oriented, and multidisciplinary. This new organisational model was significantly different from the traditional disciplinary order, in which the field of research was organised by an older member of the discipline who gave researchers of a younger generation the same kind of problems to solve as those with which he had

³⁰ ‘British Plan: The Case’, p. 2.

³¹ ‘French Plan’, p. 7.

³² ‘French Plan’, p. 7.

³³ ‘Swiss Plan A’, p. 1.

³⁴ ‘French Plan’, p. 1.

himself engaged. How was it that this new social order in science could emerge in post-war Europe and be made appealing to the older one?

4. Legitimizing molecular biology

In 1961, the MRC explained its decision to build a laboratory of molecular biology by the fact that ‘a strong case existed on scientific grounds’.³⁵ I wish to demonstrate here that the British plan, as well as the other attempts to institutionalise molecular biology in Europe, did not succeed solely because ‘a strong case existed on scientific grounds’, but also because its promoters carefully positioned their new discipline within the new science policy discourse of the 1950s, and aligned it with the current vision of scientific modernity. Indeed, comparison of the four reports shows common characteristics: molecular biology was presented as a new fundamental research enterprise, closely related to physics, relying on expensive physical instrumentation and capable of eventually bringing medical benefits. It was portrayed as being well developed in the United States, but not in Europe; its support would therefore benefit the effort towards scientific modernisation and enhance national prestige. Finally, molecular biology was presented as crossing traditional disciplinary boundaries and relying on a profoundly interdisciplinary ideal. These themes, as we will see, were precisely the ones at the centre of the different European science policy discourses of the late 1950s. In the following section, I shall show how the reports adopted these values and how they can be situated within the context of post-war European history, always bearing in mind that a fully balanced comparative cultural history of these values in the four countries discussed here, and their acceptance in each context, is beyond the scope of this paper.³⁶ The similarities drawn here between the legitimating strategies adopted by the promoters of molecular biology can only point to common European themes that were certainly played out differently at national levels and whose roots and ramifications would require further investigation.

4.1. *Molecular biology in the atomic age*

The first theme common to all four reports is the relationship between physics and molecular biology. The rise of molecular biology was ‘certainly one of the most outstanding events of modern science, comparable to the renewal of physics beginning in 1925’ claimed the French report. The authors of the British and the Swiss reports did not need to insist so much on the links between molecular biology and physics since they were all working in a physics department and were considered to be biophysicists. The German report highlighted the fact that crucial discoveries in the field of molecular genetics were being made by theoretical physicists.

³⁵ Medical Research Council Laboratory of Molecular Biology Cambridge, ‘Proposed Constitution’, 1961, MRC 61/464, Public Record Office, p. 1.

³⁶ For a general background on European cultural history, see Marwick (1998) and Hobsbawm (1994). Macrosociological approaches have also been useful, see especially Therborn (1995) and Kaelble (1988).

Physics was the inescapable yardstick for post-war science, or science in the ‘atomic age’, as the period after 1945 began to be called immediately after the bomb and until the 1960s. The French equivalent of *Scientific American*, whose first issue appeared in 1946, was simply entitled *Atomes* and subtitled *All the scientific aspects of a new age*. Physics remained the symbol of scientific modernity throughout the 1950s, holding out the greatest promises of technological innovation and hopes for higher standards of living.³⁷ After all, ‘physicists won World War II with the microwave radar, proximity fuse, and solid-fuel rockets, and they ended it with the atomic bomb’, remarked science historian Daniel Kevles, discussing the views of policymakers in the United States (Kevles, 1992, p. 211). It is understandable, therefore, that the promoters of molecular biology compared and associated the history of their discipline to that of physics.

The prestige of physics was not restricted to scientific circles. The fact that the organisers of the 1958 Universal Exhibition in Brussels chose the atom as the principal symbol for the event gives an idea of the place still occupied by physics in the popular culture of the time (Fig. 6). In 1960, a Gallup poll carried out in France included the following question: ‘Some people have described the 19th century as the civilisation of the steam engine or the railroad. If you were to characterise the present time, which of the following would be most descriptive of this era?’ 39% answered ‘the atom’, 28% ‘electricity’ and 20% ‘the airplane’ (Gallup, 1976, p. 284).

Nevertheless, the association between molecular biology and physics assumed at least three different meanings. Firstly, molecular biologists, by emphasising their reliance on techniques and instruments derived from physics—such as radioactive isotopes and electron microscopes—tried to acquire the epistemological authority associated with powerful physical instrumentation (Keller, 1990). Secondly, the links between molecular biology and biophysics—perhaps strongest in Cambridge and Geneva—played an important role in situating molecular biology in the post-war atomic energy debates. After Hiroshima and Nagasaki, research in biophysics was often considered desirable because it offered possibilities for transforming the public image of physical research and redeeming atomic energy from its association with the bombs.³⁸ This vision was promoted by such events as the United Nations International Conference on the Peaceful Uses of Atomic Energy, held in Geneva in 1955, 1958, and 1964, with the accompanying lively exhibition ‘Atoms for Peace’. Thirdly, and perhaps even more significantly, high energy physicists had succeeded—a decade before molecular biologists—in establishing a close relationship with the state and thus in gaining unprecedented support for their research (Pestre, 1992). The first directors of the Max Planck Gesellschaft in Germany and of the CNRS in France, for example, were physicists (Max Planck and Frédéric Joliot-Curie respectively). The creation of the different atomic energy commissions, providing massive support for scientific research (including research in the life sciences) in Great Britain (1944);

³⁷ For a cultural history of the early atomic age in the United States, see Boyer (1985).

³⁸ For the case of the United States, see Rasmussen (1997); for Switzerland, see Strasser (2002a,b), chapter 2.

EXHIBITION PROGRAMME

Weekly



58

THIS WEEK

Friday, October 10th, 1958 - 5. B. fr. - Nr. 26

at the Exhibition and in Belgium



Fig. 6. The Atomium, symbol of the Atomic age, at the World Exhibition in Brussels 1958.

France (1945); Switzerland (1946), and later Germany (1955) (Braun, 1997), had brought numerous physicists to the forefront of state policy towards science. Thus, by comparing their field to that of physics, molecular biologists were asking the state to make the same kind of effort (in a minor key) to that which they had shown fifteen years earlier for atomic physicists.

4.2. *Molecular biology and medical promises*

The second theme, running through all the documents except one, is the relevance of molecular biology to medicine. ‘From now on’, claimed the authors of the French report, ‘a given number of problems which are among the most important in pathology seem to come directly under the jurisdiction of molecular biology . . . above all, the problem of cancer is obviously a molecular biology problem’.³⁹

In the early post-war period, the relationship between fundamental biological research and medical benefits was represented in very different ways in the various European countries. While the British, the French, and the Swiss plans all made extensive appeals to the promises of medical advances resulting from research in molecular biology, the German plan did not even mention this eventuality. Indeed, in Germany the alliance between laboratory science and medicine was still regarded with suspicion during the late 1950s, especially where genetics was concerned. The Nuremberg doctors’ trial was not even a decade away and, although many aspects of geneticists’ work during the war had not yet become public, some of the atrocities associated with research into hereditary pathology at the Kaiser Wilhelm Institute for Anthropology in Berlin-Dahlem, for example, were well known (Proctor, 1988, pp. 306–308; Deichmann, 1996, pp. 231–250). It is hardly surprising, therefore, that the benefits for medicine were not used as a lever for institutionalising genetics in Cologne.

In other countries a quite different situation prevailed. According to the British report, molecular biology, could provide ‘the foundation . . . for a full scale assault on the problems of . . . pathology and cancer research’.⁴⁰ In the Swiss report, molecular biology enabled the study of ‘radiation effects, cancer, virology, immunochemistry’, and numerous other pathologies to be conducted from a ‘new viewpoint’.⁴¹ The French report went as far as to predict that a new field called ‘molecular pathology’ would be the next step after ‘molecular biology’.⁴² For François Jacob, this association between medical progress and fundamental biological research was particularly influential in France since de Gaulle had deliberately chosen molecular biology as an object of national support in the belief that it would transform medicine in the twenty-first century (Jacob, 1997, pp. 28–29).

The idea that fundamental biological research could yield medical benefits was a recurrent theme in the science policy debates of the 1950s. It was stated, in its most

³⁹ ‘French Plan’, p. 3.

⁴⁰ ‘British Plan: The Case’, p. 3.

⁴¹ ‘Swiss Plan A’, p. 1.

⁴² ‘French Plan’, p. 2.

explicit form in a section of France's Fourth Plan (1962–1965) dedicated to scientific and technical research. Its authors insisted that 'fundamental research in biology is at the root of all successes in medical research'. The discovery of antibiotics was cited as a good example of fundamental research with 'immediate practical applications' (Délégué Général à la Recherche Scientifique et Technique, 1961, p. 25). The Medical Research Council had long been convinced that fundamental biological research was worth supporting. Former Secretary and official historian of the MRC, Arthur Landsborough Thomson, explained that support for 'basic biomedical researchers' had been the policy followed by the MRC since 1913, irrespective of whether their work had 'any direct or immediate bearing on any particular disease'.⁴³ In 1952 the MRC justified its support for 'chemical, physical and biological investigations on proteins', by the 'enormous importance of these substances [for] the body's economy, both in health and disease'.⁴⁴ In a similar argument, the president of the FNRS explained that the main support of the Foundation for medicine was for 'fundamental biological and medical research' (Muralt, 1967).

Nevertheless, even though all the promoters of molecular biology emphasised the immediate relevance of molecular biology for medicine, their actual research and institutional choices reveal a more complex picture. As Jean-Paul Gaudillière convincingly shows, French molecular biologists, while claiming involvement in medical research, were trying to distance themselves from medical work (Gaudillière, this issue), and, unlike their American counterparts, European promoters of molecular biology had very few contacts with medical institutions.⁴⁵ Consequently, whenever molecular biology was presented as a contribution to medical progress, it relied on the idea that fundamental biological research would in the long run bring medical benefits. This idea was popularised through the 'Penicillin-model', the wonder drug of the war. In the post-war years penicillin became in fact an icon for rather different and sometimes even contradictory ideas about scientific innovation in the biomedical sciences. It was one of several cases used to exemplify the value of fundamental research (as in the French Fourth Plan) and for the importance of collaboration between the state, universities and industry.⁴⁶

In supporting their claim of medical relevance, the three reports resorted to a further argument. Crick and Perutz underlined the 'remarkable fact' that the types of chemical molecules used to carry out the basic biochemical processes were 'to a large extent similar in all living systems, from bacteria to man'. In their own 'small laboratory' the sources of their material ranged from 'viruses to man', and included 'whales, rats, horses and salmonella'.⁴⁷ The German, French, and Swiss reports made similar claims. This unifying view of the nature of the mechanisms underlying all forms of life carried not only heuristic conviction, but also political power. It allowed

⁴³ Landsborough Thomson (1975), p. 137. Quoted from the MRC's 1913 Annual report.

⁴⁴ Landsborough Thomson (1975), p. 156. Quoted from the MRC's 1950–1951 Annual report.

⁴⁵ See also Gaudillière (1994); for research related to the clinic in Cambridge, see de Chadarevian (1998).

⁴⁶ On the use of the penicillin icon in the post-war modernisation of Britain, see Bud (1998).

⁴⁷ 'British Plan: The Case', p. 1.

the promoters of molecular biology to claim that research into phage genetics or enzymatic induction in bacteria could be relevant to all organisms (including man) and therefore to medicine.

Thus, molecular biology was institutionalised as a promising discipline for medicine. But even though the appeal to medicine was purely rhetorical, the important fact is that such a justification was apparently able to provide an additional source of legitimacy for the new field. Some obvious local strategic reasons should also be mentioned. The British report was addressed to a Medical Research Council, and the authors of the Swiss report hoped to gain the support of the Medical Faculty for their project, which had to be approved at the university level. Whether and how this alliance, envisaged in the reports, between molecular biology and medicine would materialise is a delicate historiographic question that has only recently started to be addressed.⁴⁸

4.3. *Molecular biology and American science*

The third theme discussed in all four reports is American science. Even though—as mentioned above—the different authors attempted to recast the history of molecular biology within their own national research traditions, they also represented the discipline as having originated (or at least as having had a strong basis) in the United States. This had significant consequences for the successful institutionalisation of molecular biology in Europe.

‘America’ (or for the French, the ‘Anglo-Saxons’) was indeed a constant reference in 1950s science policy discourse. At the Colloque de Caen in 1956, a high point in French science policy debates of the period, the former French Prime Minister Pierre Mendès-France deplored the ‘relative scientific decline’ of France ‘causing, compared to the Anglo-Saxons, a backwardness that [our] atomic scientists have not ceased to deplore’ (Mendès-France, 1957, p. 29).⁴⁹ Several other participants at the Colloque de Caen made the same diagnosis, ‘the seriousness of the situation [being] symbolised by the absence—for more than 20 years—of any French scientific Nobel Prizes’ (Anonymous, 1957, p. 15).

The Nobel Prize attributions did in fact make it very evident that not only France, but Europe as a whole, had lost its pre-eminence in science. In the 15 years preceding the war (1925–1939), France, Germany and Britain had shared 32 Nobel Prizes in the natural sciences (physiology or medicine, chemistry, physics), whereas the United States had received only 11. But in the 15 years following the war (1946–1960), the United States had largely taken the lead, with 38 Nobel prizes, compared with only 18 for the three European countries.

A 1957 report to the DFG on the state of biology in Germany similarly deplored the lost scientific standing of the country. The Spanish neurologist Ramon y Cajal is quoted as declaring in 1898 that it was indispensable for a scientist ‘to learn

⁴⁸ See the contributions to de Chadarevian and Kamminga (1998) and Löwy (1996).

⁴⁹ On the Colloque de Caen, see Duclert (1998).

German', because 'in the field of biology, the Germans have established more facts than all other peoples together'. But today, the author of the report continued, 'in order to take part in methods and problems that have arisen in the last 20 years in important fields of research (modern genetics, microbiology, bacterial and viral research etc.), young researchers have to be sent for training to the USA . . . and when they are successful, they never return' (Meyl, 1958, p. 1). The president of the DFG shared the author's worries about the state of biological research in Germany, which he found to be 'more than [in] almost any other field', at a low point. Even worse, 'physics and chemistry have opened up brand new paths for fundamental biological research' which have been 'followed for a long time with success' abroad, but not yet in Germany (Meyl, 1958, p. III).

When the president of the FNRS reflected on the first ten years of the Swiss science funding agency he expressed very well the idea that scientific modernisation should be understood as a long journey towards America, and that the trip was essential if the country wished to retain its high standards of living:

Can and must Switzerland participate in the scientific race? On the maps of airplane pilots crossing the Atlantic, a point indicates the distance beyond which the fuel reserves are no more sufficient to regain the home airfield from which the plane left. It is the 'point of no return' [original in English] in the language of aviators. If the plane has gone beyond that point, it must continue its course. And Switzerland, a deeply industrialised country whose exports cover the world and whose citizens enjoy a high standard of living, has long since passed the 'point of no return' ... This means that we have to keep our rank among the countries of the world who are at the forefront of scientific progress (Muralt, 1962, p. 38).

In the four European countries examined here, 'America' was used as a rhetorical lever to argue for modernisation. This argument functioned all the better since the cultural value of America in Europe was on the increase in the late 1950s, having overcome the resistance it had sometimes faced earlier in the decade (Goetschel & Loyer, 1995, pp. 115–123; Kuisel, 1986). The European Recovery Programme, better known as the Marshall Plan (1947–1951), was one of the factors that initiated the wave of American products arriving in Europe. The rapid take-off of the European economies in the 1950s, beginning three decades of prosperity ('les Trentes Glorieuses'), was paralleled, after years of privation, by the rise of consumer society and a vigorous demand for new products, both cultural and material, from America. One of the effects of the wave of American products and local versions sweeping through Europe was that it supported the concept that America had discovered the organisational key to high productivity (Therborn, 1995).⁵⁰ In industry, as in science, there seemed to be an 'American miracle' to be imitated, as the French journal

⁵⁰ The United States had done much to advertise its production methods through the 'US Technical Assistance and Productivity Program'. For the French case, see Kuisel (1986), pp. 70–102 and Boltanski (1982), pp. 155–236.

Atomes had expressed it (Magat & Hadamard, 1946). A sign of the high regard for America production in the late 1950s was that the purported American character of European products was often used as a sales pitch in advertisements (Tanner, 1992). As a result, post-war modernity, which was identified with the return to good living and the rise of consumerism, was closely linked to a certain *American way of life*.⁵¹

When asked about the reasons for the higher standards of living in the United States, many French people mentioned the ‘progress of science’, and ‘very advanced technology’ (Anonymous, 1953, p. 18). Even though public attitudes towards American products, and particularly towards American culture, remained, at the very least, ambiguous, there seemed to be a large consensus that American science and American management were the key to high scientific and economic productivity. In a broad survey of French public opinion about America conducted in 1953, a subgroup of leading personalities (politicians, administrators, academics, etc.) were asked whether they would adopt American methods to run a company. Of these, 71% answered positively and only 9% negatively (Anonymous, 1953, p. 71).

The idea that European post-war economic recovery can be attributed to Americanisation, or even that American production and management techniques have been widely adopted in Europe, has been criticised by several economic and cultural historians. Current historiography rightly emphasises ‘the active reworking and transformation of the American model in post-war Europe’ (Zeitlin & Herrigel, 2000, p. 9) rather than a smooth diffusion and adoption process. This does not preclude the fact, however, that America (at least in scientific and political spheres) was widely seen as providing a model for the management of science worthy of imitation (McElheny, 1964). Thus, understandably, the promoters of molecular biology cast their discipline in the mould of an American science which should be supported in order to reverse national scientific decline and to combat the threat of a scientific ‘brain drain’.⁵²

4.4. *Molecular biology and national prestige*

The fourth theme addressed in all reports concerns national prestige. When asking for public or private funds, the authors of the different reports did not omit to mention the importance of molecular biology for national prestige. This argument took a different form in Germany, however, from that in France, Britain, and Switzerland.

In the field of molecular biology, according to the French document, ‘France ought to bring a contribution worthy of its scientific tradition’.⁵³ In a similar vein, the British report reflected on the international prestige Britain would gain by creating an institute for molecular biology. Since molecular biology had developed in a trans-

⁵¹ Americanisation, however, is a complex phenomenon that followed a different path in liberated Germany from that in socialist France. For France, see Kuisel (1986) and Costigliola (1992); for Germany, Poiger (2000); for Switzerland, Tanner (1992).

⁵² The ‘brain drain’ is explicitly mentioned in the British plan, probably because this threat was strongest in a country that shared its national language with the United States. ‘British Plan: The Case’, p. 3.

⁵³ ‘French Plan’, p. 3.

national area—a fact upon which each report insisted—its support in a local context would necessarily be relevant to the interest of governments defending their international status. In the 1950s, France and Britain were realising the extent to which they had lost their privileged place on the world political scene (with the loss of Empire, the 1954 Indochina collapse and the 1956 Suez debacle). In a similar way, on the cultural scene and especially in the realm of the visual arts, Paris was giving ground to New York (Rioux & Sirinelli, 1998, pp. 229ff.). Britain's increasingly ambiguous 'special relationship' with the United States and de Gaulle's efforts to restore France's 'grandeur', most notably *vis-à-vis* the United States, had placed the theme of regaining national prestige through science, or by any other means, high on the governmental agendas. Thus the support for molecular biology, a successful science in the United States, was presented as an essential contribution to the restoration of national status. At the 1956 Colloque de Caen, for example, the importance of scientific research for national prestige and prosperity was repeatedly acknowledged. The concluding report began with the following words: 'Considering that the immediate and massive expansion of scientific research is an indispensable condition for the maintenance of the intellectual influence and intellectual rank of France, the development of its agriculture and its industry, the rise of its standard of living and of the well being of its people . . .' (Anonymous, 1957). By 1961, when the Fourth Plan was issued (1962–1965), the link between scientific research and national strength seemed to have become even more evident: 'The 4th Plan consecrates the official recognition of research as the most important factor directing the development of the Nation' (Délégué Général à la Recherche Scientifique et Technique, 1961, p. 3).

The Swiss promoters of molecular biology emphasised more directly the value of internationalism, and the integration of Switzerland into the European scientific scene, rather than national prestige.⁵⁴ This argument had particular appeal in Geneva, a city that was actively promoting its image on the world scene in order to attract the new international organisations. Moreover, the uninterrupted commercial relationship between Switzerland and Nazi Germany and its aggressive attitude in the Washington negotiations on war reparations in 1946 had placed Switzerland in danger of international isolation. Consequently, Swiss political authorities undertook many initiatives in the post-war period in order to bring the country back onto the international scene. The support for science was a means to this end, as is particularly evident by the active political support given to CERN and EMBO. Support for molecular biology, presented in an international framework, was thus very appealing, not only as a scientific policy decision, but also for reasons of foreign policy (as a means to circumvent international isolation).

In Germany, a quite different discourse was at work: '[It is] especially regrettable that a people [Volk] that decisively influenced biology in the most diverse fields now barely follows the progress made [abroad]. If genetics in Germany does not receive a decisive and meaningful support, we will become *in biology an underdevel-*

⁵⁴ 'Swiss Plan A', p. 2.

oped people [unterentwickelten Volk].⁵⁵ The nation was not identified with the Republic, represented through its institutions, but with the ‘Volk’: a well-known difference between German and French political philosophies. This difference probably had an impact on the institutionalisation of molecular biology. Indeed, whereas the French, British and Swiss reports only proposed to teach molecular biology at a post-graduate or post-doctoral level, the German report advocated a much broader approach starting at undergraduate level. It was not simply a brilliant ‘elite’ that was to be educated to ensure the country’s international prestige, but the ‘Volk’ as a whole.

4.5. Molecular biology and interdisciplinary research

The fifth and last theme common to all documents is interdisciplinarity. All four reports insist on the necessity of crossing boundaries, disciplinary as well as national, in order to conduct successful scientific research. As expressed in the French report: ‘the most productive institutions are precisely those in which this multivalent co-operation between qualified representatives from different disciplines has been realised most completely, without losing sight of the fundamental objectives’.⁵⁶ Prina Abir-Am has shown that the promoters of these reports, who were all practising interdisciplinary research, obtained their major results through the combination of methods, objects, and researchers from different disciplinary and national backgrounds (Abir-Am, 1993). But it is interesting to conjecture why interdisciplinary collaboration *per se* became so highly valued in post-war Europe.

From the end of the war onwards, many influential scientists in Switzerland came to regard interdisciplinary research as a highly desirable goal. In the early 1950s, Swiss academics were trying to set up an agency to finance research, very much on the model of the newly created National Science Foundation in the United States. In January 1950, a series of articles explaining the project made the front page of the *Journal de Genève*:

There exists in our country, a kind of research linked to teaching, which is absolutely necessary. However, there exists another kind of pure research which is developing more and more abroad, and which is based on a tight collaboration between different fields of science; for example chemistry, biology, biochemistry, biophysics, physical chemistry and experimental medicine. And yet it is not possible to conduct this kind of research in the universities. Their structures, their spirit even, makes it impossible. Though, the questions which these researchers address are, at the present time, those most interesting for our economy (Tavel, 1950).

In Germany, the 1957 report to the DFG made the same assessment: ‘Still in 1900,

⁵⁵ ‘German Plan’, p. 4.

⁵⁶ ‘French Plan’, p. 8.

the natural sciences were supported in three completely separate directions: physics, chemistry and biology. Today, these three disciplines are developing in an overlapping way, and the most successful are those in which different specialities work together' (Meyl, 1958, p. 2). At the French Colloque de Caen a year earlier, a similar diagnosis was made by several participants. The physicist Pierre Auger, for example, affirmed that 'the reign of the specialist already belongs to the past . . . New scientific disciplines are born and link physics, chemistry and biology' (Auger, 1957, p. 62). The backwardness of French scientific research was largely attributed to the rigidity of French institutional structures, which were particularly resistant to accommodating such interdisciplinary hybrids. It thus became one of the specific tasks of national funding agencies, not only in France but also throughout Europe, to support interdisciplinary research enterprises.

It is difficult to determine precisely the origin of the high value placed on interdisciplinary research in post-war Europe,⁵⁷ but it appears once more to be due, at least in part, to what was perceived as an (Anglo-)American model of scientific research.⁵⁸ The atomic bomb, for example, was often viewed in Europe as a major achievement resulting not only from a quantitatively important scientific effort, but also from interdisciplinary collaborative research and 'team-work' (Zallen, 1991, p. 34). Teamwork was also frequently associated with the heavy physical instrumentation that became increasingly employed in post-war biomedical research. In 1947, for example, the Swiss pharmaceutical company Hoffmann-la-Roche created a foundation that exclusively supported 'team-work' research in biology and medicine (Vetter, 1963). Grants were only awarded to multidisciplinary teams, such as the biophysics group of Edouard Kellenberger in Geneva, which assembled physicists, biologists and chemists around electron microscopy research. According to a member of the first foundation committee in 1963, 'the impressive results achieved in the last years by American and British research, were not only the result of important means put at the disposal of researchers, but also of the 'team-work' spirit that inspired them' (Vetter, 1963, p. 2).

The interdisciplinary discourse had not only a strong cultural, but also an epistemological appeal. By claiming that molecular biology emerged from the convergence of various disciplines, or that it encompassed 'all physical and chemical aspects of biology',⁵⁹ the promoters of molecular biology were envisaging their field as a 'metadiscipline' that transcended the individual disciplines or research schools (Abir-

⁵⁷ Interdisciplinary research, of course, was not a new phenomenon in the post-war years; it merely became more attractive. For cross-disciplinary constructs in the 1930s, see Abir-Am (1987) and Swann (1988). Before molecular biology came to be institutionalised, and in the immediate post-war period, biophysics and cybernetics were the most successful post-war hybrids; see Rasmussen (1997) and Kay (2000) respectively.

⁵⁸ The first phrase of President Roosevelt's letter to Vannevar Bush, dated November 17, 1944, asking for a report on the OSRD's activities, mentions interdisciplinary research as a distinctive feature: 'The Office of Scientific Research and Development, of which you are the Director, represents a unique experiment of team-work and cooperation in coordinating scientific research and in applying existing scientific knowledge to the solution of the technical problems paramount in war' (Bush, 1990. First published 1945).

⁵⁹ 'French Plan', p. 1.

Am, 1993). Molecular biology was not confined to any one method, but gained its objectivity from the combination of several. It was portrayed as a ‘culture of no culture’ (Traweek, 1988, p. 162), a ‘perspective from nowhere’. In this way, it gained not only its epistemological authority, but also its social legitimacy in supplanting the more traditional disciplines.

Other cultural fields were following similar trends in post-war Europe. New cross-disciplinary and cross-cultural ventures, presenting themselves in opposition to established forms of culture, flourished from the late 1950s onwards. In France, for example, the broad cultural movement that emerged at that time and culminated around 1960 is perhaps best described as ‘avant-garde’. The *Nouvelle vague*, the *Nouveau réalisme* and the *Nouveau roman* share a form of anti-academism that featured a rejection of bourgeois cinema, painting, and literature. They aimed at a new realism that rejected the older theoretical constructions and sought its inspiration beyond the traditional disciplinary boundaries. In a similar way, the rise of structuralism and of the social sciences (sociology, for example), epitomised an anti-academism, and probably owed part of its success at that time (Lévi-Strauss entered the Collège de France in 1960) to this unusual social configuration (Goetschel & Loyer, 1995, pp. 140–141).⁶⁰

5. Conclusion

This paper has tried to explain how, around 1960, the promoters of molecular biology in Europe defined their new discipline. It has therefore brought the question concerning the origin of molecular biology into a different light. The term ‘molecular biology’ has indeed been previously employed in two different contexts. First, intellectual historians have taken it to designate scientific research (from the 1930s onward) of the kind that, in the 1960s, came to be carried out under the name of ‘molecular biology’ (Olby, 1990; Morange, 1998). This framework has been very useful in understanding the intellectual history of the field. However it is largely unsatisfactory for elaborating a social history of molecular biology, since it takes for granted precisely that which social historians are seeking to explain: namely, the process by which social objects (in this case a scientific community) are constituted.

Second, several historians have highlighted the role of the Rockefeller Foundation (RF) in the development of molecular biology (Abir-Am, 1984; Kohler, 1991; Kay, 1993; Picard, 1999). Warren Weaver, the director of the Natural Sciences Division of the RF from 1932, had designed a large support programme for basic biomedical sciences that he called ‘molecular biology’ in 1938—the first official use of the name (Weaver, 1970). Several, but far from all RF *protégés*, such as Linus Pauling, William Astbury, Max Delbrück, and George Beadle, for example, were retrospectively

⁶⁰ Pnina Abir-Am has suggested that establishment of molecular biology in the 1960s should be put in relation with the counter-culture of that decade, making a similar but chronologically different point (Abir-Am, 1997, p. 502).

recognised as being central to the development of molecular biology. Weaver's molecular biology programme was so broad, however, that it cannot easily be identified with the discipline bearing the same name in the 1960s. It supported research projects in the biochemistry of vitamins, endocrinology, and embryology, for example, none of which would be included two decades later within the confines of molecular biology.

The much narrower meaning that molecular biology acquired in the 1960s was thus a genuine innovation.⁶¹ It not only reflected a different idea of how biological knowledge should be organised, but also, for the first time, came to designate a community of researchers and a professional identity. The authors of the institutional plans examined here thus very much contributed to the construction of this new social reality and identity of molecular biology that still remains, to some extent, current today, and which has been stabilised since the 1960s through the institutions they created. It is clear that the formation of EMBO, and the nomination of 140 molecular biologists—mentioned at the beginning of this paper—could not have taken place before the early 1960s, since it was only then that a substantial number of scientists from different disciplinary backgrounds began to think of themselves as molecular biologists.

What historiographic consequences can be drawn from the results of this comparative study? Firstly, beyond the local and national accounts there is a European history of molecular biology. The specificity of the European context has to be taken into account, since several factors that played a role in the making of molecular biology—such as the economic results of national reconstruction and the value of American science—were particular to the European context. The general themes most likely to require further attention are those that are constantly present in the cases cited above, namely the role of physics in the atomic age, the relations between biological research and medical benefits, the 'Americanisation' of scientific research, the value of science in the reconstruction of national identities, and the drive towards interdisciplinary research. Unfortunately, apart from the key institutions and foundations, the absence of sufficient scholarly research on the rise of molecular biology in the United States makes it difficult to relate this European history to its American counterpart. One can point out, however, that the establishment of molecular biology in Europe was much more the result of state intervention than in the United States, where philanthropic foundations and private universities played the major role. Thus, it is not surprising that the history of molecular biology in Europe needs to be framed within the profound political and social transformation of the nation state in the post-war years. Secondly, even though a comparative approach cannot replace more local accounts, the identification of common themes running through most European cases may promote a fresh look at these studies and help to differentiate between that which pertains to the local and national configuration, and that which should be considered in a wider context. At the same time, a comparative study of molecular

⁶¹ Robert Olby has made a similar distinction between a 'broad' and a 'narrow' meaning of the term 'molecular biology' (Olby, 1990).

biology in the different European countries would appear to offer the possibility of a ‘big picture’, without losing the richness of each local story.

Acknowledgements

I am intellectually indebted for this paper to Soraya de Chadarevian, Jean-Paul Gaudillière, Ute Deichmann, Jean-François Picard and Pnina Abir-Am. Robert Olby and Bernardino Fantini critically read this manuscript, and I benefited from constant discussions with Marc Geiser. The archivists at the California Institute of Technology, the Pasteur Institute, the CNRS, the French Ministry of Education, the Public Record Office and the University of Geneva have also been extremely helpful. My warmest thanks are due to everyone concerned. Research was supported by the Swiss National Science Foundation, grant no. 31-56022.98.

References

- Abir-Am, P. (1984). Beyond deterministic sociology and apologetic history: Reassessing the impact of research policy upon new scientific disciplines (Reply to Fuerst, Bartels, Olby and Yoxen). *Social Studies of Science*, 14, 252–263.
- Abir-Am, P. (1985). Themes, genres and orders of legitimation in the consolidation of new scientific disciplines: Deconstructing the historiography of molecular biology. *History of Science*, 23, 73–117.
- Abir-Am, P. (1987). The Biotheoretical gathering, trans-disciplinary authority and the incipient legitimation of molecular biology in the 1930s: New perspectives on the historical sociology of science. *History of Science*, 15, 1–70.
- Abir-Am, P. (1992). The politics of macromolecules: Molecular biologists, biochemists, and rhetoric. *Osiris*, 7, 164–191.
- Abir-Am, P. (1993). From multidisciplinary collaboration to transnational objectivity: International space as constitutive of molecular biology, 1930–1970. In E. Crawford, T. Shinn, & S. Sörlin (Eds.), *Denationalizing science—The contexts of international scientific practice* (pp. 153–186). Dordrecht: Kluwer Academic Publishers.
- Abir-Am, P. (1997). The molecular transformation of twentieth-century biology. In J. Krige, & D. Pestre (Eds.), *Science in the twentieth century* (pp. 495–524). Amsterdam: Harwood Academic Publishers.
- Abir-Am, P. (2001). Molecular biology in the context of British, French and American cultures. *International Social Science Journal*, 168, 187–199.
- Anonymous (1953). Les Etats-Unis, 1945–1953, les Américains et la France. *Sondages. Revue française de l'opinion publique*, 2, 1–78.
- Anonymous (1957). Résolutions adoptées à la séance de clôture du novembre 1956. *Les Cahiers de la République*, 2, 28–35.
- Anonymous (1961). *Jahrbuch 1951 der Max-Planck-Gesellschaft zur Förderung der Wissenschaften E. V.* Göttingen: Huber & Co.
- Appel, T. A. (2000). *The National Science Foundation and American biological research 1945–1975*. Baltimore: John Hopkins University Press.
- Auger, P. (1957). La France et le problème mondial de la recherche scientifique. *Les Cahiers de la République*, 2, 60–64.
- Boltanski, L. (1982). *Les cadres. La formation d'un groupe social*. Paris: Les Editions de Minuit.
- Boyer, P. (1985). *By the bomb's early light*. New York: Pantheon Books.
- Braun, D. (1997). *Die politische Steuerung der Wissenschaft: Ein Beitrag zum kooperativen Staat*. New York: Campus.

- Bud, R. (1998). Penicillin and the new Elizabethans. *British Journal for the History of Science*, 31, 305–333.
- Burian, R. M., & Gayon, J. (1990). Genetics after World War II: The laboratory at Gif. *Cahiers pour l'Histoire du CNRS*, 7, 25–48.
- Burian, R. M., & Gayon, J. (1999). The French school of genetics: From physiological and population genetics to regulatory molecular genetics. *Annual Review of Genetics*, 33, 313–349.
- Bush, V. (1990). *Science. The endless frontier*. Washington, DC: National Science Foundation First published 1945.
- Centre National de la Recherche Scientifique (multiple years). *Rapport sur l'activité générale du Centre National de la Recherche Scientifique*. Paris: CNRS.
- Costigliola, F. (1992). *France and the United States. The cold alliance since World War II*. New York: Twayne Publishers.
- Crick, F. H. C. (1958). On protein synthesis. *Symposia of the Society for Experimental Biology*, 12, 138–163.
- Crick, F. (1980). Naviguer avec Jacques. In A. Lwoff, & A. Ullmann (Eds.), *Les origines de la biologie moléculaire—Un hommage à Jacques Monod* (pp. 231–235). Paris: Etudes Vivantes.
- de Chadarevian, S. (1994). Architektur der Proteine. Strukturforschung am Laboratory of Molecular Biology in Cambridge. In M. Hagner, H. -J. Rheinberger, & B. Wahrig-Schmidt (Eds.), *Objekte, Differenzen und Konjunkturen* (pp. 327–330). Berlin: Akademie Verlag.
- de Chadarevian, S. (1996). Sequences, conformation, information: Biochemists and molecular biologists in the 1950s. *Journal of the History of Biology*, 29, 361–386.
- de Chadarevian, S. (1998). Following molecules: Haemoglobin between the clinic and the laboratory. In S. de Chadarevian, & H. Kamminga (Eds.), *Molecularizing biology and medicine: New practices and alliances, 1910s–1970s* (pp. 171–201). Harwood Academic Publishers: Amsterdam.
- de Chadarevian, S., & Kamminga, H. (Eds.). (1998). *Molecularizing biology and medicine: New practices and alliances 1910s–1970s*. Amsterdam: Harwood Academic Publishers.
- de Chadarevian, S. (2002). *Designs for life*. Cambridge: Cambridge University Press.
- Deichmann, U. (1996). *Biologists under Hitler*. Cambridge, MA: Harvard University Press.
- Délégué Général à la Recherche Scientifique et Technique (1961). *Quatrième Plan 1962–1965. La recherche scientifique et technique*. Paris: Commissariat Général du Plan d'Équipement et de la Productivité.
- Deutsche Forschungsgemeinschaft (multiple years). Bericht der Deutschen Forschungsgemeinschaft über ihre Tätigkeit. Wiesbaden: Franz Steiner Verlag.
- Douglas, M. (1986). *How institutions think*. Syracuse, NY: Syracuse University Press.
- Duclert, V. (1998). Le colloque de Caen—1956. La IVe République et la mobilisation scientifique. *Historiens & Géographes*, 361, 337–360.
- Ellwood, D. W. (1992). *Rebuilding Europe: Western Europe, America, and postwar reconstruction, 1945–1955*. New York: Longman.
- Errera, M. (1997). Working at the Rouge-Cloître: A personal account. *History and Philosophy of the Life Science*, 19, 19–25.
- Fischer, E. P., & Lipson, C. (1988). *Thinking about science. Max Delbrück and the origins of molecular biology*. New York: W. W. Norton & Company.
- Flora, P. (1983). *State, economy, and society in Western Europe 1815–1975*. Frankfurt: Campus Verlag.
- Fonds National Suisse de la Recherche Scientifique (multiple years). *Rapport annuel*. Bern: OFES.
- Gallup, G. H. (1976). *The Gallup international public opinion polls. France 1939, 1944–1975*. New York: Random House.
- Gaudillière, J. -P. (1991). *Biologie moléculaire et biologistes dans les années soixantes: La naissance d'une discipline. Le cas français*. Paris: Thèse de doctorat de l'Université Paris VII.
- Gaudillière, J. -P. (1993). Molecular biology in the French tradition? Redefining local traditions and disciplinary patterns. *Journal of the History of Biology*, 26, 473–498.
- Gaudillière, J. -P. (1994). Les biochimistes français entre légitimité médicale et légitimité biologique, 1930–1960. In C. Debru, J. Gayon, & J. -F. Picard (Eds.), *Les sciences biologiques et médicales en France 1920–1950* (pp. 266–282). Paris: CNRS Editions.
- Gaudillière, J. -P. (2002). *L'invention de la biomédecine*. Paris: La Découverte.

- Geiger, R. L. (1997). What happened after Sputnik? Shaping university research in the United States. *Minerva*, 35, 349–367.
- Goetschel, P., & Loyer, E. (1995). *Histoire culturelle et intellectuelle de la France au XXe siècle*. Paris: Armand Colin.
- Gottweis, H. (1998). *Governing molecules : The discursive politics of genetic engineering in Europe and the United States*. Cambridge, MA: MIT Press.
- Harwood, J. (1987). National styles in science: Genetics in Germany and the United States between the World Wars. *Isis*, 78, 390–414.
- Hobsbawm, E. J. (1994). *The age of extremes: A history of the world, 1914–1991*. New York: Pantheon Books.
- Jacob, F. (1997). *La souris, la mouche et l'homme*. Paris: Odile Jacob.
- Kaelble, H. (1988). *Vers une société européenne 1880–1980*. Paris: Belin.
- Kay, L. E. (1993). *The molecular vision of life*. New York: Oxford University Press.
- Kay, L. E. (2000). *Who wrote the book of life*. Stanford: Stanford University Press.
- Keller, E. F. (1990). Physics and the emergence of molecular biology: A History of cognitive and political synergy. *Journal of the History of Biology*, 23, 389–409.
- Kendrew, J. C. (1967). How molecular biology started. *Scientific American*, 217, 141–143.
- Kendrew, J. C. (1970). Some remarks on the history of molecular biology. In T. W. Goodwin (Ed.), *British biochemistry past and present* (pp. 5–10). London: Academic Press.
- Kevles, D. J. (1992). Foundations, universities, and trends in support for the physical and biological Sciences, 1900–1992. *Daedalus*, 121, 195–235.
- Kohler, R. (1991). *Partners in science: Foundations and natural scientists*. Chicago: Chicago University Press.
- Kuisel, R. F. (1986). *Seducing the French: The dilemma of americanization*. Chicago: University of Chicago Press.
- Landsborough Thomson, A. (1973). *Half a century of medical research. Origins and policy of the Medical Research Council (UK)*. London: Her Majesty's Stationery Office.
- Landsborough Thomson, A. (1975). *Half a century of medical research. The programme of the Medical Research Council (UK)*. London: Her Majesty's Stationery Office.
- Löwy, I. (1996). *Between bench and bedside. Science, healing, and interleukin-2 in a cancer ward*. Cambridge, MA: Harvard University Press.
- Magat, M., & Hadamard, J. (1946). Le miracle américain en est-il un? *Atomes*, 1, 14–16.
- Marwick, A. (1998). *The Sixties. Cultural revolution in Britain, France, Italy, and the United States, c.1958–c.1974*. Oxford: Oxford University Press.
- McElheny, V. K. (1964). Research in biology: New pattern of support is developing. *Science*, 145, 908–912.
- Mendès-France, P. (1957). Pour une politique nationale de la recherche. *Les Cahiers de la République*, 2, 28–35.
- Meyl, A. H. (1958). *Denkschrift zur Lage der Biologie*. Wiesbaden: Franz Steiner Verlag.
- Morange, M. (1998). *A history of molecular biology*. Cambridge, MA: Harvard University Press.
- Muralt, A. v. (1962). Le Fonds national a 10 ans. *Communications*, 3, 37–67.
- Muralt, A. v. (1967). Probleme der Forschungsförderung in der Biologie und Medizin. *Communications*, 4, 123–130.
- Olby, R. (1990). The molecular revolution in biology. In R. Olby, G. N. Cantor, J. R. R. Christie, & M. J. S. Hodge (Eds.), *Companion to the history of modern science* (pp. 93–100). London: Routledge.
- Perutz, M. (1987). The birth of molecular biology. *New Scientist*, 21 May 1987, 38–41.
- Pestre, D. (1992). Les physiciens dans les sociétés occidentales de l'après-guerre. Une mutation des pratiques techniques et des comportements sociaux et culturels. *Revue d'Histoire Moderne et Contemporaine*, 39, 56–72.
- Picard, J. -F. (1999). *La fondation Rockefeller et la recherche médicale*. Paris: Presses Universitaires de France.
- Poiger, U. G. (2000). *Jazz, rock, and rebels: Cold War politics and American culture in a divided Germany*. Berkeley: University of California Press.
- Polanco, X. (1990). La mise en place d'un réseau scientifique. Les rôles du CNRS et de la DGRST dans

- l'institutionnalisation de la biologie moléculaire (1960–1970). *Cahiers pour l'Histoire du CNRS*, 7, 49–90.
- Proctor, R. N. (1988). *Racial hygiene. Medicine under the Nazis*. Cambridge, MA: Harvard University Press.
- Rasmussen, N. (1997). The mid-century biophysics bubble: Hiroshima and the biological revolution in America, revisited. *History of Science*, 35, 245–293.
- Rioux, J.-P., & Sirinelli, J.-F. (Eds.). (1998). *Histoire culturelle de la France. Le temps des masses*. Paris: Seuil.
- Strasser, B. J. (1999). Sickle cell anemia, a molecular disease. *Science*, 286, 1488–1490.
- Strasser, B. J. (2001). Sickle cell anemia and the origins of molecular biology. In C. Mead, & T. Hager (Eds.), *Linus Pauling—Scientist and peacemaker* (pp. 126–133). Corvallis: Oregon State University Press.
- Strasser, B. J. (2002a). Microscopes électroniques, totems de laboratoires et réseaux transnationaux: L'émergence de la biologie moléculaire à Genève (1945–1960). *Revue d'Histoire des Sciences*, 55, 5–43.
- Strasser, B. J. (2002b). *Les sciences de la vie à l'Âge atomique: Identités, pratiques et alliances dans la construction de la biologie moléculaire à Genève (1945–1970)*. Dissertation University of Paris VII and University of Geneva.
- Swann, J. P. (1988). *Academic scientists and the pharmaceutical industry*. Baltimore: John Hopkins University Press.
- Tanner, J. (1992). Zwischen 'American Way of Life' und 'Geistiger Landesverteidigung'—Gesellschaftliche Widersprüche in der Schweiz der fünfziger Jahre. *Nos monuments d'art et d'histoire*, 43, 351–363.
- Tavel, C. (1950). Où en est la recherche scientifique en Suisse? *Journal de Genève*, 16 January, p. 1.
- Therborn, G. (1995). *European modernity and beyond*. London: Sage Publications.
- The Rockefeller Foundation (1938). *Annual Report*. New York: The Rockefeller Foundation.
- Traweek, S. (1988). *Beamtimes and lifetimes—The world of high energy physicists*. Cambridge, MA: Harvard University Press.
- Vetter, R. C. (1963). *Die Tätigkeit der Fritz Hoffmann-La Roche-Stiftung zur Förderung wissenschaftlicher Arbeitsgemeinschaften in der Schweiz*. Basle.
- Walsh, J. (1968). Geneva : Molecular biology research comes of age. *Science*, 159, 718–721.
- Weaver, W. (1970). Molecular biology: Origins of the term. *Science*, 170, 581–582.
- Wright, S. (1994). *Molecular politics. Developing American and British regulatory policy for genetic engineering, 1972–1982*. Chicago: University of Chicago Press.
- Zallen, D. T. (1991). Louis Rapkine and the restoration of French science after the second World War. *French Historical Studies*, 17, 6–37.
- Zallen, D. T. (1996). Redrawing the boundaries of molecular biology: The case of photosynthesis. In S. Sarkar (Ed.), *The philosophy and history of molecular biology: New perspectives* (pp. 47–66). Dordrecht: Kluwer Academic Publishers.
- Zeitlin, J., & Herrigel, G. (Eds.). (2000). *Americanization and its limits : Reworking US technology and management in Post-War Europe and Japan*. Oxford: Oxford University Press.