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The proactive historian: methodological opportunities presented by the new archives documenting genomics

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Abstract: In this paper, I propose a strategy for navigating newly available archives in the study of late-twentieth century genomics. I demonstrate that the alleged ‘explosion of data’ characteristic of genomics – and of contemporary science in general – is not a new problem and that historians of earlier periods have dealt with information overload by relying on the ‘perspective of time’: the filtering effect the passage of time naturally exerts on both sources and memories. I argue that this reliance on the selective capacity of time results in inheriting archives curated by others and, consequently, poses the risk of reifying ahistorical scientific discourses. Through a preliminary examination of archives documenting early attempts at mapping and sequencing the human genome, I propose an alternative approach, in which historians proactively problematize and improve available sources. This approach provides historians with a voice in the socio-political management of scientific heritage and advances methodological innovations in the use of oral histories. It also provides a narrative framework in which to address big science initiatives by following second order administrators, rather than individual scientists. The new genomic archives thus represent an opportunity for historians to take an active role in current debates concerning ‘big data’ and critically embed the humanities in pressing global problems.

Keywords: Genomics, archives, administrators, historiography, big science, big data.

1. Introduction:

The website of the Arts and Humanities Research Council leads applicants to a guide that details a stipulation for history proposals: when projects address events “within the last thirty years,” they should explicitly demonstrate “why their focus is indeed predominantly historical rather than contemporary.” The public British funder appears concerned that the scarcity of archival evidence and other accepted historical sources for this period might lead applicants to embrace the contemporary and exclusively frame their projects within the social sciences, funding for which is the province of another institution, the Economic and Social Research Council. Despite flexibility in many of their overlapping research areas, regulations appear stricter in relation to historical research.¹ This largely chronological demarcation criterion reflects an aversion held by some historians towards the recent past, in part motivated by a desire to defend their disciplinary independence and distinguish their methodology from other more present-oriented fields of the social sciences (Goldthorpe 1991).

A preference for the distant past over more recent times has informed many seminal works in the history of science. The majority of classical post-World War II literature has been concerned with the scientific revolution of the seventeenth century, a focus on the early-modern period prevailing in history of science research up until the late 1980s.² The view among the community at that time was – and in some cases still is – that the *perspective of time* would facilitate an accurate historical reconstruction of the case studies selected. This commitment to the past as opposed to the present increasingly differentiated the sources, theoretical frameworks and methodological approaches of the history of science within the broader field of Science and Technology Studies (STS) (Daston 2009).

From the 1990s onwards, however, historians began to debate the advantages of addressing the more recent scientific past. The importance of developments within science and technology during the twentieth century, and the intellectual stimulus provided by engaging with living scientists, employing interviewing and other innovative social science tools, appealed to a substantial part of the community. This was to a large extent fostered by the incorporation of ethnographic approaches to the analysis of historical case studies, which gradually spurred researchers towards more contemporary science (Dear and Jasanoff 2010). The historiography turned to issues relating to World War I and II, the formation of university-industrial complexes and the scientific and socio-political orders following 1945 (Edgerton 1992; Edwards 1997; Lesch 2000, among others). This coincided with a shift of emphasis from the history of physics to the history of the life sciences and a growing interest in the emergence of big science models (Galison and Hevly 1992; Kevles and Geison 1995; Doel and Söderqvist 2006).

The increasing focus on contemporary science provoked a number of theoretical and methodological debates among historians. Thomas Söderqvist, an early advocate of tackling the recent past, justified his position with the claim that “the bulk of scientific activity in world history” had taken place “in the last half century.” The vast increase in working scientists, publications and meetings since the mid 1940s was producing a gold mine for historical research. According to Söderqvist, the lack of archives would be counterbalanced by an abundance of published material, opportunities to conduct oral histories, and the subsequent

collection of unpublished records still in scientists' possession. This plurality of sources represented a unique situation and was transforming the practice of history: from reliance on an alleged scarcity of materials to an overabundance of records (Söderqvist 1997: 2).

The historiography of molecular biology is an example of these changes in research practice. Beginning in the 1980s and '90s, a time at which most molecular biologists were still alive, historians compensated for the lack of traditional sources with interviews and creative ways of cooperating with scientists (de Chadarevian 1996; Kay 2000; Holmes 2001). This led to the identification of an increasing amount of unpublished material, most of which was subsequently acquired by libraries and made accessible in the form of catalogued archives. Historical research on contemporary biomedicine has continued, addressing not only the classical stages of molecular biology – the 1950s and '60s – but also the more recent development of recombinant DNA methods, as well as the mapping and sequencing of genes (Rheinberger and Gaudillière 2004; Yi 2008; García-Sancho 2012a; Pierrel 2012; Brandt 2013; Stevens 2013; Hogan 2014; Onaga 2014). This has resulted in newly discovered archival collections being made available to scholars.³

In this paper, I will address these newly released collections and the horizons they open for the study of recent science; recombinant DNA was developed in the mid 1970s, and the first genome mapping and sequencing projects were proposed in the mid 1980s. While acknowledging the unique situation for historical research these new archives have created, I will argue that this uniqueness does not lie in the situation being novel or specific to the history of recent science: rather, it lies in the unprecedented opportunity for historians to be involved in the filtering and organising of available sources, in cooperation with archivists as well as scientists.

Soraya de Chadarevian has claimed that every historian of the recent past is to some degree an archivist. By interacting with living actors and retrieving records before they are publicly released, these historians construct the heritage that will be transmitted to future generations (de Chadarevian 2013b, in this issue). The reverse may be said for archivists of recent unpublished materials. As Jenny Shaw argues in another contribution to this special issue, they become engaged with the stories those materials tell as they are archived (Shaw, in this issue). These categories of 'the historian' and 'the archivist' may be seen as generalisations that mask the diversity of narratives different types of historians and archivists produce. However, they also show the interests historians and archivists share and suggest ways these actors may fruitfully interact.

In what follows, I will use the term *historians* as an intentionally idealised category that designates scholars producing a "second order" narration of the past. In line with earlier historiography (Abir-Am 1985; Suárez-Díaz 2010), I will argue that when this narration differs from the first order accounts of actors involved in the events, historians escape the pretence of objectivity and critically engage with their sources, in order to independently reconstruct the past. This *proactive historian* seeking to rearrange sources may find an invaluable ally in the archivist attempting to make autonomous sense of the same records. By building on these categories, I will propose a way of collaboratively exploiting the newly available archives.

The opportunity for collaboration coexists with a growing political interest in 'big data'. Nationally and internationally, public and private funding agencies are seeking strategies to make sense of the increasing volume of information which scientists, and society in general, have to deal with in everyday life. New information technologies and the mega-projects characteristic of big science are creating an overwhelming amount of data which is difficult to digest.⁴ At the same time, funding programmes are calling for scholars within the humanities and social sciences to abandon their academic niches and embed themselves in problems such as 'big data', which transcend boundaries with the natural sciences. This has raised concerns over whether the proposed embeddedness represents a threat to the independence of the social sciences and humanities, and subordination to the interests of the natural sciences.⁵ I will demonstrate that if historians actively engage with the increasing archival sources in their field, they will develop theoretical and methodological tools to adapt to the current funding climate. In other words, I will argue for a proactive historian embedded in the 'big data' problem while maintaining epistemic identity.

I will begin by problematizing two widely accepted tropes in the historiography of recent science: 1) the 'information explosion' that some scholars perceive to be characteristic of our time, and 2) the 'perspective of time', the alleged advantage of addressing the distant rather than recent past. A review of existing literature will enable me to argue that the explosion of available data is a recurrent problem, having also occurred in earlier historical periods, and that invoking the perspective of time equates to abandoning the resolution of that problem to others. Rather, historians should participate in debates about data handling, which are highly political and, in the case of the history of science, have direct bearing on issues of scientific policy and funding.

I will then turn to my own research with archives documenting early genomic initiatives in Britain and propose a strategy that provides historians with the agency to both navigate these very large collections and adapt them to their own interests. This strategy involves using oral histories *after* identifying unpublished evidence, rather than before, and exploring administrative as well as scientific archival collections. Conducting oral histories once archival material has been analysed facilitates a historically specific way of interviewing – one different from methods within the social sciences – and administrative records provide a suitable narrative framework in which to address big science. The resulting methodology necessarily reflects on my own experience and seeks to address some of the challenges described in the historiography of genomics, particularly that of balancing the array of often disparate voices involved in large-scale mapping and sequencing projects (Ankeny 2010; Suárez-Díaz 2010).

2. The 'information explosion' and the 'perspective of time' revisited:

In the same volume in which Sörderqvist outlined the historiographical challenges involved in an engagement with recent science, Jeff Hughes questioned their novelty, suggesting these were only "respecified versions" of issues "long familiar to historians." For Hughes, the crucial feature of historicising recent science was the political nature of the endeavour, in the sense that the interests of the historian would frequently clash with the image practicing scientists had of their own past (Hughes 1997: 22; see also Aaron Dennis 2006). Hughes referred to

historical work on earlier periods to demonstrate an overabundance of scientific information was not a new problem. In subsequent years, other historians have corroborated this point, characterising the 'explosion of information' as a recurrent social representation, not specifically tied to our time. However, as I will show, historians may not have taken enough active participation in earlier political debates about data handling. This is largely due to the ethos of history as a discipline and its reliance on the 'perspective of time'.

The historiography of the early modern period has documented the perception of an "information overload" as a key characteristic of that time. The impact of the printing press, together with the exploration of new worlds and development of natural history complicated the processing of an increasing volume of literature produced between the late-fifteenth and sixteenth centuries. This literature ranged from descriptions of new animals and plants to new legislation or edicts explaining the changing scope of nations (Eisenstein 1980; Jardine et al. 1996; Rosenberg 2003). The obsession with classification and taxonomical description that characterised the Enlightenment was a response to the perceived saturation of information. Yet, most of these typologies had the opposite effect: increasing the amount of data circulating. In their study of the prominent eighteenth-century naturalist, Carl Linnaeus, Staffan Müller-Wille and Isabelle Charmantier show that his work on systematics, far from simplifying the classification of species, made it more complex and contributed to the proliferation of conflicting descriptions of the natural world (Müller-Wille and Charmantier 2012).

The archives with which historians of science work three hundred years later are the result of this never-ending classification effort. The early-modern information overload gave rise to the "sciences of the archive" and "memory practices", helping to preserve the records of different disciplines (Bowker 2005; Daston 2012). These practices of collecting and classifying were integral to the scientific endeavours of astronomy, geology, biology and the modern scientific fields configured between the late-eighteenth and nineteenth centuries. They were also increasingly field-specific as the disciplines differentiated over time. However, a common feature of these practices was the necessity, for the archive creators, of perceiving a differentiated community in the past and projecting its necessities into the future. This enabled them to establish limits in the collection of the community's record and to anticipate problems that the resulting archive would contribute to resolving.

The time gap between these memory practices and historical exploration of the resulting records means the scientists for which the archive was created and the user historians today may well disagree over the effectiveness of this past imagining and future projecting. In other words, the 'perspective of time' that historians adopt comes at the price of inheriting sources selected by others and classified according to non-historical criteria. These criteria, as Lorraine Daston and Geoffrey Bowker have shown, were often informed by the faith in progress and objectiveness characteristic of the natural sciences. Nineteenth-century geologists and comparative anatomists considered their classifications to be more accurate than those of previous researchers, a belief reflected in their archives (Bowker 2005, ch.1; Daston 2012: 181-2). This value system may square with the early historiography of science, but is clearly at odds with post-1970s research seeking a socially constructed or epistemologically critical line of inquiry.

While decisions concerning the formation of such archives were being made, historians inhabiting that period were waiting for the perspective of time to straighten out the records. This distance clearly favours historical breadth and open-mindedness, but it excludes the voice of historians from the many actors negotiating a memory system. Historians are by no means neutral subjects and their work shows their interests and approaches changing over time. However, they may bring a different viewpoint to the diverse perspectives involved in the configuration of an archive. Literature on metrology has demonstrated that the establishment of standards does not only conform to technical criteria. The selection of a given geographical or electrical measurement unit entails deliberation between sometimes conflicting economic and political – as well as scientific – agendas (Schaffer 1992; Gooday 1995). Similarly, the establishment of one or other scientific archive is a co-constructed process involving scientists and other social actors. Should historians await its conclusion before stepping in?

The answer from those historians defending an engagement with the recent past would be a definitive 'no'. The current political and scientific climate represents an opportunity to prove their point. Present-day societies are characterised by an overproduction of cultural goods (Forman 1997; Edgerton 2006, ch.3), which contributes to making 'big data' a crucial contemporary issue, with ramifications in every academic field including the humanities (Gold 2012). In biomedicine, the conclusion of the Human Genome Project in 2003 led to the public release of an enormous DNA sequence that constituted our genetic makeup (see Figure 1). This newly available information – three billion chemical units – propelled academic and science policy discussions on the best management of such large amounts of data. Current post-genomic research has consequently been labelled the era of data-driven science or biobank governance (Kaye et al. 2012; Leonelli 2012).

Recent historiography has suggested parallels between early modern natural history and post-genomic research. Both fields stemmed from a perceived overload of scientific information and were characterised by the proposal of memory practices to collect and process this data. In the early modern period, the proposed practices were classification systems to handle new animal and plant species, while today's post-genomic researchers create algorithms to manage DNA sequences stored in databases (Strasser 2012). The explosion of scientific information has found its counterpart in the archives which are being released for historical research on the Human Genome Project and other contemporary genomic initiatives.⁶ These large data repositories, most available on-line, have led historians to suggest homologies between the practices of curating scientific and historical information (Peres, in this issue; Palladino 2003).

Building on this reflexivity, I will argue that the new datasets represent an opportunity for historians to be involved in a collective memory of genomics. If the management of the current overload of biomedical information is left to scientists and other socio-political actors outside history, the resulting archives may reify a rigid separation between science and society, as well as an alleged superiority of genetic data.⁷ If, instead, historians proactively engage as one more socio-political actor in the process – rather than awaiting the perspective of time – the archives may better reflect their understanding of the genomic past and the future necessities for historical and STS research. Conceived in this way, history would be an integral part of genomics rather than contextual information at the mercy of the dominant interpretation of scientific data.

3. Proactivity and strategic choices:

While the late 1990s were an exciting period for historians of molecular biology, it is for those working on the history of genomics that the present day offers perhaps the most promising prospects. As a historian investigating the rise of recombinant DNA methods in the late 1970s and the later proposal of genome mapping and sequencing projects, I have witnessed important transformations in both the scope and depth of available sources. When I started my career in 2004, the published or upcoming literature concluded with chapters sketching important reconfigurations in the practice and funding of biomedicine during the late-twentieth century, due to both political shifts and the arrival of recombinant DNA (de Chadarevian 2002, ch.11; Chandler Jr 2005, chs. 10-11). However, the focus of this literature was the period following World War II and the Cold War, as authors had managed to engage with scientists from that generation and retrieve archival evidence in support of their claims. The period starting in the 1970s was considered a new era, marked by the possibility of altering and transferring genes from one organism to another (see Figure 1). Yet at that point little was known, historically speaking, about the recombinant DNA era.⁸

INSERT FIGURE 1 AROUND HERE

By 2004, another major scientific achievement had been made: the Human Genome Project (HGP), with completion of the first draft taking place in 2001 and in 2003, the publication of the entire human DNA sequence. When the HGP was first proposed in 1990, scientists and commentators considered it – again – to be the beginning of a new, genomic era. This, together with the parallel launch of a programme addressing the Ethical, Legal and Social Implications of the project (ELSI), gave rise to an increasing volume of social science literature, some written by STS scholars (Kevles and Hood 1992; Sloan 2000; Atkinson et al. 2006; Glasner et al. 2006). This scholarship was rooted in ethnographic methods, relying heavily on interviewing and observing the work of genomic researchers. As a result of this, and the increasing media attention the HGP received, accounts from some of the participant scientists circulated widely in both academic and lay communities.

Historians were at best sceptical of the genomic era concept, especially in light of the short time gap between this and the previous recombinant DNA-led period. Initially they tended to consider the HGP the territory of contemporary-oriented STS research or, rather, straightforward journalism. However, some of the ELSI-framed STS work analysing early attempts to map and sequence human genes was historically informed (Fujimura 1996; Fortun 1999; Keating et al. 1999). This gradually spurred an interest by historians in the continuities and changes between genomics, recombinant DNA, molecular biology and earlier periods in the development of biomedicine (de Chadarevian and Rheinberger 2006). The interest has persisted to date, with a growing volume of historical literature (Ramillon 2007; Gaudillière 2009; Rheinberger 2009; Suarez-Diaz 2009; Hagen 2010; de Chadarevian 2011; Strasser 2011).

In spite of this historical interest, up to very recently archival sources on the HGP were in closed repositories, or on extremely vulnerable shelves and the email boxes of biomedical researchers. When I started my work, this prompted me to follow the strategy that historians

of molecular biology had deployed over the preceding decade: to conduct oral histories with the participant scientists. Between 2004 and 2007, I conducted 13 interviews with scientists involved in the development of sequencing methods, which led me to 9 archival collections, most uncatalogued and still owned by the interviewees (García-Sancho 2012a: 178-9).⁹ The interviewing process created a 'snowball effect', with each scientist suggesting other names and making available – with very few exceptions – unpublished records related to the topics of our conversation. This dynamic helped to transform my research from anthropological into historical, in much the same way it had assisted biomedical historians in the past (Chadarevian 1997; Lindee 1997; Comfort 2011).

Ten years on, the situation has changed dramatically. In January 2013, I began a project on the application of DNA mapping and sequencing to early genomic projects, and was struck by the amount of archival material available. In the UK alone, the National Archives have released a significant number of unpublished records on the Human Genome Mapping Project (HGMP), a British initiative started in the late 1980s and preceding the more global and internationally-oriented HGP. The Wellcome Library, in collaboration with Cold Spring Harbor Laboratory Archives, has released the papers and correspondence of a number of scientists heavily involved in both the HGMP and HGP within the on-line *Codebreakers* collection. Wellcome archivists are also cataloguing the records of scientists who worked at the Sanger Centre, an institution established in 1993 to lead British participation in the HGP (Shaw, in this issue).¹⁰ In the next two subsections, I will describe the strategy I have utilised to make historical sense of these collections, while engaging with the socio-scientific network involved in their cataloguing.

3.1. Triangulation and oral histories after the record:

Some scholars may interpret the availability of these archives as a sign that historical research on genomics will no longer require oral histories. This view is partly the result of the criticisms interviewing has received as a historical method (Tonkin 1992; Perks and Thompson 1998, Parts I and V) and a long-entrenched stereotype that oral histories are there merely to replace written sources produced at the time of events. However, a review of the work by historians of molecular biology shows they continued conducting interviews after personal archives of their interviewees were retrieved. Their use of oral histories appears to have developed in combination with, rather than as a replacement for, archival evidence (for instance, Kay 2000; de Chadarevian 2002). If this is the case, what additional role may oral sources play for historians and in what way does this distinguish oral histories from other types of interviews conducted by sociologically and anthropologically-oriented STS researchers?

The problems associated with oral histories are not so much with the interviewing itself, but with the interview being conducted *before* archival sources have been accessed. Any retrospective account creates a conflict between the memory of the narrator and documents produced at the time of the events that are narrated (Gaudillière 1997; Hoddeson 2006). Furthermore, given that the interviewee scientist has control over these documents – the personal archive – he or she may be selective, leading the interviewer historian to some records rather than others. The interviewee scientist thus creates an account that may

overlook embarrassing or uncomfortable episodes while highlighting more successful ones. When scientists select the papers and correspondence to be transferred to an archive, there is a potential threat of unconscious or conscious reproduction of their partial accounts, a common shortcoming of individual scientific collections (Shaw, in this issue).

The existence of a wide range of retrospective accounts has been a long-standing problem in the historiography of molecular biology. Consolidation of the discipline and, in particular, the first Nobel Prizes awarded to molecular biologists in the early 1960s, prompted an increasing number of autobiographies and first-hand historical essays, written according to the interests of their authors and the collective requirements of the field (Cairns et al. 1966; Watson 1968; Jacob 1970; Crick 1988). These accounts created a first order of legitimation for molecular biology, subsequently reified by a body of historical literature too reliant on the voices of leading scientists (Abir-Am 1985; see also Aicardi, in this issue). The first historical surveys of molecular biology were based on scientists' testimonials and interviews using journalistic rather than historical tools (Judson 1979). Historians in the 1980s and '90s endeavoured to balance this literature through more historically-grounded conversations and critical triangulation between oral sources and the archives they gradually encountered (de Chadarevian, in this issue).

Edna Suárez-Díaz has argued that the problems relating to retrospective accounts are permeating the emerging historiography of genomics. As the Nobel Prizes had 40 years earlier, the completion of the HGP in 2003 triggered a proliferation of autobiographies and interview-based stories about the project (Davies 2002; Sulston and Ferry 2002; Collins 2006; Venter 2007). There was also a continuity of actors, such as James Watson, a founder of molecular biology – he co-elucidated the double helix of DNA – who was appointed first director of the HGP in the United States. Suárez-Díaz has shown that this continuity of people and narrative styles has resulted in shared methodological problems in the history of molecular biology and genomics. The *Cinderella stories* of the founding fathers of molecular biology created a view of this discipline engaged in achieving an increasingly perfect definition of the DNA molecule, and the autobiographies of leading genomicists presented the HGP as the natural outcome of this scientific endeavour (Suárez-Díaz 2010). In other words, the determination of the fine molecular sequence of the human genome is portrayed as the culmination of the historical enterprise of molecular biology: obtaining an ever-more-accurate description of the structure and function of DNA as our genetic material (see also Fortun 1993).

However, a comparative advantage for the historiography of genomics is the role archives are beginning to play in the triangulation between retrospective accounts and synchronic information sources. Historians of genomics are now able to access archival sources before conducting oral histories or even reading autobiographical or journalistic accounts. This enables them to become aware of the actors involved in the field and consider different perspectives of the field's development, unmediated by the narrative of a particular scientist years after genomics and the HGP emerged.

The fact that historians are no longer dependent on scientists and their accounts does not rule out the value of these sources. Retrospective information remains useful later in the research process, once archive-based exploration and consideration has been completed. At this point,

the narratives of scientists may be useful to fill gaps between archival records or understand why views have changed and why actors attempt to reconstruct the past in the way they do. This combination of archives and oral sources enables historians to build a pluralistic and heterogeneous second order narration, as the historiography of both molecular biology and genomics demand (Abir-Am 1985; Suárez-Díaz 2010). Being independent from the views of scientists, this second order narration creates a framework that protects future archives or scholarly work from excessive dependence on individual memories.

An example of this within the new genomic archives is a collection of meeting minutes describing how the UK Human Genome Mapping Project (HGMP) took shape. This collection dates back to 1986, when the project was originally proposed to the British Medical Research Council (MRC) by molecular biologist Sydney Brenner. The MRC's Cell Board, having examined Brenner's application, created an *ad-hoc* committee to develop the proposal and look for appropriate funding sources. In 1989, after successfully bidding for additional Government funds, the HGMP was launched as a three-year project intended to construct an ordered physical map of DNA fragments covering the entire human genome (see Figure 1). Sequence determination was only intended to be conducted in particular areas, those of interest to existing UK groups working on human genetics – for example, the genome regions in which genes involved in hereditary diseases were located (Alwen 1990; McLaren 1991; Balmer 1996a). In 1992, when the first cycle of funding was reaching an end, the MRC allied itself with the Wellcome Trust to establish the Sanger Centre. This institution, in cooperation with other international laboratories, would undertake the systematic mapping and sequencing of the entire human genome (Fletcher and Porter 1997; Bartlett 2008). This broader transnational initiative was entitled the HGP, and gradually subsumed the British HGMP.

The HGMP meeting minutes provide a day-to-day account of why the project was approved and under what conditions. Despite polite editing by the administrators in charge of minute-taking, by reading in between the lines one can see the different sensibilities involved and how their views responded to changing pressures and accountabilities. The first pattern that emerges when cross-examining these records is the expansion and overall transformation of the project in the years leading up to 1992. One of the first documents of the series summarises a 1987 meeting of the MRC Cell Board to assess Brenner's proposal, a short, single-authored document formulated in rather generic terms. By the mid 1980s, Brenner had become highly regarded due to his pioneering work on gene expression with co-elucidator of the double helix of DNA, Francis Crick, at the Laboratory of Molecular Biology, Cambridge (LMB). A year before the meeting, with funding from the MRC and private institutions, Brenner had left the LMB and established an independent Molecular Genetics Unit, in which he hoped to carry out the HGMP and other research projects.¹¹

Brenner's institutional move had been partly motivated by political and financial shifts. The LMB had traditionally been funded via block grants, awarded by the MRC over long periods of time to pursue basic research on molecular biology (de Chadarevian 2002, chs. 9-10; García-Sancho 2012a: 128-31). However, the arrival of Margaret Thatcher in the UK Government, first as Education and Science Secretary and, since 1979, as Prime Minister, had led to dramatic decreases in public science expenditure and a push for industrial collaboration and applied research. This resulted in policies advocating the concentration of human and technological

resources towards tangible scientific outcomes (Cunningham and Nicholson 1991; Balmer 1996b: 255 ff). Within the life sciences, there was demand for the clinical translation of molecular biology and the use of recombinant DNA methods, given their perceived medical promise. Brenner's new Molecular Genetics Unit was located within Cambridge's Addenbrooke's Hospital and the HGMP presented as an application of genome mapping technologies to the location of genes with potential for the study of hereditary conditions.

Shortly after receiving Brenner's proposal, the MRC decided to broaden the scope of the project and turned to human geneticist Walter Bodmer, by then Director of Research at a private charity, the Imperial Cancer Research Fund. This led to qualitative and quantitative expansion of the HGMP, with an increasing number of people and institutions becoming involved whose interests lay not only in molecular biology, but also in clinically-applied genetics. In 1989, the project became one of the few lines of research sustained with exclusively committed Government funds, as a concerted effort by UK scientists to achieve a physical map of the human genome. A complex organisational structure had been created by this time, with a HGMP Project Management Committee, a Directed Programme Committee, and subcommittees devoted to issues relating to, among other areas, biology and computing. The minutes of a meeting held in March 1990 list 16 attendees, including molecular biologists, geneticists, administrators and MRC officials (see Figures 2a and b).¹²

INSERT FIGURE 2a AND 2b AROUND HERE

This complexity of structure and actors challenges the notion of human genomics as a mere continuation of molecular biology. The fact Brenner made his career at the LMB – a renowned MRC-funded institution and the home of most of the 1960s Nobel-awarded molecular biologists – supports the idea of the HGMP resulting from Brenner's insight and research into the fundamental mechanisms of gene structure. Yet in late 1986, shortly after the submission of Brenner's proposal, the MRC made a list of UK institutions with potential interest in the mapping of the human genome; this ran over 20 pages and featured over 100 MRC-funded projects, mostly in the domain of health-related genetics.¹³ The involvement of medically and clinically-minded geneticists increased once the project was under way, with, for example, Malcolm Ferguson-Smith, Chair of Pathology at the University of Cambridge, and Nick Hastie, a group leader at the MRC Human Genetics Unit in Edinburgh, contributing significantly to the meeting in March 1990.

Crucial details of how the HGMP would be carried out were decided at this meeting, including the adoption of the cDNA approach, a sequencing strategy which limited determination of the human genome sequence to regions constituting genes. These regions represent only 1.5% of the overall sequence, the rest considered at that time to be 'junk DNA'. The meeting participants believed this approach would rapidly isolate disease-related genes and, therefore, expectations of medical applications – implicit in the commitment of Government funding – would be fulfilled (Balmer 1996a: 544 ff). There was also a desire to create a "flagship for the UK in the establishment of international credibility" at a time when the United States had launched its own project with a considerably larger budget (Cook-Deegan 1994).¹⁴

The cDNA strategy began to be questioned when the scope and funding of the national human genome projects expanded. As the 1990s continued, and both institutional collaboration and

sequencing technology advanced, the label 'HGP' emerged as an unspecific framework in which to coordinate the pre-existing initiatives. The HGP framework also induced some countries to increase their financial contributions in an attempt to lead the growing international effort. This enhanced funding and coordination enabled the major HGP participants to adopt an alternative strategy: to build large-scale genomic facilities and sequence the entire genome. In these factory-like facilities, cDNA sequencing appeared slow and ineffective.

Following publication of the HGP's initial draft in 2001, a number of scientists involved referred to whole-genomic sequencing as a characteristic approach of molecular biology. According to their accounts, cDNA sequencing was a strategy more representative of medical geneticists, given their interest in specific genes linked to diseases and their belief that genome research should be limited to those sequences. Molecular biologists, motivated to discover how genomes worked, would determine the complete sequence, including non-genetic regions and genes with, at that time, unknown functions. One of the main defenders of whole-genome sequencing in the UK was John Sulston, who was appointed Director of the Sanger Centre in 1993 and led British participation in the emerging international effort to sequence the complete human genome (Sulston and Ferry 2002).

Through careful examination of the HGMP meeting minutes, this distinction between molecular biologists and geneticists in the light of their sequencing strategies can be challenged. In March 1990, the cDNA strategy was "unanimously approved" and no scientist, including the molecular biologists attending the meeting, expressed a preference for sequencing the entire genome.¹⁵ This suggests that selective sequencing of genetic fragments was perceived to be the most convenient and feasible approach at that time – both scientifically and politically – by all researchers, regardless of their disciplinary affiliation. Biomedical investigators did not convert to whole-genome sequencing until large-scale sequencing institutions – such as the Sanger Centre – and funding schemes that favoured international collaboration – rather than, like the HGMP, prioritising national interests – had been established. Furthermore, the non-genetic regions of the human genome were still defined as 'junk DNA' in 1990, their importance as regulatory sequences only being realised in subsequent years.

The minutes of the HGMP meetings may therefore be used as a probe when conducting oral histories with scientists who led the large-scale sequencing centres. Preliminary analysis of these documents can help challenge views and categorisations that interviewed scientists have retrospectively established through their autobiographies and well-rehearsed media accounts. Given that many of these scientists were involved in the more obscure genomic initiatives of the mid to late 1980s – including the HGMP¹⁶ – archival evidence, in combination with oral histories, can shed light on the non-technical factors that prompted their approach to change. Identifying these will also result in a deeper exploration of the economic and socio-political structures that led the HGP to be configured as big science, and presented as if sequencing the entire human genome had always been the goal.

Archival research can also alert scholars to other possible interviewees. Bodmer, Ferguson-Smith and Hastie, who feature prominently in the meeting minutes, could provide a

perspective on human genomics originating from the research interests of more medically and clinically-minded geneticists. This perspective is increasingly being sought by historians as an alternative to the standard narratives of molecular biologists (Comfort 2012; Lindee, in this issue; see note 13). The Human Genetics Unit in Edinburgh is therefore beginning to attract historical researchers (de Chadarevian 2013a) and Hastie recently featured in an extended oral history. The Papers and Correspondence of Bodmer and Ferguson-Smith have also been catalogued and released for research use.¹⁷ This academic and archival interest will go some way to addressing the feeling, expressed by some geneticists, of being the forgotten actors in the HGP story (Bodmer and McKie 1997).

3.2. The synthetic voice of the invisible administrator:

The renewed triangulation between oral and written, retrospective and synchronic sources that the genomic archives promise will have consequences beyond the history of science. Anthropologists, including those working on genomics, have often described the 'snowball effect' they experience when interviewing their first scientists (Hilgartner 2004; Rabinow and Dan-Cohen 2005; Reardon 2005). The new archives now enable this snowball effect to be triggered by documents referring to relevant people at a particular time and space rather than by the retrospective account of a single scientist. In the case of the HGMP, preliminary analysis of the meeting minutes identifies actors that an interview with Brenner or any other scientific celebrity could have omitted.

These additional actors are not only scientists. As the MRC broadened the institutional and disciplinary scope of its research programmes – in response to funding policies favouring a concentration of resources – a particular kind of administrator began to play a crucial part in their day-to-day organisation. These administrators usually had a background in the biomedical sciences, often with a PhD and laboratory experience. However, at some point they had decided to move into a career in MRC administration, normally based at the Headquarters, by then located in London. The administrators were assigned management of a portfolio of topics within the remit of one of the MRC review boards at both the pre and post-award stages. Portfolios were often rotated among staff at intervals and the HGMP was run by three different administrators in the period between 1986 and '92. Commitment to the HGMP was not full-time and all administrators combined it with other responsibilities within the MRC Cell Board.¹⁸

The HGMP administrators share many of the characteristics of laboratory technicians. In her study of the MRC National Institute for Medical Research, Tilli Tansey has shown the important role technicians have taken in shaping mid-twentieth century biomedicine. These technicians are difficult to tackle historically, due to their low profile and a lack of written records. Their role tends to be overshadowed by the scientists leading the research projects who, in many cases, authored autobiographies or donated their records to archives (Tansey 2008). Similarly, the HGMP administrators are largely unknown to academics or the general public. They do not feature in the scholarship or popular literature on human genomics, which tend to focus on the scientists or senior-management officials at both the MRC and US National Institutes of Health. As a number of top genomic scientists were assigned crucial managerial positions

within the HGMP and later the HGP, due to their scientific calibre, research and managerial roles often overlap.

Scientist-managers, like other scientific celebrities, engage in published or media accounts, as well as the formation of archives about their research.¹⁹ Administrators at a lower level in the hierarchy, however, leave less traceable historical footprints, despite often being more knowledgeable about the daily running of such endeavours. Their records have traditionally been considered secondary to policy-making or laboratory work, and thus separated from mainstream scientific collections, which are often organised around principal investigators, and feature both their laboratorial and top-managerial roles. Archivists compile and catalogue these mainstream collections in cooperation with leading scientists, thereby providing a top-down view of scientific practice. Some of the newly available archives for the study of genomics still remain structured along these lines.

However, another type of archival collection is gradually becoming available to historians of genomics, consisting of the administrative records that public institutions create and transfer to centralised State archives. In the case of the HGMP, the UK National Archives are releasing the paper trail the MRC produced during the duration of the project. Unlike collections named after individual scientists or managers, the MRC records were compiled and organised by the different administrators in charge of the HGMP. These administrators combined documents authored by themselves with others produced by the wide array of geneticists, molecular biologists, Cabinet representatives and MRC officials involved in the project. It was the rolling administrators – rather than any individual scientist or chief executive – who selected and ordered the records before transferring them to the archives. The administrative records, thus, provide a different story to those belonging to leaders of genomic projects, such as Brenner or Sulston.²⁰

Each file of the MRC collections begins with various pages in which the administrators, often via handwritten notes, describe the steps involved in the processing and archiving of some records. The notes are written, signed and dated consecutively in cardboard pages – as opposed to the other paper documents – and were recorded consecutively over a given stage of the project, normally one or two years. At times, scientists and upper-level MRC officers inserted comments between the administrators' notes, suggesting there was exchange and discussion (see Figure 3). The repetitiveness of these cardboard pages in the archive's files suggests the documents were circulated among various departments within and outside the MRC, and that the administrators gradually built a meta-narrative that justified the place of the records in the HGMP history.²¹

INSERT FIGURE 3 AROUND HERE

After these introductory notes, the documents are sometimes accompanied by memos or attachments – often of a different size and colour – in which the administrators explain the background of the records. For instance, in late 1986, when Brenner's HGMP proposal was being discussed, a member of the MRC Cell Board expressed his dissatisfaction with the format of meetings. This triggered an intense paper exchange in which drafts of letters to the board member were circulated within and beyond the MRC Headquarters, highlighting the importance of the HGMP being a consensus project. The draft letters attempted to explain to

the board member the rationale behind the HGMP, its peculiar institutional organisation and the importance “of maintaining the integrity of the system” not only internally, but also “in the minds of those outside the Board room.”²² By reading the arguments gradually added to the letter and how they were amended – as well as the response of the board member, who was finally convinced – one may grasp the different interests surrounding the HGMP and the necessity of balancing them for the project to achieve the desired sustainability.

In early 1987, a journalistic report in *New Scientist* featuring the HGMP (Vines 1987) was met with criticism from scientists at the LMB, Brenner’s former home institution. The administrators liaised intensely between the disputing scientists and presented reports of letters and phone conversations summarising the negotiations to upper-level MRC managers. The dispute was not easily settled and required a letter to *New Scientist* signed by Brenner and the objecting LMB researchers emphasising the collaborative nature of the work leading to the HGMP.²³ This illustrates the difficulties in squaring the HGMP with work Brenner had previously conducted on basic molecular biology, especially given that, shortly before proposing the project, he had left the LMB and started a line of research closer to medical and human genetics.

These examples reflect the decisive role of administrators in mediating between the diverse scientific, political and managerial agendas the HGMP mobilised. The new MRC research programmes, responding to restrictive funding schemes, involved an increasing number of actors, who represented different scientific disciplines, institutional cultures and political perspectives. This created an extra responsibility for administrators: as actors devoted to ensuring continuity of the programmes and the harmonisation of the often conflicting strategic views. Administrators were regarded by other actors as neutral figures, their global view of the HGMP, together with engagement in the routine running of the project, sharply distinguishing them from members of a particular executive committee or senior managerial staff. This shadow brokering power was essential to reconcile the conflicting objectives of geneticists, molecular biologists, Government officials and MRC chief executives.

The administrators’ brokering power is reflected in their archive, which effectively balances the different voices of the HGMP story. The documents and notes various HGMP administrators gathered over the course of the project provide a compelling account of how this initiative persisted, despite the often incongruous attitudes of the actors involved. The administrative archive thus portrays the HGMP as a collective endeavour, the result of a synthesis of different political and scientific worldviews. By contrast, the collections of individual scientists project – often unconsciously – the correctness of their own approach, whether this approach was chosen or unfairly disregarded. An overview of Brenner’s archive reveals a tendency to emphasise his role as the proponent of the HGMP, despite his gradual withdrawal from the daily running of the project during the 1990s. Sulston’s collection highlights his defence of whole-genome sequencing and overlooks the dominance of the alternative cDNA approach during the early years of human genomics.²⁴

The synthetic capacity of administrators can be a powerful tool for scholars seeking more inclusive accounts of the emergence of genomics, in line with other ‘big picture’ endeavours in the historiography of science (Secord 1993; Pickstone 2000; Agar 2012). The administrative

archive, in combination with more individualised collections and oral histories, enables one to take advantage of the multiplication of historical sources without sacrificing narrative focus or falling into partisan perspectives. These administrative records also present an opportunity for historians to engage with the processing of information concerning recent science. If future historical research emphasises the advantages of the administrative archive, cataloguing projects may gradually grant administrators their rightful place in the development of contemporary big science.

4. Conclusions:

The sequencing of the human genome has been considered by many the point at which big science models entered biomedicine (Hood 1990; Fortun 1999; Lenoir and Hays 2000; Bartlett 2008: 58 ff; Parker et al. 2010, Parts 3 and 4). Expansion of research teams and the rise of large-scale collaborative projects – alongside expensive budgets and high political profiles – have made coordinating biomedical practice and aligning results with social need more complicated. There is a parallel concern among historians of science that this expansion will increase the number of available sources exponentially and render scholarship unmanageable (Doel and Söderqvist 2006). The diversity of actors and institutions involved in contemporary biomedical research has resulted in multiple and at times contrasting historical voices; the essays in this special issue suggest strategies for navigating the ever-expanding source material.

In this paper, I have argued that the problem is not so much caused by an overabundance of sources, but by a lack of narrative models with which to address big science. Most archives becoming available in the field of genomics reproduce the traditional organisation of scientific research around individual team leaders. This stands in marked contrast with the practice of genomics, which has been compared to a Deleuzian rhizomatic space, constituted by multiple interconnected nodes without a clear centre (Fortun 1998; Heeney Upcoming). The divergence between scientific practice and archival organisation results in two pressing methodological problems for historians of genomics: how to address a collective enterprise through individual records, and how to handle the large volume of single-scientist collections being released for research.

Historians have traditionally relied on the perspective of time to filter material and create the necessary distance between scholar and sources. However, the passive waiting this strategy entails has resulted in ‘received archives’, reifying the epic accounts of leading scientists. I have proposed a more proactive strategy: continuous engagement with the records of contemporary science. This approach is consistent with the current push for embeddedness of the humanities in global problems and ensures that historians will have a voice – among many others – in how the heritage of science is socially and politically assembled. The historiography of recent science argues there are fundamental differences between the contemporary and earlier scientific ages (Söderqvist 1997). I suggest it is the lack of a historical voice in the heritage of earlier periods that makes them appear so different and creates enduring problems for pre-contemporary historians.

I have proposed the administrative archives of big science projects as an alternative source to single-scientist collections. The brokering expertise of big science administrators, navigating among the many actors involved in projects and harmonising their conflicting views, constitutes a privileged point of entrance into the rhizome of genomics. Furthermore, the administrators' expertise in mediating between social worlds is a potential platform for collaboration between historical and social studies of science.²⁵ I am by no means implying that the administrative archive represents a true record, and more work needs to be conducted to fully grasp its historiographical significance. However, the synthetic capacity of administrators, combining documents from many authors and arranging them in a quest for continuity and consensus, provides a fruitful framework for triangulating their archives with other more partisan sources.

The administrative archive helps open the black box of contemporary scientific funders. As historians of molecular biology unpacked the inner workings of the Rockefeller Foundation (see note 19), emerging scholarship on genomics should address how current debates around 'big science' and 'big data' derive from contingent policy shifts and changes in the management of science. In this regard, my analysis of the HGMP records demonstrates that Neo-liberal funding schemes prompted the MRC to concentrate researchers and technologies around the mapping of the human genome. This resulted in the size of teams and, subsequently, of the research data gathered, increasing. Current concern surrounding data governance and the tendency to embed STS researchers in biomedical projects can, consequently, suggest this growth of volume is heading beyond manageable control.²⁶

Administrative records thus represent an opportunity for historians to address pressing socio-political problems. Historical research identifying the narrative voices behind archives and effectively exchanging this knowledge with archivists – as is the intent of this special issue – will potentially lead to more valuable sources for academics, scientists and society. The Wellcome Library is currently cataloguing the papers of individual researchers who worked at the Sanger Centre (Shaw, in this issue). Under these archives, in deep-storage containers, there is a collection describing how the Sanger Centre was conceived, proposed and established, and how one third of the human genome was completed in its laboratories. Authorship of these records is manifold, often featuring actors unknown to the general public. The records also promote disagreement and compromise as a formula for success. Access to these records has traditionally required lengthy negotiations and complex confidentiality undertakings. If their release becomes a collective endeavour of historians and archivists, the social role of their work may change for the better: these proactive scholars will become co-constructors of the future view of genomics rather than passive interpreters of a received past.

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References

Aaron Dennis, M. (2006), 'Secrecy and Science Revisited: From Politics to Historical Practice and Back', in R.E. Doel and T. Söderqvist (ed.), *The Historiography of Contemporary Science, Technology and Medicine: Writing Recent Science*, London and New York: Routledge: 172-184.

Abir-Am, P. (1982), 'The Discourse of Physical Power and Biological Knowledge in the 1930s: A Reappraisal of the Rockefeller Foundation's policy in Molecular Biology', *Social Studies of Science* 12: 341-382.

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.

Agar, J. (2012), *Science in the Twentieth Century and Beyond*, Cambridge: Polity.

Aicardi, C. (2014), 'Of the Helmholtz Club, South-Californian Seedbed for Visual and Cognitive Neuroscience, and Its Patron Francis Crick', *Studies in History and Philosophy of Biological and Biomedical Sciences* 45: 1-11.

Aicardi C., 'Francis Crick, Cross-Worlds Influencer: A Narrative Model to Historicize Big Bioscience', *Studies in History and Philosophy of Biological and Biomedical Sciences*, in this issue.

Alwen, J. (1990), 'United Kingdom Human Genome Mapping Project: Background, Development, Components, Coordination and Management, and International Links of the Project', *Genomics* 6: 386-388.

Ankeny, R. (2010), 'Historiographical Reflections on Model Organisms: Or, How the Bureaucracy May Be Limiting Our Understanding of Contemporary Genetics and Genomics', *History and Philosophy of the Life Sciences*, 32(1): 91-104 32: 91-104.

Ankeny, R.A. (2001), 'The Natural History of *Caenorhabditis Elegans* Research', *Nature Reviews Genetics* 2: 474-479.

Atkinson, P., P. Glasner and H. Greenslade (ed.) (2006), *New Genetics, New Identities*, London and New York: Routledge.

Balmer, B. (1996a), 'Managing Mapping in the Human Genome Project', *Social Studies of Science* 26: 531-573.

Balmer, B. (1996b), 'The Political Cartography of the Human Genome Project', *Perspectives on Science* 4: 249-282.

Bangham, J. and S. de Chadarevian (2014), 'Human Heredity after 1945: Moving Populations Centre Stage', *Studies in History and Philosophy of Science Part C: Studies in History and Philosophy of Biological and Biomedical Sciences* 47, Part A: 45-49.

Bartlett, A. (2008), *Accomplishing Sequencing the Human Genome*, PhD dissertation, Cardiff University.

Bodmer, W. and R. McKie (1997), *The Book of Man: The Human Genome Project and the Quest to Discover Our Genetic Heritage* Oxford: Oxford University Press.

Bowker, G.C. (2005), *Memory Practices in the Sciences*, MIT Press Cambridge, MA.

Brandt, C. (2013), 'Hybrid Times: Theses on the Temporalities of Cloning', *History and Philosophy of the Life Sciences* 35: 75-82.

Bryder, L. and J. Austoker (ed.) (1989), *Historical Perspectives on the Role of the Mrc: Essays in the History of the Medical Research Council of the United Kingdom and Its Predecessor, the Medical Research Committee, 1913-1953*, Oxford: Oxford University Press.

Bud, R. (1993), *The Uses of Life: A History of Biotechnology*, Cambridge University Press.

Butterfield, H. (1997 [1949]), *The Origins of Modern Science*, New York: Simon and Schuster.

Cairns, J., G. Stent and J. Watson (ed.) (1966), *Phage and the Origins of Molecular Biology*, Cold Spring Harbor.

Calvert, J. (2014), 'Collaboration as a Research Method? Navigating Social Scientific Involvement in Synthetic Biology', in N. Doorn, D. Schuurbijs, I. van de Poel and M. Gorman (ed.), *Early Engagement and New Technologies: Opening up the Laboratory*, Dordrecht: Springer: 175-194.

Cantor, D. (In press), 'Finding Historical Records at the National Institutes of Health', *Social History of Medicine*.

Collins, F.S. (2006), *The Language of God: A Scientist Presents Evidence for Belief*, New York: Simon and Schuster.

Comfort, N. (2011), 'When Your Sources Talk Back: Toward a Multimodal Approach to Scientific Biography', *Journal of the History of Biology* 44: 651-669.

- Comfort, N. (2012), *The Science of Human Perfection: How Genes Became the Heart of American Medicine*, Yale University Press.
- Cook-Deegan, R. (1994), *The Gene Wars: Science, Politics and the Human Genome*, Norton.
- Crick, F. (1988), *What Mad Pursuit: A Personal View of Scientific Discovery*, London: Weidenfeld and Nicolson.
- Cunningham, A. (1988), 'Getting the Game Right: Some Plain Words on the Identity and Invention of Science', *Studies in History and Philosophy of Science* 19: 365-89.
- Cunningham, C.M. and R.H. Nicholson (1991), 'Central Government Organisation and Policy Making for Uk Science and Technology since 1982', in R.H. Nicholson, C.M. Cunningham and P. Gummatt (ed.), *Science and Technology in the United Kingdom*, Harlow: Longman: 27-43.
- Chadarevian, S. (1997), 'Using Interviews to Write the History of Science', in T. Söderqvist (ed.), *The Historiography of Contemporary Science and Technology*, Amsterdam: Harwood Academic Publishers: 51-70.
- Chandler Jr, A.D. (2005), *Shaping the Industrial Century: The Remarkable Story of the Evolution of the Modern Chemical and Pharmaceutical Industries*, Cambridge: Harvard University Press.
- Daston, L. (2009), 'Science Studies and the History of Science', *Critical Inquiry* 35: 798-813.
- Daston, L. (2012), 'The Sciences of the Archive', *Osiris* 27: 156-187.
- Davies, K. (2002), *Cracking the Genome: Inside the Race to Unlock Human DNA*, Baltimore: Johns Hopkins University Press.
- 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. (2002), *Designs for Life: Molecular Biology after World War II*, Cambridge: Cambridge University Press.
- de Chadarevian, S. (2004), 'Mapping the Worm's Genome: Tools, Networks, Patronage', in H.-J. Rheinberger and J.P. Gaudilliere (ed.), *From Molecular Genetics to Genomics: The Mapping Cultures of Twentieth Century Genetics*, London and New York: Routledge: 95-110.
- de Chadarevian, S. (2011), 'The Making of an Entrepreneurial Science', *Isis* 102: 601-633.

de Chadarevian, S. (2013a), 'Putting Human Genetics on a Solid Basis: Human Chromosome Research, 1950s–1970s', in B. Gausemeier, S. Muller-Wille and E. Ramsden (ed.), *Human Heredity in the Twentieth Century*, London: Pickering and Chatto:

de Chadarevian, S. (2013b), 'Things and the Archives of Recent Sciences', *Studies in History and Philosophy of Science* 44: 634-638.

de Chadarevian S, 'The Future Historian: Reflection on the Archives of Contemporary Sciences', *Studies in History and Philosophy of Biological and Biomedical Sciences*, in this issue.

Dear, B.P. and S. Jasanoff (2010), 'Dismantling Boundaries in Science and Technology Studies', *Isis* 101: 759-774.

Doel, R.E. (1997), 'Scientists as Policymakers, Advisors and Intelligence Agents: Linking Contemporary Diplomatic History with the History of Contemporary Science', in T. Söderqvist (ed.), *The Historiography of Contemporary Science and Technology*, Amsterdam: Harwood Academic Publishers: 215-244.

Doel, R.E. and T. Söderqvist (2006), 'Introduction: What We Know, What We Do Not - and Why It Matters', in R.E. Doel and T. Söderqvist (ed.), *The Historiography of Contemporary Science, Technology, and Medicine: Writing Recent Science*, London and New York: Routledge:

Edgerton, D. (1992), *England and the Aeroplane: An Essay on a Militant and Technological Nation*, London: Macmillan Press.

Edgerton, D. (2006), *The Shock of the Old: Technology and Global History since 1900*, Oxford University Press.

Edwards, P.N. (1997), *The Closed World: Computers and the Politics of Discourse in Cold War America*, MIT Press.

Eisenstein, E.L. (1980), *The Printing Press as an Agent of Change*, Cambridge: Cambridge University Press.

Felt, U. (2014), 'Within, across and Beyond: Reconsidering the Role of Social Science and Humanities in Europe', *Science as Culture* 23: 384-396.

Fletcher, L. and R. Porter (1997), *A Quest for the Code of Life: Genome Analysis at the Wellcome Trust Genome Campus*, London: Wellcome Trust.

Forman, P. (1997), 'Recent Science: Late-Modern and Post-Modern', in T. Söderqvist (ed.), *The Historiography of Contemporary Science and Technology*, Amsterdam: Harwood: 179-213.

Fortun, M. (1999), 'Projecting High Speed Genomics', in M. Fortun and E. Mendelsohn (ed.), *The Practices of Human Genetics*, Dordrecht: Kluwer: 25-48.

Fortun, M.A. (1993), *Mapping and Making Genes and Histories: The Genomics Project in the United States, 1980-1990*, PhD dissertation, Harvard University.

Fortun, M.A. (1998), 'The Human Genome Project and the Acceleration of Biotechnology', in A. Thackray (ed.), *Private Science: Biotechnology and the Rise of the Molecular Sciences* Philadelphia: University of Pennsylvania Press: 182-201.

Fujimura, J.H. (1996), *Crafting Science: A Sociohistory of the Quest for the Genetics of Cancer*, Cambridge: Harvard University Press.

Galison, P. and B.W. Hevly (1992), *Big Science: The Growth of Large-Scale Research*, Stanford: Stanford University Press.

García-Sancho, M. (2012a), *Biology, Computing and the History of Molecular Sequencing: From Proteins to DNA (1945-2000)*, Basingstoke, UK: Palgrave-Macmillan.

García-Sancho, M. (2012b), 'From the Genetic to the Computer Program: The Historicity of 'Data' and 'Computation' in the Investigations on the Nematode Worm *C. Elegans* (1963–1998)', *Studies in History and Philosophy of Biological and Biomedical Sciences* 43: 16-28.

Gaudillière, J.-P. (2009), 'New Wine in Old Bottles? The Biotechnology Problem in the History of Molecular Biology', *Studies in History and Philosophy of Science Part C: Studies in History and Philosophy of Biological and Biomedical Sciences* 40: 20-28.

Gaudillière, J.P. (1997), 'The Living Scientist Syndrome: Memory and History of Molecular Regulation', in T. Söderqvist (ed.), *The Historiography of Contemporary Science and Technology*, Amsterdam: Harwood Academic Publishers: 109-128.

Glasner, P., P. Atkinson and H. Greenslade (ed.) (2006), *New Genetics, New Social Formations*, London and New York: Routledge.

Gold, M.K. (ed.) (2012), *Debates in the Digital Humanities*, Minnesota: University of Minnesota Press.

Goldthorpe, J.H. (1991), 'The Uses of History in Sociology: Reflections on Some Recent Tendencies', *The British Journal of Sociology* 42: 211-230.

Gooday, G.J.N. (1995), 'The Morals of Energy Metering: Constructing and Deconstructing the Precision of the Victorian Electrical Engineer's Ammeter and Voltmeter', in N.M. Wise (ed.), *The Values of Precision*, Princeton: Princeton University Press: 239-282.

Hagen, J.B. (2010), 'Waiting for Sequences: Morris Goodman, Immunodiffusion Experiments, and the Origins of Molecular Anthropology', *Journal of the History of Biology* 43: 697-725.

Heeney, C. (Upcoming), 'Ethical Moments and the Virtual in Data Sharing', *Science, Technology and Human Values*

Hilgartner, S. (2004), 'Making Maps and Making Social Order: Governing American Genome Centers, 1988-93', in H.J. Rheinberger and J.P. Gaudilliere (ed.), *From Molecular Genetics to Genomics: The Mapping Cultures of Twentieth Century Genetics*, Routledge: 113-128.

Hoddeson, L. (2006), 'The Conflict of Memories and Documents: Dilemmas and Pragmatics of Oral History', in R.E. Doel and T. Söderqvist (ed.), *The Historiography of Contemporary Science, Technology and Medicine: Writing Recent Science*, London and New York: Routledge: 187-200.

Hogan, A.J. (2014), 'The 'Morbidity' of the Human Genome: Tracing the Observational and Representational Approaches of Postwar Genetics and Biomedicine the William Bynum Prize Essay', *Medical history* 58: 315-336.

Holmes, F.L. (2001), *Meselson, Stahl and the Replication of DNA: A History of 'the Most Beautiful Experiment in Biology*, New Haven: Yale University Press.

Hood, L. (1990), 'Human Genome Project: Is Big Science Bad for Biology? No, and Anyway the Hgp Isn't Big Science', *The Scientist* 4: 13-15.

Hughes, J. (1997), 'Whigs, Prigs and Politics: Problems in the Historiography of Contemporary Science', in T. Söderqvist (ed.), *The Historiography of Science and Technology*, Amsterdam: Harwood: 19-37.

Jacob, F. (1970), *La Logique Du Vivant : Une Histoire De L'hérédité*, Paris: Gallimard, Cop.

Jardine, N., J.A. Secord and E.C. Spary (ed.) (1996), *Cultures of Natural History*, Cambridge: Cambridge University Press.

Jasanoff, S. (2005), *Designs on Nature: Science and Democracy in Europe and the United States*, Princeton University Press.

Judson, H.F. (1979), *The Eight Day of Creation: Makers of the Revolution in Biology* Cape Publishers.

Kaplan N (1959), The Role of the Research Administrator, *Administrative Science Quarterly*, 4: 20-42.

Kay, L. (2000), *Who Wrote the Book of Life: A History of the Genetic Code*, Stanford: Stanford University Press.

Kay, L.E. (1993), *The Molecular Vision of Life: Caltech, the Rockefeller Foundation, and the Rise of the New Biology*, Oxford: Oxford University Press.

Kaye, J., S. Gibbons, C. Heeney, M. Parker and A. Smart (2012), *Governing Biobanks: Understanding the Interplay between Law and Practice*, Oxford: Hart Publishing.

Keating, P., C. Limoges and A. Cambrosio (1999), 'The Automated Laboratory: The Generation and Replication of Work in Molecular Genetics', in M. Fortun and E. Mendelsohn (ed.), *The Practices of Human Genetics*, Dordrecht: Kluwer: 125-142.

Kevles, D. and L. Hood (ed.) (1992), *The Code of Codes: Scientific and Social Issues in the Human Genome Project*, Cambridge: Harvard University Press.

Kevles, D.J. and G.L. Geison (1995), 'The Experimental Life Sciences in the Twentieth Century', *Osiris* 97-121.

Kohler, R.E. (1976), 'The Management of Science: The Experience of Warren Weaver and the Rockefeller Foundation Programme in Molecular Biology', *Minerva* 14: 279-306.

Koyré, A. (1957), *From the Closed World to the Infinite Universe*, Baltimore: Johns Hopkins University Press.

Lenoir, T. and M. Hays (2000), 'The Manhattan Project for Biomedicine', in P.R. Sloan (ed.), *Controlling Our Destinies. Historical, Philosophical, Ethical, and Theological Perspectives on the Human Genome Project*, Indiana: University of Notre Dame Press: 29-62.

Leonelli, S. (2012), 'Introduction: Making Sense of Data-Driven Research in the Biological and Biomedical Sciences', *Studies in History and Philosophy of Science Part C: Studies in History and Philosophy of Biological and Biomedical Sciences* 43: 1-3.

Lesch, J.E. (ed.) (2000), *The German Chemical Industry in the Twentieth Century*, Dordrecht: Kluwer.

Levidow, L. (2014), 'Introduction to Sac Forum: 'Embedding Social Sciences?''', *Science as Culture* 23: 382-383.

Lindee, M.S. (1997), 'The Conversation: History and History as It Happens', in T. Söderqvist (ed.), *The Historiography of Contemporary Science and Technology*, Amsterdam: Harwood Academic Publishers: 39-50.

Lindee, S., 'Human Genetics after the Bomb: Archives, Clinics, Proving Grounds and Board Rooms', *Studies in History and Philosophy of Biological and Biomedical Sciences*, in this issue.

Lindee, S. and R. Ventura Santos (2012), 'The Biological Anthropology of Living Human Populations: World Histories, National Styles, and International Networks', *Current Anthropology* 53: S3-S16.

McLaren, D. (1991), 'The Human Genome - Uk and International Initiatives', in (ed.), *Medical Research Council Annual Report, April 1990 - March 1991*, London: 44-50.

Müller-Wille, S. and I. Charmantier (2012), 'Natural History and Information Overload: The Case of Linnaeus', *Studies in History and Philosophy of Science Part C: Studies in History and Philosophy of Biological and Biomedical Sciences* 43: 4-15.

Onaga, L.A. (2014), 'Ray Wu as Fifth Business: Deconstructing Collective Memory in the History of DNA Sequencing', *Studies in History and Philosophy of Biological and Biomedical Sciences* 46: 1-14.

Palladino, P. (2003), *Plants, Patients, and the Historians: On (Re) Membering in the Age Genetic Engineering*, New Jersey: Rutgers University Press.

Parker, J.N., B. Penders and N. Vermeulen (ed.) (2010), *Collaboration in the New Life Sciences*, Surrey: Ashgate Publishing.

Peres S. 'Saving the Gene Pool for the Future: Seed Banks as Archives', *Studies in History and Philosophy of Biological and Biomedical Sciences*, in this issue.

Perks, R. and A. Thompson (ed.) (1998), *The Oral History Reader*, New York: Routledge.

Pickstone, J.V. (2000), *Ways of Knowing: A New History of Science, Technology and Medicine*, University of Chicago Press.

Pierrel, J. (2012), 'An Rna Phage Lab: Ms2 in Walter Fiers' Laboratory of Molecular Biology in Ghent, from Genetic Code to Gene and Genome, 1963–1976', *Journal of the History of Biology* 45: 109-138.

Rabinow, P. and T. Dan-Cohen (2005), *A Machine to Make a Future: Biotech Chronicles*, Princeton: Princeton University Press.

Ramillon, V. (2007), *Le Deux Génomiques. Mobiliser, Organiser, Produire: Du Séquençage À La Mesure De L'expression Des Gènes*, PhD dissertation, École des Hautes Études en Sciences Sociales.

Reardon, J. (2005), *Race to the Finish: Identity and Governance in an Age of Genomics*, New Haven: Princeton University Press.

Rheinberger, H.-J. (2009), 'Recent Science and Its Exploration: The Case of Molecular Biology', *Studies in History and Philosophy of Science Part C: Studies in History and Philosophy of Biological and Biomedical Sciences* 40: 6-12.

Rheinberger, H.J. and J.P. Gaudillière (ed.) (2004), *From Molecular Genetics to Genomics: The Mapping Cultures of Twentieth Century Genetics*, London and New York: Routledge.

Rosenberg, D. (2003), 'Early Modern Information Overload', *Journal of the History of Ideas* 64: 1-9.

Santesmases, M.J. and E. Suárez-Díaz (2015), 'A Cell-Based Epistemology: Human Genetics in the Era of Biomedicine', *Historical Studies in the Natural Sciences* 45: 1-13.

Schaffer, S. (1992), 'Late Victorian Metrology and Its Instrumentation: A Manufactory of Ohms', in R. Bud, S.E. Cozzens and R.F. Potter (ed.), *Invisible Connections: Instruments, Institutions, and Science*, Washington: SPIE, Optical Engineering Press: 25-54.

Secord, J.A. (1993), 'The Big Picture: A Special Issue', *British Journal for the History of Science* 26: 387-389.

Serpente N., 'Justifying Molecular Images in Cell Biology Textbooks: From Constructions to Primary Data', *Studies in History and Philosophy of Biological and Biomedical Sciences*, in this issue.

Shapin, S. and S. Schaffer (1985), *Leviathan and the Air-Pump: Hobbes, Boyle and the Experimental Life*, Princeton: Princeton University Press.

Shaw J, 'Documenting Genomics: Applying Archival Theory to Preserving the Records of the Human Genome Project', *Studies in History and Philosophy of Biological and Biomedical Sciences*, in this issue.

Sloan, P.R. (ed.) (2000), *Controlling Our Destinies: Historical, Philosophical, Ethical, and Theological Perspectives on the Human Genome Project*, Indiana: University of Notre Dame Press.

Smith, R. (1994), 'Research Profile: Developing Foresight: An Interview with Sir Dai Rees', *British Medical Journal* 309: 324-326.

Söderqvist, T. (1997), 'Who Will Sort out the Hundred or More Paul Ehrlichs? Remarks on the Historiography of Recent and Contemporary Technoscience', in T. Söderqvist (ed.), *The Historiography of Contemporary Science and Technology*, Amsterdam: Harwood: 1-17.

Stevens, H. (2013), *Life out of Sequence*, Chicago: University of Chicago Press.

Strasser, B.J. (2011), 'The Experimenter's Museum: Genbank, Natural History, and the Moral Economies of Biomedicine', *Isis* 102: 60-96.

Strasser, B.J. (2012), 'Collecting Nature: Practices, Styles, and Narratives', *Osiris* 27: 303-340.

Suarez-Diaz, E. (2009), 'Molecular Evolution: Concepts and the Origin of Disciplines', *Studies in History and Philosophy of Science Part C: Studies in History and Philosophy of Biological and Biomedical Sciences* 40: 43-53.

Suárez-Díaz, E. (2010), 'Making Room for New Faces: Evolution, Genomics and the Growth of Bioinformatics', *History and Philosophy of the Life Sciences* 32: 65-90.

Sulston, J. and G. Ferry (2002), *The Common Thread: A Story of Science, Politics, Ethics and the Human Genome* Bantam Publishers.

Tansey, E.M. (2008), 'Keeping the Culture Alive: The Laboratory Technician in Mid-Twentieth-Century British Medical Research', *Notes and Records of the Royal Society* 62: 77-95.

Tonkin, E. (1992), *Narrating Our Pasts: The Social Construction of Oral History*, Cambridge: Cambridge University Press.

Turchetti, S., N. Herrán and S. Boudia (2012), 'Introduction: Have We Ever Been 'Transnational'? Towards a History of Science across and Beyond Borders', *The British Journal for the History of Science* 45: 319-336.

Venter, J.C. (2007), *A Life Decoded: My Genome, My Life*, New York: Penguin.

Vines, G. (1987), 'Mapping Genes: The Bottom-up Approach', *New Scientist* 1550 (5th March): 36.

Watson, J. (1968), *The Double Helix: A Personal Account of the Discovery of the Structure of DNA*, New York: New American Library.

Weaver, W. (1967), *Us Philanthropic Foundations: Their History, Structure, Management and Record*, New York: Harper and Row.

Wright, S. (1994), *Molecular Politics: Developing American and British Regulatory Policy for Genetic Engineering, 1972-1982*, University of Chicago Press.

Yi, D. (2008), 'Cancer, Viruses, and Mass Migration: Paul Berg's Venture into Eukaryotic Biology and the Advent of Recombinant DNA Research and Technology, 1967–1980', *Journal of the History of Biology* 41: 589-636.

¹ See <http://www.ahrc.ac.uk/documents/guides/ahrc-s-subject-coverage/>, p.2, quote under heading “History”. Last accessed September 2015.

² Examples of classical literature on the history of science, written after World War II and focused on different aspects of the early modern period are Butterfield, 1997 [1949] and Koyré, 1957. Most historiography in the 1970s and 80s revisited the episodes narrated in earlier works and, by incorporating sociological perspectives, questioned the notion of a ‘scientific revolution’ in that period: Shapin and Schaffer, 1985; Cunningham, 1988.

³ The early molecular biology collections comprise, among others, the Papers and Correspondence of Francis Crick (Wellcome Library, London), Max Perutz (Churchill College, Cambridge), John Kendrew (Bodleian Library, Oxford) and the Rockefeller Archive Centre in New York. Newer collections include *Codebreakers: Makers of Modern Genetics* (Wellcome Library and Cold Spring Harbor Archives, New York), the Papers and Correspondence of Sir Walter and Julia Bodmer (Bodleian Library) the Robert Cook-Deegan Human Genome Archive (Georgetown University, Washington DC), the Papers and Correspondence of A.D. Kaiser and Paul Berg (Stanford University Archive) and the *Towards Dolly* project (University of Edinburgh, Centre for Research Collections).

⁴ Big data has become a priority for the UK Government and a privileged focus area of its seven research councils: <http://www.rcuk.ac.uk/research/infrastructure/big-data/>; see also <https://www.gov.uk/government/news/73-million-to-improve-access-to-data-and-drive-innovation>. In line with this commitment, all major scientific funders in Britain demand open access to the data and outputs derived from the research they support: <http://www.rcuk.ac.uk/research/openaccess/>; <http://www.wellcome.ac.uk/About-us/Policy/Policy-and-position-statements/WTD002766.htm>. All links last accessed September 2015.

⁵ The idea of embedding the social sciences and humanities in broader problems is best expressed in Horizon 2020, the research programme of the European Union. This programme, rather than creating specific research areas, defines a number of “societal challenges” – such as ageing, innovation or climate change – that require interdisciplinary work across the humanities, social sciences and natural sciences: <http://horizons.mruni.eu/vilnius-declaration-horizons-for-social-sciences-and-humanities/>; see also http://europa.eu/rapid/press-release_SPEECH-13-740_en.htm. Both links last accessed April 2015. For academic debates around the idea of embeddedness, see Calvert, 2014; Felt, 2014; Levidow, 2014.

⁶ Within the newer archives listed in note 3, the most relevant collections for the historical study of genomics are **a**) the records of Sydney Brenner, Malcolm Ferguson-Smith and James Watson (*Codebreakers* repository, <http://wellcomelibrary.org/using-the-library/subject-guides/genetics/makers-of-modern-genetics/digitised-archives/sydney-brenner/>, <http://wellcomelibrary.org/using-the-library/subject-guides/genetics/makers-of-modern-genetics/digitised-archives/malcolm-ferguson-smith/> and <http://wellcomelibrary.org/using-the-library/subject-guides/genetics/makers-of-modern-genetics/digitised-archives/james-watson/>), **b**) the Papers and Correspondence of Sir Walter Bodmer (<http://www.bodley.ox.ac.uk/dept/scwmss/wmss/online/modern/bodmer/bodmer.html>), and **c**) the Robert Cook-Deegan Archive (<https://bioethics.georgetown.edu/library-materials/digital-collections/robert-cook-deegan-human-genome-archive/>). There are also ongoing initiatives at the Wellcome Library to catalogue the records of scientists based in the Sanger Institute (Shaw, in this issue; see note 10) and at the US National Human Genome Research Institute to create an institutional archive (<http://www.genome.gov/27557501>; see also Cantor, in press). All links last accessed September 2015.

⁷ The belief in the superiority of genetic data is founded on the supposed neutrality of genomics, as a science engaged in collecting and compiling DNA sequences without proposing *a priori* hypotheses (Sulston and Ferry, 2002: 58-9). Involvement of historians in preservation of the genomic legacy would show the inherently contingent dimension of this trust in the power of information. Historians, despite not being objective actors – or precisely because they reject objectivity – are in an invaluable position to demonstrate the situated dimension of genomics and, more generally, the historicity of the strategies by which science is promoted and represented: Aicardi, in this issue; Serpente, in this issue; García-Sancho, 2012b.

⁸ Most of the literature on recombinant DNA by the mid 2000s had been written by STS researchers, and economic and political historians focusing on regulatory and public debates rather than how the technologies were affecting scientific practice (Jasanoff, 2005; Wright, 1994). An exception to this was

Robert Bud, who proposed a genealogy between genetic engineering and the long-standing practices of fermentation and breeding of animals and plants (Bud, 1993).

⁹ Whereas some of these collections made their way to catalogued archives, others were left behind by the owner scientists after their retirement. Examples of now available archives are the Laboratory Notebooks of Frederick Sanger, and the Papers and Correspondence of Alan Coulson, both at the Wellcome Library (<http://wellcomelibrary.org/using-the-library/subject-guides/genetics/makers-of-modern-genetics/digitised-archives/fred-sanger/> and <http://wellcomelibrary.org/using-the-library/subject-guides/genetics/makers-of-modern-genetics/digitised-archives/alan-coulson/>, last accessed September 2015). Some collections that have not yet been catalogued are the personal archive of Graham Cameron (former co-Director of the European Bioinformatics Institute), and the papers and correspondence of André Marion (co-founder of Applied Biosystems, the company that marketed the first automatic DNA sequencers). Cameron's collection is in the process of being transferred to the Archives of the European Molecular Biology Laboratory in Heidelberg, while the whereabouts of Marion's collection are difficult to track after the demolition of Applied Biosystems headquarters. On the Archive of the European Molecular Biology Laboratory see <http://www.embl.de/aboutus/archive/about/index.html> (last accessed, September 2015).

¹⁰ a) Collections at the National Archives of the UK:

<http://discovery.nationalarchives.gov.uk/results/r/?q=human+genome+mapping+project>; b) *Codebreakers* collection: <http://wellcomelibrary.org/using-the-library/subject-guides/genetics/makers-of-modern-genetics/digitised-archives/>; c) The Wellcome Archives and Manuscripts have released the collections of John Sulston, Richard Durbin, Ian Dunham, Matthew Jones and Carol Churcher, all of them involved in the Sanger Centre, and partially released the papers of Michael Ashburner, co-founder of the European Bioinformatics Institute (Sulston, <http://archives.wellcomelibrary.org/Dserve/dserve.exe?dsqIni=Dserve.ini&dsqApp=Archive&dsqCmd=Show.tcl&dsqDb=Catalog&dsqPos=23&dsqSearch=%28%28%28text%29%3D%27john%27%29AND%28%28text%29%3D%27sulston%27%29%29>, Durbin <http://archives.wellcomelibrary.org/Dserve/dserve.exe?dsqIni=Dserve.ini&dsqApp=Archive&dsqCmd=Show.tcl&dsqDb=Catalog&dsqPos=1&dsqSearch=%28%28%28text%29%3D%27Richard%27%29AND%28%28text%29%3D%27Durbin%27%29%29>, Dunham <http://archives.wellcomelibrary.org/Dserve/dserve.exe?dsqIni=Dserve.ini&dsqApp=Archive&dsqCmd=Show.tcl&dsqDb=Catalog&dsqPos=0&dsqSearch=%28%28%28text%29%3D%27Ian%27%29AND%28%28text%29%3D%27Dunham%27%29%29>, Jones <http://archives.wellcomelibrary.org/Dserve/dserve.exe?dsqIni=Dserve.ini&dsqApp=Archive&dsqCmd=Show.tcl&dsqDb=Catalog&dsqPos=458&dsqSearch=%28AltRefNo%3D%27grl%27%29>, Churcher, <http://archives.wellcomelibrary.org/Dserve/dserve.exe?dsqIni=Dserve.ini&dsqApp=Archive&dsqCmd=Show.tcl&dsqDb=Catalog&dsqPos=0&dsqSearch=%28%28%28text%29%3D%27carol%27%29AND%28%28text%29%3D%27churcher%27%29%29> and Ashburner, <http://archives.wellcomelibrary.org/Dserve/dserve.exe?dsqIni=Dserve.ini&dsqApp=Archive&dsqCmd=Show.tcl&dsqDb=Catalog&dsqPos=3&dsqSearch=%28%28%28text%29%3D%27michael%27%29AND%28%28text%29%3D%27ashburner%27%29%29>). All links last accessed September 2015.

¹¹ Brenner (undated) "Map of man [very first draft]" and MRC (1987) "Extract from the minutes of the Cell Board meeting", National Archives of the UK, MRC Collections, files FD 23/3441 and FD 12/1192. In leaving a traditional molecular biology setting and proposing to map the human genome, Brenner was becoming a "cross-worlds influencer", much in the same way Crick had after leaving the LMB and shifting his interests to neurobiology (Aicardi, in this volume; see also Aicardi, 2014).

¹² MRC (1990) "HGMP Directed Programme Committee: strategy meeting", National Archives of the UK, MRC Collections, file FD 7/2749.

¹³ MRC (1986) "Grant record and payments computer system, search 1: human genes – molecular genetics – current grants", National Archives of the UK, MRC Collections, file FD 23/3441. The projects, carried out in university departments, medical schools or hospitals, ranged from blood grouping to prenatal diagnosis, and all involved the mapping of at least one human gene. The disciplinary scope included not only biochemistry and molecular biology, but also genetics, immunology, neurology and pediatrics. This shows the important role played by the research interests and practices of cytogenetics and population genetics within human genomics, as suggested by recent historiography (Lindee and Ventura Santos, 2012; Bangham and de Chadarevian, 2014; Santesmases and Suárez-Díaz, 2015).

¹⁴ MRC (1990) "Discussion and development of a strategy by the Directed Programme Committee", National Archives of the UK, MRC Collections, file FD 7/2749, quote from p. 4.

¹⁵ Ibid, quote from p. 5.

¹⁶ The hierarchy of this involvement tended to move up over time. During the mid to late 1980s, Sulston was member of a technical group which provided practical advice to the executive HGMP committees. This was due to his bench mastery in applying mapping and sequencing to the nematode worm *C. elegans*, one of the first subjects of genomic research. Sulston was promoted to the Directed Programme Committee in October 1990, a committee on which his close collaborator Alan Coulson had served during the March 1990 meeting (National Archives of the UK, MRC Collections, files FD 23/3445 and FD 23/3446). On the *C. elegans* mapping and sequencing project see de Chadarevian, 2004; Ankeny, 2001; García-Sancho, 2012b.

¹⁷ See note 6 for catalogue entries to Ferguson-Smith and Bodmer's archives. Oral history with Hastie: <http://www.genmedhist.info/interviews/Hastie> (last accessed September 2015).

¹⁸ T. Vickers and M. Kemp, email interviews with author, December 2013 and January 2014. See also Kaplan, 1959 for a classical essay, written when the role of science administrators was relatively new.

¹⁹ The process of becoming a top research manager as a consequence of scientific achievement connects with the concept of "cross-worlds influence" formulated by Christine Aicardi (in this issue) and applied to Crick's career. Brenner's role in the HGMP would also square with this concept (see note 11). Another example of a high-profile administrator was Warren Weaver, Director of the Division of Natural Sciences of the Rockefeller Foundation between the 1930s and '50s. He published an account of the role of charities in scientific research (Weaver, 1967) and has been the subject of scholarship by historians of molecular biology (Abir-Am, 1982; Kohler, 1976; Kay, 1993). His papers have been catalogued at the Rockefeller Archive Centre and he is unanimously considered a key figure in the configuration of modern biomedical research (<http://www.rockarch.org/collections/individuals/rf/weaver.pdf>, last accessed September 2015). In the case of the MRC, its chief executives are usually holders of knighthoods, credited for both their scientific and managerial roles, and subject to academic and media attention (Bryder and Austoker, 1989; Smith, 1994).

²⁰ These centralised archives produced by second-order administrators at Government offices are not exclusive to contemporary genomics. Other State departments produced similar types of collections for earlier periods of the twentieth century, particularly post-war science. Historians seeking to build a transnational perspective on science, war and peacetime (Turchetti, Herrán and Boudia, 2012) are fruitfully exploiting these collections, the US National Archives and Records Administration in College Park being a representative example of this: <http://www.archives.gov/about/> (last accessed, September 2015). I thank an anonymous referee of my article for this helpful point.

²¹ HGMP administrators are often more reluctant to become involved in oral history than the project's scientists and prefer email to face-to-face communication. They also tend to feel more comfortable with documents at hand and often ask to be sent PDFs. This suggests their accounts are framed by this iterative documentary process rather than by their own experience, as is the case with scientists, especially top-level ones.

²² Internal memos and correspondence between T.H. Rabbitts and MRC Headquarters, December 1986 – March 1987. Quote corresponds to letter from J. Alwen to T.H. Rabbitts, 25th February 1987. National Archives of the UK, MRC Collections, file FD 12/1192.

²³ Report of phone conversation and correspondence between D. Dunstan and M. Kemp (March 1987); letter from S. Brenner, J. Sulston and A. Coulson to *New Scientist* (undated). National Archives of the UK, MRC Collections, file FD 12/1192.

²⁴ See results of search for "human genome mapping project" within Brenner's collection (*Codebreakers*) and catalogue section *Human Genome Work* at Sulston's archive (Wellcome Library):

http://search.wellcomelibrary.org/iii/encore/search/C_S%28Cold%20Spring%20Harbor%20Laboratory%20Archives%29%20%28sb%29%20%28human%20genome%20mapping%20project%29%20w%3Ah_Orightresult_U?lang=eng&suite=cobalt (Brenner);

<http://archives.wellcomelibrary.org/Dserve/dserve.exe?dsqIni=Dserve.ini&dsqApp=Archive&dsqCmd=SHow.tcl&dsqDb=Catalog&dsqPos=23&dsqSearch=%28%28%28text%29%3D%27john%27%29AND%28%28text%29%3D%27sulston%27%29%29> (Sulston). Both last accessed September 2015.

²⁵ This collaboration would build on ongoing attempts at combining the history of science and diplomatic history in the investigation of contemporary big science (Doel, 1997).

²⁶ The embeddedness of STS researchers in big science projects may enable an extreme instance of proactivity and commitment to history. The embedded STS scholar could capture the sources and workings of science-as-it-is-produced. This grants the STSer with a privileged position to have a voice –

among many, and independent from scientists – in the historical packing of the project when it becomes past rather than present. I thank Christine Aicardi for flagging this valuable point.