DNA Repair: a spatially rooted analysis of the development of a scientific community

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1. Introduction

Our aim is to track the emergence of the DNA Repair field (1964-1975) using both bibliometric data and historical sources (interviews, archives, historical accounts). We intend to focus on the geographical diffusion of the research specialty: how did the scientific interest for DNA Repair mechanisms spread at the worldwide level? What role the first scientists specialized in the field play in the diffusion process? In order to localize specialized teams, we follow the use of the keyword "DNA Repair" in scientific publications indexed in bibliometric databases. At first, in analyzing a bibliometric corpus derived from Scopus we draw a general overview of the DNA Repair field geography during the emergence stage (1965-1975). For each territory, we localize the different teams involved in the scientific specialty from the beginning. In a second time, we focus on pioneers' trajectories. In following individual trajectories with the help of both bibliometric materials and qualitative sources, we shed light on networks of places critical for the field's diffusion. We are not just dealing with the place where scientists are at one moment but with their trajectory which allow us to capture networks of places. Networks of places determine as well as are built by individual trajectories. They are central to our analysis. Our mixed-methods approach using both qualitative and quantitative data draws on influences that range from spatial scientometrics to evolutionary economics up to sociology of science and innovation sciences. The ambition of this experimental work is to make a seat for geography of science in the science studies framework.

1.1. State of the Art: spatial scientometrics and scientific mobility

Spatial scientometrics methods for geography of science's purposes are still under progress. In particular, recent advances have been made in processing bibliometric data at the city level (Eckert, Baron, and Jegou 2013; Grossetti et al. 2013). Among the opportunities offered, retrieving information on scientific mobility is less usual than analyzing co-authorship or citation data (Frenken, Hardeman, and Hoekman 2009). One of the few references in science studies is the work of Grit Laudel discussing the possibility of studying the mobility of scientific elites thanks to publication data (Laudel 2003; Laudel 2005). To our knowledge, the other scientometric analyses dealing with scientific mobility are related to innovation studies. In this respect they are more often using patent data than publication data. For instance, there is a category of works processing patent data, initiated by Adam B. Jaffe et al. in 1993, to assess the importance of human mobility for knowledge flows and spillovers (Jaffe, Trajtenberg, and Henderson 1993; Almeida and Kogut 1999; Breschi et Lissoni 2009). In innovation studies, the other reasons to study scientific mobility are to explore the links between mobility and productivity for instance, to question the "brain gain" process such as Anna Lee Saxenian (Saxenian 2006; Agrawal et al. 2011). Also, in geography of innovation, a developing research area needs to be mentioned which is investigating the spatial determinants of mobility using the proximity framework (Agrawal, Cockburn, and McHale 2006; Bernela, Bouba-Olga, and Ferru

2013). Those researches show the importance of personal networks (social links) to explain mobility over factors related to the quality of cities, disputing the creative class theory developed by Richard Florida (Martin-Brelot et al. 2010). They demonstrate how much long distance mobility is a rare phenomenon which is not surprising considering the embeddedness of personal networks in geographically constrained areas and the tendency to homophily (Grossetti 2005). For this reason, when migrants are maintaining home linkages, we can observe a willingness to return home which, in our opinion, is not really specific to scientific activities (Baruffaldi and Landoni 2012). In this whole literature, bibliometric data are not used very often compared with data retrieved from interviews, *curriculum vitae* or surveys.

If they are more precise, those kinds of data can only be used to work on specific samples so that most of the studies are analyzing the mobility of scientists from a given geographic region. It must be point out that statistic departments of international organisms do not register scientists' mobility and therefore, it is difficult to have a complete overview of scientific mobility at the world level. As a consequence, authors are often complaining about the lack of data on mobility (Cañibano, Otamendi, and Solís 2011). Nevertheless for the innovation science purposes we have mentioned before, it is not necessary to have results at the world level because what is at stake is to capture general trends of scientific mobility without respect to the geo-historic and scientific heterogeneity of places. By contrast, we believe good reasons to consider place heterogeneity in relation with scientific mobility can be found in science studies. Indeed, the variability of institutional settings from a country to another as well as the variability of scientific practices from a laboratory to another are critical for science studies. One way of capturing the diversity of mobility patterns, according to Grit Laudel, is to investigate the scientific mobility of elites at the specialty level. For now on, very few studies on scientific mobility are considering the content of science and are pursued at the level of world scale scientific specialties (contrary to studies on scientific collaboration). Following Paul D. Allison and J. Scott Long, when mobility is investigated in sociology of science it is often to study the link between career advancement and mobility in association with human factors such as sex or age (following Allison and Long 1987). Yet, in their recent study on temporary mobility, Carolina Cañibano et al. have found differences in mobility profiles (destination countries) from a discipline to another (Cañibano op.cit.).

1.2. A geographic study of the emergence of a scientific specialty

The level of the specialty or the "invisible college" level is interesting because even when they are from different countries, scientists are supposed to know each other since they share common interest and are part of the same scientific community. For such communities to emerge, there is no doubt mobility has a role to play. Indeed, mobility, even temporary is important for knowledge transmission, particularly tacit knowledge (Torre 2008). Thus, we believe mobility is an important mechanism to take into account to understand the formation of world scale scientific groups. Moroever, Warren Hagstrom in its seminal work on the scientific community has shown that a way to avoid concurrence in a new field is to disperse specialists in different laboratories at the national scale (Hagstrom 1965). In so doing, the research area has more chance to spread and become a recognized specialty. Aware of institutional variability across countries in the 1960s, Warren Hagstrom suggests that the geographical dispersion of scientists is more an American specificity than a Soviet one. It means that the role of mobility for the spatial development of a specialty might be different from a country to another but there is no empirical evidence to confirm this hypothesis.

Warren Hagstrom together with Diana Crane and Joseph Ben David contributed to the development of specialty studies in the seventies (Crane 1972; Ben-David and Freudenthal 1991). This literature has demonstrated that the emergence of a specialty cannot be explained without respect for institutional settings. However, the studies were generally conducted at the country level. Nevertheless, in the classic models of emergence, primary teams are located in different places in the world without being aware they are working on similar problems (Mullins 1962; Lemaine et al. 1976). To our knowledge, the question of how the different teams begin to interact at the world level has never been fully investigated within a geographic paradigm. During the 1980s, speciality studies became marginal because of a growing focus on scientific practices in laboratories (Knorr-Cetina 1982). From the 2000s, there has been a revival of specialty studies. Interpretations of this revival are contradictory (Wray 2005; Morris et Van der Veer Martens 2008). Nevertheless, it is likely that this revival is related to the need for a better integration of geography in speciality studies (Shapin 1995). Indeed, even if the institutional contexts were described by sociologists in the 1970s, space was more contextual than explanatory. Finally, we believe the online access to bibliometric data has also contributed to this revival (Cristofoli 2008). Grit Laudel's work is characteristic of this revival. She confirms that the scientific and geographical environment in which a scientist is involved is very important to understand the way he defines oneself as member of a world scale community (Glaser and Laudel 2001). In the geography of science framework, our aim is to propose ways of capturing the structuring of scientific groups at the world level. Indeed, if most of the time knowledge transmission is localized in geographically limited areas, how can we track and explain the building and surviving of world scale groups of scientists? Considering previous finding, mobility of scientists has a role to play in this regard. For all that, we wonder if it is possible to capture the geographical spreading of a specialty at the world level in tracking scientists' trajectories.

This present contribution aims at focusing on the individual trajectories of the pioneers of a scientific field in order to understand its development. We want to see to what extent individual trajectories of pioneers can explain the emergence and the geographical expansion of a world group of specialists. The specialty we are focusing on is the DNA Repair specialty. It is now a branch of molecular biology although it used to be a "deviant" specialty following Hagstrom's definition (Hagstrom op. cit.). In previous works, we have focused on a specific research area in the specialty and on the current geography of the field (Maisonobe, Giglia-Mari, and Eckert 2013; Maisonobe 2013). In comparing a contemporary bibliometric corpus with an older one (the "DNA Repair" documents published during the emergence stage 1965-1975) we have found that the current geography of the field is largely influenced by its primary geography and that most of the diffusion process happens in the vicinity of pioneers' teams (Figure 1). We have also isolated some general trends such as the decline of the DNA repair researches done in nuclear research centers and in the soviet territory. At the same time, we have noticed the apparition of teams in countries previously inactive on the topic such as China or Spain (blue dots on the Figure 1). The use of bibliometric data has proven to be interesting to localize scientific activities and detect specialized teams. However, the bibliometric data from 1965-1975 were found to be incomplete with a lot of addresses of authors missing. Still, bibliometric data were found a rich material to explore the past of the community. For this present contribution, we have decided to go deeper in the study of the emergence of the community in order to improve our understanding of the current geography of the field. In order to do so we have opted for a mixed-methods approach.

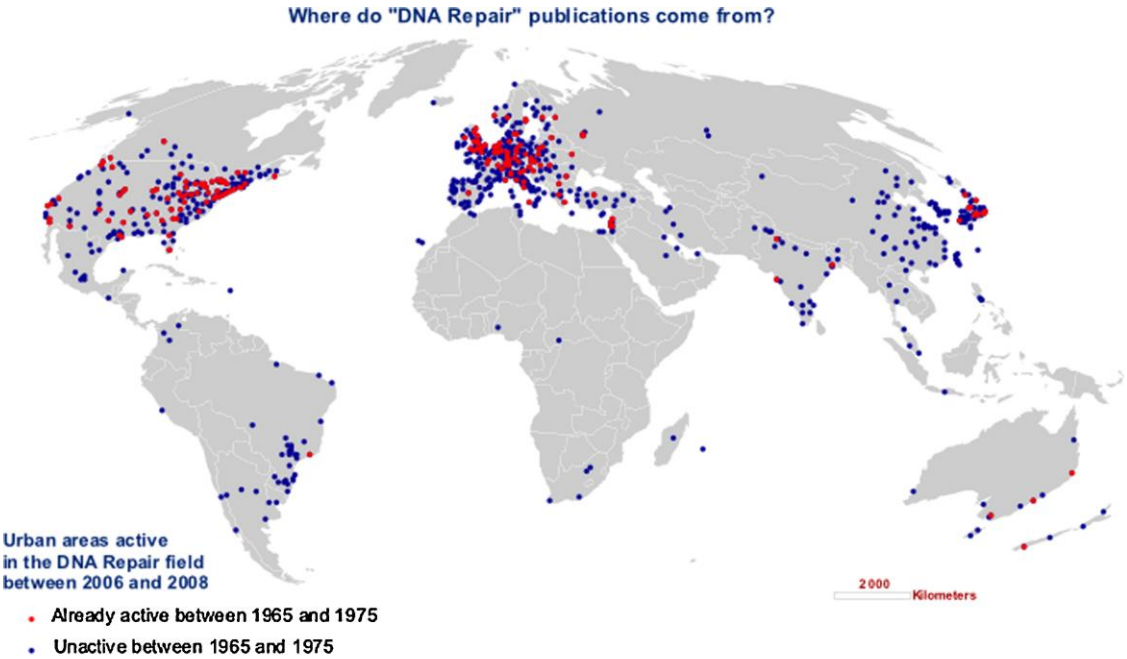

FIGURE 1: LOCATION OF DNA REPAIR PUBLICATIONS AT THE URBAN AREA LEVEL (FIGURE EXTRACTED FROM MAISONOBE, GIGLIA-MARI, ET ECKERT 2013)

2. Sources

Until now the geographic diffusion of research areas is a rarely studied phenomenon but attempts to follow the historical path of a research area by using bibliometric data are not new. Thus, it has been already shown that bibliometry is useful for historical purpose. In 1989, Norman P. Hummon and Patrick Doreian explored "the development of DNA theory" in analyzing "connectivity in a citation network" (Hummon et Doreian 1989). During the 80s, the different biases associated to such a use of bibliometric databases have been discussed by scientometrics' specialists (the databases' coverage, the efficiency of scientific keywords and references to follow the path of a research area, the link between scientific practices and bibliometric indicators) (Blickenstaff et Moravcsik 1982; Hurt 1983; Callon et al. 1983; MacRoberts et MacRoberts 1986; Zuckerman 1987; Stokes et Hartley 1989). In history, the fact that sources are incomplete and biased is common and cannot be a reason not to exploit them. However, here it legitimizes our choice to enrich the bibliometric analysis with qualitative data retrieved on the DNA Repair field and to prefer a narrative approach to a spatial evolutionary economics entry.

2.1. Quantitative sources: The delineation of a bibliometric corpus

In the case study we present, what we capture with the 1965-1975 bibliometric corpus is the way the keyword has spread from the United-States to other countries which should not be confused with the way the researches about the different mechanisms dealing with DNA damages have developed worldwide. Indeed, according to Errol C. Friedberg such researches existed long before the use of the keyword "DNA Repair" generalized (Friedberg 2007). The first DNA Repair mechanism was discovered at the end of the 50s whereas the keyword "DNA Repair" was indexed for the first time in the thesaurus of the National Library of Medecine (NLM) in 1971. For this reason, the adoption of the keyword is not a linear phenomenon and does not reveal a scientific turn among biologists. As we can see on Table 1, the number of "DNA Repair" publications has been multiplied by five between 1970 and 1971. It means that once the keyword has been indexed in the thesaurus, all the scientific teams working on the topic suddenly start to specify it in their writings. For this reason, we don't consider this corpus can be used to analyze the chronology of the diffusion process that is to say the order in which scientific teams have entered the field, at least during the emergence period. This is one of the reasons why a spatial evolutionary economics framework would not suit the 1965-1975 biliometric corpus: at the emergence stage, the entry date of teams in the field does not coincide with the year the keyword "DNA Repair" was first used by scientific teams.

Years	Number of "DNA Repair" publications in Scopus
1964	1
1965	1
1966	3
1967	4
1968	11
1969	8
1970	27
1971	139
1972	301
1973	334
1974	411
1975	565
N/A	30
TOTAL	1835

TABLE 1: NUMBER OF "DNA REPAIR" PUBLICATIONS INDEXED IN SCOPUS PER YEAR IN 1965-1975

It is important to specify that we have preferred Scopus over the Web of Science to extract the 1965-1975 bibliometric corpus because there are much more "DNA Repair" publications written before 1990 which are indexed in Scopus. Moreover, the authors' addresses are more often indexed in Scopus than in the Web of Science. On the contrary, after 1990, a "DNA Repair" query gives similar results in the two databases (Figure 2). In order to exploit the 1965-1975 corpus, when an author address was missing for a given article, we have used, when available, the address of this author as it was specified in other articles of the corpus. At last, on 1805 articles considered for this period of time, we were unable to attribute an address for only 129 of them.

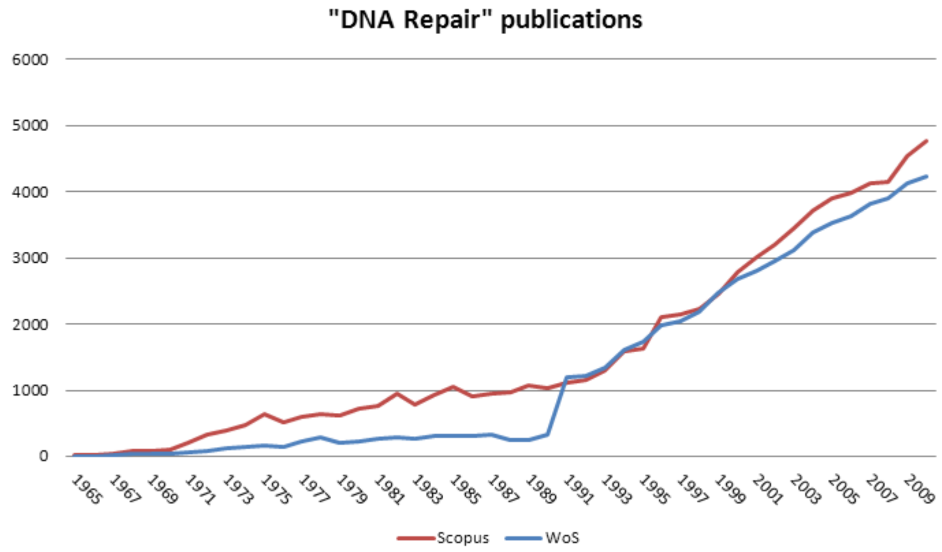

FIGURE 2: NUMBER OF "DNA REPAIR" PUBLICATION PER YEAR IN SCOPUS AND THE WEB OF SCIENCE (FIGURE EXTRACTED FROM MAISONOBE, GIGLIA-MARI, ET ECKERT 2013)

2.2. Qualitative sources: interviews, writing testimonies of participants, obituaries, biographies, archives, research literature.

At the beginning of our study on the DNA Repair community is a meeting with a DNA Repair biologist in Toulouse. She has entered the field in the 1990s on a specific research question: understanding the link between Nucleotide Excision Repair and DNA Transcription and cloning the genes involved. The evolving geography of this research question is the object of a previously published article (Maisonobe 2013). Since this research question was promising in the 1990s, it contributed to attract new teams in the field and to give the field some publicity among molecular biologists. However, we have found that the central teams for the development of this research question were mainly teams already working on DNA Repair for a long time. In particular, the Dutch teams at the initiative of the research question were involved in the DNA Repair field from the beginning. Before we went to Netherlands to meet DNA Repair scientists (6 of them were interviewed in June 2011), we began to collect documents on the field history. Two of them deserve to be mentioned. First, there was a testimony of Dirk Bootsma, one of the Dutch pioneers we had met later (Bootsma 2001). The first sentence was: “DNA repair has been, and still is, an important topic of research of a relatively large group of scientists in The Netherlands”. Together with this article, we discovered a very useful book for our investigation. Written by Errol C. Friedberg, an American DNA Repair scientist, this book was counting the story of the field with a chapter per every branch of the specialty (Friedberg 1997). It refers to Dutch contributions at the very beginning of the field by scientific teams in Delft and Rijswijk. Also, in an article on Nucleotide Excision Repair studies, James E. Cleaver et al. refers to the notable contributions of the “Dutch DNA Repair group” in the 1990s (Cleaver et al. 2001). To complete the picture, for Ambra Mari, our informant in Toulouse, being hired in Rotterdam for a postdoctoral position in the 1990s meant she was going to “enter the legend”. For all that, the interviews we realized in June 2011 in Rotterdam, Leiden, Amsterdam and Utrecht aimed at understanding the Dutch phenomenon and the position of the Dutch group in the global DNA Repair context (interview realized in November 2012 at the IPBS laboratory in Toulouse).

In Netherlands, we have realized "DNA Repair" was not perceived as an independent specialty by all scientists. Following Grit Laudel's findings, we have found the definition scientists have of the DNA Repair field and their membership varies according to their own experience of the field and to the history of their laboratory. For instance, the Leiden laboratory, contrary to the Rotterdam laboratory was created before the emergence of DNA Repair studies. It was a laboratory specialized in mutagenesis and the genetic aspects of mutations. Thus, according to scientists in Leiden, the specialty they belong to is "DNA mutations and damages" which is a wider area than "DNA Repair". On the contrary, the scientists met in Rotterdam consider themselves as DNA Repair scientists. Originally, Dirk Bootsma (Rotterdam) was hired in the 1970s to lead a team in the newly created Rotterdam University. Before that, he was working for the Dutch Contract Research Organization TNO in Rijswijk (largely founded by the Dutch Ministry of Defense). In the 1970s, the TNO was financing less and less its medical biology division in Rijswijk. The budget cut particularly affected the basic researches performed in this division. As a consequence, several scientists from the radiobiology team in Rijswijk left for either Rotterdam or Leiden. In Rotterdam, Bootsma's team specialized in Nucleotide Excision Repair (NER) and in the early 1980s, opened to molecular biology in hiring Ian Hoeijmaker, current head of the team. Later, new teams have developed in Rotterdam investigating other DNA Repair pathways. On the contrary, Paul Lohman, who used to work with Bootsma in Rijswijk, stayed in Rijswijk in the 1980s until he became the head of the Leiden team. Therefore, Lohman has never been entirely specialized in NER. In Amsterdam, the situation is also different since during the 1980s, DNA Repair, particularly Homologous Recombination (HR), was used as a tool not as a research topic. It is only in the early 1990s that Hein Te Riele went to Dirk Bootsma to ask him if he could start researches on Mismatch Repair (MMR). The Rotterdam laboratory was not working on this pathway at that time so it was found to be a good idea. The important thing was to avoid competition between the different Dutch teams and maintain a collaborative climate. According to Hein Te Riele, the history of MMR differs from the history of other pathways. The other pathways are repair systems dealing with DNA damages caused by exposures (chemicals, radiations), hence originally the link with nuclear research centers; whereas "*MMR is not so much dealing with DNA damages but with errors made spontaneously by the organism*". Indeed, as Errol C. Friedberg explains in his book, the discovery of the DNA Repair is historically related to researches on the effects of UV and ionizing radiations on cells. By this way, DNA Repair happens to be an area related to radiobiology and photobiology which were marginal disciplines evolving apart from mainstream biology at the end of World War Two. Thus, the genesis of DNA repair researches is embedded in the history of radiation researches founded originally by the army.

When reading Friedberg's book, it seems that DNA Repair is mainly an American field and that it has born in America, notably in federal laboratories such as Oak Ridge (Tennessee) created in War time to perform the Manhattan Project. In talking with Dutch scientists the discourse is different since Dutch scientists insist on their strength, their seminal contributions, and their role in organizing the community at the European level. The question is not to know if the discourses are right or wrong, it is just that scientists are looking to the field's history with different lenses. According to us, mixing the discourses of scientists with bibliometric data and online archives is a way to explore the past of the community with more objectivity.

3. Methodology

In specialty studies, the use of qualitative data is common, particularly the use of interviews with participants. In their famous study on radioastronomy, Michael Mulkay and David Edge both used data retrieved from interviews and bibliometric analyses (Edge 1976). In posterior works, Michael Mulkay has insisted on the limits of both approaches (Mulkay in Lemaine et al. 1976). To analyze bibliometric data only was problematic in order to take the content of science into account but also because qualitative theories on bibliometric data were missing (Gilbert and Woolgar 1974; Loet Leydesdorff 1989). As far as interviews are concerned, in the frame of the Parex Project, Michael Mulkay has shown that errors can be done in according too much credit to the field's participants because of their lack of objectivity. Believing that discourse analysis was necessary to interpret participants' statements, he with Nigel Gilbert developed criticisms against historians' methods. In the eighties, Steven Shapin answered them taking the historians' side (Shapin 1984). Indeed, while specialties studies were exploratory studies not so much tackling methodological issues in the 1970s, debates discussing the methodological biases related to both qualitative and quantitative approaches of specialties intensified in the 1980s. David Hurt for instance demonstrated that a bibliometric corpus extracted with the help of experts was significantly different from a corpus derived from a citation analysis (Hurt 1983). As a consequence, at the end of the 1980s, the advantages of mixed methods were pointed out by several authors (Lievrouw et al. 1987). With the specialty studies' revival, mixed methods are one more time promoted by many authors (Glaser et Laudel 2001; Laurens, Zitt, et Bassecoulard 2010; Brunet et Dubois 2012). With the quantitative and qualitative materials we possess regarding the emergence of the DNA Repair field, they are many options. To begin with, one way of understanding the emergence of the field in space is to question the geographic repartition of publications mentioning the keyword "DNA Repair" when this keyword has just been coined in the United-States. To do so, we have to process the geographical information indexed in the 1965-1975 bibliometric corpus. This is the first step only which aims at getting a picture of the field at the emergence stage. Once we have a picture of the field, we have guidelines to perform qualitative researches.

3.1. Mapping the emergence stage

Once the authors' addresses geolocalized, we group the data at the level of urban areas to obtain the following map (Figure 3). To group the data, the counting method we have chosen is the whole normalized counting method which is supposed to give more importance to articles written in local autonomy by teams from only one urban area compared to articles written by teams located in several urban areas (Gauffriau et al. 2008). Since for the 1965-1975 there are only few articles indexed with more than one address, whatever the counting method we chose, it might not have any significant effect on the results[1]. We observe publications are concentrated

[1] Indeed, for the documents published before 1990, even if they are a collaboration product, it is likely that only one address has been indexed in the database. It is an important bias to remember because it makes difficult to compare the collaborative pattern of the past with the present collaborative pattern given by bibliometric data.

in 4 areas during the emergence stage: California and the East Coast in America; Northern Europe (in particular, London, Brighton, Paris, the Netherlands and Belgium); USSR (the Moscow region and St Petersburg then called "Leningrad"); and Japan (Kyoto and Tokyo). Above, we have extracted a list of the 42 most publishing urban areas in 1965-1975 (at least 10 publications with the keyword "DNA Repair" before 1975). Indeed, it is necessary to distinguish between using the keyword once and being specialized in DNA Repair studies which implies publishing several times about it. It confirms the American dynamism on the topic but surprisingly we have found that the number of "DNA repair" paper written in Moscow was almost as high as the number of "DNA repair" paper written in San Francisco. This is a fact we were not expecting since the keyword was coming from America and that Soviet scientists were isolated during the Cold War.

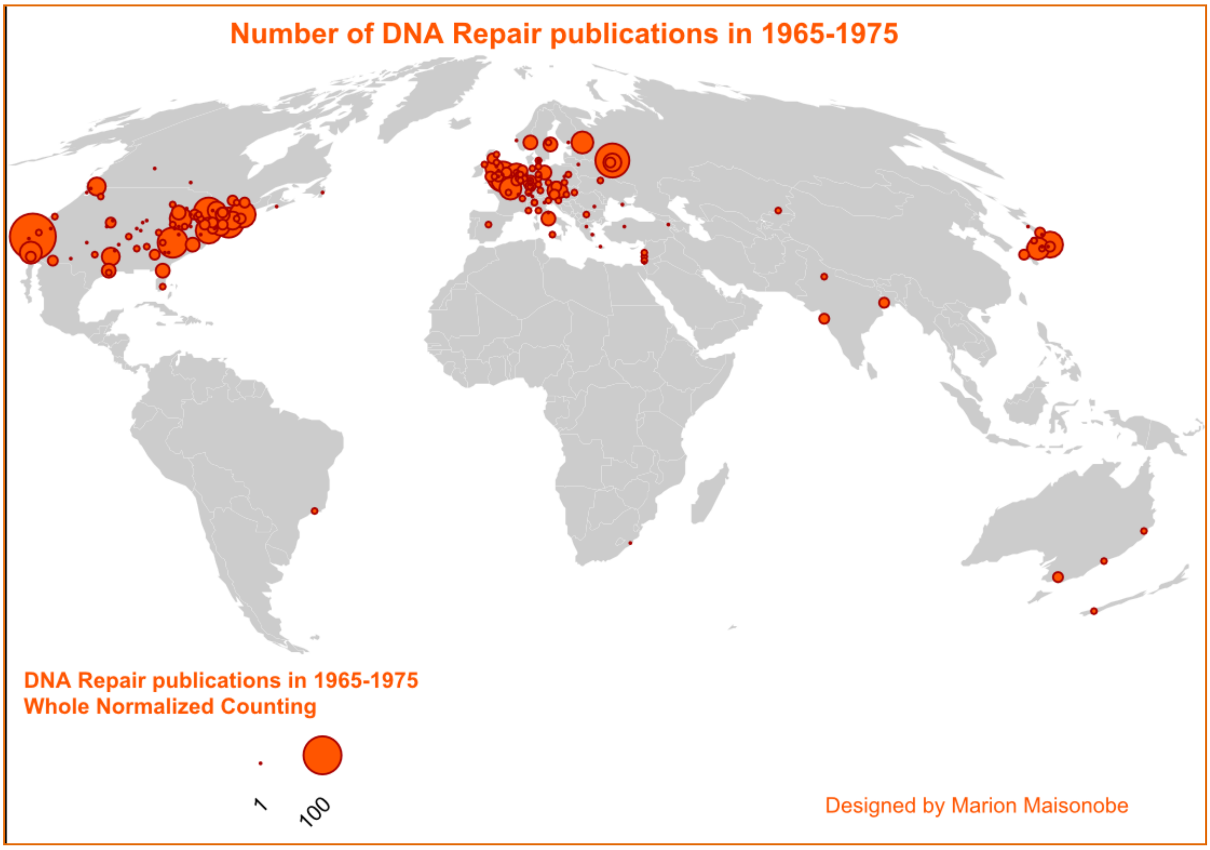

FIGURE 3: MAP OF THE DNA REPAIR FIELD AT THE EMERGENCE STAGE (1965-1975)

Les agglomérations urbaines d'où proviennent au moins 10 publications "DNA Repair" en 1965-1975		
San Francisco Bay Ca United States	Philadelphia Pa United States	Rome Italy
Moscow Russia	Vancouver Bc Canada	Houston Tx United States
New-York Ny United States	Manchester England United Kingdom	Oslo Norway
Knoxville Tn United States	Vienna Austria	Ithaca Ny United States
London England United Kingdom	Dallas Tx United States	Birmingham Al United States
Boston Ma United States	New-Haven Ct United States	Mishima Shizuoka Japan
Tokyo Tokyo Japan	Pushchino Russia	Baltimore Md United States
Bethesda Md United States	Toronto On Canada	Rochester Ny United States
Leiden-Rotterdam Netherlands	Durham Nc United States	Edinburgh Scotland United Kingdom
Los-Angeles Ca United States	Berlin Germany	Heidelberg Germany
St-Petersburg Russia	Gainesville Fl United States	Fukuoka Fukuoka Japan
Brighton England United Kingdom	Bratislava Slovakia	Brussels Belgium
Kyoto Kyoto Japan	Madison Wi United States	
Paris France	Frankfurt Germany	
Chicago Il United States	Stockholm Sweden	

TABLE 2: URBAN AREAS TOTALIZING AT LEAST 10 DNA REPAIR PUBLICATIONS IN 1965-1975

3.2. Tracking the field's first specialists: a prosopography

As soon as we have the picture of the emergence stage (Figure 3), we have to find a way to analyze it. We have already specified that according to us, the chronological information (the year of publication of the first DNA Repair paper) was not relevant to process. As far as we know, all the teams located on the map entered the field during the emergence stage, the important issue is not exactly "when" but "how" did they entered the field regarding "where" they are. To answer this question, quantitative methods can be helpful but are undoubtedly insufficient. As Andrew Abbott explains advocating the narrative approach over purely quantitative approaches, stochastic models cannot consider together all the dependencies (Abbott 2011). Even if it legitimizes stochastic models, the evolutionary economics framework is interesting since it helps to take into account the effects of "path dependencies" and "routines" (Boschma and Frenken 2006; de Vaan, Frenken, and Boshma 2011). Furthermore, we do believe a stochastic model could be worth to measure to what extent the present geography is the result of the past geography of the field (Figure 1). Yet, this is not the point of this contribution which only focuses on the emergence stage. To understand the geography of this stage, we need data on the prehistory of the field, that is to say on what was happening before the first "DNA Repair" articles were published. Following Abbott we think, the emergence stage is not the linear consequence of the prehistory of the field (in particular, the geography of nuclear research centers, the distribution of photobiology and radiobiology researches), but it is linked to scientists trajectories embedded in this prehistory[2]. According to Abbott, the social dynamic can be analyzed in term of trajectories and bifurcations: "bifurcations are occurring when cases are passing from a trajectory to another, and then entering a new causality regime" and therefore, "bifurcations allow the structure to play a role". Scientific mobility is a type of bifurcations in a scientist career while networks of places have structural characteristics. In

[2] In stochastic models, the "causal trajectory would always be the same" whereas "causalities are context dependent". The narrative approach advocated by Abbott is more descriptive than causal: "In this frame, studying a succession of steps does not imply answering why questions, but describing."

focusing on several scientists' trajectories, we would like to capture the role played by networks of places for the DNA Repair field emergence together with the role DNA repair pioneers' trajectories have played in networking scientific places.

Among the different ways of studying individual trajectories, there are sequence analysis (a method partly developed by Abbott) which aims at comparing trajectories (finding regularities and specificities). Sequence analysis is one of the options when performing a prosopography but it is not the one we have retained here (Lemercier and Picard 2011). According to the historians Claire Lemercier and Emmanuelle Picard, prosopography is a research approach whose goal is to "describe, classify and count" the cases in order to highlight a group of individuals' biographical characteristics. Following Grit Laudel, we want to show that not only can bibliometric data be used as variables in stochastic models, but also can they be used as materials for a prosopography. To perform a prosopography, we have to select a group of individuals. We suppose, based on our first qualitative findings that the trajectories of pioneers such as Dirk Bootsma in the Dutch case have a role to play in the organization of the emergence stage. The methodology we have established to detect such pioneers is disputable: we have made the assumption that scientists who used the keyword "DNA Repair" at least 10 times before 1975 were early specialists (Table 3). As a consequence, they are only 35 and are not representative of the whole 1965-1975 geography of the field (also, they are not numerous enough to perform a sequence analysis). Together they have written 397 "DNA repair" publications between 1965 and 1975 (about 20% of the 1965-1975 corpus). To track their trajectories, we have registered their affiliations (authors' addresses) between 1960 and 1975. We have extracted them manually from Scopus. Between 1960 and 1975, those scientists went through 33 "specialized" institutions and 25 "specialized" urban areas (about the half of the total number of "specialized" urban areas). Two third of the places they went through are in the United-States (14 "specialized" urban areas on 25). Therefore, this group of pioneers his only partially relevant to understand the 1965-1975 geography. Indeed, several Japanese and Europeans cities, unless occupied by authors publishing on the topic during the emergence stage, are not passed through by the extracted group. It has to be remembered that the bibliometric database is biased and this is why our present methodology is not perfect to select all the important pioneers. The database indexes more articles published in English than in other languages. In 1960-1975, there is still a part of the biomedical journals which are not published in English. Therefore, with the "*having published at least 10 DNA repair publications before 1975*" criteria we may miss some pioneers from the non-English speaking countries. However, the picture we obtain as a result is consistent with the emergence story exposed in the book of Errol C. Friedberg in that it highlights the American seminal role for the field's development. In this way, it is still an interesting group to study since it gives an image of the most visible part of the field at the emergence stage. Indeed, using the American keyword "DNA Repair" and publishing in journals cited enough by American scientists to be indexed in bibliometric databases was the best option to be recognized as a member of the "DNA repair" field and to become part of the "myth". Because they did so, the 35 scientists listed in table 3 deserve to be studied in detail.

To represent the trajectories of our selected group of scientists, we have designed the figure 4. It is a two-mode network (authors, institutions). The links' color depends on the chronology of the relations. Black links are related the authors (with at least two affiliations between 1960 and 1975) to the institutions they were previously occupying. Grey links are linking the authors to the last institutions they were attached to in 1975. The principal component of the graph is populated mostly by American scientists and institutions (the biggest connected part of the network).

Auteurs ayant signés au moins 10 publications "DNA Repair" en 1965-1975		
Smith, K.C.	Skavronskaya, A.G.	Elkind, M.M.
Cleaver, J.E.	Witkin, E.M.	Harm, W.
Bridges, B.A.	Eberl, R.	Sedgwick, S.G.
Stich, H.F.	Kondo, S.	Byfield, J.E.
Setlow, R.B.	Regan, J.D.	Fox, B.W.
Painter, R.B.	Roberts, J.J.	Friedberg, E.C.
Altmann, H.	Setlow, J.K.	Klein, W.
Hanawalt, P.C.	Trosko, J.E.	Robbins, J.H.
Fox, M.	Wu, R.	Sedliakova, M.
Lieberman, M.W.	Bootsma, D.	Youngs, D.A.
Zasukhina, G.D.	Cerutti, P.A.	Paterson, M.C.
Gaziev, A.I.	Dubinin, N.P.	

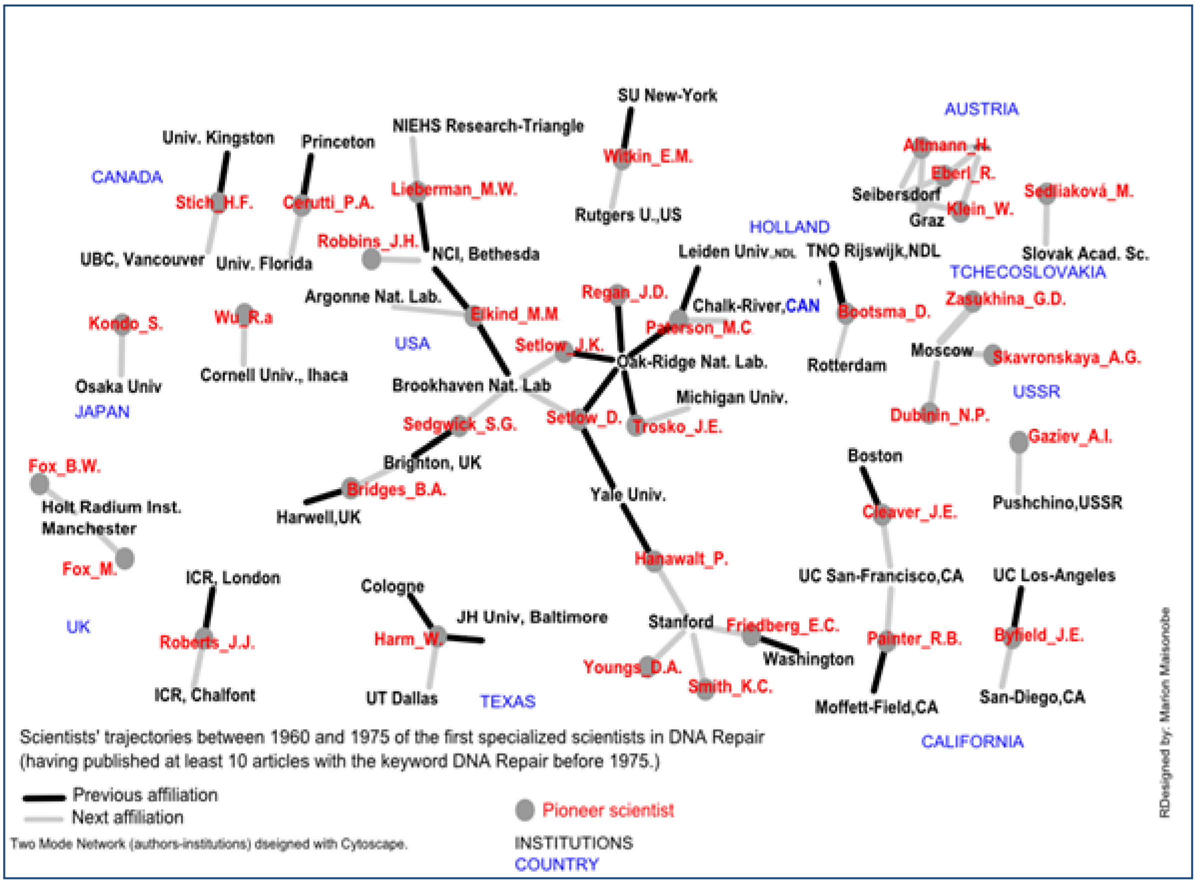

TABLE 3 AND FIGURE 4: DNA REPAIR PIONEERS AND THEIR TRAJECTORIES BETWEEN 1960 AND 1975

4. Mobility and communication of DNA repair pioneers during the cold war

In order to comment the figure we have obtained thanks to bibliometric data, we need to refer to the qualitative materials available about the scientific field's history and the actors of the field. In the present contribution, the bibliometric data and Figure 4 in particular, have been used to orient the "qualitative" researches. We try to capture the role played by DNA repair pioneers' trajectories in networking scientific places and to highlight the role of central places for the DNA Repair field's emergence.

4.1. The transnational mobility of DNA repair pioneers

Among the selected group of scientists and according to the Figure 4, only 3 scientists experienced a transnational bifurcation between 1960 and 1975. Two of them are part of the principal component of the network (MC Paterson and SG Sedgwick).

1. Malcolm C. Paterson (green arrow on Figure 5) is a Canadian researcher who has been one of the first Phd students of Richard Setlow in the Oak Ridge Laboratory (Knoxville, Tennessee). Richard Setlow is one of the American scientists who contribute to prove the existence of the Nucleotide Excision Repair pathway in 1964. Before Paterson was hired to work on DNA Repair in human cells in the Canadian nuclear laboratory of Chalk River (Ontario, Canada), he went in Holland for a post-doctoral journey. In Holland, he was affiliated to the Leiden laboratory but co-authored a paper with P.H. Lohman, then at the TNO in Rijswijk. In 1985, Paterson went to Alberta at the Cross Cancer Institute in Edmonton to set up a molecular oncology program. He would later work in Saudi Arabia (Riyadh) and Singapore before retiring in British Columbia (Canada)[3].

2. Steven G. Sedgwick (blue arrow on Figure 5) is a British researcher who was a Phd student at the Medical Research Council (MRC) cell mutation Unit in the University of Sussex (Brighton). The leader and creator of this unit was Bryn Bridges coming from the MRC radiobiology unit in Harwell (Figure 4). After his Phd, Sedgwick had fellowships not only in the Brookhaven National Laboratory (Figure 4) but also in Oak Ridge and in France (Raymond Devoret's team in the Laboratoire d'enzimologie du CNRS de Gif Sur Yvette). After that, in 1978, Sedgwick was hired in the genetics division of the National Institute for Medical Research in Mill Hill (NIMR, London). There, he recalls "*I organised the first DNA Repair network meeting at NIMR in 1979. At the time, it was a one-off meeting but then it developed into a programme of meetings which I ran until the early 1990s. The original emphasis was to encourage more junior scientists and this theme has continued to the present day*"[4]. Since there is no indexed article signed by Sedgwick in Oak Ridge and that the articles he co-authored in Gif-Sur-Yvette were only published in 1978, we miss those steps in Sedgwick's 1960-1975 bibliometric trajectory (Figure 4).

[3] Source: http://www.aihealthsolutions.ca/researchnews/2008/fall/followingup/

[4] Source: http://www.nimr.mrc.ac.uk/news/steve-sedgwick-awarded-inaugural-genome-stability-network-medal/.

3. Walter Harm (red arrow on Figure 5) is a German researcher who worked with his wife Helga Harm and Stan Rupert in John Hopkins University (Baltimore) before they were all hired in the mid-sixties by Carsten Bresch at the Southwest Institute for Advanced Studies (SCAS). The recruitment was facilitated since Carsten Bresch used to be a colleague of Walter Harm in the Institut Für Genetik in Cologne established by the famous Max Delbrück (one of the renowned founder of Molecular Biology). In his book, Errol C. Friedberg details this story because the entire german group, included Delbruck, has played a role in the discovery of photoreactivation. Moreover, because Friedberg works in Dallas from the early 1990s, he has had the opportunity to share a lot of information with the protagonists. Thus, we learn that Stan Rupert first met Walter Harm in Cologne. Rupert, while he was on sabbatical in Copenhagen, was invited there by Delbruck to give a seminary. When Delbruck finally returned to the United-States after his two-year stay in Cologne, "*he left a huge leadership vacuum, and the institute fell into crisis*". In 1965, Bresch left the institute, in order to lead the Biology Division of the SCAS in Dallas. Founded by Texas Instrument in 1948, the SCAS was bequeathed to the state of Texas in 1969 to become the University of Texas in Dallas. There, Walter Harm was part of a group of photobiologists or UV biophysicists. According to Errol C. Friedberg "*The Southwest Institute/UT Dallas group was perhaps the beginning of what has more recently been referred to as the "Texas Mafia" in DNA Repair, with prominent research groups now established in Dallas, San Antonio, Smithville, Houston and Galveston*" (Friedberg 1997, 50-56).

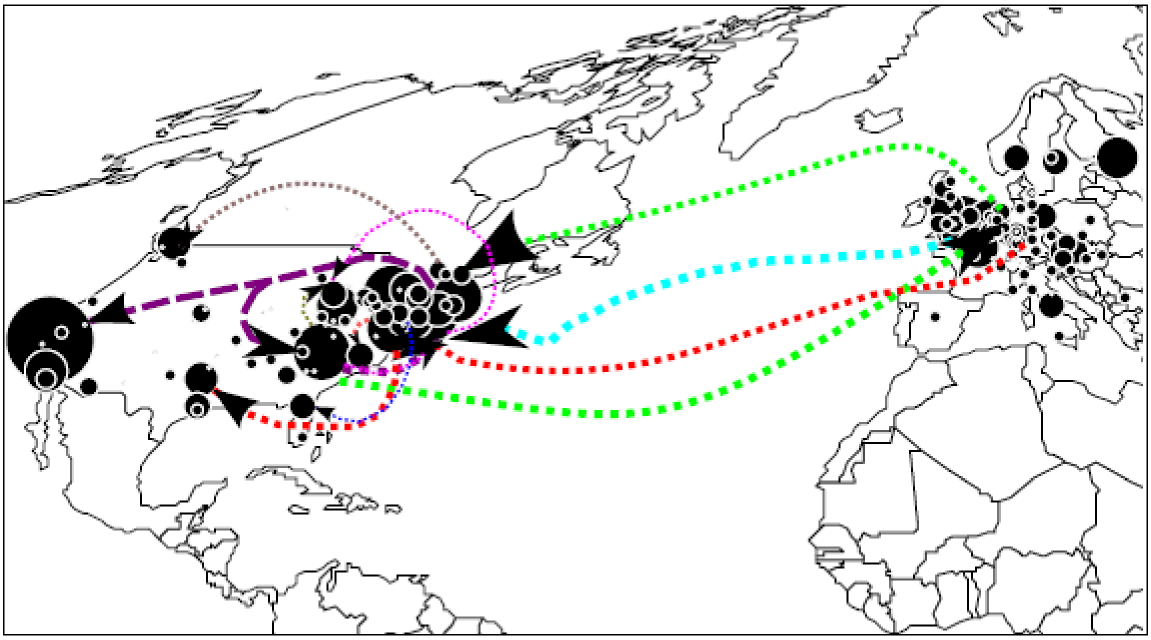

FIGURE 4: LONG DISTANCE BIBLIOMETRIC BIFURCATIONS OF DNA REPAIR PIONEERS (1960-1975)

Together those three scientists, not the most famous DNA Repair scientists of that time, have passed through places which have been or become important for the DNA Repair field. In so doing, they contributed to connect places at the global level. The details of their trajectories suggest existing relationships between the American, the British, the Canadian, the Dutch and the French scientific fields. All the other bifurcations we have registered in the selected group happened inside national frameworks and almost all of them in the United-States. Indeed, the kinds of bifurcations we can track thanks to bibliometric data are likely to reflect a professional mobility, implying a change of affiliation, instead of a one-year fellowship abroad.

In focusing on trajectories and bifurcations, it appears some places are occupying a hub function for the diffusion of the specialty. Figure 4 can also help us to detect laboratories which have been critical for the field organization at the global level.

4.2. The detection of central places for the emergence of the DNA repair specialty

On the Figure 4, most of the institutions have been occupied by only one pioneer. However, there are 5 institutions which are passed through by at least 3 pioneers between 1960 and 1975. Four of them are in the United-States and are part of the principal component of the network (Oak Ridge laboratory, Stanford laboratory, Brookhaven laboratory and the National Cancer Institute (NCI) laboratory) and one is in USSR (the Institute of General Genetics of the Academy of Science in Moscow).

The Biology division of Oak Ridge laboratories has been critical for DNA repair researches. According to Richard Setlow, « *As a result of the efforts of the Division Director, Alexander Hollaender, it was one of the largest biology research centers in the world. It had scientific personnel and expertise in biophysics, biochemistry, genetics, immunology, pathology, carcinogenesis, etc. and state-of-the-art equipment in all fields, that included a high–energy monochromator*» (Setlow 2005). Alexander Hollaender was a famous radiation scientist who can be considered as an ancestor of the DNA repair field. He hired the Setlows in the early 1960s. Previously the Setlows were in Yale University (Figure 4). In Yale, Richard Setlow first met Philip Hanawalt and was his mentor in biophysics. Then, Phil Hanawalt was hired in Stanford by the radiologist Henry Kaplan.

In 1964, Richard Setlow and Phil Hanawalt independently find evidence for the Nucleotide Excision Repair pathways (Hanawalt 2010; Setlow 2005). The same year, Paul Howard-Flanders from Yale University also published about the NER pathways but, according to Friedberg's book, without recognizing he received the help of Richard Setlow. Following the articles of those pioneers, the word "repair" entered the scientific vocabulary instead of "recovery" or "restoration". Meetings about "repair" mechanisms started to develop, a part of which were organized by Hanawalt and Setlow; so was it for the 1974 colloquium in Squaw Valley (California) which attracted 200 participants. California became an important region for DNA repair. Just hired in Stanford, Friedberg attended this event. According to him, there was in Stanford a "DNA repair community" in miniature with K.C. Smith at the radiology department, P. Hanawalt at the biology department and A. Kornberg in the biochemistry department (Friedberg 2005).

After 1964, a lot of young scientists went in Hanawalt's team and Setlow's team to be trained as DNA repair scientists. Notably Hanawalt's team has been linked to Latin American scientists *via* the Environmental Mutagen Society (Hanawalt 2003). After 1964, other DNA repair teams developed in Stanford's neighborhood. In particular, a laboratory of radiobiology opened in the University of California in San Francisco. Robert Painter from the Ames Research Center in

Moffett-Field (a NASA institute in California) became the head of this department (Figure 4). In 1968, his postdoctoral student James Cleaver found that an orphan disease (Xeroderma Pigmentosum) was the result of a deficient NER pathway. This discovery enabled to establish a link between DNA repair studies and cancer researches. Thanks to this breakthrough, DNA repair researches started to develop in cancer research centers such as the National Cancer Institute in Bethesda which remains an important place for DNA repair researches until now. Although the Stanford's team is still active, there is no DNA repair team in Oak Ridge anymore. From the mid-1970s, a budget cut touched the biology division and most of the DNA repair scientists left. The Setlows left for Brookhaven laboratory on Long Island, where we have detected an important turnover of DNA repair scientists as well (Figure 4). While DNA repair researches were first sponsored by defense money, they became more and more related to cancer and rare disease budgets. This evolution has also had consequences on the fields' geography. For instance, places were Xeroderma Pigmentosum cells were easy to access might have been advantaged to perform DNA repair researches on the NER pathways.

According to Figure 4, in the Old World, only Dubinin's laboratory in USSR has been occupied by several DNA repair specialists between 1960 and 1975. It appears Soviet DNA repair scientists were concentrated in a few laboratories and immobile. Actually, the Figure 4 is not very helpful to figure out the non-American contexts of emergence. It highlights the existence of specialized teams in other countries than the United-States but they appear isolated. Indeed, according to the bibliometric data, no selected pioneers have moved from one team to another between 1960 and 1975. On Figure 4, we observe all the selected pioneers from USSR (4), Austria (3), Tchecoslovakia (1) and Japan (1) have occupied only one affiliation between 1965 and 1975. As a consequence, we can wonder if the DNA Repair scientists from those countries were truly isolated or if they were connected to the rest of the group by other means, such as temporary mobility in some central places. We suppose so because they were aware of the keyword "DNA repair", but can qualitative data help us to be more specific about the relationships between the different teams at the emergence stage?

4.3. The communication between different institutional contexts of emergence

Three main factors explain the bifurcations we observe on Figure 4: postwar research policies regarding radiation researches and molecular biology, the success of the DNA Repair field justifying the creation of new teams, and career's advancements. The fact that geographic bifurcations related to career advancement mostly concern American scientists is consistent with the aforementioned Hagstrom's hypothesis (p. 2). Indeed, it seems that to develop the field at the national level, its protagonists have dispersed on the American territory (notably to avoid competition at the local level) and that the flexibility of the American research system has allowed them to do so. According to Dirk Bootsma, it is also what happened in the Dutch context, but to another scale: Dutch specialists decided to divide their strength, to spread on the territory and not to compete with each other's. They decided to collaborate at the national level. Even if the development of up-to-date researches in biology was less affordable than in the United-States; at least in Western Europe and Japan, the marginality of the DNA Repair field has been pointed out by pioneers as an advantage for its development compared to more basic molecular biology areas.

The Eastern bloc

In Tchecoslovakia and USSR, the lack of movement may be a characteristic of the research system, based on the Academy of Science, as suggested by Warren Hagstrom. Contrary to what was happening in the United-States, geographic mobility was not a dimension of career advancement in those scientific systems. Moreover, as far as, transnational mobility is concerned, it was not made easy at that time. Soviet scientists are almost never mentioned as DNA Repair meetings' participants until the early 70s. However, we have found Jane and Richard Setlow (Oak-Ridge, Figure 4) were aware of the biophysics researches pursued in USSR and *vice versa*. Indeed, in 1961, the Setlows published a review of soviet science specifying that: « *Soviet geneticists are apparently divided into two warring camps: those who believe in "creative Darwinism" (akin to Lysenkoism) and those individuals who have been influenced by Western work, such as Dubinin (whose 1956 article shows acquaintance with the work of Benzer, Muller, Hershey and Chase, and the Watson-Crick DNA model).*» (Setlow and Setlow 1961). Dubinin's team is visible on Figure 4. According to Friedberg's book, the Setlows' also went to USSR in 1972 to attend an International Congress on Biophysics. There, they invited Evelyn Waldstein to visit Oak Ridge laboratory "*any time that she could manage to leave Russia, which Waldstein had confided to the Setlows she was passionately eager to do*". Friedeberg adds: "*Several years after this meeting, Waldstein was permitted to emigrate from the Soviet Union and in 1974 she spent a brief stint in Setlow's laboratory.*" (Friedberg 1997, p. 94). Waldstein eventually settle in Israel were she published 10 DNA repair publications between 1974 and 1990.

Another illustration of the relative isolation of USSR is the history of the International Association for Radiation Research involving several DNA Repair pioneers. In the early 60s, "*Strong efforts were made to involve the Russian radiation research community in the association and it was proposed that the second congress be held in Russia. In the event this did not prove possible; England was chosen as the host country*". However, at Harrogate (UK) in 1963, a soviet scientist is elected as a member of the IARR Council. It is Alexander M. Kuzin (head of the Puschino team in Greater Moscow, with Ajub I. Gaziev present on Figure 4) who is elected Councilor for Biology[5]. Kuzin is also known on the international stage as a member of the afterwar Pugwash movement and is nowadays still co-authoring with Gaziev from Puschino[6].

Austria

Austria occupied a special place during the Cold War. In this regard, Austria was a strategic territory for international policies monitored from the United-States. Thanks to bibliometric data, we have found an Austrian team of pioneers publishing often on "DNA Repair" during the emergence stage although we have not found any mentions of them in the pioneers' histories.

Following the bibliometric data, we cannot really know if the Austrian scientists are in the nuclear research center of Seibersdorf, in Wien or in Graz because the indexed address differ

[5] Source: http://timssnet2.allenpress.com/ECOMRADRES/timssnet/RadeFTP/IARR/History_of_the_IARR.pdf
[6] http://fr.wikipedia.org/wiki/Mouvement_Pugwash

for each paper whereas the authors are the same. Actually, we think they were belonging to different institutions but were co-authoring together and the data are too incomplete to be more specific. The research laboratories of the International Atomic Energy Agency (AIEA) opened in Seibersdorf in 1961 (35 km away from Vienna) and we believe DNA Repair researches performed in Austria were founded by the AIEA. Created in 1957, the AIEA is an independent international organization related to the United Nations system, whose headquarter is in Vienna. Its creation was inspired by President Eisenhower in his "Atoms for Peace" speech[7]. Therefore, it is part of the after-war American policies launched under the auspices of "scientific internationalism". According to this ideology, Science should be use to make peace and a radiation research community should developed at the global level to promote a pacific use of nuclear energy (Miller 2006). According to the qualitative data we have collected, the Austrian team was certainly aware of the emergence of the DNA Repair field since the AIEA sponsored meetings in Vienna. Notably, in a brief history of the field evolution, Philip Hanawalt (Stanford, Figure 4) recalls a meeting about mechanisms of repair held in Vienna as early as 1966. However, in his recollection Hanawalt does not mention any Austrian scientists. Instead, he specifies there were fewer participants at the Vienna meeting than at the Chicago meeting (organized one year before) and he only refers to the interventions of Arthur Rörsch (Netherlands) and Raymond Devoret (France). It is not very surprising because even if they are not among the pioneers of our selected group, those two scientists have played an important role in organizing the DNA Repair community at the European level in particular during the "prehistory" stage of the field.

Western Europe

According to Paul Lohman, the Phd researches performed by Arthur Rörsch in Delft in the late 1950s were the starting point of DNA Repair investigations in the Netherlands and were also very critical for the DNA Repair field emergence in general (Beukers, Eker, and Lohman 2008). In 1963, Rörsch left Delft for Leiden and for the rest of his career has been involved in administrative positions notably in committees at the European level. Raymond Devoret has studied radiation damages on bacteria starting with his Phd in Latarget's laboratory. Therefore, he was aware of the American works in this field. Besides, he went to Yale for a fellowship in Paul Howard-Flanders' laboratory in 1996-1967, two years after the evidence for the NER pathways were published separately by the Howard-Flanders' laboratory, the Setlow's laboratory (Oak Ridge) and the Hanawalt's laboratory (Stanford). He recalls: "*At the end of my stay, Paul let me take about 150 E. coli strains constructed in his laboratory, which my group distributed to scientists from all over Europe (from Belgium to the Soviet Union) upon organizing and teaching European Radiation Biology courses with Arthur Rörsch at CEA (Saclay, France) and TNO (Rijswijk, The Netherlands)*" (Devoret 2001). This citation confirms the two men have been instrumental for the field's development. We have also found evidence for this in Friedberg's book when Friedberg refers to the important contribution of Miroslav Radman to the DNA Repair field. Friedberg compares Devoret and Rörsch's courses to the summer Cold Spring Laboratory courses and explains Radman attended the first course. Radman was sent to this course by his Phd director Maurice Errera, the head of the Belgium radiobiology team. As

[7] Source : http://www.unesco.org/archives/sio/Eng/presentation_print.php?idOrg=1013

a result, Radman's postdoctoral fellowships was performed in Devoret's laboratory (Gif sur Yvette) and pursued in the United States. Under the direction of Devoret and in partnership with Evelyn Witkin (Figure 4), Radman has contributed to prove the existence of the SOS repair phenomenon (Friedberg 1997, 171-183). The Devoret and Rörsch's courses were planned under the auspices of EURATOM. According to the Dutch DNA Repair scientists we met in the Netherlands, EURATOM has been a very important organism for the emergence of a DNA Repair European community. From 1973, EURATOM has founded the researches of a consortium of DNA Repair teams included Dutch teams (in particular, Leiden and Rotterdam), British teams (in particular, Brighton) together with French (in particular, teams located in the Paris Region) and Italian teams (in particular, Pavia). Following the "scientific internationalism" ideology, EURATOM has been a pioneering organization for the development of international collaborations at the European level. It might even be that EURATOM's funding programs served as models for the development of the European framework programs in the 1980s. In this regard, the specificity of the DNA Repair field and notably, its link to the radiation research area has been an advantage. However, there is no sign of this specificity of the European context on Figure 4, probably because the keyword "DNA Repair" is not yet used very often by European scientists and that there is still a limited number of European protagonists involved in the field in the early 1970s.

Japan

As Austria, during the Cold War, Japan benefited from being in a strategic position between the so-called "free world" and the Soviet world. As a consequence, US-Japan collaboration programs were launched from the early 1950s. Friedberg refers to the relationship between the American teams and Japan in a chapter on the discovery of Base Excision Repair: "*anticipated by Dick Setlow and Bill Carrier as early as 1966 and independently discovered by Mutsuo Sekiguchi and his colleagues in Japan*". After "*like many of the best and brightest young scientists in Japan*", he did a postdoctoral training in the United-States, Sekiguchi was appointed to a faculty position at Kyushu University. This is where he and his local team started to work on DNA Repair. Considering the lack of basic equipment and research funds in Japan at that time, it appeared less complicated to tackle exciting new problems. Besides, Bernard Strauss, who observed repair of UV radiation damage in bacteria in the early 1960s, also played a role in introducing DNA repair issues to Japanese scientists (Friedberg 1997, 114-115). Strauss first went to Japan in 1956 to participate in "*one of the earliest postwar scientific meetings*" held in Japan and returned there in 1958 for a sabbatical. He spent his sabbatical at Osaka University where he first met Mutsuo Sekiguchi. Also, Strauss hosted Japanese fellows in his laboratory at the University of Chicago.

However, the only Japanese pioneer on Figure 4 is Sohei Kondo (Department of Fundamental Radiology, Faculty of Medecine, Osaka University). We have found little information on this scientist apart that he participated to the first important international conference held in Squaw Valley in 1973 (California). Also, the references Kondo used in an article published in 1970 about "DNA repair" demonstrate a very good acquaintance with the early American literature on DNA Repair. Regarding the relationships between the Japan group and the European groups, there also is little information. According to the interviews held in Netherlands, we can conclude there was some competition between the Dutch group and the Japan group since they were tackling similar problems from the mid-1970s, but also that some Japanese scientists were attending the regular DNA repair meetings organized in the Netherland from the 1970s.

With the help of qualitative data, we are able to demonstrate the different DNA repair teams were connected to each other from the emergence of the field. Moreover, we have found evidence showing that the emergence of the DNA repair specialty was embedded in the radiation research field. Following the "scientific internationalism" ideology designed in the United-States, the radiation research field has benefited from postwar policies and military founding. In Europe, some places were found to be important for the field organization such as Rijswijk (Netherlands) and Saclay (France) where young scientists have been trained to radiation research or places where radiation research events and later DNA repair events happened. Americans have played important roles outside their own country to promote the development of DNA repair researches. Thus, about the International Conference on Radiations held in Evian in 1970 Devoret remembers: « *Once more, the number and quality of the American scientists participating in such an international meeting impressed me. Among them, the most prominent was Dick Setlow, who had discovered nucleotide excision repair.* » (Devoret 2001).

Conclusion

To track the emergence of the scientific community in 1965-1975, we have established a methodology mixing quantitative and qualitative approaches. It is ideal considering both the lack of data and the nature of the object: a scientific group at its emergent stage. With the help of mapping and prosopography, we have highlighted a network of places. Places and scientists critical for the DNA repair community to emerge have been detected. Considering both bibliometric data and pioneers' stories has been a way to assess the role played by Americans in building the community. We have found the DNA repair mythology is born in America and has spread at the global level. American pioneers coined the keyword "DNA repair" and have been instrumental in training scientists and organizing DNA repair meetings. We have emphasized the seminal role of Richard Setlow and Philip Hanawalt which laboratories served as hubs for the diffusion of DNA repair researches.

The field developed in Europe and Japan under the auspices of radiation specialists. It benefited postwar policies at national and international levels influenced by the "scientific internationalism" ideology. According to our findings, the community emergence is related to the structuring of a global space of interaction with centers and peripheries and scientists are embedded in different institutional contexts. Few examples of transnational mobilities have been detected compared to national bifurcations. Our data have suggested that at the global level, the circulation of scientists has more to do with temporary mobility which is more difficult to track through a bibliometric analysis. Nevertheless, in enriching the bibliometric analysis by a prosopographic approach, we have found evidence that mobility was an important phenomenon for the field diffusion and the emergence of the community.

Since Soviet scientists were not mobile during the cold war, whereas they were productive on the topic, they did not contribute to the field diffusion. On the contrary, by traveling American scientists contributed to promote the field. Since we have limited our investigation to 1960-

1975, the role of Americans for the entry of Israel, India and Latin America in the field during the 1970s is out of the reach of this contribution.

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