Chapter Three

LIVING IN RELATIONS

BIOGRAPHIES OF SCIENTISTS IN THE CONTEXT OF THE ACTOR-NETWORK THEORY

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Introduction

It is a cliché to say that existence is a complex and intricate matter. If we consider our lives, we become aware of the multiplicity of issues that need to be dealt with in order to achieve a given goal. At the same time, we also distinguish a number of factors that either restrict or facilitate our actions. Each one of us belongs to a particular institutional field, occupying certain space, meeting certain people, and following certain patterns of behavior. Concurrently, each of us also operates within a milieu comprised of objects, values, and ideas, all of which are used to carry out our duties while allowing for creative activities that enrich this intricate structure with new elements.

Nevertheless, it seems that we tend to neglect these complexities when studying the lives of scientists. Why is that so? First of all, it stems from the fact that we enter a space that has been perceived in our culture as special, and within which a scientist has been enjoying a privileged status. To understand the nature of these relations, it may be useful to refer to the concept of an epistemological relation (Zybertowicz, 1995, pp. 73-74), which serves as the basis for the realist paradigm of practicing science conditioning its distinguished status. It consists of: a self-transparent knowing subject (one that is able to abstract from its pre-judgments), a language

(whose meanings are rooted in the rational thought), and an object (a reality that can be directly known).

Adopting an epistemological relation, which carries the baggage of naive realism, results in picturing scientists' actions as walking a straightforward way to meet the goal, be it a breakthrough discovery or a revolutionary invention. In that way, a scientist's life becomes a project, with him/her playing the lead role and being the privileged entity with an access to an objective reality. Thus, unlike the so-called regular people, scientists are able to achieve their objectives by virtue of the three elements making up an epistemological relation, and not through dealing with other individuals, particular objects, values, ideas, and the whole complex tissue of everyday life. It would seem that some people on the planet are cut from a different cloth-floating above the worldly matters and capable of ground-breaking discoveries. A scientist is not limited by his/her prejudgments, the society he/she lives in, or the culture he/she comes from, since ultimately these factors do not influence the content of the produced knowledge. Relativity and contingency of the context in which scientists operate are perceived only as obstructions on the way to cognition. A truly outstanding scientist is able to abstract from the socio-cultural noise that surrounds him/her in order to focus his/her efforts exclusively on uncovering, in an objective manner, the regularities concealed in nature.

Nonetheless, if we stray from the paths set out by the traditional philosophy of science¹ as well as the classical sociology of knowledge² and focus on the life stories of scientists,³ it can be observed that the epistemological relation is to a large extent a factor that mythologizes scientific investigation. Biographies of great inventors along with the stories of their

Insistence on granting a privileged status to scientific knowledge has been most pronounced in philosophical debates on the criterion for demarcation, whose objective was to delimit an objective area that for scientists constitutes the main object of interest. The line of thought striving to separate 'knowledge' from 'non-knowledge' constitutes, in one way or another, the unalterable core of science, which is not subject to external influence (social, cultural, etc.).

An example of the traditional approach is the sociology of knowledge interpreted by Max Scheler. As indicated by the commentators of his writings, "assuming that social determinants of knowledge did not prove its epistemological validity, he in a away accepted in advance the fundamental compatibility between the principles of the sociology of knowledge he had been developing and the epistemological phenomenological program, at the same time regarding them to be logically primary to social-cognitive claims" (Czerniak & Węgrzecki, 1990, p. XXI). For a division into the classic and non-classic sociology of knowledge see Zybertowicz (1995, pp. 18-25).

For stylistic reasons, the phrases 'lives of scientists' and 'biographies of scientists' will be used interchangeably.

achievements prove particularly helpful in this regard. Browsing through their voluminous stories makes one realize that the accounts capture in their entirety the heterogeneity and complexity of the various spheres of social life, both of which our culture has removed from the field of science. In other words, a thorough overview of the biographies of scientists creates an opportunity for demythologizing the figure of scientist while making away with false beliefs concerning how a particular discovery or invention was made.

In the present paper, I have outlined some lives of scientists as seen through their complexities. I have rejected the notion concerning the teleological meaning of a given cognitive activity (a self-transparent subject-scientist sets his/her own objective, chooses the means for its fulfillment, and, by virtue of being innately rational, strives to achieve it) as well as the individualistic idea of subjectivity (a subject-scientist is the only acting element that can lead to the achievement of the aim). My analysis draws on the Actor-Network Theory (ANT), which has been widely discussed also in Poland. Dating back to the end of the 1970s, the approach has been developed predominantly by Michel Callon, John Law, and Bruno Latour. My aim consists not so much in discussing this enormously interesting theoretical proposition, but rather in demonstrating why adopting ANT can yield numerous interesting and cognitively productive interpretations, which can be useful to all researchers of scientists' biographies.

Initially, ANT was used to study the dynamics of modern science. The Actor-Network Theory stems from the so-called laboratory ethnography, whose goal was to reach to the practical actions of researchers from all fields of science (Abriszewski, 2010). This was to be done using empirical studies similar to those conducted by anthropologists who collect their material through field studies. As a consequence, ANT is suitable for analyzing biographies of researchers from the natural sciences and humanities alike.

I am going to try to answer the following questions concerning biographies of researchers: what shapes the life of an individual in such a way that it follows a particular scenario? What affects the individual? Which factors determine the individual's behavior, and which are subject to the individual's influence? What exactly defines the context of the individual's activity? What makes the individual achieve his/her objective (make a breakthrough discovery, elaborate a pioneering invention)? What issues does he/she face? What kind of negotiations have bearing on the course of his/her life and the ability to reach a goal?

This has been successfully done by others: cf. Sojak (2004, pp. 233-266), Bińczyk (2007, pp. 189-250), Abriszewski (2008a).

Network, or the Context

A study of a scientist's life often begins with a reconstruction of the context in which he/she came to live and work. The life of Copernicus is described in the context of the Neo-Platonic philosophy which regards the Sun as a metaphor of God or the great geographical discoveries (Kuhn, 1957). Plato's work becomes comprehensible only in a context that takes into account the cultural process of shifting from oral to written communication (Havelock, 1963).

ANT steers clear from a simple understanding of the term 'context,' claiming that the majority of researchers accept it as a given, unproblematic term that does not call for an in-depth understanding. Although it continues to be examined, its meaning is subject to extensive modifications. Latour and others interpret context using the metaphor of a 'network.' What is a network? To begin with, it is a set of *acting actors* who influence one another in the course of organizing the string of events. Moreover, is it also *a system of heterogeneous elements* connected with specific relations. Networks are produced as a result of *translations*. Translations involve attaching new elements (actors) to the network in such a way that the entire network consequently undergoes a transformation, while the essence of the actor itself also becomes modified. The context/network is never static; it perpetually continues to *reconstitute* itself.

The Actor-Network Theory involves various types of translation. A translation takes place each time a complex system is reduced with the aim of exercising control over heterogeneous factors and placing them in the media in which they can be addressed. A good example of a translation is drawing a map (Latour, 1999a, pp. 24-79). Cartographic skills make it possible to 'squeeze' a very large and three-dimensional space on a two-dimensional piece of paper that fits on a desk. Hence, a map stands for translating a complex element into an uncomplicated one in such a way that it generates a simple chain of relations between the person looking at the map and the territory itself. As a consequence, a man tracing a route to a destination refers to the real space, but does so through the medium —a piece of paper.

Obviously, the situation can be easily made more complicated. Drawing an adequate map requires adopting the appropriate system of measurement determining e.g. the scale, distance, and heights. Thus, it is yet

⁵ "I have never understood the fascination with the context. A frame can embellish a painting, direct the viewer's attention, or increase the value, but it does not add anything to the work itself. The frame, or context, is a sum of factors, with no bearing on the data, as is commonly known," claims Latour (2010, p. 207).

another example of translation. The real space becomes translated into symbolic meters, ratios, and segments. Various relations are established between the traveler and the space in which he/she operates. The traveler is required not only to be able to read, but also to comprehend the symbols used in geography and cartography. Would it be possible to go even further and ask why the symbols look the way they do? What made it possible to generate the terms which describe spatial relations in an adequate manner? Is the meter a result of a given social context? Who created the scale and for what purpose? Following one translation after another produces a network of dependencies, where material, symbolic, academic, social, and even psychological and economic elements will be in a state of constant flux. This is what ANT considers to be a network.

Adopting the ANT point of view means that subject's actions need to be placed within the translation-shaped network of relations. In other words, it is possible to understand quite fully the actions of a particular person only after all relevant factors have been taken into consideration. In addition, the relational context is so closely 'interwoven' with the individuals situated in it that from the methodological perspective there is no point in separating these two entities, as it would inevitably distort the larger picture. Human identity is in fact constituted as a consequence of a series of translations between the networks it is related to. Man is a collection of heterogeneous materials determining who he is. John Law summarizes the idea as follows: "If you took away my computer, my colleagues, my office, my books, my desk, my telephone I wouldn't be a sociologist writing papers, delivering lectures, and producing 'knowledge.' I'd be something quite other" (Law, 1992, p. 4). Who I am is determined by a number of factors which I deal with, but cannot control. As an acting subject I possess a range of individual skills (such as education or manual talents). Although I can make use of them in order to achieve a particular goal, my actions are always filtered through an exterior network of relations. I can be a Ph.D. student not only because my innate intelligence proved useful in passing the exams, but predominantly because there is such an institution as a university (characteristic for the Western culture) along with the technical (books as the material reproductions of knowledge) and economic infrastructure (a monthly scholarship).

The network determines to a large extent the scope of my actions, 'restricting' some of them while 'facilitating' others. Take the example of a simple direct interaction between a professor and students: an interactionist sociology perspective would analyze the situation using an interpretive framework. The interpretive framework defines the meaning and

development of a given interaction.⁶ In the case of an academic lecture, the framework is imposed by the institution of the university itself. We have been taught that within university facilities people play the roles of lecturers (those who should be listened to) and students (those who listen). ANT advances the idea of reconsidering the issue from a new perspective, paying special attention to the relations that enable and facilitate interactions. As may be guessed, a lecture is more complex than it might seem at the first glance (Latour, 2005, pp. 199-204). Firstly, the importance and outcome of the lecture hinges on a number of actions performed outside the lecture hall. Before the professor may begin to speak, the building needs to have a power supply, which is provided by a power plant. If for some reason the power is not being delivered, the lecture will have to be cancelled. Secondly, the network elements that are active during the lecture surpass its temporal location. The time passing in the course of regular social interactions is also a heterogeneous concept. It passes in one manner with regard to material objects (desks were produced five years before the lecture and possess characteristic durability), in another when it comes to the institution of the university (the lecture has to fit into the approved time schedule, otherwise it will be interrupted), and in yet another if we consider its very content (which may concern classical philology and works dated to times before Christ). Thirdly, not all the elements constituting the lecture are immediately visible. For instance, we do not see the power cables and are not aware of the components fitted inside the lecturer's computer. While creating a network of translations, these elements also exert influence on the progress of the lecture. Fourthly, the elements active during the lecture are not homogeneous. In fact, they may be material (desks at which the students sit), social (the aforementioned interpretive framework assigning social roles), and economic (financial standing of the university). Fifthly, not every element is active to the same extent. It may so happen that a microphone malfunctions during the lecture, and therefore it becomes the main actor shaping the outcome of the event. It is also possible that the weather gets worse and the rain pounding against the windows will make it impossible to continue the lecture. Thus, the weather may become an obstruction in accumulating knowledge.⁷

[&]quot;[...] in many cases the individual in our society is effective in his use of particular frameworks. The elements and processes he assumes in his reading of the activity often are ones that the activity itself manifests—and why not, since social life itself is often organized as something that individuals will be able to understand and deal with" (Goffman, 1974, p. 26).

The lecture example has been used in order to make the reader aware that even a simple event is made up of complex elements. In the context of a scientist's life, a single

The network/context can also be analyzed from the global, instead of a local, perspective. It then turns out that the context, be it Ancient Greece or science of the fifteenth century, continues to be relational networks, not differing in that regard from the discussed interaction between the lecturer and students. This is because we always deal with objects, institutions, human beings, ideas, and practices of a well-defined and established nature, regardless of the extent to which these elements impact one another. In other words, the aim of ANT is to describe in a most detailed manner possible all the elementary particles of the context, which influence the behavior of the involved subject. Such complex entities as the Renaissance or the free market cannot be part of the explanation, but they need to be defined in relation to the studied biography. A history of the Renaissance can be written by analyzing academic culture. The culture, in turn, can be reconstructed with the help of histories of particular universities, which are linked with economic and political institutions, entailing another set of translations and actors. Finally, a history of the Renaissance can be based on the biography of Erasmus of Rotterdam, who attended a particular university in a particular country, met particular people, used particular objects, etc.

When dealing with a biography, the emerging translations resist any attempts to divide them into local and global ones (ibid., pp. 173-218). A biography is determined by a set of materials that extend beyond simple ontological, spatial, and temporal boundaries. In other words, human life is shaped by virtually all factors, which makes the task of choosing the most appropriate translations from their multitudes particularly challenging. In fact, it is one of the arguments cast against the Actor-Network Theory. As Olga Amsterdamska (1990) rightly observed, a researcher does not receive any tools which could be helpful in separating the significant networks from the non-significant ones. In the case of a biography, one ought to ask: is it necessary to analyze all networks in which the studied individual is involved? If yes, the researcher's task would become extremely difficult. In the end, it might even turn out that the biography resembles the Borgesian map, with the area amounting to that of the represented territory (Borges, 1972).

lecture does not have to prove decisive for his/her future. It does not have to—but it may. A good example here is Michel Foucault. It is commonly known that he delivered lectures at the prestigious Collège de France in the years 1971-1984. The lectures possessed certain characteristics: their total time had to amount to 26 hours, and the content was to be grounded in original research. As a result, the lectures have come to stand out as unique among the oeuvre of the author of *The Order of Things*, being a series of spontaneous ideas conceived in the lecture hall. What is interesting, the development and growing availability of tape recorders made it possible to publish the lectures as books. In that way, they have been functioning in the manner similar to the most important works by Foucalt (cf. Ewald & Fontana, 2003, pp. ix-xiv).

What can be done to solve this dilemma? A piece of helpful advice can be found in an article by a Finnish scholar Päivi Kaipainen (2010), whose suggestion is to begin by narrowing down the scope of the study. When analyzing a biography, we should ask ourselves, 'what is this process we are trying to capture?' Is it a network of dependencies leading to a particular scientific discovery? Or maybe it covers only the period before the studied individual became a well-known, outstanding researcher? Any restrictions we impose on ourselves at the very beginning will make it easier to navigate through the maze of heterogeneous translations. Another piece of advice, coming from Latour himself, is noticeably less optimistic. Scholars who describe networks always overlook some elements and the status of their work is prone to rearticulation (Latour, 2005, pp. 128-133). This means that by definition the analysis of a life story does not need to be an exhaustive study. A researcher creates a network of dependencies around the investigated individual with the help of the accumulated material. The level of the completeness of such description is more important than methodological accuracy, which in the case of ANT imposes the necessity to notice the relations between the elements. The focus of ANT lies predominantly with action. Thus, within a relational network, only those elements are meaningful that prompt actions of the investigated subject.

Network/Context: World War II, Hitler, Curie-Skłodowska, Uranium, Spies, Diplomats, and Twenty Six Containers of the Heavy Water—the Biography of Frédéric Joliot

To illustrate how the Actor-Network Theory pictures scientists' work, I will present the story of Frédéric Joliot, a French chemist, Nobel laureate, and husband of Irène Curie, the daughter of Marie Curie-Skłodowska. Joliot's input played a crucial role in the development of the atomic bomb by the Allies. His story is worthy of telling here for two reasons. Firstly, it will help us understand what it means that an individual operates within a context that cannot be grasped using only one general category, but rather dissolves into a number of details, dependencies, and active actors. In addition, it can also demonstrate why scrutinizing scientists' biographies is advisable when trying to explain the dynamics of science.⁸

⁸ The following section tells a story reconstructed on the basis of three sources. The first one (Latour, 1999a, pp. 81-84) is representative of the ANT approach, and served as my main point of reference. The second one is a multi-plot story of the atomic bomb development, in which Joliot played one of many parts (Rhodes, 1986). Finally, the third source gives an account of the race between the Nazis and the Allies to get hold of the heavy water (Dahl, 1999, pp. 104-110); again, the French scientist was not the leading

As mentioned before, biographies provide resources necessary to debunk a few persistent myths regarding scientists' work.

Research on energy from uranium fission entered a critical stage in May 1939. With World War II looming large, Joliot managed to interest in his results both the French Ministry of War and the French National Center for Scientific Research (Centre National de la Recherche Scientifique-CNRS). Joliot desperately needed to forge contacts such as these as his experiments relied on uranium, whose supply was in deficit at the time. However, the issue was resolved with the help of the French government, since it turned out that Union Minière, a Belgian company, was extracting the element in a recently opened mine in the Congo. Union Minière mined uranium predominantly for the production of radium, which was much in demand in laboratories and medical centers all over the world after the discoveries made by Pierre Curie and his wife, Marie Curie-Skłodowska. Whereas the company did not have any use for uranium oxide, a by-product of the radium extraction, it was precisely what Joliot was after. According to the agreement negotiated by the French officials, Union Minière was obligated to deliver uranium oxide to France and to pay the scientist five million francs. In return, the Belgians were to receive 50% of the profits from all Joliot's patents.

Having secured the supply of the precious compound, Joliot and his two associates, Hans von Halban and Lew Kowarski set to work. Early on, they established that upon being bombarded with neutrons every uranium atom splits into two elements, releasing large amounts of energy. Joliot and his team tried to prove that the process of splitting could be turned into a chain reaction, with each atom produced as a result of splitting undergoing further bombardment with neutrons, generating further splitting and releasing even larger amounts of energy.

Even though the chain reaction was merely a hypothesis, it could be proven theoretically. Excited by the discovery, the French scientists were eager to share the news with the world. On the other side of the Atlantic, a Hungarian immigrant living in the United States by the name of Leo Szilard became concerned about their plan and tried to dissuade Joliot from publishing the article on chain reactions. Szilard had been deliberating

role. I have decided to extract a number of elements from different stories in order to illustrate the level of complexity and heterogeneity of the contexts in which Joliot was involved. I am fully aware that my choice has been arbitrary, and that sources always carry the risk of being problematic data. However, bearing in mind that the chain reaction story serves only as an example supporting my more general claim, I refrain from the in-depth analyses at this point. Otherwise, instead of discussing ANT in the context of researching scientists' lives, my paper would become an account-based analysis of Frédéric Joliot's story, which is virtually the same as writing a biography from scratch. Unfortunately, I have neither the skills nor the resources to attempt such a task.

over splitting atomic nuclei with neutrons since 1934, but had no idea as to which element would be best suited for the process. He was also familiar with Joliot's Nobel-winning work presenting the hypothesis that nuclear fission could produce vast amounts of energy. More importantly, the Hungarian scientist was convinced that discoveries in the field of nuclear physics would eventually lead to the creation of a deadly weapon. Burdened by the experience of his 1933 escape from the Third Reich, he also knew that the Germans would use the new tool to cause an unbelievable tragedy. To avoid this scenario, Szilard decided to patent his discovery in secret, communicating with the British and American governments. In addition, he also persuaded other scientists to conduct experiments on chain reactions in strict isolation from the exterior scientific world. The Hungarian had managed to enforce their code of silence until 22 April 1939, which was when Joliot, von Halban, and Kowarski published their article in the prestigious journal *Nature*. At that point everyone, including the Nazis, fascists, and Bolsheviks, intensified their efforts to build an atomic bomb. As the war grew close, ten parallel research teams were established in order to accomplish the objective.

After the outbreak of World War II, Joliot and his colleagues did not abandon the experiments. The main obstacle preventing them from producing an effective, sustainable, and safe chain reaction was excessive speed of neutrons bombarding the atom. To maintain fission, the scientists needed a suitable moderator that would slow down the neutrons. Perhaps the atomic bomb would have never been created but for the simple idea of Joliot's co-worker, Hans von Halban. His suggestion was to replace hydrogen found in water molecules with deuterium, which exhibited the same chemical behavior. The obtained compound became known as the heavy water. With the increase of the weight of water neutrons became heavier, their speed decreased, and the chain reaction was not interrupted. However, another issue arose. Owing to its low availability, obtaining deuterium, an isotope of hydrogen, proved extremely expensive.

As the war was raging on, French authorities began paying more and more attention to Joliot's work. This, however, did not win the sympathy of the left-leaning scientist. From the very onset of his career, Joliot was deeply convinced that his experiments should result in the production of a cheap energy source, not a nuclear weapon posing danger to people. Here I should mention the role of Raoul Dautry, an economist and engineer, who in the years 1939-1940 served as the French Minister of Armaments. His interest in the work on chain reactions had begun considerably earlier. The lives of the two gentlemen had intertwined at the end of 1939, before France was taken over by the army of the Third Reich.

The fact that the Nazis occupied Poland and intended to invade France as well as the difficulties in obtaining heavy water forced Joliot to reconsider his political views and reach a compromise with Dautry. While the scientist obligated himself to build an atomic bomb as soon as possible, the minister promised to provide him with a large supply of the necessary material. In Europe, the heavy water was produced exclusively in Norsk Hydro-Elektrisk in Norway. Upon Dautry's request, negotiations with the Norwegian company commenced. On that occasion, Deuxième Bureau, the French secret service, sent a spy by the name of Jacques Allier to Oslo. His task was to convince Norsk Hydro-Elektrisk to work together with the French. However, it was apparent that after Joliot's publication in *Nature* Germans also became intrigued by the heavy water and the Norwegian factory. Needless to say, Allier was acting in coordination not only with Dautry, but also with Joliot and the French president. He brought to the negotiations a check for 1.5 million kroner. The talks were successfully concluded on 9 March 1940. In the following days, two scheduled flights to France transported twenty-six specially made containers holding 185 kilograms of heavy water. Joliot, Halban, and Kowarski were able to continue their work, first in France, and later in England. The research and experiments conducted at that time led to the production of a chain reaction, construction of the bomb dropped on Hiroshima, and the post-war development of nuclear energy in France and all around the world. Owing to the scientist's exceptional skills, in 1945, general de Gaulle appointed Joliot the High Commissioner for Atomic Energy, and in 1948 he became the chief consultant for the construction of the first French nuclear power plant.

Let us now consider what measurable research benefits can be obtained from the Frédéric Joliot's story. To begin with, the story teaches us how to comprehend the action's context. As has already mentioned, ANT suggests viewing the relational network as a structure that determines the efficiency of its constituent elements. In this case, the acting subject of the analysis is Joliot, and the investigated process is the role that the French scientist played in developing the atomic bomb. However, contrary to the teleological assumption (stating that an autonomous individual seeks to achieve the goal set before commencing the action), the story of the chain reaction discovery seems to be a set of negotiations between a number of actors that exerted a measurable influence on the final result. Using the terms provided by the Actor-Network Theory, a series of translations had to occur in the challenging World War II conditions before the links critical to the final success could be created. The outbreak of the war itself proved to be crucial. It could be hypothesized that if it had not been for the rise of Adolf Hitler, chain reactions would have been used for peaceful purposes, as Joliot originally intended. To put it briefly, the outcome of Joliot's work could have been entirely different.

Let us consider for a moment what were the links that shaped Joliot's actions. First and foremost—a configuration of interests. Operating in a slightly different context, Michel Callon and John Law (1982) coined the term "map of interests" to denote those relations which are constituted by objectives of individual actors. The French government's interest was to build an atomic bomb and win the war. The Hungarian scientist Leo Szilard did a lot to prevent the publication in *Nature*. As any private company, Union Minière wanted to make money and fully exploit the potential of the Congo-based mine. Norwegian Norsk Hydro-Elektrisk focused their efforts on achieving profits by establishing the only facility in Europe capable of industrial-scale heavy water production. German spies sought to 'win' something for their superiors while their French counterparts tried to thwart their attempts. The relations among all these actions sketch out a map of interests across which Frédéric Joliot tried to navigate, aiming to trigger a sustainable and safe chain reaction. Some of the map elements had a direct influence on the scientist, such as when Raoul Dautry, acting on behalf of the French government, persuaded Joliot to act against his own political beliefs. Other elements gave rise to opportunities for achieving the goal, such as the case of Union Minière's unused uranium oxide, a by-product of radium production. Finally, there were also elements which Joliot simply could not ignore, such as Szilard's request. All these issues had an effect on the scientist's actions, and what is more, they were not the sole important factors in this context. In a sense, even Adolf Hitler, with his own set of interests that placed conquering the world at the forefront, influenced Joliot. It was the war unleashed by the Führer that forced the scientist to adjust his work to the French authorities' objective of defeating the Nazis.

Another type of links worth discussing concerns the economic, or, as ANT would call them, non-human factors. Their role in constituting networks was discussed on a number of occasions by the advocates of the Actor-Network Theory (Callon, 1986; Latour, 1992; 2005; Law, 1986a) and its commentators (Abriszewski, 2008b; Bińczyk, 2005). The most important argument put forward states that non-human factors, such as things, standards, values, and elements of nature, are just as important as human

When considering these observations, it is worth noting that anthropologists inspired by, among other things, ANT advocate writing social histories of things, or even biographies of things (Domańska, 2008). Therefore, it is possible to imagine that the past of science could be analyzed not from the point of view of human actors, but foregrounding particular discoveries or inventions.

factors when it comes to triggering actions. Bearing in mind the biography and the relational context that a scientist has to deal with, what strikes me as particularly interesting are the negotiations with non-human factors in order to enable operations within particular relational networks (Latour, 1987, pp. 70-94; 1999a, pp. 174-215). Let us consider what actors Joliot faced. To become successful, in the privacy of his laboratory he had to negotiate the agency of neutrons by conducting a series of experiments. As mentioned above, their speed noted during the first split was too high, which resulted in the rupture of the chain reaction. The problem was solved only after an appropriate translation occurred, which here consisted in introducing a new actor (deuterium) and putting it in the place of the hydrogen molecule. Another good example are the containers in which the French spies, led by Jacques Allier, transported the heavy water. Since they were built in accordance with Joliot's detailed instructions, their special properties determined the successful outcome of the operation. While the material was being transported by scheduled flights heading to France, the containers turned into the leading actors that supported the success of the French scientist. As we may see, a non-human actor gives rise to certain problems (neutrons traveling too fast), which are solved by another nonhuman actor (heavy water) with the assistance of yet another non-human actor (special containers).

Let us reflect now on the benefits stemming from visualizing human life in terms of a relational network. In addition to capturing heterogeneous factors that influence the scientist, we are also offered a perspective that surpasses the individual. The notion of an individualistic nature of a scientific discovery, entailing that success is achieved by one particular scientist, is yet another myth deconstructed by the Actor-Network Theory. 10 Returning to Joliot's story, we may observe that his success was the outcome of cumulative efforts of his fellow scientists, Hans von Halban and Lew Kowarski, as well as his political allies: Raoul Dautry (representative of the French prime minister) and the spy, Jacques Allier. Joliot's colleagues assisted him in negotiations with neutrons, proposed a method of solving the problem of molecules' speed, and came up with an idea of translating the chain reaction experiment with deuterium as the key element. Relying on their diplomatic contacts, politicians forged a relation with the Belgian company Union Minière, and the designated spies showed their typical careful and tactful manner smuggling the containers

Bruno Latour acknowledges that remarks on the collective nature of knowledge production can be found in the works of an eminent philosopher of science, Ludwik Fleck (Latour, 2005, pp. 112-114). As a matter of fact, the thought collectives theory (Fleck, 1979) is very similar to the Actor-Network Theory (Bińczyk, 2009).

with the heavy water without alerting the Germans. All of the agents acted, carried out translations, and maintained relations to allow Frédéric Joliot to successfully perform a continuous series of nuclear fissions and to be remembered in the history as the father of the French atomic energy.

Actor, or Acting in a Context, i.e. Networks

The relational network description presented above could be used to conclude that the context can subdue a person to such an extent that the individual cannot do virtually anything to control the course of his/her life. Nothing could be further from the truth. To portray a scientist's life following the Actor-Network Theory approach, it is essential to discuss the subject's mode of operation, translation, negotiation, and the way in which he/she influences other actors.

It is true that within the ANT framework the actor "is not the source of an action but the moving target of a vast array of entities swarming toward it" (Latour, 2005, p. 46), which could be seen in the case of Joliot. The actor can also be defined in a more subjective manner: "the actor makes changes in the set of elements and concepts habitually used to describe the social and the natural worlds. [...] [the actor] defines space and its organization, sizes and measures, values and standards, the bases and rules of the game—the very existence of the game itself" (Callon & Latour, 1981, p. 286). Being an active element, the actor (both human and non-human) can be so powerful as to constitute and 'organize' the surrounding environment in such a way that other actors will have to adjust to his/her rules.

The actor's actions can be described using the previously discussed concept of translation. Gathering actors within a network, modifying their attributes, and making them work for one's benefit are all included under translation, which can be understood as a practice determining the network's shape. Thus, establishing an actor's subjectivity consists first and foremost in weaving together numerous interconnected links. Let us refer once more to the academic lecture example. To be able to successfully deliver a presentation, the professor has to collect and control a number of heterogeneous elements, which include: mastering a given domain of knowledge (preparing the lecture for instance on the basis of his notes gathered through years of academic work); practicing specific speech techniques (so that the students do not doze off after 15 minutes of the lecture); and polishing a set of practical skills (writing on the blackboard, operating the microphone, communicating with the audience through computer presentations). The very fact of including the lecture into the curriculum is a result of the lecturer's efforts. He had to become employed by the university (fitting the university's

demands for academic staff), push the idea for the lecture (getting the university administration interested in his achievements), and even negotiate the date of the lecture so that it would be acceptable for the speaker, the students, and other lecturers. Consequently, the actor/lecturer creates a network of translations. The lecturer's scope of work is translated into the will of employing a particular scholar at a certain university, while his interests are translated into the interests of students.

A relational network, as has been discussed earlier, is also prone to continuous rearticulation. The strength of its constituent links hinges of the techniques used for maintaining relations, attracting new actors, and adapting to the changing circumstances. Meanwhile, the potential of a given actor depends on his/her ability to transform the entire network. As network-constituting practices, translations do not so much attach new elements, but rather, by virtue of forming links change both themselves and the new elements. The basis of the Actor-Network Theory lies in continuous transformative actions. As Latour (2005, p. 45) observes, these actions often become unpredictable and unexpected: "Action should remain a surprise, a mediation, an event." Though seemingly insignificant, one actor can act in such a way as to establish global influence whose scope would far outreach the original, local context. The mobile phone can serve as a good example here. It may be viewed as a device typical of the information age of the Western world, allowing for the unrestricted transfer of messages, voice, and images regardless of the distance. At the same time, this small object has been transforming family relations, economic liaisons, emotional life, and work environment. Within each of these networks, it operates in an entirely different manner and is capable of yielding unexpected consequences. In contexts that are utterly different from the West in terms of culture, the device can be turned into a weapon, for instance by Islamic terrorists who detonate bombs using mobile phones.

Let us now consider some practical methodological suggestions concerning acting within relational networks (ibid., pp. 52-58). If the 'essence' of the actor are his/her actions, then this is the first aspect that should be discussed. According to the ANT guidelines, every action leaves a trace. The actor may write a diary, draft legal acts, write poems, or work on new inventions, all while keeping notes, having conversations, and so on. Each of these traces is at the same time the evidence of the individual's actions, as they illustrate how the given actor behaves in different contexts. A diary will produce a certain influence while being written, but will have a different effect after a few years' time. A similar observation applies to inventions: the printed word at the end of the fifteenth century behaved in a different way than it does now, in the Internet age. Following these

traces is tantamount to following the actor, analyzing his/her actions and evaluating the degree to which he/she constitutes a network.

Secondly, special attention should be paid to what Latour calls "figuration" (ibid., p. 71). Every actor operates taking advantage of various forms and assuming different characters, which significantly expands the scope of his agency. In the discussed example, the mobile phone could serve as a communication tool in one situation, turn into a 'scaffolding' in a love game between two people, and become an effective weapon in another context. When considering the figure of a scientist, he/she may alternate between a positivistic ('I practice science for the truth') and a political one ('as a communist I will not focus on that'). Since each figure entails a different mode of acting, a great deal of thoroughness and carefulness is required to take into account the actor's mutable nature. Still, mutability with regard to the assumed figures is a desirable trait in actors. When operating within a heterogeneous network of dependencies, as demonstrated above, the actor has to freely navigate it. The liquidity of figures allows him/her to grasp the complexity of the world in which he/she functions, making him/her able to perform broader rearticulations, negotiations, and transformations.

Thirdly, actors that influence the network's shape, determine its actions, and define the agency of other actors continuously create antagonistic relations between one another. Actors fight among themselves, define counter-actors, deny the agency of others, and strive to accumulate such wealth of resources that would turn them into the dominating actor. A respected scientist who has achieved a high-ranking institutional position in a given field becomes surrounded by a network constituted so strongly that he/she is the one defining what it means to be a scientist. Thanks to the owned resources he/she can set the rules of the game.

It does not mean, however, that a strong actor plays the role of an absolutist hegemon, as every network can undergo some reconstitution. The process, known as the "trials of strength" (Latour, 1987, p. 78), denotes the moment when two actors meet in order to test the durability of each other's network. For instance, if two scientists compete to prove a given theorem, each of them participates in the duel by means of arguments, research instruments, and financial resources. It is a time when scientific controversies erupt, and only the final results will have the power to shape a given scientific theory. Importantly, the trial of strengths relies on translations that gather and acquire actors capable of defeating the opponent, i.e. creating a stable network that will withhold future attacks.¹¹

An emblematic example of trials of strengths is the conflict between Pasteur and Pochet, which Latour described in *Pandora's Hope* (Latour, 1999a, pp. 153-173).

The fourth factor that should be given special attention when studying an active actor is focusing closely on what the actors actually say. Latour (2005, p. 50) calls this stage "practical metaphysics." Every actor accepts different beliefs regarding the world in which he/she operates, as well as a particular model of behavior. It may be a realist ontology, and if a scientist were to embrace it, he/she would perceive his/her actions from the point of view of reaching the truth or capturing an entity in its realness. Conversely, a political ontology imposes a method of conceptualizing the world in accordance with a given ideology, i.e. a set of ideas concerning collective life. What is equally important is the actor's self-definition as an acting element. A scientist convinced of the significance of his/her work will behave in one way (defining his/her subjectivity as exerting real influence on the surrounding world), while an amateur inventor locked in his/her workshop will be quite different in this regard (being devoid of ambitions to become a scientific revolutionist).

Let us return to life stories of scientists. As has been indicated before, a relational network exerts influence over an individual by means of translation, which in turn causes behavioral changes. Some elements help the subject achieve its targets, while other function as obstacles. My intention, however, was neither to deprive the scientist of his/her subjectivity nor to knock him/her off the pedestal to which he/she was raised by the history. In the context of the Actor-Network Theory it is possible to distinguish outstanding individuals, remarkably creative ones, and geniuses. Rather than being determined by an isolated entity with a solitary will, these characteristics are governed by a series of mobilized relations. In other words, an outstanding individual, firstly, is capable of creating a large number of links; secondly, he/she is able to skillfully maintain them; and thirdly, he/she has the capacity for exerting a considerable influence on other actors and their relations (the greater the impact, the more outstanding the individual) (see Chapter Five in this book).

Building relations, as I have already stated, stands for weaving networks. This involves gathering allies and spokespersons, acquiring nonhuman factors, identifying and rearticulating interests in a particular context. On the other hand, maintaining relations covers all the practices aimed at moving the actor to a dominant position—and they also are contingent on successful translations. Finally, exerting an influence entails having an impact, setting the rules of the game, as well as modifying and rearticulating the existing networks. It is worth noting that this influence escapes the restrictions that are not only spatial, but also, more interestingly, temporal in nature. According to Latour (1993, p. 74), "time is not a general framework, but a provisional result of the connection among

entities." The time that a scientist has for acting does not need to be seen as a closed period between his/her birth and death. Rather, it is a set of relations between a given discovery and all the relational systems into which the discovery will later be embedded.

Actor in a Network/Context: a Double Helix, Linus Pauling, Cardboard Cut-Outs, Mysterious Data General Project, and a 32-Bit Computer, or Biographies of Francis Crick, James Watson, and Tom West

To illustrate the way in which an actor/scientist operates in a given context/network, I will once more give a rather elaborate example. This time it covers the stories behind the invention of the DNA double helix model and the Eclipse MV/8000 minicomputer. Although quite different at the first glance, these accounts have much in common; in fact the stories come together in the late 1980s, when advances in computer science contributed to unprecedented discoveries in the research on the human genetic code.

Let us go back to 1951. In the Cavendish Laboratory in Cambridge, two scientists, Francis Crick and James Watson, are working on the first model of the deoxyribonucleic acid in the history of science. At that stage, it is still not known whether they are dealing with a double or a triple helix, and whether the phosphate bonds are inside or outside the molecule. Seeking to solve the puzzle, Watson and Crick follow the paths of contemporary science, trying to obtain the DNA structure using X-rays. Meanwhile, a renowned chemist and physicist residing in the United States, Linus Pauling, announces that he is close to revealing the DNA structure, and that the project should be completed within a few months. To make things worse, Sir Lawrence Bragg, the supervisor of the English scientists, does not share their enthusiasm and advises them to focus on more serious matters.

Pauling makes a discovery. He postulates that the DNA structure is a triple helix with a sugar-phosphate backbone in the centre. A scientist and friend of Watson and Crick brings them the American's article before the publication. At first, both are furious at their superior. Had he not

I reconstruct portions of the rather complicated stories relying predominantly on Latour's Science in Action (1987, pp. 1-13), where he uses them to illustrate his own claims. His work is based on Tracy Kidder's The Soul of the New Machine, a detailed chronicle narrating the struggle of Tom West and his colleagues with the prototype Eagle under the conditions offered by his company, Data General. For the DNA story, the main source was a book by James Watson himself, entitled The Double Helix: Personal Account of the Discovery of the Structure of DNA, to which I also refer (Watson, 1968).

stopped the research, maybe they would have achieved their goal sooner than Pauling. However, upon closer inspection of the triple model, the scientists make a surprising discovery. Pauling did not include hydrogen atoms in any of the three chains, which defied the fundamental laws of chemistry—a model without hydrogen would not hold together. Watson and Crick realize that the American committed a schoolboy error, which means they can still make a revolutionary discovery. What they also realize is that the moment the article is published in the prestigious *Proceedings of the National Academy*, the mistake will be immediately detected, and Pauling will continue his work on the DNA structure. Watson and Crick know the article will appear in six weeks, which means they need to hurry.

Encouraged by the failure of his American colleague, Watson ponders upon the DNA structure, taking into account its many variants. In popular chemistry textbooks, he encounters a principle defining tautomeric forms and notices a surprising symmetry in the structure of nucleic acid: adenine corresponds to adenine, cytosine to cytosine, guanine to guanine, etc. However, Watson does not know that the tautomeric forms he has found are wrong. He probably would have never learned that if it had not been for the fact that in those times he shared his office with Jerry Donohue, an American chemist who came to Cambridge on a six-month grant from the Guggenheim Foundation. Donohue tells Watson that the model relying on tautomeric forms, found in the classical James N. Davidson's textbook, was not based on a reliable research. As a replacement, the American suggests using the model applying keto forms and obtained through more thorough analyses.

Watson does not have to take his advice. The American is only a visiting scientist from the outside world and not a member of the research collective. Besides, he used to study with Pauling, the main rival in the race to discover the DNA structure. Still, Watson decides to follow his advice. He locks himself in the laboratory, makes cardboard cut-outs of the elements found in the model of the deoxyribonucleic acid, and tries fitting them together. Thanks to the visual presentation and the use of manual skills, the British scientist succeeds in building a working model. Watson makes sure that it complies with the fundamental laws of chemistry. Donohue and Crick confirm that the model is correct. As it turns out, the cardboard cut-out double helix represents the actual DNA structure.

Nearly 30 years later, in the Data General facilities in Massachusetts, we find Tom West and his team trying to eliminate design flaws in the Eagle minicomputer prototype. Data General has great hopes for the invention because DEC, a rival company, has recently began selling their VAX 11/780 model. Work on the new computer has been delayed due to

the failure on the part of the manufacturer (supplying special PAL processors that were to be fitted in Eagle) to ensure a timely delivery. Just like Watson and Crick, West is not supported by his superior, de Castro, who being disappointed by the recent unsuccessful project Ego (also managed by West) has been considering providing support to an entirely new enterprise in North Carolina, where a rival team operates.

Considering the unfavorable circumstances, West probably would not have been as motivated as he was if it had not been for a peculiar event. One day, a colleague working for DEC takes him in secret to the company's basement to show him the VAX 11/780 model. At that point West realizes that his competitors have assembled a working, but highly inefficient and expensive computer. West knows the organizational structure of DEC and is aware of the fact that it is a rather bureaucratic, conservative company that does not take unnecessary risks. This policy is clearly reflected in the design of their flagship product, VAX 11/780.

West decides to take the risk. Not intimidated by the delay in comparison to DEC, the newly-established rival group in North Carolina, and the failure of the previous project, West believes that he will be able to design a computer that is more efficient, faster, and cheaper. To do so, he isolates his team from the rest of the company, making sure that his colleagues would be able to work on the revolutionary invention without being bothered. In short, he creates a new collective and hides it within the structure of Data General. The task is far from being easy. West has to supply his immediate subordinates with appropriate materials and funding while conducting negotiations and acting as the team representative in front of his superior, the North Carolina group, and the marketing department that is predominantly focused on gaining quick profits.

The enterprise lasts two years. For 24 months West keeps the project in secret, pretending that his team is busy with an altogether different task. In addition, he lobbies his superior and the marketing department, in that way obtaining the resources necessary for achieving the goal. With time, West engages in the project the most crucial sectors of the company. As the North Carolina team suffers a failure (unable to design a new computer), and with DEC becoming ever more powerful and competitive, project Eagle becomes the last hope of Data General. As a result, expectations towards the members of the West's team are growing. Inevitably, there comes the moment when the clandestinely working team will have to demonstrate the final product. However, new issues arise continuously: Eagle operates in a stable way only for a few seconds, and the PAL processor manufacturer is on the verge of bankruptcy. West has to agree to let experts in software and hardware diagnostics into his laboratory. The

efforts of the whole team of computer design specialists, who for weeks have continuously numerous flaws, finally result in the development of the 32-bit Eclipse MV/8000 microcomputer.

These stories come to a climax in 1985. In that year, John Whittaker, working at the Institut Pasteur in Paris, develops a computer program for analyzing DNA. To do so, he takes advantage of the computer assembled by West and his team, as well as the double helix model proposed by Watson and Crick. At this point, the two inventions triggered an avalanche of discoveries linked with the human genetic code. The 1980s witness a surge in the DNA sequencing research, which involves determining the order of the nucleotide pairs. Thanks to the combination of the computer developed by Data General and the discovery of the double helix, it has become feasible to describe the entire human genome, which gives rise to inconceivable cognitive benefits.

What conclusions could be drawn this time about the scientist's activity? First of all, the story presented above reveals active agency. Although the network/context demarcates the scope of activity (as has been mentioned before), it is the decisions taken by the individuals that have the greatest significance. Watson did not have to listen to Donohue simply because he might have mistrusted him. West could have refused to let external specialists enter his laboratory and attempted to finish the project on his own. The moments when these seemingly insignificant decisions were made became decisive to the given scientist's success when considered in the context of the whole story.

Second the outcome achieved by both West and the DNA researchers was to a large extent dependent on skilful gathering of resources. To reach the goal, a successful chain of translations needs to be created in such a way so as to make heterogeneous elements operate as one entity. What was it that our individuals gathered? To begin with, all the non-human elements associated with their work. Watson and Crick had to combine nucleic acid components observing the laws of chemistry and introduce hydrogen into them, the sugar-phosphate backbone, and helices. On the other hand, West had to solve issues stemming from the use of faulty software and hardware.

This still does not exhaust the list. Watson, Crick, and West had to sort out a number of arrangements with their superiors, institutions, and companies. Engaging oneself in science- or technology-related activity does not involve solely designing experiments and inventions within the safe confines of closed research institutes, but also covers generating interest about the project, and acquiring financial resources and equipment. This is best illustrated by the example of West. In order to establish a comfortable

work environment for his team, he had to become the collective's representative. This obligated him to review their progress in front of the marketing department, software department, and, more importantly, in front of his superior, de Castro. But for West's diplomatic skills, Eclipse MV/8000 would probably have never been built.

Acquiring funds for activity is linked with an issue known in ANT as translation of interests. As has been signaled earlier, the context/network is co-created, among other things, by a map of interests, which stands for the collection of different actors' objectives. To perform a successful translation, and also achieve one's goal, the interests should be identified and rewritten in such a way so as to make all the involved parties aware that they are acting toward their personal goal. As Latour (1999a, p. 88) notes, "translations consist of combining two hitherto different interests [...] to form a single goal." West sought to build Eclipse MV/8000; the Data General marketing department wanted to offer their customers the best possible product; the boss did everything in his power not to incur a loss of profits; the dedicated, young, but at the same time inexperienced computer science specialists had a unique chance to demonstrate their skills. To combine these largely dispersed goals into one objective and subsequently use it to advance the project, a series of negotiations, transformations, and gathering the spokespersons had to be carried out. As we have seen, West coped brilliantly with the task. He managed to convince the marketing department that his computer would be cheaper and more efficient that the one offered by DEC. Choosing a suitable moment (after the failure of the North Carolina team), he also persuaded his superior that project Eagle was the company's last hope. Finally, he let into his laboratory a group of promising specialists, who worked day and night on removing design flaws.

When studying biographies, it is vital not only to pay attention to the acts of mobilization and translation, but also to notice what the actors themselves have to say about their actions. The third element that can be observed in the stories of Watson, Crick, and West is the way in which their conceptualization of both the actions taken up by them and the environment influenced their behavior. We would not have been able to comprehend Watson's decision to follow Donohue's advice if we had not known he considered the American to be an expert in the field. Similarly, we would not have understood West's decision to take the risk of working for two years in secret if we had not been aware of the fact that he knew about the flaws of the computer designed by the rival company.

The fourth point which should not be overlooked is the creation of a dense relational network that expands well beyond the contexts of the DNA discovery or constructing Eclipse MV/8000. Let us not forget that

one of the indications of how outstanding an individual is lies in the number of relations he/she has managed to generate around himself/herself, thus exerting an influence capable of impacting other actors. A powerful actor is an actor who defines the rules of the game, establishes the framework for actions, and determines the standards as well as areas of objectivity. To use a term occasionally employed by ANT (Latour, 1987, p. 132; Law, 1986b, p. 34), an outstanding individual sets "obligatory points of passage." Once the double helix has been discovered, every scientist researching DNA has to study the structure proposed by Watson and Crick, and conduct his/her research in accordance with their guidelines. Therefore, the double helix has become an obligatory point of passage which needs to be crossed before making further progress.

Still, there is something more to add. The discoveries of the British scientists as well as the American invention influence networks which seem to be far from their original contexts. The DNA helix is present not only within the fields of molecular biology and genetics, but also in medicine and forensics. Hence, the agency of Watson and Crick makes an impact touching not a narrow group of specialists, but also people dealing with healthcare or prosecuting offenders. Doctors and detectives alike have to cross the obligatory point of passage established in 1953. The networks of influence could be traced even further. By accepting the double helix discovery as a scientifically proven fact, each of us conceptualizes and visualizes deoxyribonucleic acid following the model of Watson and Crick. When thinking about DNA, the first image coming to mind is that of the two interwoven ribbons.

Conclusions, or Why it is Worth Following the Actors

Although I have chosen separate stories to illustrate two issues (*the context* and *acting within the context*), they are not markedly different from the Actor-Network Theory perspective.¹³ If there is no distinction between the actor and the network, the acting subject remains embedded in the context of his actions. While the actor is the network and the subject is the context, the scientist creates a series of relations, determines the scope of other actors' actions, sets the rules of the game, and establishes obligatory points of passage. Owing to all these practices, rather than being an individual scientist, he/she becomes a set of non-human factors, practices, financial resources, institutions, etc. At the same time, the network is the actor, and

[&]quot;'Actor' does not play here the role of subjectivity, and 'network' does not play the role of the society. Actor and network [...] mean two sides of the same phenomenon [...]" (Latour, 1999b, pp. 18-19).

the context is the subject—networks of dependencies continue to function, triggering modifications and negotiations, creating frameworks for actions, multiplying some possibilities while doing away with others.

Let us conclude. The life story of a scientist is far more complex than has been traditionally viewed by the philosophy of science or the classical sociology of knowledge. As suggested in the introduction, scientific activity is subject to mythologization, which stems from the exceptional status granted to science in our culture. As a consequence, a scientist is perceived as a lone genius, a creative individuality who can reach his/her intended goal. Interpreting the role of the scientist along these lines obscures the real picture of how knowledge is generated. If we examine all the intricate elements (cultural, social, financial, political) involved in conducting scientific work, it will be possible to adopt an altogether different approach. Another analysis of the stories presented above can make us aware of the fact that no absolute divisions exist between the content of science and its context. The division postulates that a scientist, possessing innate rationality, operates within the former and merely exists in the latter, without exerting any measurable influence on his/her cognitive activity. As I have attempted to show, such division is artificial. It is not possible to separate interests, values, ideas, things, and politics from neutrons, heavy water, uranium, radium, guanine, cytosine, and sugar-phosphate backbone.

This is precisely the lesson to be learned from ANT and transferred into the field of traditional reconstruction of scientific knowledge: no absolute separation exists between factors that are social and natural, material and non-material, human and non-human, political and non-political, subjective and objective. Originating in the dynamics of science, that is in a series of transformations, negotiations, and rearticulations, a dynamic relational network emerges, defying simple ontological distinctions. However, the Actor-Network Theory would not prove particularly useful for the history of science if it were not for the previously collected examples. Thanks to well-written biographies, the heterogeneity of scientists' actions reveals its true extent before our eyes. Obviously, ANT cannot evaluate biographies in terms of being better or worse from a historical point of view. There are no tools suitable for determining which biography uses more adequate sources and represents the past in a more accurate manner (this type of analysis belongs to the domain of historical research, which possesses tools fitting the purpose). Nevertheless, ANT makes it possible to evaluate their usefulness in explaining the complexities of research processes. To do so, it employs a number of biographies which facilitate the creation of a relevant network. In the case of the atomic bomb example, one network would explain Joliot's success, another the role of Szilard,

and yet another could analyze Einstein's influence. It is also possible to rewrite the story in such a way as to place the atomic bomb itself in the centre. ¹⁴ Each of the networks can use different sections of the biography.

Whenever analyzing a biography with the aim of evaluating the status of a scientific discovery, we should observe the basic methodological advice provided by ANT: follow the actors (!) (Latour, 2005, p. 68). This is the heuristic profit that can be obtained by means of the Actor-Network Theory. Studying life stories and biographies of scientists in order to find the explanation of the dynamics of science in terms of relational networks, makes it possible to observe the practice of translations, which in turn contributes to a deeper understanding of the actors' actions. We can dig out the origin of a given discovery, and also understand what the motivation was behind the agency of the involved actors and what the consequences were of such discovery. By adopting this approach, we reject the naive belief in the superior role played by an entirely rational, individually acting subject in the process of knowing. According to the ANT model, the scientist continues to work and to be an outstanding individual. The difference consists in that his/her exceptionality is no longer defined by a solitary will following a straight path to a revolutionary discovery, but rather by a set of relations, allies, and practices that the actor is capable of mobilizing.

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¹⁴ This approach has been adopted by the previously mentioned Richard Rhodes (1986).

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