Radioisotopes «economy of promises»: On the limits of biomedicine in public legitimization of nuclear activities

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SUMMARY: 1.—Introduction. 2.—From radium to radio-isotopes: the construction of an «atomic medicine». 3.—Biomedicine and radioisotopes in France. 4.— Biomedicine and the construction of the social acceptability of nuclear energy. 5.—Conclusion.

ABSTRACT: This paper aims to examine the rise and the fall of biomedicine in the public legitimization of the development of nuclear energy. Until the late 1950s, biological and medical applications of radioisotopes were presented as the most important successes of the peaceful uses of atomic energy. I will argue that despite the major financial investment, the development of the uses of radioisotopes and their important impact on biology and clinical practices, the assessment of medical uses remained relatively limited. As consequence, the place of biomedicine in the public legitimization of financial investment and civilian uses of nuclear energy began to decline from the late 1950s.

PALABRAS CLAVE: Biomedicina nuclear, legitimación de la energía nuclear, Comisariado para la Energía Atómica en Francia, radioisótopos, radioterapia.

KEY WORDS: Atomic biomedicine, nuclear energy legitimization, Commissariat à l'énergie atomique (CEA), radioisotopes, radio therapy, cancer therapy.

1. Introduction

Until the late 1950s, biological and medical applications were presented as the most important successes of the peaceful uses of atomic energy. The eagerness with which this discourse of promotion was developed almost represented a kind of«incantation»which can be interesting to investigate. Several scholars proposed the idea of viewing investment in biological and medical questions as a symbolic operation that involved asserting that the use of nuclear energy to understand and support life would help conjure its deadly potential [1] and an attempt at«redeeming»the act of having used the nuclear bomb [2]. This desire for redemption made it possible to understand the «moral economy» of a part of the scientific community after the use of a destructive weapon that it had taken part in developing. However, it only realised part of what was at stake in the development of the biological and medical applications of the atom, and more generally its «peaceful» uses. These applications found a place on the agenda for a variety of reasons, strongly interlinked with each other, related to the context instigated by World War II and the interests of professional and political legitimization. This paper aims to clarify some of these by studying the making of atomic biomedicine at a nuclear complex and the stakes underlying its development.

The making of a «biomedical complex» in the atomic age has been investigated by many scholars [3], mainly from a history of biology and medicine perspective [4]. Using these different studies, one can argue that the policy

1. Strasser, Bruno. La fabrique d'une nouvelle science: La Biologie Moléculaire à l'Age Atomique (1945-1964). Florence: Olschki; 2006.
2. Lindee, Mary Susan. Suffering made real: American science and the survivors at Hiroshima. Chicago: University of Chicago Press; 1994. Rasmussen, Nicolas. The midcentury biophysics bubble: Hiroshima and the biological revolution in America, revisited. History of Science. 1997; 35: 245-293. Creager Angela; Santesmases, María Jesús. Radiobiology in the atomic age: Changing research practices and policies in comparative perspective. Journal of the History of Biology. 2006; 39: 637-647.
3. Hewlett, Richard; Anderson, Oscar; Duncan, Francis. A history of the United States Atomic Energy Commission. 2 vols., Berkeley: University of California Press; 1990, Beatty, John. Genetics in the atomic age: The Atomic Bomb Casualty Commission, 1947-1957. In: Benson, Keith; Maienschein, Jane; Rainger, Ronald, eds. The American expansion of biology. New Brunswick: Rutgers University Press; 1991, p. 284-324. Rasmussen, n. 2. De Chadarevian, Soraya. Designs for life molecular biology after World War II. Cambridge: Cambridge University Press; 2002. Strasser, Bruno; de Chadarevian, Soraya, eds. Molecular Biology in post-war Europe. Studies in the History and Philosophy of Science. 2002; 33C (special issue). Strasser, n. 1. Gaudillière, Jean-Paul. Inventer la biomédecine: la France, l'Amérique et la production des savoirs du vivant (1945-1965). Paris: Éditions de la découverte; 2002. Creager, Angela. Nuclear energy in the service of biomedicine: The U.S. Atomic Energy Commission's Radioisotope Program, 1946–1950. Journal of the History of Biology. 2006; 39: 649–684.
4. In addition to the history of biomedicine in the nuclear age, another fairly well documented aspect is the role of radioisotopes as instruments of foreign policy during the Cold War. See : Krige, John. The politics of Phosphorus-32: A cold war fable based on fact. Historical Studies in the Physical and Biological Sciences. 2005; 36: 71-91. Krige, John. Atoms for peace, Scientific internationalism, and scientific intelligence. Osiris. 2006; 21: 161-181. Creager, n. 3.

of promoting and financing the biomedical activities, first implemented by the American Atomic Energy Commission (AEC), then taken up in several European countries responded to a set of three problems. One of these was to study the effects of atomic weapons on the population and therefore gain better control of atomic tests in the atmosphere or to act for civilian defence. The second deals with biologists and physicians' anxiety to benefit from previously unknown resources, for the reinforcement of pre-war practices, or to construct new disciplinary or institutional ones. The third concerns the difficulty of publicly explaining and socially legitimizing nuclear energy. I will focus my interest on this third aspect by examining the rise and the fall of biomedicine in the public legitimization of investment and uses of nuclear energy.

The starting point for this paper is the observation of a shift between the central place of biological and medical applications in institutional and political discourses and their effective place in the nuclear complex: their place in public discourse went so far as to exceed the place they occupied in nuclear institutions' concerns and investments, in comparison with the construction and study of reactors, research into physical science or the prospecting of uranium. The nuclear programs were expensive. Huge amounts of money were used to finance the construction of nuclear reactors and weapons. These activities were rather difficult to publicly legitimize. One way of doing this was to show the major benefit of a reactor's large-scale production: radioisotopes. Nuclear institutions therefore created a veritable «rhetoric space» [5], which maintained the promises of application in various fields —health, industry and agriculture. The construction of «rhetoric space» did not only mean producing discourses. Indeed, in addition to the public promotion of the applications of radioisotopes, nuclear institutions, including the first of them, the Atomic Energy Commission (AEC), financed the development of such applications. The decisions and actions undertaken in the USA were generally used as the basis for what was tried in Europe. The American policy of the production, distribution and application of radioisotopes formed much of the framework for their uses [6]. The adoption of this policy

5. Van Lente, Haron and Rip Arie. The rise of membrane technology. From rhetorics to social reality. Social Studies of Science. 1998; 28 (2): 221-254.
6. Krige, John. American hegemony and the postwar reconstruction of science in Europe. Cambridge MA: The MIT Press; 2006.

by European countries and later the International Atomic Energy Agency (IAEA), reinforced and amplified the biomedical practices associated to radioisotopes. The case of France is an interesting illustration of how this policy was taken up and readapted to the conditions of the country and its institutional stakes.

Financial investment and the collaborations involved finally managed to generate a social reality for the medical applications of radioisotopes. First, I would like to describe how this field of research and its applications materialized. In doing so, if it is heuristic to think of biomedicine as an ensemble that integrates both biological and clinical research, then in order to understand the range of practices and to evaluate what the applications of radioisotopes were, it is essential to make a distinction between biology and medicine. Indeed, radioisotopes proved to be an instrument of primary importance in investigations of living things and became a traditional tool for use in biomedical laboratories. I would like to show that in therapy, the situation was somewhat different. Their employment only became possible after nuclear institutions adopted a voluntarist policy that made them available at low cost, financed work for their applications and especially engaged in a policy of systematically replacing radium in the therapeutic niches, mainly cancer therapy, where these radioisotopes could be used. Secondly, I will argue that despite the major financial investment, the development of the uses of radioisotopes and their important impact on biology and clinical practices, the assessment of medical uses remained relatively limited. In consequence, the place of biomedicine in the public legitimization of financial investment and civilian uses of nuclear energy began to decline from the late 1950s.

2. From radium to radio-isotopes: The construction of an «atomic medicine»

At the beginning of the 1950s, fundamental and applied research into «atomic biology and medicine», financed by nuclear institutions, expanded rapidly. In medicine, the place of radioisotopes was built up around their internal and external use in diagnosis, on the one hand and, on the other, in therapy. In diagnosis, the first work was undertaken in the period before the war, and was centred on the functional exploration of organs, through the tracer method, which had been devised by Georg Von Hevesy in 1923 and gradually proved to be a powerful tool for the investigation of living metabolism [7]. The discovery of artificial radioactivity by Irene and Frederic Joliot in 1934 in Paris, followed by the production of radioisotopes with accelerators at Ernest Lawrence's laboratory in Berkeley widened the range of mobilizable radioisotopes in such investigations. This led to the development of studies of the diagnosis and treatment of thyroid metabolism and diseases [8]. Encouraged by this early success, their other work sought to widen the range of explored organs and to improve the techniques for doing so [9]. Along with the functional exploration of organs, a second matter was studied: that of medical imaging. In the early 1950s, the replacement of the Geiger-Müller counter with scintigraphy techniques, initiated by the American Ben Cassen, paved the way for the installation of a new instrumentation that made it possible to transform the radiation curves emitted by radioisotopes in the body into images. The development of a scintillations camera by Harold Anger at the UCLA, an exploration apparatus, was a significant development [10], as it became the apparatus *par excellence* for nuclear medicine services.

Symbolically, it was in therapy that the promoters of nuclear energy sought to obtain results. The capacity of certain radioisotopes to be concentrated in human tissue gave hope for new therapeutic applications. Contrary to diagnosis, in which the use of radio-isotopes was seen as an

7. Kevles, Daniel; Geison, Gerald. The experimental life sciences in the twentieth century. Osiris. 1995; 10: 97–121, 233–241. Creager, Angela. The industrialization of radioisotopes by the U.S. Atomic Energy Commission. In: Grandin, Karl; Wormbs, Nina; Widmalm, Sven, eds. The science-industry nexus: History, policy, implications. Sagamore Beach. MA: Science History Publications; 2004, p. 143-167. Kohler, Robert; Schoenheimer, Rudolph. Isotopic tracers and Biochemistry in the 1930s. Historical Studies in Physical and Biological Sciences. 1977; 8: 257-298. Creager, Angela. Tracing the politics of changing postwar research practices: The export of «American» radioisotopes to European biologists. Studies in History and Philosophy of the Biological and Biomedical Sciences. 2002; 33C: 367-388.
8. Sawin, Clark; Becker, David. Radioiodine and the treatment of hyperthyroidism: the early history. Thyroid. 1997; 7: 163-176. On the French situation, see Fragu, Philippe. How the field of thyroid endocrinology developed in France after World War II. Bulletin of the History of Medicine. 2003; 77 (2): 393-414. On Spain see: Santesmases, María Jesús. Peace propaganda and biomedical experimentation: Influential uses of radioisotopes in Endocrinology and Molecular Genetics in Spain (1947–1971). Journal of the History of Biology. 2006; 39: 765-794.
9. Tubiana, Maurice. Les isotopes radioactifs en biologie et en médecine. Paris: Masson; 1950.
10. Blahd, William; Bauer, Franz; Cassen, Benedict. The practice of Nuclear Medicine. Springfield Ill: CC Thomas; 1958. Rheinberger, Hans-Jörg. Putting isotopes to work: Liquid scintillation counters, 1950-1970. In: Joerges, Bernward; Shinn, Terry, eds. Instrumentation: Between science, state and industry. Dordrecht: Kluwer Academic Publishers; 2001, p. 143-174.

innovation, radioelements were widely used in therapy [11]. At the turn of the 20th-century, the use of radium in medicine (such as in x-rays) led to expansion in the use of physical agents in medicine: electrotherapy, hydrotherapy and mechanotherapy, among others. The deployment of radium as a «therapeutic agent», and the extension of its uses from physics to medicine was anything but automatic; it was largely related to the activity of the manufacturers of radioactive elements [12]. To create a market for radium, these industrialists developed a plethora of actions intended for the medical world: the cost-free availability of radium sources, the financing of biological research laboratories and the marketing of the various apparatuses intended to facilitate its employment. Radium was therefore a non-specific therapeutic agent in the sense that it was used for a broad range of pathologies: in dermatology-syphiligraphy and gynaecology, as well as for certain nervous afflictions and rheumatology.

In the interwar period, centers specialized in the treatment of cancer were created in several countries. In these centers, besides surgery, there were major strides forward in one particular technique: radiotherapy. The term 'radiotherapy' was used from the First World War to indicate the ensemble of methods of radiation treatment. Radium was used in accordance with two techniques. The first, curietherapy (a denomination that replaced «radiumtherapy» in 1919) generally indicated therapy using radioactive elements that consisted of introducing radium tubes into natural cavities or bringing them into contact with lesions. The second method, telecurietherapy, was developed in the late 1920s due to the growth of the radium industry. An increasing quantity of radium, about a few grams, was placed in increasingly imposing apparatuses [13]. These

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11. Vincent, Bénédicte. Naissance et développement de la pratique thérapeutique du radium en France, 1901-1914 [PhD thesis]. Paris 7 University; 2002. Mould, Richard. A history of X-Rays and radium with a chapter on radiation units, 1895-1937. Surrey: IPC Building & Contracts Journals Ltd; 1980. Hayter, Charles. An element of hope: Radium and the response to cancer in Canada, 1900–1940. Montreal/Kingston: McGill-Queens University Press; 2005. On history of cancer in the US, see: Patterson, James T. The dread disease: Cancer and modern American culture. Cambridge MA: Harvard University Press; 1987. On France: Pinell, Patrice. Naissance d'un fléau: histoire de la lutte contre le cancer en France (1890-1940). Paris: Editions Métaillié; 1992.
12. Vincent, n. 11.
13. Cottenot, Paul; Laborde, Simone. Radiothérapie. Rayons X. Radium. Paris: Éditions Médicales Norbert Maloine; 1934. Bordry, Monique; Boudia, Soraya, eds. Les rayons de la vie, une histoire

apparatuses, sometimes called «radium bombs», were useful in external treatment of cancer with gamma rays of radium.

In the post-war period, when nuclear institutions were seeking to promote therapeutic research for radioisotopes, they «naturally» made the treatment of cancers their predilection. Angela Creager showed that, in its desire to promote the use of radioisotopes in therapy, from April 1948 onwards, the AEC decided to place radiosodium, radiophosphorus, and radioiodine at free disposal for use in cancer research, diagnosis, or therapy. This exemption from payment was extended to all radioisotopes at the beginning of 1949 [14]. This provision policy was reinforced by the construction of clinical cancer research hospitals at Argonne and Oak Ridge. However, as one of the promoters of radioisotopes pointed out in the 1950s: «Until now the most important use of radioisotopes has been to replace traditional means of radiotherapy» [15]. Indeed, the increasing mass of radioisotopes was only able to completely integrate into medicine when radium was replaced. After the installation of the medical division at Oak Ridge in spring 1949, researchers examined the most promising isotopes as potential externally administered radiation sources. Feasibility studies were undertaken in parallel in Canada by Jones and Smith and in the USA by Grimmet and Fletcher. Cobalt 60 was the first radioisotope to be promoted as a replacement for radium. In 1951, the radioisotope service at Chalk River in Canada manufactured, for experimental and clinical reasons, two sources of Cobalt 60 of 1,000 curies each, i.e. a hundred times more powerful than the sources of radium used before in telecurietherapy [16]. By increasing the power of the sources, the idea was to shorten treatment times. In August 1951, an item of telecobaltotherapy apparatus was installed in the hospital at the University of Saskatchewan in Saskatoon, and the second source was used in another system installed in the Victoria Hospital, London (Ontario). At Oak Ridge, the Medical Division also worked on the design of a piece of telecobaltotherapy apparatus in collaboration with the General

des applications médicales des rayons X et de la radioactivité en France. Paris: Institut Curie; 1998.

14. The program was modified in 1952, for radioisotopes used in the treatment, diagnosis, and study of cancer, users had to pay 20% of production costs. Creager, 2002, n. 7.
15. Veall, W. Quelques applications chimiques et thérapeutiques des isotopes radioactifs. Atomes. 1955; 108: 77-80 (80).
16. IAEA. Emploi en radiotéléthérapie des radioisotopes et des appareils à haute énergie. Situation actuelle et recommandations. Vienne: IAEA; 1960.

Electric Company, which was responsible for building the apparatus. In September 1953, the first system was installed at the M. D. Anderson Hospital, Houston (Texas). Another radioisotope was studied for its use in radiotherapy: Cesium 137 [17]. It was at Oak Ridge that the first Cesium 137 teletherapy apparatus was developed in January 1955 [18]. A second system of the same power was installed at the Royal Marsden Hospital, London in October 1956. Three years later, according to data collected by the IAEA, there were about 700 cobaltotherapy systems in 44 countries, including 264 in the USA, 40 in France and 33 in Great Britain [19].

The extension of the therapeutic uses of radioisotopes by the replacement of radium in teletherapy and curietherapy was impelled and supported by a voluntary policy which did not find its justification in better or new results but in the low cost of radioisotopes. Simone Laborde, one of the pioneers of curietherapy and telecurietherapy noted in 1953 in an article in *Science et Vie*, one of the most popular popularization magazines in France: «the use of Cobalt 60 does not offer new scientific interest and its use depends only on practical factors: its price being much lower than that of radium» [20]. Six years later, an expert group convened by the IAEA to assess radioteletherapy radioisotopes wrote in its report: «There can be no doubt that the fast development of telecobaltotherapy is explained mainly by its simplicity and its advantageous price» [21]. This low cost was brought about by the policy of nuclear power institutions. To promote their use, they took responsibility for a part of the expenses of their production and preparation. They promised to deliver them «without profit, at a price far from high, barely representing even the handling expenses» as Bertrand Goldschmidt, one of the promoters of this policy in France, put it [22]. This choice was initiated by the AEC which did not charge for the production

17. Amalric, Robert; Vigne, Jacques-Paul. Le Césium 137 en téléthérapie. Paris: Gauthier-Villars et Cie; 1962.
18. Brucer, Marshall. Special report of medical division on teletherapy design problems, I Cesium 137. Oak Ridge Institute of nuclear studies, Report TID 5086 (second revision); 1955. Brucer, Marshall. The industrial Atom-Teletherapy devices with radioactive isotopes. Technical information Service, report TID 8007; 1956. Comas, Frank; Brucer, Marshall. First impressions of therapy with Cesium 137. Radiology. 1957; 69: 231-235.
19. IAEA, n.16.
20. IAEA, n.16.
21. IAEA, n.16, p. 34.
22. Goldschmidt, Bertrand. L'aventure atomique- ses aspects politiques et techniques. Paris: Fayard; 1962.

expenses of their radioisotopes, but sold them at only 60% of their cost. The calculation of this figure is actually a difficult operation, insofar as it should include a share of the costs of the construction and maintenance of the reactors.

Due to this policy of radium replacement, the very cheap provision of radioisotopes and the financing of fundamental and therapeutic research, nuclear institutions succeeded in durably installing radioisotopes in therapy.

3. Biomedicine and radioisotopes in France

In France, just as in the United States, the leader in the production and distribution of radioisotopes was the organization in charge of nuclear programs, the *Commissariat à l'énergie atomique* (CEA). This institution, created by order on October 18, 1945, had the role of continuing «scientific and technical research for the use of industry and national defense» [23]. At its head was one of the great international figures of nuclear science, Frederic Joliot-Curie [24]. Winner of the Nobel Prize for Chemistry in 1935, along with his wife Irene Joliot-Curie, for the discovery of artificial radioactivity, Joliot was regarded to be the leader of a French scientific community anxious to give a new impetus to French nuclear research. He became involved in the construction of the CEA, surrounded by a close team out of which Lev Kowalski and Hans Halban emerged, who had worked in Canada during the Second World War, and Bertrand Goldschmidt, the only Frenchman to have been briefly admitted onto the Manhattan project. Their main project was the construction of an atomic pile. However, biological issues very quickly found a place in their concerns. Joliot had a very real interest in working in biology. From 1935 onwards, in financing research for the construction of a cyclotron at the College of France, where he managed a laboratory, radioisotope applications in biology and medicine were proposed. With Antoine Lacassagne at the chair of experimental radiobiology at the College of France, he carried out work from 1941 onwards on rabbit cancers caused

23. Weart, Spencer R. Scientists in power. Cambridge, Mass.: Harvard University Press; 1979. Hecht, Gabrielle. The radiance of France. nuclear power and national identity after World War II. Cambridge MA: MIT Press; 1998.
24. Pinault, Michel. Frédéric Joliot-Curie. Paris: Odile Jacob; 2000.

by the irradiation of neutrons [25]. Collaborations were also started up in the endocrinology laboratory that Robert Courrier directed [26]. In 1944, Joliot, Pierre Sue, a radiochemist and sub-manager of Joliot's laboratory, Courrier and one of his collaborators, Alain Horeau, carried out the first synthesis of a thyroxin hormone marked by radioactive iodine. When Joliot was working on the foundation and direction of the CEA, it was almost «natural» for him to ask, in late 1946, Lacassagne and Courrier to join the scientific committee of the CEA and deal with biomedical questions. One of this committee's concerns was the implementation of American requirements that accompanied the marketing of radioisotopes by the AEC. Joliot asked Lacassagne and Courrier to organize a biology and medicine service within the CEA, in charge of channelling doctors' requests and proposing a regulation project on the distribution of radioactive products. The policy of control, put in place by the AEC for the delivery of radioisotopes, far from representing a constraint for the CEA, was to be used as a springboard to assert its own control on the circulation and uses of radioisotopes in France.

The CEA and Joliot's laboratories were not the only places where interest in radioisotopes was being shown. Somewhere else would go on to occupy an increasing amount of space in the landscape of the use of radiation in biology and medicine. This was the National Institute of Hygiene (INH). This Institute was created by initiative of the Vichy government with the support of the Rockefeller Foundation, by a law of November 30, 1941. Louis Bugnard was put in charge of it in 1946. Trained as an engineer and a physician at the same time, he was a specialist in radiotherapy and a professor of medical physics at the University of Toulouse. As Gaudillière showed, Bugnard played an active role in the movement of the «modernization of health» in France, the use of radioisotopes being then one of the most important components of this project. Bugnard's sustained interest in radioisotopes was born out of a four-month trip he took to the United States from 1945-1946 [27]. At the head of the INH, he set up a grant-system to train young doctors in research with radioisotopes, by sending them to the United States. He also obtained funds for the acquisition of radioisotopes, in particular at the

25. Chamak, Brigitte. Un scientifique pendant l'occupation: le cas d'Antoine Lacassagne. Revue d'Histoire des Sciences. 2004; 57: 101-133.
26. Fragu, Philippe. How the field of thyroid endocrinology developed in France after World War II. Bulletin of the History of Medicine. 2003; 77 (2): 393-414.
27. Gaudillière, n. 3.

Natural Sciences Division of the Rockefeller Foundation. At Rockefeller, he did not hesitate to point out the fact that in France a monopoly on radioisotopes was being exerted by Joliot, Lacassagne and Courrier [28].

The end of 1948 saw the first step in the French nuclear program: the setting up of a pile called Zoe that was intended for the study of chain reactions, neutron physics and the production of radioisotopes. From 1949 onwards, the CEA started to provide radioisotopes intended for public use. So, a double policy was coming into play: on the one hand national control of an administrative nature and on the other hand a promotion of the use of radioisotopes by financing research into their uses. In 1949, a decree established an inter-ministerial commission on the purchase of artificial radioelements abroad, the principal concern being the verification of the conditions imposed by the United States for the export of its radioisotopes. Requests emanating from people or institutions in France were subject to approval either from the Ministry of Health via the INH if they were intended for research into human biology or medicine, or from the Ministry of National Education (CNRS), for radioisotopes intended for research into physics, chemistry, and animal and vegetable biology. The representatives of the CEA were the only ones to rule on all requests, whatever their origin.

The use of radioisotopes was thus managed jointly by the CEA, the INH and CNRS throughout the 1950s. After Joliot-Curie's revocation from the CEA in 1950 because of his communist links, the institution saw important changes with the progressive arrival of new figures. Concerning biology and medicine, Lacassagne, whose stance against atomic testing was public knowledge, did not have his membership of the scientific committee renewed. From 1951 onwards, Bugnard, named as a member of this committee, saw the influence of his group widen with the arrival of young people trained in particular in the USA. From 1953 onwards, the French field of radioisotopes saw several changes. Up until this date, the CEA's orientation had been primarily scientific; in 1952 a decision was made for the French nuclear program to be industrialized and militarized. This same year, a second reactor, more powerful than Zoe, came into operation, bringing about an

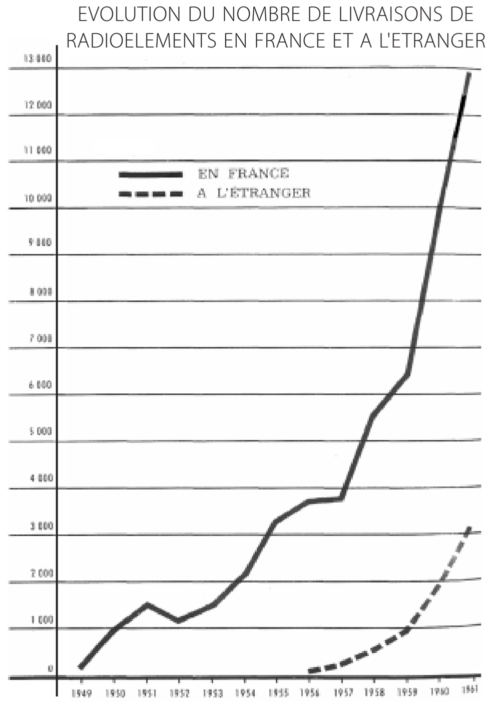
28. Gaudillière, Jean-Paul. Normal pathways: Controlling Isotopes and building biomedical research in postwar France. Journal of the History of Biology. 2006; 39: 737-764. Kraft, Alison. Between medicine and industry: Medical Physics and the rise of the radioisotope 1945-65. Contemporary British History. 2006; 20: 1-35.

increase in the quantities of radioisotopes available. In parallel, more explicit provisions were adopted on the circulation and use of these radioisotopes. A new inter-ministerial commission, replacing the preceding one, was from now on in charge of formulating opinions and proposals on all questions of a general nature that were raised by the development and application of regulations relating to radioelements [29]. It brought together representatives of different ministries: Bugnard at the IHN, one representative from the CNRS and two from the CEA. Bertrand Goldschmidt, the CEA's director of international relations, was the vice-president and Charles Fisher, in charge of the CEA's Department of Radioisotopes, was the secretary of the committee. So the CEA played a determining role. Moreover, it was the only organization that did not face checks on the import and export of radioisotopes. Along with the control policy, the use of radioisotopes was promoted. A twice-yearly course was set up in 1950 by the CEA, the INH and CNRS. In addition to this, subsidies, initially from the INH, the CNRS and the National Social Security Office were granted to several laboratories and hospital services in order to acquire the necessary material for the use of radioisotopes [30].

Biology and medicine's place was nevertheless still limited within the CEA. It was only in 1953 that a biology department was set up. Two objectives presided over the installation and structuring of this department: the use of radioisotopes and the study of the biological effects of radiation [31]. A young «protégé» of Bugnard's, Jean Coursaget, was named head of department. The CEA also created an «advisory commission on biological research» whose purpose was to help it to define its policy. Several important specialists of institutional importance in the fields of biology and medicine in association with radiation were invited. Its presidency was entrusted to Courrier, who had also become the permanent secretary of the Academy of Sciences, and the vice-president was Bugnard, the directed the INH and the «experimental medicine» section of the CNRS. The director of the Institute Pasteur,

29. Bugnard, Louis; Vergne, Jacques. Réglementation de l'utilisation des radio-isotopes en France. August 1955. Archives of CEA. Fontenay aux Roses. CEA Report n°438. Technical reports.
30. Coursaget, Jean. Utilisation des radioéléments en France dans le domaine de la médecine et de la biologie. Saclay: Centre d'études nucléaires, Service de documentation; 1955. For a study of one French radioisotopes site, see the study of Gaudillière on The Hospital Necker, Gaudillière, n. 28.
31. Commissariat à l'énergie Atomique. Programme 1954 – biologie. Archives of CEA. Fontenay aux Roses. F4.20.22.

Graph. 1. Isotopes deliveries in France (1949-1961)



Source: Reproduced from Commissariat à l'énergie Atomique. Rapports. 1961. Archives of CEA. Fontenay aux Roses.

Jacques Tréfouël, and the person in charge of research in the Army's health service were also members. This commission met several times a year and its principal activity was to choose which of the research projects on and with radioisotopes that had been suggested by French laboratories should be financed by the CEA [32]. This production and promotion led to an increase in the number of radioisotope consumers in France. There were 6 in 1949, 33 in 1950, 45 in 1951, 49 in 1952, 59 in 1953, 104 in 1954 [33],

32. Lacassagne Papers, Fonds. Relations avec des organismes de recherche nationaux. Archives of Pasteur Institut. Paris. CEA LAC. Org.1-12, Org6.
33. Fisher, Charles. Statistiques sur la production et l'emploi des radio-éléments artificiels en France. Paris: Commissariat à l'énergie Atomique; 1955.

981 in 1960 and 1,171 in 1961[34]. If, in the first years, radioisotopes had initially been partly imported, primarily from Great Britain, by 1960, the CEA was able to satisfy 90% of the French requirements for radioisotopes and exported 30% of its production[35]. Just as in the American case, biologists and doctors represented a significant number of consumers, using 2/3 of the quantity of radioisotopes produced by CEA reactors[36]. However, this extension should not disguise the fact that throughout the 1950s and 1960s, biology and medicine remained marginal spheres of activity within nuclear institutions, the construction of reactors and nuclear plants being the true heart of their activity.

French production is clearly lower than American production. Between 1946 and 1955, the AEC made 64,000 shipments of radioactive materials available to laboratories, industries and clinics[37].

4. Biomedicine and the construction of the social acceptability of nuclear energy

The policy of the promotion of peaceful nuclear energy applications quickly expanded with the launch of the American operation *Atoms for Peace*[38]. Several biologists and physicians working with nuclear organizations resumed, through conviction or for strategic reasons, the mission that President Eisenhower, in his famous speech, had assigned to them at the United Nations: to apply atomic energy to the needs of agriculture, medicine, and other peaceful activities. The result was the creation or development of departments of biology within nuclear institutions, the financing of whole sectors of biological and medical research, as well as the installation of clinical structures using radioisotopes.

However, despite much effort, the assessment of medical uses remained relatively limited in comparison to the promises, expectations and investments

34. Commissariat à l'énergie Atomique. Rapports. 1961. Archives of CEA. Fontenay aux Roses.
35. CEA Commissariat à l'énergie atomique. Paris: Département des relations extérieures du C.E.A; 1960.
36. In the US, ¾ of radioisotope production was used in biomedicine. Creager, 2004, n. 7.
37. CEA, n. 34.
38. Weart, Spencer. Nuclear fear: a history of images. Cambridge MA., London: Harvard University Press; 1988. Hewlett, Richard G.; Holl, Jack M. Atoms for peace and war, 1953-1961: Eisenhower and the Atomic Energy Commission. Berkeley: University of California Press; 1989.

made. From the very start of the 1950s, Maurice Tubiana, a key French actor in the biology and medicine of radioisotopes declared that: «concerning the immense services rendered by artificial radioelements in physiological and metabolic studies, their clinical applications, in the functional and diagnostic exploration of the patient, seem relatively poor» [39]. A few years later, Lacassagne, one of the international specialists in the treatment of cancers made a similar report: «at present, the results for the use of nuclear energy in the therapy of cancers are still of little importance» [40]. In its report at the Geneva conference on the peaceful applications of nuclear energy in 1955, one of the most important French popularization journals, *Atomes*, estimated that «in biology and medicine few new results or treatments have been announced» [41]. At the third Geneva conference, a group of experts from the IAEA and the World Health Organization (WHO) reported that in ten years, the projections in the uses of radioisotopes in diagnosis and therapy suggested an increase in the power of the sources of cobalt, a simplification and standardization of the techniques, increased reliability of isotopically labelled materials and counting equipment, and the subjection of a wider variety of organs and conditions to scrutiny by isotopic methods. The conclusion was that «further refinement of applications without the development of startlingly new ones» was required [42]. From the start of the 1960s, certain leaders of nuclear programs made a lucid assessment of the medical applications of radioisotopes: «the great hopes that had become quickly widespread in the public on the therapeutic use of radioisotopes for cancer have been partly disappointed» [43].

The limits of the therapeutic prospects for radioisotopes were seldom publicly discussed but several signs indicated the possibility of subtle changes. In the mid 1950s, the AEC commission's budget for biomedical research was about 25 million a year. 37% of this was spent on research into the effects of radiation, mainly to understand risks of radiation, while the «beneficial

39. Tubiana, n. 9, p. 237.
40. Lacassagne, Antoine. L'emploi des radioéléments en médecine. Industries atomiques. 1956; 2: 3-5.
41. La conférence internationale sur l'utilisation de l'énergie atomique à des fins pacifiques. Atomes. 1955; 115: 327-328 (328).
42. Belcher, E. H. et al. Advanced in the use of isotopes and radiation sources in medicine. Proceedings of the 3rd International Conference on the peaceful uses of atomic energy. United Nations, vol. 15; 1965, p. 275-284 (278).
43. Goldschmidt, n. 22, p. 231.

effects of radiation» accounted for 34%, and 21% was devoted to studies of industrial health and safety [44]. These figures indicated that studies of the biological effects of radiation —hazards and protection— outdid those on the biological and therapeutic applications of radioisotopes. This change was due to the development of public controversy surrounding the effects of fallout. From the early 1950s, with the nuclear arms race and the multiplication of atomic tests in the atmosphere, an intermingling of scientific and social controversies developed on the consequences of radiation [45]. Apart from the threat of nuclear destruction, which worried many people during the Cold War years, a series of other problems arose: the direct and indirect effects of radiation, potential contamination of the soil and water and its consequences on animals and plants, and therefore food, or the genetic effects of radiation and climate change.

The debates on the effects of radioactive fallout were initially limited to specialist circles, but took on an increasingly more important public role after the accidental contamination of Japanese fishermen by an American test in 1954 [46]. Genetic effects —changes induced by radiation and its consequences— emerged as one of the central subjects of these controversies. They particularly caught the attention of the various protagonists because they had both an immediate effect, and also an effect that would last for several generations. Because of this, there was an irreversible deterioration

44. Hewlett; Holl, n. 38.
45. Boyer, Paul. By the bomb's early light: American thought and culture at the dawn of the atomic age. Chapel Hill: The University of North Carolina Press; 1994. Hacker, Barton. Elements of controversy: the Atomic Energy Commission and radiation safety in nuclear weapons testing, 1947-1974. Berkeley: University of California Press; 1994. On the history of public mobilization against the nuclear bomb, see: Wittner, Lawrence. The struggle against the bomb. One world or none: A history of the world nuclear disarmament movement through 1953. Stanford: Stanford University Press; 1993. Wittner, Lawrence. The struggle against the bomb. Resisting the Bomb: a History of the World Nuclear Disarmament Movement, 1954-1970. Stanford: Stanford University Pres; 1997. Kopp, Carolyn. The origins of the American scientific debate over fallout hazards. Social Studies of Science. 1979; 9 (4): 403-422.
46. On March 1, 1954, the displacement of the radioactive cloud generated by an H-bomb test, 700 times more powerful than that of Hiroshima, led to the contamination of several thousand square kilometers of territory, and effected several Japanese fishermen who were 160 km from the testing ground, i.e. outside the safety-zone. The event led to strong reactions and clearly showed that despite the words of the promoters of atomic tests, they were far from controlling all parameters. The position of the AEC played a major role in the amplification and promotion of such controversies. While seeking to minimize, indeed even to deny the dangers incurred, the AEC pushed a certain number of American scientists to publicly voice their dissention.

of human-beings, which drove people's imaginations towards images of the decay of the species and the potential for the production of monsters. The risk of radiation cancers was also a broad subject of research and debate. Attention was particularly focused on leukaemia caused by dissemination into the environment of radioisotopes resulting from nuclear explosions, in particular Strontium 90 and Cesium 137. In these controversies, radiation specialists played a slightly ambivalent role. In many cases, they were the very cause of these controversies, which they expressed publicly, in turn giving voice to concerns or latent distrust in other areas. These same specialists, or at least some of them, were also those to whom the decision-makers turned to for help to put an end to the controversies. Between 1955 and 1958, following the development of various controversies, there was a «flowering» of committees of national and international experts that were all working in inter-connection. The same governments that had performed the most tests in the atmosphere were those that contributed to the creation of commissions whose role was to gauge the degree of danger and to seek the means to remedy it. Expertise and regulation activity also developed on an international scale with several expert committees being set up to study the effects of radiation and work out standards to ensure that it was used safely. Specialist physicians in medical physics or radiation were largely present in commissions, such as those established by the World Health Organization and the United Nations (UN) or in national frameworks such as the committee of the American Academy of Sciences and the committee of the Medical Research Council (MRC) [47].

Public controversies on fallout opened windows of opportunity for certain groups of researchers who, seizing on the question of the study of the effects of radioactivity and the mechanisms of contamination, were able to drain finances. Whole fields of research, whose objects of study were the mechanisms of health and environment contamination by radioactivity experienced unprecedented development, such as the cases of radiobiology looking into the mechanisms of the biological effects of radiation, or genetic studies that were closely related to the question of the effects of radiation. On the environmental level, the first major studies of the impact of pollutants on the environment and the consequences

47. Boudia, Soraya. Global regulation: Controlling and accepting radioactivity risks. History and Technology. 2007; 23 (4): 389-406.

on human health were produced[48]. Because it was possible to follow radioactivity through the atmosphere, the oceans, the soil and food chains, radioisotopes resulting from exploded bombs were the first pollutants to be taken into account on a global scale. Fields of research that are indirectly related to the study of nuclear risks, such as oceanography[49], climatology or Earth sciences[50] benefited from this movement and in particular from the finances it generated.

5. Conclusion

The making of the «atomic-biomedical complex» was the result of a convergence of interests involving several stakes, and was a highly successful policy. For a part of the community of biologists and physicians, it made it possible for them to find a place in the nuclear complex and to be given important resources to develop their activity. For nuclear institutions, it offered a market for the use of the radioisotopes that were mass-produced by reactors and a justification of the social utility of the colossal investments in the building of nuclear technologies. In a way, biomedicine's place and effective contribution was, above all, political. «Political» should be understood to have different meanings: the demilitarization of the image of the atom, the construction of the neutrality of technologies, or a response to the controversies surrounding the effects of radioactive fallout. With these different contributions, biomedicine played a role in the installation of nuclear technologies. This installation was an irreversible reality due to the extent of the investment and the collaboration networks, as well

48. Beatty, John. Ecology and evolutionary biology in the war and postwar years: Questions and comments. Journal of the History of Biology. 1988; 21: 245-263. Bruno, Laura A. The bequest of the nuclear battlefield: Science, nature, and the atom during the first decade of the Cold War. Historical Studies in the Physical and Biological Sciences. 2003; 33 (2): 237-260.
49. Rainger, Ronald. A wonderful oceanographic tool: The atomic bomb, radioactivity and the development of American oceanography. In: Rozwadowski, Helen M.; Van Keuren, David K., eds. The machine in Neptune's garden: Historical perspectives on technology and the marine environment. Sagamore Beach: Science History Publications; 2004, p. 93–131. Hamblin, Jacob Darwin. Oceanographers and the Cold War: Disciples of marine science. Seattle: University of Washington Press; 2005.
50. Doel, Ronald E. Constituting the postwar earth sciences: The military's influence on the environmental sciences in the USA after 1945. Social Studies of Science. 2003; 33 (5): 635-666.

as the construction of its social acceptability, which made it possible for atomic energy not only to be «a scientific novelty but a economic world reality» [51]. Stressing the political contribution of biomedicine does not mean denying that effective and important scientific results occurred. Research and clinical practices in biomedicine were deeply affected and changed by nuclear energy and the major investments that were made helped improve the diagnosis and therapy of cancers.

From the early 1960s, because of the weakness of innovation, biomedicine's place in the public legitimization of nuclear technologies began to decline. The argument of energy production that had been developing since 1945 became, along with nuclear power, the dominant argument for the following decades, reinforced by the oil crisis of the early 1970s. This movement to renew the social and political justifications of nuclear power has since continued with, for example, of the contemporary concerns regarding the Greenhouse Effect. This reminds us that although nuclear technologies have become a massive reality, they are nonetheless just as consistently questioned.

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51. Eklund, Sigvard. Preface. In: Proceedings of the 3rd international conference on the peaceful uses of atomic energy. Vol. 1, Geneva: United Nations; 1965, p. VI-VII (VI).