• *ABSTRACT*

Studies of the creation of networks in science have rarely focused on the role of research materials in establishing relations between actors. This paper considers the question of how scientists' changing needs for research materials in the study of sex hormones, which emerged as a new field of the life sciences at the turn of the century, shaped both the character of the relations between the actors in endocrinological research, and the strategic position of each actor. The accessibility of research materials not only shaped the social organization, but also affected the cognitive development, of sex endocrinology. In this process, gender bias in science was reinforced and metamorphosed.

On the Making of Sex Hormones: Research Materials and the Production of Knowledge

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In the last decade, the study of laboratory practices has emerged as a new line of enquiry in social studies of science. To understand the construction of the laboratory, Latour suggests that laboratory scientists should be studied in their daily practices. According to Latour, laboratories are characterized by the activities of laboratory scientists who create networks with other actors, both human and non-human, in order to improve and maintain the position of the laboratory as the very centre of authority.[1] However, Latour does not specify the role of non-human resources (for example, research materials) in the building of networks. The role of research materials in the production of knowledge has recently been studied by Clarke. In her analysis of the impact of research materials on the social organization of research in the reproductive sciences, Clarke described how, in the life sciences at the turn of the century, the shift from descriptive morphological approaches to experimental physiological approaches radically altered scientists' needs for research materials. The new experimental approaches entailed drastically different means of gaining access to research materials, and

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had a crucial impact on the infrastructure of the reproductive sciences. Clarke has described the emergence of the formal and informal networks reproductive scientists created in order to obtain the required research materials.[2] However, Clarke's analysis did not take into account the role of the clinic and the pharmaceutical industry, both major actors in the life sciences.

This paper seeks to evaluate the role of research materials in structuring the relationships between the laboratory, the clinic and the pharmaceutical industry. It focuses on the study of sex hormones, which emerged as a new field in the life sciences at the turn of the century. How did the scientists' changing needs for research materials affect the relationships between the actors involved in the emerging field of sex endocrinology? To answer this question I will follow the actors in their efforts to gain access to the required research materials. I will describe how laboratory scientists had to create networks with both gynaecologists and the pharmaceutical industry to satisfy that need. The accessibility of research materials affected both the character of the relationships between the actors, and the strategic position of each actor involved in these networks.

Furthermore, I will analyze how access to research materials affected cognitive developments in the emerging field of sex endocrinology. These materials were not merely a resource, but functioned as carriers of knowledge claims. I will describe how gender bias in science was reinforced and metamorphosed in this process.[3]

Under the Spell of the Glands

The study of hormones emerged as an important field of research in the life sciences at the turn of the century. Since the 1890s, physicians had suggested that the 'internal secretions' of certain organs were crucial to an understanding of physical processes in the human body. At the beginning of the twentieth century, British physiologist Ernest H. Starling reformulated this theory of internal secretions with the introduction of the concept of hormones: 'these chemical messengers or "hormones" as we may call them, have to be carried from the organ where they are produced to the organ which they affect, by means of the blood'.[4] The most conspicuous actor advocating the doctrine of the glands was French physiologist Charles-Edouard Brown-Séquard, who drew attention to the role of the sex glands. In 1889 he announced to his colleagues in Paris that preparations made of testes (the male sex glands) could promote eternal youth and sexual activity in men. Brown-Séquard also reported the practice of a medical woman in Paris who had injected women with the filtered juice of guinea-pigs' ovaries (the female sex glands) in treatment of various uterine affections and hysteria. Brown-Séquard's advocacy gave rise to a widespread interest in the 1890s in what was called 'organotherapy': the use of extracts of animal organs as therapeutic agents.[5] The very idea that animal organs contained potent substances regulating all kinds of physical processes created an atmosphere full of expectations and excitement: 'It's all in the glands'.[6]

The concept of the glands as organs that secreted potent substances regulating physical processes indicated a new line of research. In the nineteenth century, physiologists had assumed that all responses in the body were regulated by nervous stimuli. Many physiological responses, however, could not be explained adequately in terms of the model of nervous pathways. The concept of chemical substances secreted by the glands and transported by the blood provided scientists with a new model of explanation, and triggered a new experimental approach in laboratory science. At the turn of the century, scientists began to search actively for the chemical substances in the sex glands, using the techniques of castration and transplantation.[7] In this surgical approach, scientists removed ovaries and testes from animals like rabbits and guinea-pigs, cut them into fragments and reimplanted these into the same individuals at locations other than the normal positions in the body. With these experiments, scientists tested the concept of hormones as agents having control over physical processes without the mediation of nervous tissue. In transplantation, the nervous tissue of the glands was dissected, so the effects of the reimplanted glands on the development of the organism had to take place through another medium – for instance, the blood. Following advances in organic chemistry in the late 1910s, the surgical approach of transplanting gonads was replaced by chemical extraction of the gonads. These extracts were subsequently injected into castrated animals in order to investigate their function.

The chemical substances believed to originate in the sex glands were designated sex hormones: the male sex hormone secreted by the testes, the female sex hormone secreted by the ovaries.[8] This terminology constructed a sexual duality: sex hormones were conceptualized as the chemical agents of masculinity and femininity, thus emphasizing the ancient folk-wisdom that femininity and masculinity resided in the gonads.[9] Although, in the 1920s and 1930s, scientists had to reconsider the conceptualization of sex hormones as strictly sexually specific both in origin and function, the terminology was never revised. Since the

1920s, the names 'male' and 'female' sex hormones have continued in use, both inside and outside the scientific community.[10]

The assumption that sex hormones were the agents of masculinity and femininity functioned as a paradigm. Previously scattered research was focused around a generally accepted theory, 'opening new lines of research into sexual differentiation, menstruation, and fertility'.[11]

The emerging field of the study of sex hormones attracted different groups of actors to the scene. Surprisingly, gynaecologists, and not the laboratory scientists, were the first to recognize the relevance of the theory of internal secretions to the sex glands. Gynaecologists were already familiar with the changes in the body that followed the removal of ovaries, and directed their research to the chemical messengers of the ovaries: the female sex hormones. As early as 1896 and 1900, two Viennese gynaecologists, Emil Knauer and Josef Halban, described the secretion of chemical substances by the ovaries.[12] Gynaecologists came under the spell of the glands because of their therapeutic promises. The concept of female sex hormones promised a better understanding of, and therefore greater medical control over, the complex of disorders in their female patients frequently associated with the ovaries, such as disturbances in menstruation and various nervous diseases. Moreover, by linking female disorders to female sex hormones, 'women's problems' remained inside the domain of the gynaecologists.[13]

Although no one yet knew what the physiological effects of injections of extracts of the testes and ovaries might be, there already existed a widespread paramedical practice in gonadal preparations at the turn of the century. Pills and powders prepared by midwives and practitioners from dried ovaries and testes were used against a wide variety of diseases. Women were treated with ovary preparations for all sorts of disorders, physical as well as mental, ascribed to malfunction of the ovaries. Elderly men were treated with testicular preparations to recover declining sexual and mental abilities. This popularity of testicular and ovarian preparations attracted a second actor to the stage: the pharmaceutical industry. Following the paramedical practice, the pharmaceutical companies also came under the spell of the glands. The manufacturing of extracts from animal organs offered a new and promising line of production. Pharmaceutical companies started producing ovarian and testicular preparations, with some success. At the turn of the century, the advertising pages of medical journals were full of recommendations for the prescription of these preparations under a wide variety of trade names, indicating a flourishing trade in 'biologicals'.[14]

Besides the gynaecologists and the pharmaceutical industry, laboratory scientists, in this period mainly physiologists, also gradually came under the spell of the glands.[15] After the turn of the century, the laboratory of Edward Schäfer, professor of physiology at University College London, took up the study of the ovaries.[16] The physiologists were particularly interested in the study of the glands because the concept of hormones provided a new model for understanding the physiology of the body. In the first decade of this century, physiologists included the study of the ovaries and testes as a branch of general biology.[17] By this move, the traditional borders between two different groups of actors – the physiologists and the gynaecologists – changed dramatically. Before the turn of the century, the study of ovaries, particularly in relation to female disorders, had been the exclusive field of gynaecologists. With the introduction of the concept of sex hormones, laboratory scientists explicitly linked female disorders with laboratory practice, thus entering a domain that had traditionally been the reserve of gynaecologists. Whereas gynaecologists were particularly interested in the function of the ovaries to control all kind of disorders ascribed to ovarian malfunction, physiologists had a broader interest in the role of ovaries and testes in the development of the body.

Summarizing the situation at the beginning of this century, we can conclude that three groups of actors were interested and actively involved in research into the sex glands: the gynaecologists, the pharmaceutical industry and the laboratory scientists. It is also clear that the accessibility of research materials did not yet interfere with the relationship between these actors. Although interested in the same subject, the actors could operate quite independently from one another. In this period each actor had the techniques, as well as the research materials, required for research on sex glands at his or her disposal.

The techniques and research materials of the gynaecologists were provided in their clinical practice. Gynaecologists were already familiar with the surgical technique of castration, and the research materials could be obtained from their own patients. Since the 1870s, surgical operations for the removal of human ovaries had become common practice in gynaecology, and consequently gynaecologists had the necessary skills and easy access to the research materials required for their experiments.[18] Later, the placenta and animal ovaries were also used as research materials.[19]

The physiologists were able to perform their experiments in continuation of their tradition of laboratory practice, applying techniques and materials that came into general use in the last decades of the century. Of particular importance was the introduction of laboratory animals like guinea-pigs and rabbits, and somewhat later, mice and rats, which became the major subjects in their experiments to study the role of the ovaries and testes.

The third actor in the emerging field of sex hormones found it somewhat more difficult to gain access to research materials.[20] The pharmaceutical industry had no tradition or practice to lean on, so it had to make other arrangements. To obtain the material they needed for the production of testicular and ovarian preparations, pharmaceutical companies entered into contracts with local slaughterhouses to guarantee a steady supply of animal glands – organic matter that was not used for the production of food.

In this early period, the activities of the three groups involved in research on sex hormones did not yet interfere with one another. Every individual in these groups interested in the subject of sex hormones could enter the field and perform experiments without assistance or interference from the other actors.

Capturing Each Others' Interest

Although the actors involved in research on sex hormones focused on the same research object, their daily practices were not linked to one another. In spite of this relative independence, the relationships between the actors were not unproblematic. In fact, disputes arose among them, both between the gynaecologists and the pharmaceutical companies and between the physiologists and the gynaecologists.

In the 1910s, gynaecologists began to criticize the pharmaceutical industry for the production of ovarian preparations. Although there appeared many enthusiastic reports on the therapeutic effects of ovarian preparations in menstrual disorders, gynaecologists became sceptical about the quality of the commercial products. In clinical trials, gynaecologists compared the commercial preparations with their own extracts, and observed negative results for the former. Gynaecologists claimed that the powders and pills available in the drug trade did not contain the active substance from the ovaries. In addition to clinical trials, gynaecologists had developed a physiological test to evaluate the activity of ovarian preparations by measuring the growth of the uterus in experimental animals.[21] The criticism of gynaecologists was part of a growing professional concern about the quality of all types of drugs. In the 1910s, drug regulation gradually became institutionalized. In the US, the Congress had passed the Biologics Control Act (1902) and the Pure Food and Drug Act (1906). In 1905, the American Medical

Association established the Council on Pharmacy and Chemistry to set standards for drugs. In the Netherlands, the authorities installed the Governmental Institute for Pharmaco-Therapeutical Research (1920) in order to gain control over the quality of commercial pharmaceutical products. Following these drug regulations, the pharmaceutical industry laboured under more rigid constraints about the claims they could make.[22]

The critical approach of gynaecologists towards the pharmaceutical companies challenged them to improve the quality of their products.[23] The implicit message in this criticism was: if you want to make better products, you have to consult the gynaecologists; only the gynaecologists have the knowledge required to make effective preparations. Although gynaecologists succeeded in drawing the interest of the pharmaceutical companies to fundamental research on sex hormones, they subsequently could not prove their claim to be the real experts on this subject.

In the dispute over the quality of commercial preparations, the third actor began to criticize the expertise of gynaecologists. Laboratory scientists and gynaecologists could not agree about what would constitute sufficient evidence to demonstrate that extracts of ovaries and testes contained an active ingredient. The laboratory scientists criticized the gynaecologists for testing ovarian preparations in the clinic before their physiological and pharmacological effects were known. They argued that extracts should not be evaluated merely in terms of their therapeutic value, but should also be assessed with physiological tests.[24] The dispute over the appropriate methods of assaying sex hormones was part of a more general struggle between scientists and clinicians, which can be seen to characterize this period in medical history. The early decades of this century were characterized by a growing professionalization of the sciences, a process in which laboratory scientists presented themselves as the dominant profession among those, including clinicians, concerned with natural phenomena. By emphasizing the superiority of physiological methods over therapeutic test methods, laboratory scientists transferrred the study of sex hormones from the domain of the clinic to the laboratory, thus defining the demarcation lines of their own profession. Physiologists began to develop biological assay systems for the evaluation of the active substances in ovarian and testicular preparations. In this quest, laboratory scientists used a great variety of physiological methods.[25]

Through this strategy, the laboratory scientists succeeded in developing a basis for their claim to provide the knowledge needed so badly by the pharmaceutical industry. In 1923, American laboratory scientists introduced a test that in their opinion was much better for the evaluation of ovarian preparations than the tests used by the gynaecologists. Using histological techniques (developed by the American histologists Stockard and Papanicolou in 1917) to detect changes in the reproductive tract of the organism during the oestrus cycle, Edward Doisy, a professor of biochemistry at the Medical School of the University of St Louis, and Edgar Allen, a professor in anatomy at the School of Medicine at Yale University, had developed a new test method for the evaluation of ovarian preparations: the monitoring of changes in the epithelial cells in the vaginas of mice and rats. These histological changes could be easily detected with the vaginal smear method. Now scientists could infer what was happening in the body without surgery, simply by microscopic examination of vaginal smears. At the first International Conference of Standardization of Sex Hormones in 1932 in London, laboratory scientists decided to accept the 'Allen and Doisy test' as the standard test in research on female sex hormones.[26]

With the development of this test, laboratory scientists were in a position to provide the other actors with the techniques required to improve the quality of hormonal preparations. In the 1920s, both gynaecologists and the pharmaceutical companies began to apply this test in their research. The introduction of the standard test stimulated research on female sex hormones enormously. Thus, the problem of finding a standard test for research on female sex hormones was solved by the physiologists, and not by the pioneers in the field, the gynaecologists.

Summarizing again these developments in the emerging field of research on sex hormones in early decades of the century, we can conclude that the three groups of actors succeeded in capturing each other's interest. The gynaecologists succeeded – by their scepticism over the quality of commercial products – in drawing the interest of the pharmaceutical companies to assay techniques to control the quality of their products. The laboratory scientists succeeded – by criticizing the gynaecologists and introducing new techniques – in claiming the position of being the real experts in the field, a position previously held by the gynaecologists. And the pharmaceutical companies succeeded in capturing the interests of both gynaecologists and laboratory scientists with the promise of improving the quality of their hormone products. In this period, alliances between the laboratory scientists and the pharmaceutical companies began to emerge.

Although, in the years 1910–20, the three actors became more closely linked to one another than in previous years, they could still work relatively independently. This situation changed dramatically during the

1920s. In the quest to prepare gonadal preparations that could stand the test of the laboratory scientists, research was extended over a larger scale. At this point in the history of research into sex hormones, access to research materials became the pivot around which everything turned.

Gaining Access to Research Materials

By the 1920s, scientists were confronted with a specific handicap – namely, the problem of how to obtain adequate quantities of the research materials required for the preparation of gonadal extracts. Previous research had been focused on the biological function of gonadal extracts. Relatively small amounts of raw material were required for these experiments. One kilogram of testes was sufficient to study the effects of gonadal extracts in the organism. In the early 1920s, the central focus in research shifted from biological function to chemical isolation and identification of sex hormones.[27] However, the active substances scientists were seeking so desperately happened to occur only in small amounts in masses of inert matter.[28] To obtain purer extracts, scientists had to use tons of gonads. A few cattle in a stable near the laboratory, adequate to meet the need for materials in the preceding period, were no longer sufficient.[29]

The limited availability of research materials constrained research enormously. Scientific publications from this period are filled with complaints about their scarcity. Scientists had to spend much time looking for large supplies of gonadal material. To understand how the three actors gradually became more and more dependent on one another, we can simply trace how they succeeded in meeting this new need.

Some scientists were very creative in finding a solution to this problem. Alan Parkes, physiologist at the National Institute for Medical Research in London, described how – thanks to the intervention of the British Museum – he was able to obtain ovaries from the southern blue whale. This enormous creature, weighing up to 70 tons, has correspondingly large ovaries: 'a splendid opportunity of obtaining gonadal tissue in bulk'. Unfortunately, a great deal of the precious material was lost because of bad preservation.[30] Because whales do not habitually swim near laboratories in the western world, this source was not a structural solution to the problem of scarcity. To gain access to the enormous quantities of required material, scientists had to create new infrastructural arrangements to secure a large and steady supply of organic material.

The most likely places where large quantities of ovaries and testes could be obtained were the slaughterhouses.[31] However, this supply was not equally accessible to all the actors involved in research on sex hormones. As we have seen, the pharmaceutical companies had already contracted with local slaughterhouses for the delivery of organic material, thus gaining control over an essential source of research materials. With these contracts, the pharmaceutical companies almost entirely blocked the access of others to this resource. Scientists often found pharmaceutical concerns to be their competitors in this quest. The American biochemist Edward Doisy described how he had to obtain permission from a pharmaceutical company to purchase ovaries, because this company had a contract with the local packing plant.[32] To gain access to the supply of gonads present in slaughterhouses, gynaecologists and laboratory scientists had to ally themselves with the pharmaceutical companies. Both in Germany and the Netherlands, gynaecologists and laboratory scientists created networks with pharmaceutical companies connected to slaughterhouses, thus guaranteeing a steady supply of gonadal material.[33]

In the Netherlands, the infrastructural arrangements show a slightly different pattern that is nevertheless very illustrative in clarifying how the networks between scientists and pharmaceutical companies were built. Dutch scientists could not ally themselves with the pharmaceutical industry simply because no Dutch pharmaceutical company then existed. This situation forced scientists to opt for the strongest form of alliance they could create – namely, to take part in the founding of a pharmaceutical company.

The leading Dutch research group in the emerging field of endocrinology was the Pharmaco-Therapeutical Laboratory of the University of Amsterdam, usually referred to in the literature as 'the Amsterdam School'. This group consisted of physiologists, physicians and chemists, and was headed by Ernst Laqueur.

Laqueur, born in Obernigk (Breslau) in 1880, was trained as a physician at the Universities of Breslau and Heidelberg. Besides his medical training he was educated in physical and organic chemistry and pharmacology. After several appointments at German and Belgian universities, he became professor of pharmacology at the University of Amsterdam in 1920.[34] In memorials, Laqueur is usually described as an excellent manager, a scientist who did not shine so much in laboratory experiments but as a brilliant organizer of scientific labour.[35] This is very obvious from the way in which he knew how to handle the problem of gaining access to research materials.

In 1923, Ernst Laqueur made contacts with Saal van Zwanenberg, the director of a Dutch slaughterhouse. At that time Zwanenberg – following the tradition that already existed in other countries – was looking for customers for the organic remains from his slaughterhouse. Among the waste products, mostly organs that could not be used for the production of food, were the glands of the slaughtered animals. This meeting marked the start of the founding of Organon, the Dutch pharmaceutical company. In June 1923, Ernst Laqueur signed a contract with Zwanenberg's Slaughterhouses and Fabrics Limited Company in which Laqueur allied himself as scientific consultant for the preparation of medical organ products. Laqueur became one of the three founders of what was now renamed Organon Limited Company. Organon committed itself to processing the organic material from Zwanenberg's slaughterhouse.[36]

In this manner, Ernst Laqueur solved the problem of acquiring research materials. Now the Amsterdam School was guaranteed a steady and reliable supply of all the organic material required for research, both on the pancreatic hormone (insulin) and on gonadal hormones. For Organon, too, this was a very successful arrangement. The cooperation with laboratory scientists provided the pharmaceutical company with the biological assay techniques necessary in order to manufacture hormonal preparations of a better quality than the commercial products previously made by other companies. The hormone preparations produced by Organon were controlled for quality in the laboratory in Amsterdam, and not without success. In the following years, the Dutch company gained a strong position in the industrial market as a producer of sex hormones. During the 1930s, up to World War II, Organon was the major producer of female sex hormones throughout the world.[37] Through the following decades, the Amsterdam School maintained its close cooperation with Organon: the connection proved to be of great research value, not only for the supply of gonads, but also when gonads were replaced by urine as a source of pure hormones.

The creation of such networks between scientists and the pharmaceutical companies was of central importance for research on sex hormones. The data suggest that those scientists who had succeeded in making arrangements with pharmaceutical industries became the leading research groups in the new study of sex hormones.[38]

Evaluating developments in the 1920s, we can conclude that the quest for access to research materials had a significant impact on the research network. It led to a structural change, both in the relationship between the actors in the network and in the strategic position of each actor. During the 1920s, the relative independence of the previous decades was replaced by a strong interdependence of those involved in research on sex hormones. Laboratory scientists and gynaecologists had become dependent on the pharmaceutical companies for the supply of research materials. The pharmaceutical companies gained the strategic position of controlling the supply of these materials. However, the pharmaceutical companies in turn, as well as the gynaecologists, had to rely on the laboratory scientists. The laboratory scientists had gained the strategic position of possessing biological assay techniques to guarantee the quality of commercial hormone products. Thus, in addition to the supply of research materials, the availability of techniques also had an impact on the inter-relationships between the actors, strengthening the network created around the materials.

In the course of the 1920s, the character of the relationships between the actors shifted from that of critical partners sharing a mutual interest, to a network in which the actors were heavily dependent on one another to gain access to research materials.

The Quest for Female Sex Hormones

Although the problem of gaining access to research materials had been solved, scientists continued searching for new sources. The main reason for this was the enormous expense of gonadal material.[39] Scientists working on female sex hormones were eager to find less expensive sources than cows' ovaries. Horse ovaries happened to be less expensive than cows' ovaries, but horse ovaries were not easily available because few horses were slaughtered in those days. Another possible source was the human placenta. Owing to the expense and scarcity of ovaries, many investigators turned their attention to this more abundant and relatively inexpensive source.[40] However, this source was not a good substitute for cows' ovaries because placental extracts could not be purified to the same extent as ovarian extracts.

But the quest for new sources would soon take a happy turn. In 1926, two German scientists happened to find the long-sought-for source: human urine.[41] S. Ascheim, gynaecologist at the Gynaeco-Pathological Laboratory of the City Hospital in Berlin, was involved in developing diagnostic tests for disorders in menstruation and fertility.[42] Gynaecologists analyzed blood, and later urine, to detect differences in hormonal content between healthy women and their patients.[43] Together with his colleague Bernhard Zondek, Ascheim also analyzed urine from their pregnant patients. This last endeavour would turn out to be the moment that many colleagues had eagerly awaited. Human pregnancy urine – even in the raw state – happened to be far more active than the best ovarian extracts so far obtained.[44] Bernhard Zondek acknowledged the relevance of his colleagues' achievement outside gynaecology. Through his connections with the Dutch pharmaceutical company Organon, Zondek promoted this new source.[45]

The discovery of Ascheim and Zondek had a significant impact on the relationship between the three groups of actors involved in research on female sex hormones. In this period, the gynaecologists regained a somewhat stronger position in the emerging field of sex endocrinology. To gain access to the new source of pregnancy urine, the actors had to rely on the gynaecologists: scientists could only obtain urine from pregnant women from gynaecological clinics. This became a new source of inexpensive and easy available material for research on female sex hormones,[46] and signalled the end of the period in which research was constrained by the scarcity of research materials. Urine proved to be an ideal source. Being a liquid, it could be extracted with ease. Owing to its composition there were only small amounts of inert products in the extract. And what was even more important, the supply of urine was both abundant and inexpensive.

In addition, the position of the laboratory scientists changed radically during this period. With the introduction of urine, chemical analytical methods became more important: the new discipline of biochemistry consequently became increasingly involved in research on sex hormones. The biochemists had mastered one technique that gynaecologists and their colleagues in the laboratory did not possess – the technique to make invisible female and male substances visible. After the discovery of Ascheim and Zondek, chemists devoted their energies to the isolation of female sex hormones from human pregnancy urine. The new source stimulated chemical work, and turned out to be one of the major factors contributing to the isolation and chemical identification of female sex hormones.[47] Within two years of Ascheim and Zondek's 1926 publication, three research groups in the United States, Germany and the Netherlands reported the isolation and identification of the female sex hormone from human pregnancy urine.[48]

The use of urine as a research material reinforced the relationship between scientists and the pharmaceutical industry. Although the use of urine solved many problems, individual scientists still had to spend quite some time collecting the material they needed.[49] Those scientists working in close cooperation with pharmaceutical industries could profit once more from this relationship. In some cases the pharmaceutical company undertook both the collection and the processing of human pregnancy urine.[50] Scientists could simply obtain the extracted hormones from the companies.

In this period, laboratory scientists were strengthening their position. With the introduction of urine and the application of chemical methods, research gradually shifted from the gynaecologists to the laboratory scientists. The individual gynaecologist of the earlier days, experimenting on a small scale with extracts prepared from ovaries obtained from the clinic, was replaced by laboratory scientists working with enormous quantities of research material provided by the pharmaceutical companies.

In the years to come, gynaecologists also lost their strategic position as suppliers. In 1930, Zondek suggested that the urine of pregnant mares was superior to human urine as a source of female sex hormones. Now scientists were no longer dependent on the gynaecological clinic to obtain the material they needed. This did not in itself greatly affect the direction of research, because the female sex hormone had already been isolated from human pregnancy urine. However, the urine of pregnant mares turned out to be of great importance for the commercial production of female sex hormones by pharmaceutical companies, for it was even less expensive than human urine. For the second time, the Dutch company Organon followed Zondek's advice.[51] In the years to follow, Organon processed millions of litres of mares' urine (an operation that could not remain unnoticed by the people living near the factory!). To collect this urine, Organon organized special campaigns among horse owners.[52] One can imagine that farmers (and even the ministry of agriculture) were most surprised to discover that they could sell the liquid waste products from their mares for prices equal to the price of cows' milk.[53]

Clearly, the introduction of urine had an impact on the position of the three groups of actors. In the late 1920s and the early 1930s, research on female sex hormones definitely shifted from the clinic to the laboratory. Although gynaecologists temporarily had strengthened their position as suppliers of female urine, they totally lost their position in research on sex hormones. The laboratory scientists and the pharmaceutical companies, however, strengthened their positions in the network. Thus, of the three groups of actors previously involved in research on female sex hormones only two retained their position – the pharmaceutical companies and the laboratory scientists. Moreover, inside the laboratory a shift in positions had also taken place: after the late 1920s, biochemists became increasingly involved in the subject of sex hormones, and partly took over the subject from the physiologists who had done the pioneer work in the laboratory.[54]

The Quest for Male Sex Hormones

The success story about gaining access to new sources for female sex hormones cannot be told about male sex hormones. Research on male sex hormones was far more constrained by the limited availability of organic material than was research on female sex hormones. In the early years, female gonads had been relatively easy for gynaecologists to obtain, because human ovaries were regularly removed in the clinic.[55] However, no comparable clinical practice existed for human testes.[56] This difficulty led to the search for other sources of male hormones. After the isolation of female sex hormones from human pregnancy urine in 1929, it was not surprising that laboratory scientists began to examine human urine for male sex hormones.[57]

Remarkably, the availability of urine as a source of male sex hormones did not have the same impact on research as it had had on research on female sex hormones. Male urine was a suitable source in theory, but in practice it was not, simply because there was no institutional context for its collection, as there was for female urine. Men's clinics specializing in the study of the male reproductive system did not exist in the 1920s. The collection of urine from male patients in normal hospitals could not solve the problem, because the content of male sex hormones in the urine of sick males turned out to be much lower than in the urine of healthy men.[58] Nor was animal urine a solution, because it contained very little male hormone. Human urine appeared to be unique with respect to male hormonal content.[59] Thus scientists remained totally dependent on human male urine.

How did scientists eventually gain access to male urine? To collect it, scientists had to look for institutions other than the clinic – places where men regularly gathered, like big factories or other male occupational spheres. In 1931, the German chemist Adolf Butenandt collected 25,000 litres of men's urine in the police barracks in Berlin, from which he isolated 50 mg of a crystalline substance to which he subsequently gave the name 'androsterone' in the belief that it was the essential male hormone.[60] However, this supply of male urine was quite problematic. Scientists had to rely on the delivery of male urine from institutions in which the collection of urine was not a common practice. Both German and Dutch scientists described how difficult it was to gain access to male urine in these institutions. Butenandt's colleague Koch described how it took Butenandt two years before he could obtain enough material to revise the formula for and potency of the male sex hormone he had isolated in 1931.[61] Laqueur, in his function as a member of the board of Organon, had to take great pains to obtain permission from the Ministry of Defence and the directors of prisons to collect male urine in military barracks and penitentiaries. In 1930, Laqueur addressed the Ministry of Defence, formulating his request as follows:

> In order to produce male sex hormone preparations, it is absolutely necessary to have access to a large quantity of raw material, in this case a large amount of urine from, not too elderly, men. Although this material is abundant in rather huge quantities and has the additional advantage of being valueless, it is very difficult to collect. . . . The production of female sex hormones only succeeded by the cooperation of directors of women's clinics and midwife schools. Concluding, I want to emphasize the scientific and therapeutic interests that are in stake and that legitimate your cooperation in order to obtain the required raw material from the barracks.

Organon first obtained male urine from its German subsidiary in Berlin, Degewop; later Organon obtained the urine from Dutch factories, military barracks and penitentiaries.[62]

Thus, scientists had once again to rely on the pharmaceutical companies for their supply. In Germany, the collection and processing of the urine was carried out by the pharmaceutical company Schering AG.[63] Dutch scientists could profit once more from their close cooperation with Organon, which provided them with the large quantities of urine required for research on male sex hormones.

It was only when male sex hormones could be made synthetically, and organic materials were no longer needed, that an increase took place in research on male sex hormones. The chemical characterization of male sex hormones, and their synthesis, made possible a burst of biochemical and biological work.[64] At last scientists could easily gain access to male sex hormones. The pharmaceutical companies could provide them with any quantity of synthetic male sex hormones they needed. Research was stimulated by the distribution of a wide range of male sex hormones by the pharmaceutical companies.[65] The number of research publications on male sex hormones that appeared in the 1920s and 1930s indicates the impact of this synthetic supply.[66]

Summarizing the quest for male sex hormones, we can conclude that in this case (even more than for female sex hormones), laboratory scientists had to rely on the pharmaceutical companies to provide them with the required material. In contrast to female sex hormones, the study of male sex hormones was dominated from the beginning by two groups of actors – the laboratory scientists and the pharmaceutical companies. The gynaecologists were more interested in the role of the ovaries in female disorders, and focused only on the study of female sex hormones.

Research Materials as Carriers of Knowledge Claims

The availability of research materials not only had an impact on the interrelationship between the actors involved in research on sex hormones: research materials also functioned as carriers in the transmission, and consequently the selection, of knowledge claims. To understand the role of research materials in the cognitive development of research, we can simply trace the movement of research materials from one actor to another.

In the period of the introduction of the concept of sex hormones, the three groups of actors involved in research on sex hormones focused on different research questions. The gynaecologists were particularly interested in the role of female sex hormones in female disorders associated with the ovaries, and processes of reproduction in the female body. Gynaecologists tentatively began to wonder if and how the internal secretions of the ovaries might control ovulation, menstruation and pregnancy. The pharmaceutical companies followed up these claims by producing ovarian preparations for therapeutic purposes. The laboratory scientists shared a broader interest. Besides issues of reproduction, laboratory scientists were particularly interested in the role of both female and male sex hormones in the growth and development of the body in general, and more specifically, in the process of sexual differentiation – the development and maintenance of both the sexual organs and the secondary sexual characteristics.

In the early period, when the three actors still worked independently from one another, all claims were investigated with equal attention. This situation changed significantly from the moment the actors had to rely on each other for the supply of research materials. With the transfer of research materials from one actor to another, knowledge claims specific to the actor in control of the research materials were also transferred. In this process a selection of knowledge claims took place: some claims became stronger, others weaker.

The first time this happened was in the period when scientists were using human female gonads in their research. Only the gynaecologists could easily gain access to this type of research material. To translate their claims from animals to human organisms, all actors had to rely on the gynaecological clinic, as the only place where human gonads could be obtained. Here we see the first selection of claims. The claims attached to the male gonads could not be transferred from animals to humans because a medical practice able to provide human testes did not exist. In this way, the knowledge claims gynaecologists attached to female sex hormones became stronger than the claims of the other actors. Thus, claims concerning the role of female sex hormones in female disorders and female reproduction gained more momentum than claims concerning sexual differentiation and male reproduction.

This initial selection of claims was further reinforced in the period when scientists began to use human urine. As we have seen, human urine as a source for research materials stimulated research on female sex hormones, because female urine could easily be obtained and processed. Because the gynaecologists could gain access to the urine of women more easily than the other actors, the process of selection of claims was further strengthened in the direction of their own interests. With the transfer of the urine of their female patients from the gynaecological clinic to the laboratory and the pharmaceutical companies, the claims concerning women's diseases and reproduction were also transferred. Particularly during the period when urine was becoming established as a source of research materials, claims about the inter-relationships between female sex hormones, women's diseases and reproduction became stronger: gradually, they became the major focus on the research agenda of all three sets of actors.

Because both methods and research materials were well developed and easily available, more and more scientists became involved in research on female sex hormones. To quote Robert Frank, a gynaecologist at the Mount Sinai Hospital in New York:

> Since 1923 the subject [female sex hormones] has attracted innumerable workers who are elbowing and jostling each other and jockeying for position in the neck and neck race to isolate and synthesize the much desired and long sought for hormone, which is bound to relieve many of the ills from which women suffer.[67]

Through the 1920s and 1930s, the number of publications on female sex hormones increased steadily, and outnumbered those on male sex hormones.[68]

In the urinary period, both the laboratory scientists and the pharmaceutical companies became definitely committed to the specific interests of the gynaecologists in the female sex hormones. Dutch laboratory scientists and pharmaceutical industrialists compared their interest in the female sex hormone with 'the pursuit of the goddess of luck', and talked about 'finding gold in the urine of pregnant mares'.[69] Since the 1920s, all three sets of actors have shared a mutual interest in female sex hormones as a field that has gradually developed into big science and big business.

Summarizing the situation at the end of the 1930s, we can conclude that in the selection process of knowledge claims that resulted from the transfer of research materials, women and reproduction became the central focus of research. In the triangle – gynaecology-laboratory-pharmaceutical industry – the male gradually disappeared from sight as an object of research. Although most actors were male, the object of research was almost entirely female. Knowledge claims linking men with reproduction could not be stabilized simply because there did not exist an institutional context for the study of the process of reproduction in men. The medical specialty of andrology – the study of the physiology and pathology of the male reproductive system (and in this respect the counterpart of gynaecology) – emerged only in the 1960s.[70] This gender bias in the institutionalization of the life sciences exerted an all-pervasive impact on the cognitive development of reproductive research. Consequently, the development of knowledge about male reproduction was long delayed.[71]

Conclusions

This reconstruction of research on sex hormones in the early decades of this century illustrates the impact of research materials on the social organization and the cognitive development of science.

In the first place, we can conclude that research materials were the pivot on which the relationships among the different actors involved in the making of sex hormones turned. Simply by following scientists in their actions to gain access to these materials, we can see how the different actors, at first operating independently, gradually became enmeshed in a network of dependence and alliance.

The story of the 'making' of sex hormones, including the extraction, synthesis and investigation of biological activity and possible therapeutic effects, resembles the story Latour has written on the work of Pasteur with microbes.[72] In both cases, the laboratory became the very place through which all actors who wished to solve their problems (with respect to women's diseases or to anthrax) had to pass. With the introduction of the concept of sex hormones, scientists explicitly linked women's diseases with laboratory practice.[73] Laboratory scientists entered a field until then relatively untouched by laboratory science. Before the turn of the century, the study of women's diseases, traditionally ascribed to the dysfunction of the ovaries, was the exclusive field of gynaecologists. In the decades to follow, research on ovaries shifted from the clinic to the laboratory. Laboratory scientists succeeded in becoming experts on issues concerning disorders in the ovaries and female reproduction. In this manner, laboratory scientists gained a new realm of influence, claiming authoritative knowledge over a subject previously allocated to gynaecologists. The gynaecologists lost their position as the sole experts on women's diseases and reproduction. Or, to paraphrase the conclusions of Latour on the work of Pasteur:

> If you wish to understand women's diseases and female reproduction, you have one place to go to, the laboratory, and one science to learn that will soon replace yours – endocrinology. If you want to save your patients from diseases of the ovaries, order a hormone flask from Laqueur/Organon.[74]

The laboratory could only gain strength by creating networks both with gynaecologists and with the pharmaceutical industry. As in the case of the Institute of Pasteur, Laqueur's laboratory was always situated in such a way that all the medical and commercial interests had to pass through there.[75] However, it must also be emphasized that the laboratory itself could not exist apart from the other actors. To maintain their position, the laboratory scientists had to rely on the pharmaceutical industry. If first the gynaecologists, and later the laboratory scientists, had not succeeded in capturing the interests of the pharmaceutical companies, research on sex hormones would have stayed inside the walls of the laboratory forever. Only by close cooperation with the pharmaceutical companies could they transform the theoretical construct of sex hormones into chemical products that could circulate outside the walls of the laboratories. In this manner, laboratory scientists redefined the complex relationship between women and reproduction, an issue that would be continued in the 1950s when laboratory scientists, again in cooperation with the pharmaceutical industry, transformed female sex hormones into the contraceptive pill.[76]

In the second place, we can conclude that in the construction of the laboratory in the life sciences, medical practice is an important – though often ignored – factor in the structuring of knowledge claims. Amsterdamska has suggested that the development of the life sciences – in particular, in those fields that are institutionalized as medical fields – is structured not only by theoretical considerations, but also by the concerns of the clinical practice.[77] Research materials can be considered as one of the factors linking research in the laboratory to clinical concerns. By following how research materials are moved from one actor to another, it becomes possible to see how knowledge claims were transferred from the clinic to the laboratory, thus directing the latter's research agenda. Moreover, the laboratory would not have gained its control over female sex hormones if it had remained disconnected from the gynaecological clinic. By creating networks with the clinic, the laboratory ended up at the centre of gynaecological interests, a subject with which it had no relationship before. To retain its strength, the laboratory had to keep the interests of gynaecologists in mind. In order to do so, the laboratory had to rely on the clinic to test its hormonal preparations on female patients.

Reflecting on the role of research materials in the production of knowledge, I want to suggest a different conceptualization of them. I think it is beyond dispute that we cannot simply adopt the positivistic account in which research materials are thought of as independent resources. However, Latour's suggestion that research materials should be considered as non-human actors that can be equated with human actors is also inadequate; this conceptualization tends to obscure the differences that do exist between human and non-human actors. Their role can be characterized better by the metaphor of 'carriers'. With this metaphor, we can understand how research materials mediate, both in establishing relationships between actors, and in the selection of knowledge claims.

Last, this paper also has relevance for women's studies. In analyzing the relationship between gender and science, most scholars in women's studies tend to conceptualize gender bias as something that comes from 'outside'. This conceptualization is based on the assumption that in science there exists an 'inside' and an 'outside' – a social/cultural context, and, apart from this, science itself. From this point of view, gender bias is located in the social context, or 'society', and then must be transferred into the realms of science. Although this approach has been valuable in signalling the presence of gender bias in science, in other respects it is quite problematic. In constructing a distinction between science and society, the image of science as a gender-neutral activity is preserved. If gender bias comes from 'outside', it can also be removed, or kept 'outside', leaving science untouched. But, as demonstrated here, gender bias is an integral part of the whole fabric of science, and consequently cannot be simply 'removed'. Because the subject of women and reproduction has been institutionalized in a medical specialty, whereas the same processes in men have not been institutionalized, gender bias is at the centre of the life sciences. In new fields of the life sciences related to this medical practice, like the study of sex hormones, this gender bias is reinforced and modified. The differences in the institutionalization of research on male and female reproduction not only led to bias in the access of research materials derived from the male and the female body: the existence of gynaecological clinics also provided an available and established clientele for the products of research on female sex hormones. This has been another powerful factor in directing attention to female sex hormone research.[78]

We can conclude that, for the analysis of the relationship between gender and science, it is not necessary to search for (conscious or unconscious) ideologies or political drives in the actors of science. Instead, it is worthwhile to analyze how scientists operate in their laboratories, performing activities that are enmeshed with the social context to such an extent that it is not useful to make a distinction between 'science' and 'society'. In the making of sex hormones, laboratory scientists had to leave their laboratories to create networks with the clinic and the pharmaceutical companies, bringing both materials and knowledge claims back into their laboratories, in a process in which the *man*, as subject of research, became an attenuated item on the research agenda. The laboratory not only reflects gender bias in society, it is the very place where gender is constructed and metamorphosed.

• *NOTES*

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1. B. Latour, *Science in Action: How to Follow Scientists and Engineers through Society* (Milton Keynes, Bucks.: Open University Press, 1987).

2. A. E. Clarke, 'Research Materials and Reproductive Science in the United States, 1910-1940', in Gerald L. Geison (ed.), *Physiology in the American Context 1850-1940* (New York: American Physiological Society, 1987), 323-51.

3. The scope of research analyzed in this paper is limited to basic and clinical research on sex hormones, undertaken by workers in biology and medicine, excluding agricultural scientists. The development of the agricultural approach in the reproductive sciences in the United States has been analyzed by Adele Clarke: see A. Clarke, *Emergence of the Reproductive Research Enterprise: A Sociology of Biological, Medical and Agricultural Science in the United States, 1910-1940* (unpublished PhD dissertation, University of California, San Francisco, 1985). Moreover, this analysis is largely restricted to the development of sex endocrinology in Europe, focusing more particularly on the situation in the Netherlands. Recent studies of the history of the reproductive sciences suggest that the development of reproductive science did not proceed similarly in the several countries

involved (UK, France, Germany, Netherlands, USA). While there were similarities, there were also national differences, but these have, however, not yet been historically specified.

4. Ernest H. Starling, *The Croonian Lectures on the Chemical Correlations of the Body* (London: Women's Printing Society, 1905), 6.

5. For a description of the introduction of the theory of internal secretions, see M. Borell, 'Brown-Séquard's Organotherapy and its Appearance in America at the End of the Nineteenth Century', *Bulletin of the History of Medicine*, Vol. 50 (1976), 309–20; Borell, 'Organotherapy, British Physiology and Discovery of the Internal Secretions', *Journal of the History of Biology*, Vol. 9 (1978), 235–68.

6. D. Long Hall, 'Biology, Sex Hormones and Sexism in the 1920s', in M. Wartofsky and C. Could (eds), *Women and Philosophy* (New York: Putnam, 1975), 81–95.

7. M. Borell, 'Organotherapy and the Emergence of Reproductive Endocrinology', *Journal of the History of Biology*, Vol. 18 (1985), 1-30.

8. The basic criteria for assays of sex hormones were established in the surgical epoch. Scientists decided that the label of male or female sex hormones should be attached to substances isolated from the gonads that could provoke the recovery of the male or female organism (respectively) after castration. Theoretically, any character or function which changes in the organism after removal of the ovaries or testes could serve the purposes of assay for sex hormones. The actual choice of the bio-assay for sex hormones was more the result of practical than cognitive considerations. Scientists preferred to perform easy and inexpensive assays. For female sex hormones, two types of tests were introduced, both based on changes in the internal reproductive organs – the growth of the uterus, and the cornification of epithelial cells in the vagina. These changes were considered characteristic of the period of sexual activity (oestrus), a common feature in laboratory animals like mice, rats and guinea-pigs. Also, for male sex hormones, theoretically any characteristic which changes as a result of castration was considered appropriate as an assay. Practical considerations limited the biological tests principally to two types. Male sex hormones were defined as those substances that regulated the growth of the comb of castrated roosters, and the growth of seminal vesicles in rats and mice.

9. Long Hall, op. cit. note 6, 83.

10. N. E. J. Oudshoorn, 'Endocrinologists and the Conceptualization of Sex 1920–1940', forthcoming in the *Journal of the History of Biology*, Vol. 23 (1990).

11. Borell, op. cit. note 7, 2.

12. Surgical operations for the removal of human ovaries have been common practice in gynaecological clinics in Europe since the 1870s. These operations were advocated for disorders in menstruation and for various neuroses: see G. W. Corner, 'The Early History of Oestrogenic Hormones', *Proceedings of the Society of Endocrinology*, Vol. 33 (1965), iii–xiv. The fact that European gynaecologists (in particular Viennese gynaecologists) were the first to recognize the relevance of the theory of internal secretions is described in Borell, op. cit. note 7, 13.

13. I am grateful to Adele Clarke for drawing my attention to the fact that the notion of female sex hormones as associated with female disorders is in itself a medical construction. In the 1920s and 1930s, female disorders became increasingly linked to hormones, thus excluding social and psychological dimensions.

14. Corner, op. cit. note 12, vi.

15. At this point, there are major differences between the USA and Europe. In the USA, many of the major laboratory scientists of the first generation of sex endocrinologists were zoologists and anatomists, not physiologists: see Clarke, op. cit. note 3. In a reconstruction of this early period of research on the glands, Borell has analyzed the reasons why British

physiologists were relatively slow in recognizing the relevance of the theory of internal secretions for the sex glands. According to Borell, one of the main reasons was the association of the sex glands with human sexuality and reproduction, an area that previously had been taboo in biomedical research. This negative association was reinforced by the therapeutical claims of Brown-Séquard on the effects of testis extracts on sexual activity of men, claims that caused a controversy among clinicians and laboratory scientists. Physiologists who took up the study of ovaries and testes preparations did so cautiously, avoiding association with these therapeutic claims. Obviously, the subject was less illegitimate for gynaecologists: see Borell, op. cit. note 5, 2. Clarke argues that this taboo subsequently delayed the development of reproductive science: see Clarke, op. cit. note 3.

16. Borell, op. cit. note 7, 13.

17. Corner, op. cit. note 12, vii.

18. After the 1870s, the removal of ovaries became widely popular in England and Germany as well as in the United States, and thousands of women were subjected to this drastic procedure advocated for disturbances in menstruation and various nervous disease ascribed to the ovaries: ibid., iv.

19. Ibid., x.

20. In the pharmaceutical industry, animal organs were in fact used in two ways – both as research materials, and as raw materials for the production of gonadal preparations. Research in the pharmaceutical industry focused mainly on investigating means of extracting the hormones from natural sources, and synthesizing them in order to produce or manufacture them. Research at the Dutch pharmaceutical company Organon also included the performance of bio-assays in order to test the quality of the hormone products. In this paper, I will not differentiate between research materials and raw materials, because the same materials were used in both contexts. I am grateful to Adele Clarke for drawing my attention to these differences in focus between the actors.

21. In fact, for many gynaecologists, in particular in Germany, the scepticism over the quality of commercial ovarian products was the very reason why they became involved in research on ovarian preparations: see B. Zondek and M. Finkelstein, 'Professor Bernhard Zondeck, An Interview', *Journal of Reproductive Fertility*, Vol. 12 (1966), 5.

22. J. P. Swann, *Academic Scientists and the Pharmaceutical Industry* (Baltimore, MD, and London: The Johns Hopkins University Press, 1988), 35; P. Starr, *The Social Transformation of American Medicine* (New York: Basic Books, 1982), 131–2; Pharmaco-Therapeutical Instituut', *Nederlands Tijdschrift voor Geneeskunde*, Vol. 64 (1920), 1473.

23. One prominent scientist in the 1920s and 1930s, the American anatomist George W. Corner, even testified in the late 1930s for the United States Food and Drug Administration in a lawsuit entitled 'The United States against four dozen tablets of corpora lutea substance'. Corner claimed that the tablets, made from sows' ovaries, contained neither of the ovarian hormones known in the 1930s: see Corner, op. cit. note 12, vi.

24. The physiological test developed by the gynaecologists was criticized by laboratory scientists as inadequate: see Zondek & Finkelstein, op. cit. note 21, 5.

25. Borell, op. cit. note 7, 4, 11, 18.

26. H. H. Dale, 'Conference on the Standardisation of Sex Hormones Held at London on July 30th and August 1st 1932', *Quarterly Bulletin of the Health Organisation League of Nations*, Vol. IV (1935), 121–7.

27. The shift from biological approaches to chemical approaches was not restricted to the study of sex hormones, but characterized the broader field of the life sciences at the turn of the century: see Clarke, op. cit. note 3, 390. This shift of emphasis can be traced, at least in part, to the laboratory scientists' concern to move away from therapeutic concerns

to the more reductionist concern of the new professional scientist: see D. Long Hall, 'The Social Implications of the Scientific Study of Sex', *The Scholar and the Feminist*, Vol. IV (New York: The Women's Center of Barnard College, 1977), 11-21. The introduction of the chemical approach in the study of sex hormones was (compared to other fields) somewhat belated. This delay was partly due to technical problems. In the 1910s, biochemists were merely preoccupied with proteins. In this period the biochemists had 'neither the incentive nor the information' to enter the field of sex hormone research. This situation changed in the 1920s, when lipid chemistry emerged as a new line of inquiry in biochemistry. In the 1920s, sex hormones came to be known as steroids, a class of substances that could be extracted with the same solvents applied in extracting lipids, thus providing biochemists with the information and the tools to enter the study of sex hormones: see Long Hall, op. cit. note 6, 83.

28. A. S. Parkes, 'The Rise of Reproductive Endocrinology 1926–1940', *Proceedings of the Society of Endocrinology*, Vol. 34 (1965), xix-xxxii.

29. The Dutch chemist Elisabeth Dingemanse mentioned the existence of a stable next to the laboratory in one of her letters (31 July 1931) to Ernst Laqueur, the director of the Dutch research group involved in research on sex hormones: private archive of the letters of Elisabeth Dingemanse.

30. A. S. Parkes, *Off Beat Biologist: The Autobiography of Alan S. Parkes* (Cambridge: The Galton Foundation, 1985), 128.

31. The function of abattoirs in providing the scientists with the required research materials has been discussed by Adele Clarke: see Clarke, op. cit. note 2, 329–31.

32. E. A. Doisy,'Isolation of a Crystalline Estrogen from Urine and the Follicular Hormone from Ovaries', *American Journal of Obstetrics and Gynaecology*, Vol. 114 (1972), 701-03.

33. German scientists like the chemist Adolf Butenandt worked in close cooperation with the German pharmaceutical company Schering-Kahlbaum AG, in Berlin. During his experimental work on female sex hormones, the gynaecologist Bernhard Zondek worked as an employee of the Dutch company Organon. In his later work on hormones of the hypophysis, Zondek chose the German pharmaceutical company I. G. Farbenindustrie as an industrial partner: see M. Tausk, *Organon, De geschiedenis van een byzondere Nederlandse onderneming* (Nijmegen: Dekker & Van de Vegt, 1978), 29-32.

34. *Wie is dat?* (s'Gravenhage: Martinus Nijhoff, 1938).

35. Tausk, op. cit. note 33, 12.

36. The Organon Limited Company was founded in July 1923, starting as a small laboratory inside the buildings of Zwanenberg's slaughterhouse. The full name of this new company was: Organon Limited Company for the Manufacturing of Organ Preparations on a Scientific Basis. The very name of Organon was most probably suggested by Laqueur, having in mind the Greek word for organ. Laqueur became one of the three members of the board of directors, specifically in charge of scientific and medical management of the company: ibid., 15, 17, 19.

37. Ibid., 35, 120-22.

38. Although the cooperation of laboratory scientists with pharmaceutical companies had major advantages, relationships with pharmaceutical companies could also be difficult, in particular with respect to the funding of research by grant agencies. In the Netherlands, the close connection between a private company like Organon and a university laboratory like the Pharmaco-Therapeutical Laboratory was often criticized, both inside and outside the scientific community. In 1931, the cooperation between Ernst Laqueur and Organon became a topic of debate in the City Council of Amsterdam, when Laqueur was called

to account for the financial consequences of his connection with Organon. Laqueur had to convince the City Council that the municipal financial budget allocated to the Pharmaco-Therapeutical Laboratory in Amsterdam was not being (indirectly) spent on scientific equipment for Organon. (Source: Notes of the meetings of the City Council of Amsterdam: Gemeenteblad afd 1 no. 598 Pharmaco-Therapeutisch Laboratorium en Gemmenteblad afd 1 no. 760 Pharmaco-Therapeutisch Laboratorium.) In this debate, Laqueur also described the role of Organon in supplying his laboratory with the required research materials:

> Large quantities of material are needed before substances can be obtained in a pure condition. The pharmaceutical Laboratory does not have the means to purchase the required materials. Organon provided livers, urine and testes and whatever else might be needed for research. . . . This cooperation is of importance both for the Pharmaco-Therapeutical Laboratory and for Organon. If the Regulations regarding the University were to prohibit professors from providing consultation, this would disadvantage the University, and the laboratory would have much to show in terms of scientific results. (Source: Notes of the Extraordinary Meeting of Guardians: 'Buitengewone vergadering van curatoren 22 juni 1931 om twee uur ten stadhuize'.)

39. E. Laqueur, P. C. Hart and S. E. de Jongh, 'Over een vrouwelijk geslachtshormoon', *Nederlands Tijdschrift voor Geneeskunde*, Vol. 1 (1927), 2077–89. Laqueur's American colleague, the biochemist Edward Doisy, also complained about the high cost of sows' ovaries, which in his opinion delayed the isolation of female sex hormones: see Doisy, op. cit, note 32, 701.

40. E. A. Doisy, 'Biochemistry of the Estrogenic Compounds', in E. Allen (ed.), *Sex and Internal Secretions* (Baltimore, MD: Williams & Wilkins, 2nd edn, 1939), 848.

41. Corner, op. cit. note 12, xv.

42. Zondek & Finkelstein, op. cit. note 21, 6.

43. In the 1930s, the analysis of the hormone content of urine had developed into a general diagnostic method in the clinic. Gynaecologists expected that the excretion of hormones in urine indicated an abnormally high quantity of hormones in the female body, which was considered to be the cause of female disorders: see E. Laqueur, 'Orgaan en hormoontherapie', *Het Hormoon*, Vol. 7 (1937), 2–8. However, in the late 1930s, gynaecologists acknowledged that the relationship between illness and the excretion of hormones was not so simple: see M. Tausk, 'Uitscheiding van hormonen in de urine van normale menschen', *Het Hormoon*, Vol. 7 (1938), 89–97.

44. Parkes, op. cit. note 28, 125. The activity of ovarian extracts was measured by monitoring the effects of the extract on the cornification of cells in the vagina of the castrated animals. Hormone preparations made from urine had a more pronounced effect on changes in the vaginal cells than preparations made from the ovaries.

45. In the 1920s, Bernard Zondek worked for some years as an employee of Organon. Organon, as well as Zondek's colleagues, were impressed by his suggestion that urine was the ideal source for female sex hormones: see Tausk, op. cit. note 33, 30.

46. The practice of collecting urine in the clinic is perceptible in the acknowledgements of publications in this period, in which scientists express their thanks to the staffs of hospitals for collecting urine: see N. H. Callow and R. K. Callow, 'The Isolation of Androsterone and Transdehydroandrosterone from the Urine of Normal Women', *Biochemical Journal*, Vol. 32 (1938), 1759–63. The Amsterdam School collected human pregnancy urine at the gynaecological clinic of one of the city hospitals, Het Wilhelmina Gasthuis: see letter from Elisabeth Dingemanse to Ernst Laqueur, 7 February 1924.

47. Doisy, op. cit. note 40, 851.

48. Parkes, op. cit. note 28, xxi.

49. Doisy described how he collected urine with the help of a nurse in the outpatient clinic of St Louis University School of Medicine, who gave each obstetric patient a one-gallon bottle with instructions to fill it with urine and bring it on her next trip to the clinic. Later, when more urine was needed, Doisy had to deliver and collect two-gallon bottles to the homes of obstetric patients himself – a time consuming task! See Doisy, op. cit. note 32, 701.

50. The German research group that had successfully isolated female sex hormones obtained large quantities of pregnancy urine from the German pharmaceutical company Schering-Kahlbaum AG: see A. Butenandt, '50 Years Ago: The Discovery of Oestrone', *TIBS*, Vol. 4 (1979), 215–17.

51. Tausk, op. cit. note 33, 32.

52. The director of Organon in those days was Marius Tausk, who evaluated the relevance of this new source for the production of female sex hormones with the significant words: 'Gold from the urine of pregnant mares'. Organon continued to supply mares' urine throughout the 1950s: ibid., 116.

53. Ibid., 119.

54. Corner, op. cit. note 12, xv. Although biochemists became increasingly involved in the study of sex hormones, there were differences between practices in different places. In the USA, the biochemists largely worked as 'handmaidens' to other scientists: see R. E. Kohler, *From Medical Chemistry to Biochemistry: The Making of a Biomedical Discipline* (Cambridge & New York: Cambridge University Press, 1982). Biochemists worked in other scientists' laboratories, often on grant money and not as tenured faculty. I would like to thank Adele Clarke for this remark on national differences in practices.

55. Zondek & Finkelstein, op. cit. note 21, 6.

56. Human testes were very difficult to obtain. Scientists even went to prisons to await executions to gather fresh materials: see D. Hamilton, *The Monkey Gland* (London: Chatto & Windus, 1986).

57. F. C. Koch, 'The Biochemistry of Androgens', in Allen (ed.), op. cit. note 40, 807–46.

58. J. Freud, 'Uber Männliches (Sexual-) Hormon', *Klinische Wochenschrift*, Vol. 9 (1930), 772–74.

59. R. G. Gustavson, 'The Bioassay of Androgens and Estrogens', in Allen (ed.), op. cit. note 40, 877–901.

60. Parkes, op. cit. note 28, xxv.

61. F. C. Koch, 'The Biochemistry and Physiological Significance of the Male Sex Hormone', *Journal of Urology*, Vol. 35 (1936), 383–90.

62. Source: correspondence from E. Laqueur, letters dated 14 October 1929, 7 and 12 December 1929 and 31 March 1930: Archive Laqueur, Organon.

63. Tausk, op. cit. note 33, 56.

64. Parkes, op. cit. note 28, 25; E. Tschopp, 'Die Physiologischen Wirkungen des kunstlichen mannlichen Sexualhormons', *Klinische Wochenschrift*, Vol. 14 (1935), 1064–68.

65. Parkes, op. cit. note 28, xxv. Many publications of these years include acknowledgements in which scientists express their gratitude for the provision of male sex hormones. Companies often mentioned include the Schering Corporation (Germany) and Ciba Pharmaceutical Products (Switzerland): see Tschopp, op. cit. note 64, 1068; C.D. Kochakian, 'Excretion and Fate of Androgens; Conversion of Androgens to Estrogens', *Endocrinology*, Vol. 23 (1938), 463; F. L. Warren, 'Alleged Oestrogenic Activity of the Male Sex Hormone', *Nature*, Vol. 135 (9 February 1935), 234. As had happened in research

on female sex hormones, scientists tried once more to obtain male sex hormones from gonads, after the successful adventure with urine. In 1935, the Amsterdam School reported the isolation from tons of bull testes of 15 mg of a pure substance to which they gave the name 'testosterone'. Soon thereafter, this compound could also be produced synthetically: see Tausk, op. cit. note 33, 89.

66. If we consider the number of publications included in the *Quarterly Cumulative Index Medicus* as an indication of progress, research on male sex hormones only became substantial after 1936, the period when scientists were no longer handicapped by a scarcity of research material. From 1927–36, the number of publications on male sex hormones included in the *Quarterly Cumulative Index Medicus* varied between two and thirty-five. After 1936, the number of publications increased from twenty-eight in 1936 to 140 in 1937, and 222 in 1938.

67. R. T. Frank, *The Female Sex Hormone* (Springfield, IL: Charles C. Thomas, 1929), Preface.

68. The number of publications on female sex hormones indexed in the *Quarterly Cumulative Index Medicus* gradually increased from eighty in 1927 to 448 in 1938. The total number of publications in the period between 1927 and 1938 on female and male sex hormones was 2688 and 585, respectively.

69. Laqueur et al., op. cit. note 39, 2080; Tausk op. cit. note 33, 116. During the 1930s, another hormone – gonadotropin – was isolated from pregnant mare serum, enlisting mares in even more research.

70. Although the need to establish a separate and distinct specialty for the study of the male reproductive system was suggested as early as 1891, not until the late 1960s was andrology institutionalized as a medical specialty. The first andrological journal (*Andrologie*) was founded in 1969. The first andrological society is either the Nordic Association for Andrology or the American Association of Andrology, both of which were established in 1973: see M. Niemi, 'Andrology as a Specialty: Its Origin', *Journal of Andrology*, Vol. 8 (1987), 201–03. Clinics focused on male reproduction are currently – at least in the USA – still very rare. Andrology is usually still studied in urology departments. Moreover, there still exist vast differences in the use of gynaecological clinics and andrological clinics. The routine use of gynaecological clinics by women, including for regular Pap smears, provides clinicians with access to large numbers of women. A routine use of andrological clinics by men has not (yet?) developed, due to the lack of any regular screening programme for men (for example, for prostate cancer). So, in addition to the institutionalization of specialties, the introduction of screening programmes may also differentiate the access to research materials derived from the bodies of women and men. I am grateful to Adele Clarke for pointing out this important addition to me.

71. In an interview in 1981, the German gynaecologist Eberhard Nieschlag, director of the Gynaecological Clinic of the Max-Planck-Gesellschaft in Munster, compared the progress in fundamental research on male reproduction with the position of research on female reproduction at the time of World War I: see T. Kohaus-Altmeyer, 'Die Verhutung der Mannerpille', *Emma*, Vol. 3 (1981), 6–8.

72. B. Latour, 'Give Me a Laboratory and I Will Raise the World', in K. Knorr-Cetina and M. Mulkay (eds), *Science Observed* (London: Sage, 1983), 141–70.

73. The application of sex hormones was not restricted to biological and medical issues, but also involved agricultural work: see Clarke, op. cit. note 3, 396–401.

74. Latour, op. cit. note 72, 149, 152.

75. Ibid., 159.

76. J. Reed, *The Birth Control Movement and American Society: From Private Vice*

to Public Virtue (Princeton, NJ: Princeton University Press, 1984).

77. O. Amsterdamska, 'Medical and Biological Constraints: Early Research on Variation in Bacteriology', *Social Studies of Science*, Vol. 17 (1987), 657-87.

78. N. E. J. Oudshoorn, 'Dutch Endocrinologists and the Marketing of Sex Hormones 1923-1940', unpublished manuscript. I would like to thank Adele Clarke for advising me to include this argument in this paper. The argument links to the literature on medicalization: see C. Kohler Riessman, 'Women and Medicalisation: A New Perspective', *Social Policy*, Vol. 14 (1983), 3-18; S. E. Bell, 'A New Model of Medical Technology Development: A Case Study of DES', in J. Roth and S. B. Ruzek (eds), *Research in the Sociology of Health Care*, Vol. 4: *The Adoption and Social Consequences of Medical Technology* (London: JAI Press, 1986), 1-32.

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