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The Organization of Industrial Research as a Network Activity: Agricultural Research at Philips in the 1930s

Business historians have shown the importance of industrial research in the process of innovation. Most have focused on the industrial research departments themselves. Less attention has been paid to the position of these departments within research networks outside the firm. This article explores the story of networking at the Dutch company Philips & Co. during the interwar period. Gilles Holst, director of Philips's Research Department at the time, became involved in an agricultural research network that comprised growers, university scientists, and the Dutch government. These networks were essential for Philips's success and provided an opportunity for the company's researchers to keep in touch with scientific circles.

Historical research has shown that the establishment of industrial laboratories is an important element in the process of technological development in the twentieth century.[1] During the first decades, several industrial firms in the United States and Europe established in-house research departments and sought to provide themselves with sources of up-to-date knowledge. Historians have studied how individuals established stable, internal company structures that are needed for

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[1] See Joel Mokyr, *The Lever of Riches: Technological Creativity and Economic Progress* (New York, 1990); David C. Mowery and Nathan Rosenberg, *Technology and the Pursuit of Economic Growth* (Cambridge, U.K., 1989); and Richard R. Nelson, *The Sources of Economic Growth* (Cambridge, U.K., 1996), 114–18. The knowledge-creation process in R&D settings has more than once been described as the heart of the whole complex of innovation. See Christopher Freeman and Luc Soete, *The Economics of Industrial Innovation* (London, 1997), 5; and Nelson, *Sources of Economic Growth*, part 3.

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research activities.[2] They have focused on the strategies that resulted in research departments becoming an essential part of industrial activities.[3]

At the same time, however, these historical studies make clear that the intensified (and complex) relationship between science, technology, and product development did not evolve in a linear manner, but rather grew in response to broad social demands, including the desires of both individual consumers and interest groups, such as user organizations and standardization foundations. The cooperation of firms, universities, and interest groups resulted in knowledge-intensive networks. Industrial researchers not only developed internal structures for research activities; they also created methods of interacting with the environment that transcended the laboratory's boundaries. Industrial research organization was embedded in a wider technical, social, economic, and political context. Doing research in an industrial setting, in other words, became a networking activity.[4]

Today, many social scientists, in particular those engaged in organization studies, are investigating how social networks are formed and how they function. Within current social science, concepts such as network externalities, national systems of innovation, and actor–network theories have been used to explain networking activities.[5] The work of sociologist Mark Granovetter has stimulated business historians to explore how social networks operate.[6] Granovetter sees effective networks as a combination of "strong ties" and "weak ties." He maps patterns of relationships among actors operating within firms that have the potential to expand into long-lasting arrangements involving both individuals and institutions.

The process of information exchange within a network can become an effective coordinating mechanism if the partners to the exchange have developed a common goal. However, the state of equilibrium among

[2] Michael A. Dennis, "Accounting for Research: New Histories of Corporate Laboratories and the Social History of American Science," *Social Studies of Science* 17 (1987): 479–518; and Michael A. Dennis, "Historiography of Science: An American Perspective," in *Science in the Twentieth Century*, eds. John Krige and Dominique Pestre (Amsterdam, 1997).

[3] David A. Hounshell, "The Evolution of Industrial Research in the United States," in *Engines of Innovation: U.S. Industrial Research at the End of an Era*, eds. Richard S. Rosenbloom and William J. Spencer (Boston, 1996), 13–84.

[4] For a recent discussion of innovation in Dutch firms, and especially Philips, see Mila Davids, "Knowledge-Business Networks in the Netherlands: The Case of Philips." Paper presented at the Business History Conference on Networks, Le Creusot, France, 17–19 June 2004.

[5] W. Richard Scott, *Organizations: Rational, Natural, and Open Systems* (Englewood Cliffs, N.J., 1998); Martin Kildruf and Wenpin Tsai, *Social Networks and Organizations* (London, 2003).

[6] See Doreen Arnoldus, *Family, Family Firm, and Strategy* (Amsterdam, 2002), in which she refers to Mark Granovetter, "Economic Institutions as Social Constructions: A Framework for Analysis," *Acta Sociologica* 35 (1992): 3–11; and Mark Granovetter, "The Strength of Weak Ties," *American Journal of Sociology* 78, no. 6 (1973): 1360–80.

the group's members may be upset when the goal is adjusted owing to changes in external circumstances or revisions in one partner's internal strategy.

In this article, I explore the changes that occurred in a research network over a period of about fifteen years. I examine how Philips & Co., a Dutch electronics firm, persuaded partners from industry, the Dutch government, the scientific community, and the company's clients to collaborate on a small agricultural research project.[7] The story of Philips reveals the tensions that emerged when individual participants disagreed over goals. Philips's participation in this network during the 1930s did not come about in a straightforward manner, but was the result of numerous negotiations.

Research at the Philips Research Department

The Philips Electronics company (in Dutch, *De N. V. Philips' Gloeilampenfabrieken*) was established in the Netherlands in 1891 by an engineer named Gerard Philips as a light-bulb company.[8] Industrial companies like Philips were critical to the process of modernization in the Netherlands. Most of them, Philips included, were small-scale firms started with family capital.[9] Large-scale industrialization started relatively late.[10] Dutch industry, once driven by wind, water, and animal power, made the transition to steam, although in many sectors traditional energy sources and steam engines functioned side by side. Toward the end of the nineteenth century, small engines became available, and Dutch entrepreneurs began to power their machines with steam and electricity. Most businessmen imported innovations, such as engines,

[7] The empirical part concerning the history of the Philips NatLab is based upon Kees Boersma, *Inventing Structures for Industrial Research: A History of the Philips Nat.Lab., 1914–1946* (Amsterdam, 2002).

[8] The content of this section is based upon two books (in a series of five) on the history of Philips: Andries Heerding, *The History of N.V. Philips' Gloeilampenfabrieken.* Vol. 2: *A Company of Many Parts* (New York, 1988); and Ivo Blanken, *The History of Philips Electronics N.V.* Vol. 3: *The Development of N.V. Philips' Gloeilampenfabrieken into a Major Electrical Group* (Zaltbommel, 1999). Both books, originally written in Dutch, have been translated into English.

[9] Keetie Sluyterman, *Kerende kansen: Het Nederlandse bedrijfsleven in de twintigste eeuw* (Amsterdam, 2003).

[10] Dutch technology historians have analyzed the transition to a highly integrated society through national schooling systems, transportation, electrification, communication, and a growing sector of modern industrial firms. The Netherlands went through a process of "modernization," which featured demographic transition, urbanization, industrialization, secularization, and bureaucratization. See: Karel Davids, "Recasting the History of Technology in the Netherlands," *Traxtrix* 5 (1993): 161–71; and Dick van Lente, "Technology in Dutch Society during the Nineteenth Century," *Tractrix* 2 (1990): 127–39.

from other countries. However, in order to put these innovations to use, they had to adapt, test, and improve their own manufacturing processes.

The Philips company was a successful innovator from the start. In its early years, it operated as a mass producer of incandescent lamps, soon gaining control of this market niche. Philips increased its production levels constantly. For example, in 1894, it manufactured 75,000 lamps, and the next year its total production jumped to 200,000 lamps. In 1895 Gerard Philips's brother Anton, a salesman, entered the company. Andries Heerding, in his history of the Philips company, describes Gerard as the technician and Anton as the salesman, and he elaborates further on the brothers' distinctive characters, noting that the differences in make-up between Anton and his older brother were exceptional. Gerard, being an engineer, obviously had a good deal of technical knowledge, but was less at home with sales techniques. Anton was more flamboyant, and he turned his aggressive personal style to good use in developing sales strategies. Five years later, Philips produced close to three million lamps, indicating that it had adopted methods of mass production. Moreover, Anton had initiated the policy of selling Philips's products abroad, a move that was important to the firm's growth, since the Netherlands represented only a small market for their products. Foreign sales quickly surpassed sales in the domestic market. The brothers' ability to combine technical and organizational capability was essential to their success in entering new markets, as were their innovations in manufacturing.[11]

Philips eventually became a dominant player in the European incandescent lamp market, accumulating an 11 percent share of this specialty market by 1902.[12] At the time of its founding, a powerful rival had appeared in the United States. The Edison General Electric Company of New York and the Thomson–Houston Company of Lynn, Massachusetts, had merged to form General Electric in 1892—an event that was to have global significance. In order to combat General Electric and other rivals, the major European companies dealing in electricity, such as Siemens & Halske, the Compagnie Générale d'Electricité, and Philips, together with several smaller companies, formed a cartel of carbon-filament lamp manufacturers, called the *Verkaufsstelle Vereinigter Glühlampenfabriken* (VVG), in 1903. According to the Dutch historians Keetie Sluyterman and Hélène J. M. Winkelman, the participation of Dutch firms in industrial cartels in the years before World War I was the exception rather than the rule.[13]

[11] Hans Veldman, *Innovaties in de lampenfabricage bij Philips, 1900–1980* (Eindhoven, 1994).

[12] Heerding, *The History of N.V. Philips*, ch. 3.

[13] Keetie E. Sluyterman and Hélène J. M. Winkelman, "The Dutch Family Firm Confronted with Chandler's Dynamics of Industrial Capitalism, 1890–1940," *Business History* 35 (1993): 152–83.

During negotiations with their competitors within the cartel about markets and products, the Philips brothers realized that they needed to establish long-term solutions if they were to keep up with the technology and maintain their market position. A tradition of innovation was not enough; they also needed to create a stable company structure that nurtured the conditions for innovation, a challenge that required the coordination of human and material resources.

The Philips Research Department

The first research-type activities—or, more specifically, activities not directly related to production—carried out in Dutch companies like Philips took place on the shop floor, not in separate, designated departments. The research involved testing and monitoring products and was conducted by ordinary workers, rather than being assigned to specialized personnel. According to Harry W. Lintsen, a leading Dutch historian of technology, the first such activities were made up of three segments: investigating the quality of raw materials and parts; monitoring production; and testing the quality of final products.[14] Simple instruments—in some cases, unaided sense organs—were used to perform these tests. But the company also took steps to become more knowledgeable about the technology. One approach was to hire foreign craftsmen who were familiar with the imported methods and instruments.

Thus, there were alternatives to the establishment of a research department.[15] Methods of acquiring knowledge included touring other countries and companies, visiting exhibitions, reading technical journals, and buying new machines, such as those needed for making lamp filaments, from which they could gain technical information. Still, confronted with the explosion of technical knowledge and the rising importance of patents, Philips began to think about reorganizing its testing and monitoring activities. The absence of a patent law in the Netherlands before 1912 had enabled Philips to make extensive use of the inventions of others.[16] Dutch industrialists were free to exploit inventions made by foreign, though not domestic, industrial companies. This freedom to expropriate, however, was to change with the passage of a new

[14] Harry W. Lintsen, "Kennisverwerving in de Nederlandse industrie in de 19e eeuw," in *Werkplaatsen van wetenschap en techniek: Industriële en academische laboratoria in Nederland, 1860–1940*, eds. Rob Visser and Casper Hakfoort (Amsterdam, 1987), 175–89.

[15] See Jasper Faber, "Het Nederlandse Innovatiesysteem, 1870–1990," *NEHA Jaarboek* 66 (2003): 208–32.

[16] The earlier patent legislation had been abolished in 1869. See Eric Schiff, *Industrialization without National Patents: The Netherlands 1869–1912, Switzerland 1850–1907* (Princeton, 1971); and F. Gerzon, *Nederland, een volk van struikrovers? De herinvoering van de Nederlandse octrooiwet (1869–1912)* (The Hague, 1986), 1–8.

patent law by the Dutch Parliament in 1910, propelled by strong international pressure. The law went into effect on June 1, 1912. Professional societies recognized the importance of this legislation, as evidenced by the appearance of several articles in *De Ingenieur* (*The Engineer*—the official journal of the Royal Dutch Engineering Association), which discussed the new law's significance to Dutch industry and alerted firms to its potential impact.[17] Philips thus had another incentive to build a research department: coming up with patents of its own.

The Philips Research Department was inaugurated in 1914. At that time, Gerard and Anton decided to found a research organization as a separate part of their company in Eindhoven. They called this department the *Natuurkundig Laboratorium* (Physics Research Laboratory), usually abbreviated as "NatLab." The Philips brothers hired Gilles Holst, a physicist who was working at the university laboratory of the Nobel Prize winner Professor Kamerlingh Onnes, to become their research director. He and other scientists carried out experiments in order to improve the existing light-bulb technology. Over the years, the technological research at NatLab enabled Philips to expand into new markets.

In 1924 the establishment of the Phoebus International Incandescent Light Cartel led to a period of calm for the international incandescent-lamp industry, and, partly as a result, the company started a diversification program, which they expanded through the 1920s and 1930s.[18] Expansion of the laboratory space and the entrance of new researchers gave NatLab the resources to expand its scope of activities to include gas-discharge lamps, X ray tubes, radio tubes and apparatus, and, later, television.

Negotiations with competitors in market cartels had brought home to Philips the importance of patents. Ownership of important Edison patents had allowed General Electric to dominate the incandescent-lamp market for a long time. However, Philips managed to gain ownership of the rights to some of the most important patents after many negotiations with General Electric. As part of its diversification strategy, Philips established a patent department in 1921, appointing Ernst Hijmans, an engineer who had worked at the Dutch Patent Board and at the German *Patentambt* (patent office) in Berlin, as its first director.

[17] See articles (without title) in *De Ingenieur*, 1912, vol. 27, no. 20: 409–13; *De Ingenieur*, 1912, vol. 27, no. 22: 479; *De Ingenieur*, 1912, vol. 27, no. 23: 499–505; *De Ingenieur*, 1912, vol. 27, no. 36: 734.

[18] The Phoebus International Incandescent Lamp Cartel was a Swiss corporation that set the rules, controlled prices, regulated sales and implemented policy. It had established a testing laboratory to ensure the product quality of its members. See Heerding, *The History of N.V. Philips*; and Geoffrey Jones, *The Evolution of International Business: An Introduction* (London, 1996).

Commenting on the necessity of securing patents, Holst remarked: "A favorable condition for the development of a laboratory is that the relevant company occupies itself with mass-manufacture, especially when such mass-produced products can be protected by patents, thus making it possible to earn back the costs invested in research."[19]

Between 1926 and 1937, Holst employed scientists and engineers from a range of educational backgrounds and levels of experience, including engineers with advanced degrees, medical doctors, technicians, instrument makers, and administrators.[20]

For Holst, the industrial laboratory had a practical purpose. He once wrote: "An industrial laboratory is a facility where problems relevant to the industry are investigated with the aid of scientific methods and instruments. . . . Whereas, for example, in a university laboratory one can always think up a problem that can be solved with the aid of the available tools, in an industrial laboratory where the problems are given, one must always ensure that the necessary tools are available."[21] Scientists who worked at NatLab demonstrated the business value of industrial research by becoming the Philips company's new industrial "knowledge workers." In the 1920s and 1930s, Holst and his researchers had become exemplary scientific and technological pioneers in Dutch industrial research. By acquiring good resources, modern equipment, and a laboratory building, NatLab entered a period of growth that enabled it to attract researchers, scientists, engineers, and laboratory assistants to its employee rolls.

The diversification of Philips's research activities has been described as a process of (internal) organization and institutionalization. Perhaps a more important outcome was that it allowed the company to transcend the borders of the research laboratory.

Philips's Research in the Dutch Context

NatLab researchers did not work in isolation. Over the years they became part of broader networks. Holst realized that in order to diversify its line of products, the company would have to combine its internal organizational and administrative structures with an extensive system of external contacts.

[19] Gilles Holst, "Industrielaboratoria." Inaugural speech given in Leiden in 1930 (The Hague, 1930), 3.

[20] Philips Company Archives/Jaarverslagen Natuurkundig Laboratorium (hereafter PCA/NL), Annual Reports.

[21] A remark made by Holst in a proposal relating to the reorganization of the physics laboratory. Quote is from Blanken, *The Development of N.V. Philips*.

Beginning in the 1920s, NatLab began strengthening its ties with government, industry, and universities.[22] This move was part of a broader trend at that time in the Netherlands. It was not unusual for research workers in industry to keep in touch with professors at universities. Such relationships were being forged by the larger companies, such as the *Bataafsche Peteroleum Maatschappij* (now the Koninklijke Shell group) and Philips, and also by the smaller ones, such as Noury & van der Lande, which operated in the dyestuff industry (and is now part of the Akzo Nobel group). The relationship was reciprocal, as university professors became board members at Dutch industrial companies.[23] Such cooperation was a means for professors to gain some extra income or to enhance their own research projects. Dutch professors also saw these connections as a way to remove university research from the exclusive confines of the academic ivory tower in order to conduct research geared toward the larger society. The chemist Hugo R. Kruyt, for example, organized research colloquia with his former students who had found work in industry, while the physicist Leonard S. Ornstein placed eighteen of his former doctoral students at Philips between 1920 and 1941.[24] For the firms, this wider collaboration was a means of learning about the latest scientific investigations and of locating new employees.

Holst also established liaisons with partners outside the industry, a policy that helped initiate the Dutch "system of innovation," best described as the sum of the relationships among Dutch knowledge-intensive institutions, both public and private. Through their participation in the Dutch Electrical Committee, the Dutch Society for Lighting, the Foundation for Materials Research, the Foundation for Sound, the Dutch Institute for Electro-heat and Electro-chemistry, and, finally, the Foundation for Bio-Physics, the NatLab researchers helped to create a system of scientific cooperation that fostered the growth of their own knowledge.

One product of Holst's effort to encourage academic–industrial relations was the establishment of a course on applied physics at the Delft

[22] See for this theme Eda Kranakis, "Hybrid Careers and the Interaction of Science and Technology," in *Technological Development and Science in the Industrial Age: New Perspectives on the Science-Technology Relationship*, eds. Peter Kroes and Martijn Bakker (Dordrecht, 1992).

[23] This dynamic has been beautifully described in the series on the history of technology in the Netherlands. See Peter Baggen, Jasper Faber, and Ernst Homburg, "Opkomst van een kennismaatschappij," in *Techniek in Nederland in de Twintigste Eeuw: Deel VII Techniek en Modernisering*, ed. Johan Schot (Zutphen, 2003), 141–73.

[24] See Ernst Homburg's inaugural speech, "Speuren op de tast: Een historische kijk op industriële en universitaire research," given on the occasion of his appointment to full professorship at the University of Maastricht on 31 Oct. 2003 and published by the University of Maastricht in 2003.

Polytechnic, sponsored by Philips.[25] The effort paid off, as at the end of ten years seventy-nine physics engineers had taken this course.[26] Nineteen of these became employees of Philips, eleven went to the Shell group, and the rest were hired by other, smaller companies.

Despite Philips's eagerness to keep in touch with the universities as a way of facilitating its research activities and recruiting young talents, cooperation was not always easy to achieve. Researchers in industry and at the universities had to seek out ways to work with each other, but they managed to collaborate successfully in a study of the use of artificial light in agriculture.

Using Artificial Light to Cultivate Plants

In November 1931, an agricultural research foundation was established in the Netherlands under the name *Stichting voor Bio-Physica* (Foundation for Bio-Physics).[27] Holst became a member of the foundation's first board of directors. He clearly thought that joining forces with experts in this field would be helpful to Philips, which was planning to diversify its areas of expertise. Researchers at NatLab had done work in biophysics, such as developing special tubes to study the effects of ultraviolet radiation.[28] They had also conducted research in X ray technology, examining its applications in medicine and biophysics.[29]

A strong factor in Holst's eagerness to become affiliated with the foundation was that he felt the connection would enable the company to continue to participate in a study being conducted by the Dutch biologist Johannes M. W. Roodenburg at the University of Wageningen.

[25] For the history of Applied Physics at Delft, see also A. F. Kamp, ed., *De Techniische Hogeschool te Delft, 1905–1955* ('s Gravenhage, 1955), 281–3; R. Kronig, "De opleiding in de technische natuurkunde in Nederland," *Nederlands Tijdschrift voor Natuurkunde* 37, no. 7 (1971): 186–8; P. Aarts, W. Dries, and F. Spierings, "Apparatenbouwers of wetenschappers: De eerste natuurkundige ingenieurs," *Intermediair* 17, no. 36 (1981): 55–63; Wil Kuijpers, *De Technisch Physische Dienst en de Electronenmicroscopie* (Eindhoven, 1987), 10–13; and Henri Baudet, *De lange weg naar de Technische Universiteit Delft I: De Delftse ingenieursschool en haar voorgeschiedenis* (The Hague, 1992), 269, 462–7; and *De lange weg naar de Technische Universiteit Delft II: Verantwoording, registers, tabellen, namenlijsten en bijlagen* (The Hague, 1993), 677–81.

[26] "Laboratorium voor Technische Physica T.H. Delft: Herdenking, 1930–'40," *De Ingenieur* 55, no. 50 (1940): A448.

[27] PCA/NL 327. Stichting Bio-Physica. Minutes of the first official meeting of the Stichting voor Biophysica, 25 Nov. 1931.

[28] PCA/NL 324. Bestralingslampen. Verdere ontwikkeling van den verkoop van Ultrasolapparaten van ir. Verff, 11 Dec. 1931.

[29] See Kees Boersma, "Tensions within an Industrial Research Laboratory: The Case of the X-ray Department of the Philips Research Laboratory between the Two World Wars," *Enterprise and Society* 4 (Mar. 2003): 65–98.

Dr. Roodenburg was using Philips lamps to study the effects of artificial light on plant growth. He had written to Philips in 1928 about the promising application of artificial light in greenhouses, offering to use the company's lights to cultivate plants for the benefit of horticulture.[30] Roodenburg's uncle, Jan Feith, who was a personal friend of Anton Philips, later recommended his nephew to Holst as a potential researcher.[31]

In his letter, Roodenburg, who until then had worked as an independent biologist, described his plans for the research project, which entailed using artificial light during the winter, when the amount of daylight in the Northern Hemisphere, even in glass houses, is insufficient to allow plants to achieve their full growth. Referring to international research, he described how a grower could make use of artificial light to improve this situation.[32] Holst's communication with this biologist was an important first contact in creating a network of institutes, researchers, and government agencies that would open up new sources of knowledge and would prove its worth in the coming decade.

NatLab's Position in the Research Network

Roodenburg was familiar with the literature on artificial lighting in agriculture that had been carried out in Berlin and at the Dutch University of Wageningen, largely to find the most effective color for

[30] PCA/NL 546. Plantenbestraling. Letter from Dr. J. W M. Roodenburg to Gilles Holst, Baarn, 18 July 1928.

[31] Roodenburg wrote a thesis about the relation of oxygen to humus and plant rot. See J. W. M Roodenburg, *Zuurstofgebrek in den grond in verband met wortelrot* (Baarn, 1927).

[32] See A. E. Canham, *Artificial Light in Horticulture* (Eindhoven, 1966). Not investigated in this paper, but worth mentioning here, is that research into artificial lighting for agriculture also took place at other industrial companies, such as General Electric. In the first decade of the twentieth century, GE's electrotechnical wizard Charles Proteus Steinmetz experimented with the effects of lighting on the growth of plants in a little greenhouse. See Schenectady Museum Archives, Hammond File, L 5118; and Bernard Gorowitz and George Wise, eds., *The General Electric Story, 1876–1986: A Photohistory*. Part 2: *The Steinmetz Era, 1892–1923* (Schenectady, N.Y., 1989), 38. Later, this agricultural research became more serious within GE. See F. H. Kranz and J. L. Kranz, *Gardening Indoors under Lights* (New York, 1957). Like Philips, GE was searching for new markets for incandescent lamps—the market niche of gardeners seemed to be a promising one. As far as specific research into artificial lighting is concerned, Philips and GE did not exchange information—both firms operated independently (and in different markets) in this case. On a more general level, we can find similarities in the way both firms developed structures for industrial research. However, both companies' R&D managers developed local strategies for research activities. See Kees Boersma, "Structural Ways to Embed a Research Laboratory into the Company: A Comparison between Philips and General Electric," *History and Technology* 19, no.2 (2003): 109–26.

lighting and also to classify the ways plants respond to light.[33] Roodenburg wished to discover the most suitable light source for plant irradiation, and he was also interested in the question of how artificial light affected growth in different plant species. He asked Philips to finance his research project and to provide expert knowledge on lighting.

Within a few months, Roodenburg had found a place at the University of Wageningen to start his research, and he had located a biologist, Professor A. M. Sprenger, who was willing to lend his laboratory and greenhouse and to collaborate on the project.[34] Roodenburg's liaison at NatLab was Dr. G. Zecher, who had worked at Philips since 1924 and had built up considerable expertise on gas-discharge lamps. In the first months of 1929, NatLab delivered light bulbs, neon lamps, and mercury-vapor discharge lamps to Roodenburg. Moreover, Zecher and Roodenburg engaged in a lively exchange of ideas and information about lighting research.

Philips offered Roodenburg a contract, beginning in the fall of 1928, to study the effects of artificial light on plant growth in the laboratories at Wageningen.[35] In drawing up the contract, Holst listed three conditions: Roodenburg was not allowed to publish any results without Philips's permission; he had to clarify his findings whenever Holst wanted him to; and he would receive a salary of 200 guilders each month and would be given the required light sources free of charge.

Philips also agreed to finance the extra electricity Roodenburg would need for his experiments—a major expense—and to pay the salaries of his assistants. Eventually, the company would also fund the construction of more research space for Roodenburg's experiments.[36]

Roodenburg had thus managed to construct a network that met the requirements for his research activities. He could make use of a university laboratory, and he had Philips's financial backing. For his experiments, he used Philips's lamps and accessories, and he had access to Zecher's expertise at NatLab. For Holst, this project was a new experience. The "Roodenburg project" was described in NatLab's Annual Reports as a network of industry and university members based on the idea of reciprocity.

[33] See: G. Höstermann, *Versuche mit Neonlicht* (Dahlem, 1918) and A. H. Blaauw, *Die Perzeption der Lichtes* (Utrecht, 1909). For the context of the biological research activities at the Dutch universities, see Klaas van Berkel, Albert van Helden and Lodewijk Palm, *A History of Science in the Netherlands* (Leiden, 1999), 183–9; Patricia E. Faasse, *Experiments in Growth* (Amsterdam, 1994), ch. 3.

[34] PCA/NL 546. Plantenbestraling. Letter from Roodenburg to Holst, 3 Sept. 1928. Letter from Roodenburg to Oosterhuis, 17 Sept. 1928.

[35] PCA 881. Contract file 940. Letter from Van Walsem, secretary of the Philips Board of Directors to Roodenburg, 19 Sept. 1928.

[36] Ibid.

Forging Contacts with the Dutch Agricultural Experimental Stations

Once Roodenburg had the financial resources to expand his project, he contacted other knowledgeable experts. In the autumn of 1930, Roodenburg corresponded with researchers at agricultural experimental stations, whose work for the benefit of Dutch growers was funded by the government.[37] Roodenburg met Johannus Marinus Riemens, an engineer who worked as a government consultant and was the head of the state agricultural experimental station in the Dutch village of Naaldwijk. Riemens had experimented with artificial light in his greenhouse before 1930 as part of a national research program.[38]

Similar government-financed experiments took place in other agricultural experimental stations, such as Aalsmeer, Horst, Groningen, and Naaldwijk. The heads of these stations shared their knowledge with researchers from interest groups and universities. Riemens, for example, worked with researchers from the University of Wageningen. After meeting with Roodenburg, Riemens decided to investigate artificial light for growers in *Het Westland* (the Westland), a region in the western part of the Netherlands where many growers worked in greenhouses.[39]

On Roodenburg's recommendation, Philips agreed to support Riemens's research as well, and he was given lamps, neon tubes, and various devices, such as reflectors.[40] Riemens used artificial light to grow

[37] D. J. Maltha, *Honderd jaar landbouwkundig onderzoek in Nederland, 1876–1976* (Wageningen, 1976). Also see *Gedenkboek uitgegeven bij het vijftigjarig bestaan der Rijkslandbouwproefstations, 1927* ('s Gravenhage, 1927); and A. J. Vijverberg, *Glastuinbouw in ontwikkeling: Beschouwingen over de sector en de beïnvloeding ervan door de wetenschap* (Delft, 1996). At the same time, these experimental stations contributed to the application of scientific findings of the food industry. See Anneke H. van Otterloo, "Nieuwe producten, schakels en regimes, 1890–1920," in *Techniek in Nederland in de Twintigste Eeuw: Deel III Landbouw, Voeding*, ed. Johan Schot (Zutphen, 2000), 254. Indirectly, these stations influenced the food supply of the Dutch consumer. See Anneke H. van Otterloo, "Voeding in verandering," in *Techniek in Nederland in de Twintigste Eeuw: Deel III Landbouw, Voeding*, ed. Johan Schot (Zutphen, 2000), 242–5.

[38] ARA Deelarchief 2.11.09, Verslagen en Mededelingen van de Landbouw, 1815–1966, Bestanddeel 21 Lijst van officiële personen, instellingen en verenigingen op land- en tuinbouwgebied 1914–1933 (a list of key persons and the main institutes that participated in the Dutch agricultural sector). See also *25 Jaar Tuinbouw—onderwijs—voorlichting—onderzoek in het Zuid-Hollands Glasdistrict, 1924–1949: Jubileum-uitgave aangeboden aan Ir J. M. Riemens ter gelegenheid van het 25-jarig directeurschap van de Proeftuin Zuid-Hollands Glasdistrict* (Amsterdam, 1949), 139–43. Harro Maat describes the features of the Dutch argicultural innovation system in "Het innovatiesysteem voor de Nederlandse landbouw," *NEHA Jaarboek* 66 (2003): 233–62.

[39] "The Westland" is part of the province of Zuid Holland (South Holland), in the western part of the Netherlands. In this part of the Netherlands there were, and still are, a lot of greenhouses.

[40] See also *25 Jaar Tuinbouw*, 139–43.

cucumber plants in 1930, reporting on his activities to Philips in February 1931.[41] He cited the positive reactions to his research activities from growers, who reported significantly better crop results than usual, and he pointed out that news of such outcomes would stimulate a new market for Philips's lamps. He even argued that his experiments were more beneficial to the company than Roodenburg's, because his close contact with individual growers allowed him to become familiar with the practical problems they faced.

A Growing Network: The Involvement of Other Research Institutes

Philips's research also benefited from the involvement of the Dutch *Vereeniging van Directeuren van Electriciteitsbedrijven in Nederland* (Society of Directors of Dutch Electricity Companies), or VDEN. This association was founded by independent Dutch provincial electricity companies in 1913 in order to improve cooperation among the electric companies and to form a unified coalition in discussions and negotiations with the government, which set the rules for the internal electricity market during this period.[42] In the 1920s and 1930s, VDEN promoted the use of electricity in the Netherlands and participated in several cooperative projects to create electricity for industrial, agricultural, medical, and household use. In carrying out this campaign, VDEN provided free electricity to faculty who were conducting industrial experiments at Wageningen, including Sprenger, and to the government agricultural experimental stations. Johannes C. van Staveren, director of VDEN, wrote to Philips requesting an increase in financial support to the work on artificial light being conducted in the experimental stations.[43] Van Staveren also asked Philips to provide technical details on neon tubes so that VDEN mechanics could install them in the growers' greenhouses.

In March 1931, VDEN invited Holst to a meeting to discuss the benefits of studying artificial light in agricultural experimental stations, and he was given a tour of the laboratories at Wageningen. In the following years, VDEN held annual meetings to discuss the results of research experiments with artificial light and to plan further research.

[41] PCA/NL 545. Plantenbestraling. Report of Riemens, Proeftuin Westland Naaldwijk, 9 Feb. 1931.

[42] Geert Verbong, "Energie," in *Techniek in Nederland in de Twintigste Eeuw. Deel II Delfstoffen, Energie, Chemie*, ed. Johan Schot (Zutphen, 2000), 113–267.

[43] PCA/NL 544. Plantenbestraling. Letter from J. C. van Staveren on behalf of the VDEN to the Philips Board of Directors, 27 Jan. 1931.

The meetings became a way for the organization's members to communicate on a regular basis.

While relations were being forged between Philips and the electricity association, a new participant from outside the industry joined the network, expressing its willingness to aid Holst and Roodenburg. The *Nederlandsche Verlichting Comité* (NVC) (Dutch Lighting Committee) had been started by partners from industry and the university to promote the use of lighting and to send delegations of Dutch lighting experts to meet with international standardization committees. During meetings of the *Nederlandsch Natuur- en Geneeskundig Congres* (Dutch Physical and Medical Congress), several NVC physicists, physicians, and biologists decided to establish a new foundation for the purpose of studying collective research questions emanating from their three disciplines. An NVC subcommittee was assigned to produce a plan that would strengthen contacts between physicists and biologists and encourage cross-fertilization of ideas about lighting. The subcommittee organized a meeting in April 1931, where representatives of both disciplines discussed the features of the new foundation. Professors Cornelis J. Gorter and Hendrik B. Dorgelo invited Holst to attend the meeting, where the participants began to make plans for building the network and structuring the newly conceived multidisciplinary organization.[44]

The association that grew out of the proceedings of this subcommittee was called the *Stichting voor Bio-Physica* (Foundation for Bio-Physics), and Holst, as representative of the Dutch industry, eventually became a member of the board.[45] Another foundation that enabled Holst and Roodenburg to share information about artificial lighting was the *Nederlandsch Genootschap voor Verlichtingskunde* (NGVV) (Dutch Society for Lighting), which was established in 1926 and became a leader in establishing standards for lighting. One member of the association, for instance, played a pivotal role in changing the unit measure for lighting with neon tubes.[46]

Roodenburg's Output: Artifacts and Articles

A 1932 issue of the journal *Philips Industry* listed some of Roodenburg's accomplishments. One of his inventions was an apparatus

[44] PCA/NL 327. Stichting Bio-Physica. Letter from Professor Dr. E. Gorter and Professor Dr. H. B. Dorgelo, 20 Apr. 1931; and letter from Dr. E. H. Reerink to Professor Dr. E. Gorter and Professor Dr. H. B. Dorgelo, 24 Apr. 1931.

[45] PCA/NL 327. Stichting Bio-Physica. Letter from Professor Dr. E. Gorter and Professor Dr. H. B. Dorgelo to Holst, 15 May 1931; and Ontwerp Statuten voor de Stichting voor Bio-Physica, May 1931.

[46] PCA/NL 546. Plantenbestraling. Letter from Zecher to Roodenburg, 19 Nov. 1932; and letter from Zecher to Roodenburg, 2 July 1934.

featuring a reflector that shone direct light on the plants. Another was a germination box containing lamps that maintained a consistent temperature of heat.[47] In addition to publishing in the company journal, Roodenburg described the findings of his research in the popular and scientific press. His main scientific article, "Kunstlichtcultuur" (Artificial Light), appeared in *Mededeelingen van het Laboratorium voor Tuinbouwplantenteelt'* (*Journal of the Laboratory for Horticultural Botany*) published by Wageningen University. In it, Roodenburg declared that a practical use of artificial light would be in permanent installations, an idea that, if adopted, would mean a big potential market for Philips. The article reveals Roodenburg's willingness to share his work, as he described the conditions under which he carried out his experiments, adding details of the environmental temperature, the distance of the light source from the plants, the light intensity, the mechanics of the reflectors, and the peculiarities of the plants.

Philips's cooperation with Roodenburg, Sprenger, and Riemens got the attention of foreign researchers as well as domestic scientists. A special committee was established in Sweden, for instance, to study the possibilities of using artificial light in greenhouses.[48] As occurred in the Netherlands, the Swedish Electricity Companies became involved in research projects that benefited from receiving free electricity. Once Philips established contacts with Swedish researchers, Holst insisted on maintaining close cooperation with them.[49] Roodenburg was also convinced of the usefulness of international scientific contacts.

In addition to communicating with colleagues in the world of agricultural science, Roodenburg wrote for design engineers. In 1936, he and Zecher published a technical article in the *Philips Technisch Tijdschrift'* (PTT) (*Philips Technical Review*) that described tubes in some detail and outlined procedures for the electric and mechanical installation of artificial lights.[50]

Apart from his scientific and technical papers, Roodenburg wrote in popular magazines for a broader audience. In an issue of *Natuur en Techniek* (*Nature and Technology*), he wrote an article entitled "Als de zon ons in de steek laat" (If the Sun Deserts Us), in which he explained the practical benefits of artificial light for plant growth, emphasizing the

[47] R. van der Veen and G. Meijer, *Light and Plant Growth* (Eindhoven, 1959), 130–5.

[48] PCA/NL 546. Plantenbestraling. Letter from Zecher to Roodenburg, 20 Apr. 1931.

[49] PCA/NL 517. Plantenbestraling. Kunstmatige Plantenbelichting in Nederland. A Report from Dr. Roodenburg, June 1937.

[50] J. W. M. Roodenburg and G. Zecher, "Plantenbestraling met Neonlicht," *Philips Technisch Tijdschrift* 1, no. 7 (1936): 193–9.

suitability of Philips's technology for professional application and its usefulness for private persons and hobbyists.[51]

Philips also promoted Roodenburg's findings. In 1934 the Philips information office published an article on its plant irradiator, analyzing the results of research projects that had used neon tubes made by Philips.[52] Contributors to the article worked in several agricultural experimental stations, both in the Netherlands and in Belgium and Sweden, and all reached the same conclusion: lighting with neon tubes produced the best results for plant growth.

After five years of research and an investigation that became international in scope, Roodenburg had turned artificial lighting into a promising business proposition for Philips. Philips had not only developed plant irradiators for the professional market but had also produced neon tubes suitable for irradiating plants in private living rooms. Even architects of private homes used neon tubes designed for small-scale nurseries in planning windowsills for their clients' houses.[53] Thus, even a market of this small size did not escape Philips's attention.

Retreat from Research

In the early 1930s, economic crisis caused Dutch industry major difficulties.[54] The depression of the 1930s forced the company's management to think about cutting back its activities. In the summer of 1928, a Dutch professor of business economics, Jan Goudriaan, was made head of the Business Organization Department.[55] His first move was to set up a budget in order to slow the growth of the workforce and cut back its salary requirements. A newly established Central Budget Committee enabled the company's managers to exert more control over the allocation of financial and workforce resources, including those directed to NatLab.

Philips still gave Roodenburg financial aid but pressed him to curtail expenditures. In the late 1930s, Holst began to express doubts

[51] J. W. M. Roodenburg, "Als de zon ons in de steek laat," *Natuur en Techniek* 1 (1931): 276–9 and J. W. M. Roodenburg, "Rood licht voor kasplanten," *Weekblad voor de Koninklijke Nederlandse Maatschappij voor Tuinbouw en Plantkunde* 28 (1934), esp. p. 8.

[52] PCA/NL 545. Resultaten verkregen met den Philips Plantenbestraler. Vroege bloei—Rijkere oogst, Afdeling Industrie Centraal Bureau voor Documentatie, 15 Sept. 1934.

[53] A design of a windowsill created by the architect Ir. P.H.N. Briër is discussed in B. Roodenburg-Van der Harst, "Het bloemenvenster met Neonlicht," *Floralia, Weekblad voor bloem en tuin* 57, no. 38 (1936).

[54] Jan Luiten van Zanden, "The Dance Round the Gold Standard: Economic Policy in the Depression of the 1930s," in Jan Luiten van Zanden, ed., *The Economic Development of The Netherlands since 1870* (Cheltenham, 1996).

[55] Blanken, *History of Philips*, 362–8.

about the project's financial benefits to Philips, and in 1936 he announced plans to halt the company's participation within a period of three years. Roodenburg was, of course, disappointed about this plan to halt support so soon. He was also disappointed with the attitude shown by Philips's salesmen.[56] Friction between Roodenburg and the Philips salesmen grew out of their different interests. Roodenburg had made recommendations to growers about the ideal intensity of illumination for plant growth, which he backed by citing the results of his scientific experiments. Philips sales agents, however, advised the growers to cut down on the intensity of illumination in order to save energy costs. This advice conflicted with Roodenburg's scientific finding that a decrease in intensity was unfavorable for plant growth. Roodenburg accused the salesmen of giving the growers inaccurate instructions in order to improve Philips's sales numbers.[57]

Holst informed Roodenburg that his research had to produce a benefit to Philips. The stumbling block to Philips's continuing participation was the installation for artificial lighting, which was proving too expensive for individual growers, with the result that the number of installations dropped and sales were disappointing, both in the Netherlands and abroad. Philips then decided not to continue sponsoring the research. In 1939, Roodenburg's contract with Philips ended, and he left Wageningen to start a new research project at the agricultural experimental station of Aalsmeer.

During the German occupation, Philips was not involved in any botanical research, and thus the only contacts that remained between Holst and Roodenburg were informal. Although he continued to inform Holst about some of his projects at Aalsmeer, Roodenburg's formal working relationship with Philips was over.

Conclusion

In the first decades of the twentieth century, Philips's Research Department joined an effective Dutch network of representatives from the agricultural industry, universities, the government, and various interest groups (including plant growers and home consumers). Philips's participation in this networking activity was part of a broad company innovation policy.

[56] PCA/NL 546. Plantenbestraling. Letter from Roodenburg to Holst, 25 Nov. 1936.

[57] Roodenburg's opinion that the Philips's salesmen could not do justice to their promises was shared by Riemens's agricultural experimental station. See *25 Jaar Tuinbouw –onderwijs –voorlichting –onderzoek in het Zuid-Hollands Glasdistrict 1924–1949. Jubileumuitgave aangeboden aan Ir J.M. Riemens ter gelegenheid van het 25-jarig directeurschap van de Proeftuin Zuid-Hollands Glasdistrict* (Amsterdam, 1949), 139–43, esp. 140.

During its first twenty years, Philips became a mass producer of light bulbs and began operating in an international market. As part of a strategy to strengthen its organizational capabilities, it launched in-house research activities in 1914. Beginning in 1920, Philips sought out new markets, both for its existing light-bulb technology and for new products, such as radio and X ray tubes. Philips was innovative, launching its own internal research-and-development department and sustaining its networking activities. The network approach reveals the ongoing reciprocal interaction between Philips researchers and their environment. Holst, as the research director, knew that it was not enough to match the company's inventions to the local situation. He and the NatLab researchers were convinced of the benefits of participating in scientific and technological networks, viewing collaboration as a way to keep in touch with scientific circles and to influence technological developments outside the firm.

Philips's decision to participate in networks was not entirely trouble free. The company had to decide what it wanted to share with network partners. Should it, for example, give away its knowledge to partners in the agricultural sector? After all, competitors might be interested in exploiting the company's research. Philips created a Patent Department to protect its "intellectual property" rights to innovations. Moreover, by stipulating in its contract with Roodenburg that he had to obtain permission from Holst before publishing any of the results of his experiments, the company placed limits on the exchange of knowledge. Philips was thus able to share its knowledge within the scientific–technical (agricultural) network without losing control of its technical expertise.

The goal of NatLab's research division was to stimulate researchers to participate in networks made up of scientists and other representatives from universities, industry, and the government. Partners within the network had their own motives for cooperating, but over the course of time these motives did not always mesh. Still, the network facilitated the company's access to outside technological and scientific developments, providing a means to control the direction it would take in manufacturing and diversifying its products.