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Creating an Agricultural Research Network: Irradiation of Plants with Artificial Light at Philips Research in the 1930s

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This paper tells the story of a networking activity of Philips' researchers in the inter-war period. Holst, the director of Philips Research (in Dutch: Natuurkundig Laboratorium) at the time, became involved in an agricultural research network with partners from the universities, the Dutch government, standardization committees, and growers. Building upon social-network and organization theories, I show that this activity was an opportunity for the Physics Lab researchers to keep in touch with scientific circles. Philips offered money and knowledge to Johannes Roodenburg, a biologist, who initiated the network-activities by starting research programs on artificial lighting of plants. As a result of the economic crisis and disappointing sales results, Holst cut back financial support at the end of the 1930s. It was only after the Second World War that Philips gave agricultural research a renewed impetus, but within a new research-context.

Historical research has shown that the establishment of industrial laboratories is an important element in the technological development process of the twentieth century. The outcomes of industrial, scientific research are often conceived as one of the driving forces of economic growth.[1] In the first decades of the twentieth century, several industrial

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[1] See Joel Mokyr, *The Lever of Riches: Technological Creativity and Economic Progress* (New York, 1990); and David C. Mowery and Nathan Rosenberg, *Technology and the Persuit of Economic Growth* (Cambridge, U.K., 1989), and Richard R. Nelson, *The Sources of Economic Growth* (Cambridge, Mass., 1996), 114-8. The knowledge-creation process in R&D (Research & Development) settings has more than once been described as the heart of the whole complex of

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firms in America and Europe established in-house research departments and consciously sought to provide themselves with up-to-date knowledge. Thus far, historians have studied how individuals established the stable, internal company structures needed for research activities.[2] Thus, the focus has been on individual activities and strategies that have resulted in the institutionalization of the industrial research department.[3]

At the same time, these historical studies make clear that the intensified (and complex) relationship between science, technology, and product organization was not a linear process from industrial firms to the market. Broader social demands, interest groups, and consumers in society also guided such processes. Cooperation among firms, universities, and interests groups has resulted in knowledge-intensive networks. Industrial researchers not only developed internal structures for research activities, but also pro-actions and reactions vis-à-vis the environment, transcending the laboratory's boundaries. Industrial research organization became embedded in a wider technical, social, economic, and political context. Doing research in an industrial setting was a networking activity. This raises the question of how the historian can understand, describe, and analyze industrial research networks. While historians typically focus on the activities of scientists and technologist within the research and development (R&D) setting, I focus on broader networks of researchers and research institutions.

Today, many social scientists, in particular those engaged in organization studies, use different theories to understand the implications of social networks. Within current social science theory, concepts such as network externalities, business networks, national systems of innovation, and actor-network theories, have emerged for understanding and explaining networking activities.[4] In-depth historical studies of the knowledge attributes involved and of the characteristics of the innovation process itself, have contributed to the analysis of internalization's role of in the evolution of firms' capabilities. The knowledge-based view of the firm emphasizes that the accumulation and application of knowledge builds organizational capabilities.[5] From a resource-based perspective, partnerships are driven by strategic resource needs. These resources can

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innovation; see Christopher Freeman and Luc Soete, *The Economics of Industrial Innovation* (London, 1997), 5.

[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.

[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*, ed. Richard S. Rosenbloom and William J. Spencer (Boston, Mass., 1996), 13-84.

[4] W. Richard Scott, *Organizations: Rational, Natural, and Open Systems* (Englewood Cliffs, New Jersey, 1998).

[5] Robert Grant, "Toward a Knowledge-Based Theory of the Firm," *Strategic Management Journal* 17 (Winter 1996): 109-122.

be found inside and outside the firm. Examining the networks that constitute the firm, and the inter-organizational networks in which the firm is embedded, can help us understand the firm's strategic choices.[6]

Sociologist Mark Granovetter's contribution is especially important in social network analyses.[7] In his theory, Granovetter tries to map patterns of individual social partners' relationships, for example within and between firms. In his view those contacts can expand into durable social networks of both individuals and institutions. It is especially the contacts with other networks (the so-called weak ties) that provide individuals with new knowledge.[8] Strong ties are the network relationships between people in close contact with each other (for example, colleagues within a laboratory). Weak ties will bridge certain cliques (such as homogeneous networks with internal-focused members) and permit organized action by collective members. The concepts of strong and weak ties enable us to understand network enrollment. Without the use of weak ties, the overall structure of the collective would be fragmented.

This does not mean, however, that each network will become well-balanced and stable. In accordance with the contingency approach, the idea of a coordinated, balanced network is irrelevant here.[9] Organizational contingency frameworks involve coordination mechanisms based on information exchange. The information exchange within a network can become an effective coordination mechanism if partners adjust their cognitive frameworks and develop a joint goal. However, these cognitive frameworks and goals can be changed over time by external circumstances and/or strategic choices inside the firm. The question here is to investigate the mix between strong and weak ties in an R&D network at any given time and to study how the network's choices and actions made it subject to change.

In this paper, I use the notion of networking behavior with respect to the firm's research activities to illustrate strategies at the Dutch

[6] Martin Kildruf and Wenpin Tsai, *Social Networks and Organizations* (London, 2003).

[7] Mark Granovetter, "Economic Institutions as Social Constructions: A Framework for Analysis," *Acta Sociologica* 35 (Fall 1992): 3-11. Granovetter's theory has proven useful in business historical research; see Doreen Arnoldus, *Family, Family Firm, and Strategy* (Amsterdam, 2002).

[8] Mark Granovetter, "The Strength of Weak Ties," *American Journal of Sociology* 78 (Winter 1973): 1360-80.

[9] John Child, "Strategic Choice in the Analysis of Action, Structure, Organizations and Environment: Retrospect and Prospect," *Organization Studies* 18 (Jan. 1997): 43-76; and Norman Jackson and Pippa Carter, *Rethinking Organisational Behaviour* (London, 2000).

multinational Philips.[10] The major empirical question is: how did a small amount of agricultural research activity at Philips become part of a bigger network of partners from industry, the Dutch government, the scientific community, and clients? Although the network enabled researchers to develop new ideas, the story also shows that tensions grew within the network because the aims and goals of the individual participants were not always compatible. Philips' participation in this network in the 1930s was not a straightforward matter, but, rather, the result of numerous negotiations. In sum, in this paper I trace how Philips' researchers got involved in the network of agricultural research institutes in the 1930s and how this network developed over the years.

Research at the Philips Research Lab, 1914-1940

Gerard Philips, whose research department is the focus of this paper, established the Philips company as a light bulb company in the Netherlands in 1891.[11] Production levels of the incandescent lamps made by Philips increased constantly: 75,000 lamps were manufactured in 1894 and 200,000 lamps during the following year. By 1900, Philips produced about 3,000,000 lamps, indicating that it had realized mass-production; Philips' growth and development towards a multinational was unique in the Netherlands.[12] From the very start, Philips wanted to sell its products in foreign countries. The Netherlands had only a small market; thus, sales to markets abroad quickly eclipsed those in the domestic market.

The Philips brothers' ability to combine technical and organizational capability was an essential ingredient for entering new markets. Conservative financing methods resulted in a strong competitive position. Philips had a commanding presence in the international incandescent lamp scene, which proved to be a turbulent market. The merger between the Edison General Electric Company of New York and the Thomson-Houston Company at Lynn, Massachusetts to form General Electric (GE) resulted in the formation of one dominant U.S. company, which was to have significant influence worldwide.

Unlike the situation in the United States, the major companies in Europe, like Siemens & Halske, the Compagnie Générale d'Electricité, and

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[10] The empirical work concerning the history of the Philips Natuurkundig Laboratorium is based upon: Kees Boersma, *Inventing Structures for Industrial Research: A History of the Philips Nat.Lab.:1914-1946* (Amsterdam, 2002).

[11] This section is based on Heerding and Blanken's two books (of the series of five) on the history of Philips: A. Heerding, *The History of N.V. Philips' Gloeilampenfabrieken vol. 2: A Company of Many Parts*, trans. Derek S. Jordan (Cambridge, U.K., 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).

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

Philips & Co., together with several smaller companies got together in 1903 after some years of struggle and formed the European cartel of carbon-filament lamp manufacturers, called the Verkaufsstelle Vereinigter Glühlampenfabriken (VVG). 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 technological and market race. It was not enough for Philips to simply have a tradition of innovation; they also needed a stable company structure that permitted the coordination between people and resources necessary for developing innovations.[13]

The Philips Research Department was started in 1914. At that time, Gerard Philips and his brother 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]. The Philips brothers hired Gilles Holst as research director. He and other researchers carried out scientific experiments in order to improve existing light bulb technology. The establishment of the research laboratory was not the only indicator of Philips' innovative character. The Dutch historian Veldman has described Philips' innovations in the manufacture of incandescent lamps. This manufacturing process was characterized by mass production, the pursuit of standardization, and improvements made to the production process by engineering work.[14]

Over the years, research at the Physics Lab became important in Philips' attempt to grow into new technological markets. Philips implemented a diversification policy. Part of this policy in the 1920s and 1930s was a new research program in the Physics Lab designed to fulfill Philips' wishes. Expansion of means and labor gave the Physics Lab needed resources and enabled researchers to expand the scope of their activities. Research into artifacts, such as gas discharge lamps, X-ray tubes, radio tubes and apparatus, and later into television and materials, expanded from then on.

Holst employed many new scientists and engineers in the 1930s. Table 1 shows the total number of employees (together with their educational backgrounds) working at the Physics Lab between 1926 and 1937.

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[13] Other historians also emphasize this point, for example, Louis Galambos, "The American Economy and the Reorganization of the Sources of Knowledge," in *The Organization of Knowledge in Modern America 1880-1920*, ed. Alexandra Oleson and John Voss (Baltimore, Md., 1979), 269-282.

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

TABLE 1
Physics Lab employees.

Annual report	31 Dec. 1926	31 Dec. 1927	31 Dec. 1928	31 Dec. 1929	31 Dec. 1930	1 Jan. 1932	1 Jan. 1933	1 Jan. 1934	1 Jan. 1935	1 Jan. 1936	1 Jan. 1937
Doctors	14	16	22	26	31	30	33	34	43	48	47
Masters	2	4	1	4	4	2		1	5	3	3
M.D.s					1	1	1	1			
Engineers	12	16	24	27	34	24	23	35	47	52	57
Subtotal.	28	36	47	57	70	57	57	71	95	103	107
Asst. HBS	26	33	48	62	75	56	49	48	45	42	42
Asst. MTS	13	16	19	20	31	23	19	16	9	11	13
Asst. misc.	2	4	5	13	16	14	16	17	15	15	18
Subtotal.	40	53	72	95	122	93	84	81	69	68	73
Instr. makers	3	4	5	7	8	5	5	6	8	12	11
Misc.					6	7	8	9	9	12	11
Designers					5	2	1	2	3	3	4
Administr.					8	9	8	10	10	11	12
Subtotal	72	93	124	159	219	173	163	179	194	209	218
Rest of group		81	95	154	169	135	134	161	211	206	213
TOTAL		174	219	313	388	308	297	340	405	405	431

Source: Philips Company Archives/Natuurkundig Laboratorium (PCA/NL) Jaarverslagen Nat.Lab. (Annual Reports).

Holst's idea about what an industrial laboratory's task should be, became clear in a proposal in which he said that:

> ...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.[15]

Scientists who worked in the Physics Lab proved the business value of industrial research for the Philips company. They became the new industrial "knowledge workers" of the first decades of the twentieth century. In the 1920s and 1930s, Holst and his researchers had set an example for scientific and technological pioneers in Dutch industrial research. The Physics Lab went through a period of growth, having good resources, modern equipment, and a laboratory building at its disposal. A growing number of researchers, scientists, engineers, and assistants

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[15] Holst made this remark in a proposal relating to the reorganization of the physics laboratory; see Ivo Blanken, *The History of Philips Electronics N.V.*, 189.

worked in this industrial research organization; they were the source of the Physics Lab's specific knowledge.

I have characterized the research activities at Philips as a process of (internal) organization and institutionalization. In what follows, it will be clear that diversification at the Philips research department transcended the borders of the research lab.

External Contacts of Physics Lab Researchers

The fact that the Physics Lab researchers worked within an industrial setting does not mean that they were isolated persons locked away in the company. Over the years, they became part of broader research networks inside and outside the firm. Holst realized that a diversification process needed not only stable internal organizational and administrative structures, but also intensive external contacts. Research, as he saw it, was about building networks, because professional ties and alliances outside the firm enabled further research. Therefore, Physics Lab-researchers developed "hybrid careers," with both industry and university contacts.

Since the mid-1920s, the Physics Lab has provided an interesting partnership for several actors from government, industry, and universities. Holst was conscious of the role of the Physics Lab as a player in an industrial network. As a result, Physics Lab researchers formed part of important foundations in the (Dutch) "system of innovation"[16], for example, 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. Thus, Philips researchers were engaged in various fields within the electrotechnical sector.

In addition to working together with researchers outside Philips, Holst was also eager to keep in touch with the academy to recruit and retain young scientists and engineers. A major example of his efforts to establish academic-industrial relations was the establishment of an applied physics course at the Delft Polytechnic (THD). The urgent need to combine physics with practical skills provided the occasion for Philips to insist on the creation of the applied physics curriculum at the THD.[17] The

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

[17] For the history of Applied Physics at Delft see also A. F. Kamp, ed., *De Technnische Hogeschool te Delft 1905-1955* ('s-Gravenhage, 1955), 281-283; R. Kronig, "De opleiding in de technische natuurkunde in Nederland," in: *Nederlands Tijdschrift voor Natuurkunde* 37 (1971): 186-188; P. Aarts, W. Dries, F. Spierings, "Apparatenbouwers of wetenschappers: De eerste natuurkundige ingenieurs," *Intermediair* 17 (1981): 55-63; Wil Kuijpers, *De Technisch Physische Dienst en de Electronenmicroscopie* (Eindhoven, 1987): 10-13; H. Baudet, *De lange weg naar de Technische Universiteit Delft I: De Delftse ingenieursschool en haar voorgeschiedenis* (Den Haag, 1992), 269; 462-467; H. Baudet, *De lange*

course in Applied Physics proved its value for Philips. Several main achievements were mentioned in a report published in conjunction with the celebration of the program's first 10 years.[18] The program had produced a total of 79 graduate physics engineers, Philips employed 19 of them, the Bataafsche Petroleum Maatschappij (the Dutch Oil Company, now the Shell group) 11, and other smaller companies hired the rest. The laboratory had become a big organization, as reflected in the staff composition, organization of colloquia, and success of the research projects carried out for industry.

Although Philips was eager to recruit young university talent, direct financial support by Philips to universities was relatively insignificant with the emphasis on project cooperation with only a small financial input.

Research Work with Artificial Light for the Cultivation of Plants

An example illustrates the many reasons Philips had for investing in such research cooperation. In November 1931, the agricultural research foundation was established in the Netherlands under the name "Stichting voor Bio-Physica" [Foundation for Bio-Physics].[19] Holst became a member of the foundation's first Board of Directors. He clearly explained why Philips was willing to participate, and in doing so referred to three Physics Lab research programs. The research projects were part of the larger diversification program of Philips'.

First, Holst mentioned Physics Lab research projects studying the effects of ultraviolet radiation on human health. Under Holst's supervision, researchers had developed special tubes for this application. Second, Physics Lab researchers were engaged in research into X-ray technology including many applications in both medicine and biophysics.[20] Finally, Holst referred to ongoing cooperation with a University of Wageningen research project. In that program, Dutch biologist, Dr. Johannes M. W. Roodenburg studied the effects of artificial light on plant growth using Philips lamps and Physics Lab expertise during. It was a small, but promising niche in the international lighting market.

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weg naar de Technische Universiteit Delft II: Verantwoording, registers, tabellen, namenlijsten en bijlagen (Den Haag, 1993), 677-681.

[18] "Laboratorium voor Technische Physica T. H. Delft. Herdenking 1930-40, 1940," *De Ingenieur* 55 (50), p. A448.

[19] Philips Company Archives/Natuurkundig Laboratorium (PCA/NL) 327. Stichting Bio-Physica. Minutes of the first official meeting of the Stichting voor Biophysica, 25 Nov. 1931.

[20] 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: The International Journal of Business History* 4 (March 2003): 65-98.

The "Roodenburg research-program" began in the summer of 1928 when Roodenburg, approached Philips with a request in a letter to Holst. He explained his plans to do research work with artificial light for the cultivation of plants for the benefit of horticulture. Roodenburg had learned, both through experience and from scientific literature, about the importance of light and the promising application of artificial light in greenhouses. He also knew that Philips could deliver the lamp technology he needed. Jan Feith, Roodenburg's uncle and a personal friend of Anton Philips, had written a letter to Holst, recommending his nephew as a researcher.[21] Moreover, at the same time Jan Feith sent a letter to Anton Philips, which opened informally with "Dear Ton," in which he introduced his nephew as a suitable candidate for a research project with Philips technology.[22] According to his uncle, Roodenburg was a good experimenter.

In his letter to Holst, Roodenburg described his plans as promising, although he could not guarantee any profit for Philips. The aim of the research project, however, was clear: in the winter (at least in the Northern Hemisphere), the amount of daylight is insufficient for full growth even when plants are raised in glasshouses. This led several scholars such as Roodenburg to consider the possibilities of using supplementary artificial lighting in glasshouses. He built upon international research in the first decades of the twentieth century on growers' use of artificial light.[23] In retrospect, Holst's contacts with this biologist can be seen as the first weak

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[21] Roodenburg's thesis concerned the relationship of oxygen to humus and plant rot; see J. W. M Roodenburg, *Zuurstofgebrek in den grond in verband met wortelrot* (Baarn, 1927).

[22] PCA/NL 546. Plantenbestraling. Letter from Jhr. Jan Feith to Anton Philips, Den Haag, 18 July 1928.

[23] See Allan E. Canham, *Artificial Light in Horticulture* (Eindhoven, 1966). It is also worth mentioning that other industrial companies such as General Electric (GE) were also conducting research on artificial lighting for agriculture. In the first decade of the twentieth century, GE's electrotechnical wizard Steinmetz experimented with the effects of lighting on the growth of plants in a small 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 II, The Steinmetz Era 1892-1923* (Schenectady, N.Y., 1989), 38. Later, this agricultural research became more serious within GE; see Frederick H. Kranz and Jacqueline L. Kranz, *Gardening Indoors under Lights* (New York, 1957). Like Philips, GE was searching for new markets for incandescent lamps; the gardening market niche seemed a promising one. Philips and GE did not exchange information concerning research into artificial lighting; both firms operated independently (and in different markets). Generally, there were 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 (June 2003): 109-126.

tie in a network of institutes, researchers, and government that would grow in the coming decade.

Roodenburg's Specific Knowledge

Roodenburg proved to be familiar with existing literature on artificial lighting in agriculture. He concluded from earlier research by Professor Höstermann from Berlin that red light is best for photosynthesis.[24] Höstermann had used neon lamps for artificial lighting, because they generate red light. He began his research in 1916 during the First World War, a time of war-induced food scarcity in Germany; technology was applied in an attempt to raise crop yields and improve food production. During a personal discussion, Höstermann informed Roodenburg that he had been forced to stop his experiments on plant life in 1923 because of lack of money. He declared, however, that the results of his experiments were promising enough for further research and he advised Roodenburg to continue the study of the influence of artificial light on plant growth.

To demonstrate his familiarity with recent research programs, Roodenburg referred to experiments carried out by Professor A. H. Blaauw in the 1920s at the Dutch (agricultural) University of Wageningen, a researcher with a lot of experience. Around 1910 Blaauw had researched the influence of light on plant growth and written a thesis at the University of Utrecht under the supervision of the Professor of Botany F. A. F. C. Went.[25] Blaauw developed a theoretical classification scheme in which plant movements were classified as a function of particular ways in which a plant perceives a stimulus such as energy and light.[26] Roodenburg had contacted Blaauw in Wageningen and proposed a plan to carry out irradiation experiments with artificial light.

In his July 1928 letter to Holst, Roodenburg exactly described his research plans for the immediate future. The first question he wished to answer was what light source is most suitable for plant irradiation. Roodenburg was also interested in the question of how artificial light affected growth in different plant species. He stated that the University of Wageningen laboratories were best qualified to carry out verifiable experiments and asked Philips to finance his research project and provide expert knowledge on lighting. He also went to Eindhoven for an oral clarification of his plan and to discuss ways of knowledge exchange.

Within a few months, Roodenburg found a place in Wageningen where he could start his research. Professor Ir. A. M. Sprenger, a colleague of Blaauw's, was willing to cooperate by allowing Roodenburg to use part

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[24] G. Höstermann, *Versuche mit Neonlicht* (Dahlem, 1918).

[25] A. H. Blaauw, *Die Perzeption der Lichtes* (Utrecht, 1909). For context on 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.

[26] Patricia E. Faasse, *Experiments in Growth* (Amsterdam, 1994), chapter 3.

of his greenhouse. Roodenburg started his research project at the end of 1928 with the financial help of Philips. Dr. Zecher, the contact person for the Physics Lab, had worked at Philips since 1924 and had expertise on gas discharge lamps research. In the first months of 1929, the Physics Lab delivered several kinds of lamps to Roodenburg, including light bulbs, neon lamps, and mercury-vapor discharge lamps. Zecher and Roodenburg engaged in an extensive exchange of ideas and knowledge about lighting research.

The Physics Lab's Position within the Research Network

Roodenburg visited the Physics Lab in September 1928 to discuss the details of his research contract. Philips offered him a year's contract to do research in the laboratories of the University of Wageningen, which would be extended each year to enable him to study the effects of artificial light on plant growth.[27] Holst formulated three important contractual conditions, Roodenburg a) was not allowed to publish any results without Holst's permission, b) had to clarify his findings whenever Holst wanted him to, and c) would receive a salary of 200 guilders each month and the required light sources free of charge. Roodenburg signed the contract and began the project, beginning his research in Wageningen in November 1928 at Sprenger's laboratory. The major aim of his project was to find out how lamplight could be of use for plant growth.

Roodenburg's decision to join Sprenger's laboratory was not unusual if we take Sprenger's ideas and the history of the University of Wageningen into consideration. Researchers working at the University of Wageningen had a lot of experience with cooperative research projects with representatives outside the university.[28] Professor Sprenger had been involved in several "contract" research projects in his greenhouse known as Laboratorium voor Tuinbouwplantenteelt [Laboratory for Horticultural Botany]. These research projects touched on refrigeration technology, necessary technology for the storage of fruit, particularly in the tropics (the Dutch East Indies).[29] Sprenger preferred to do research for practical purposes; for one reason, it was useful for him to stay in close contact with interested parties outside the university. Clearly, his promise to Roodenburg and Philips to cooperate was not an unusual one; in 1930,

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[27] PCA 881. Contracten map 940. Letter from Van Walsem, secretary of the Philips Board of Directors to Roodenburg, 19 Sept. 1928.

[28] J. van der Haar, *Van school naar hogeschool, 1873-1945: De geschiedenis van de Landbouwuniversiteit Wageningen* (Wageningen, 1993).

[29] See Anneke H. van Otterloo, "Prelude op de consumptiemaatschappij in voor- en tegenspoed 1920-1960," in *Techniek in Nederland in de Twintigste Eeuw. Deel III Landbouw, Voeding*, ed. Johan Schot (Zutphen, 2000), 264-79, especially p. 266; and Hans Buiter, "Koelen en vriezen," in *Techniek in Nederland in de Twintigste Eeuw. Deel III Landbouw, Voeding*, ed. Johan Schot (Zutphen, 2000), 339-51, especially p. 346.

Sprenger and his co-workers participated in at least four cooperative research projects with non-university researchers.[30] He enumerated these projects in the annual reports produced by his Laboratorium voor Tuinbouwplantenteelt.[31]

In the first instance, the Nederlandsche Vereeniging voor Koeltechniek [Dutch Association for Refrigeration Technology] provided Sprenger financial aid. Dutch government had an important voice in this association because the Dutch Minister for Agriculture was the main contact person. In the second, the N.V. Geldersche Electriciteits-Maatschappij [Gelderland Electricity Company from Arnhem, a Dutch city] offered financial aid. This organization promised a pecuniary contribution for a new greenhouse to be built and it even delivered free electricity. The third contribution came from the "Fonds der Electro-technische Industrie" [Fund for the Electrical Technical Industry], which donated money for research projects and for study tours.

Before Roodenburg could continue his research activities, he had to overcome several practical problems. The first problem was the large amount of electricity needed for his project. To bear the costs of his research he needed more financial aid. Sprenger instructed Roodenburg to look for other partners to extend the research network. Industrial sponsors were essential for further price reductions. The Dutch Vereeniging van Directeuren van Electriciteitsbedrijven in Nederland (VDEN; the Society of Directors of Dutch Electricity Companies) was the most important partner in Sprenger's research projects. This big national association had great interest in Dutch agriculture and also gave Sprenger free electricity for several research projects. Roodenburg, however, decided to ask Philips to finance the extra electricity he used for his experiments.[32] Philips complied with this request for a financial contribution, because Holst viewed this project as a promising one.

A second contribution that Philips made to Roodenburg was to provide assistants in the greenhouse in Wageningen. Roodenburg had asked Philips for assistants because the intensive care the plants required. In the first years of his research, Roodenburg received help from University of Wageningen student-assistants. As the work intensified, he engaged a number of full-time assistants for his experiments. Philips

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[30] Rijksarchief Gelderland, Arnhem. Deelarchief 0740 Landbouwhogeschool 1914-1958 te Wageningen. Nr. 1142 Stukken betreffende schenkingen, hoofdzakelijk in geld, aan Professor A. M. Sprenger t.b.v. proefnemingen op het gebied van tuinbouwplantenteelt 1926-1935, 22 April 1930: Onderzoekingen in het Laboratorium voor Tuinbouwplantenteelt met steun van derden.

[31] Although he had contacts in industry, Professor Sprenger was not only competent in applied research but in basic research as well.

[32] PCA/NL 546. Plantenbestraling. Letter from Roodenburg to Holst, 26 Sept. 1929.

employed these people on a temporary basis and paid their salaries on short notice

To sum up, Roodenburg found the resources a good research network required. He could make use of a university laboratory, where he could rely upon the help of Physics Lab researchers and Philips' financial backing. For his experiments, he used lamps and Philips accessories and also made use of Zecher's expertise. The parties' cooperative agreements were formalized in several contracts.

For Holst, such a cooperative structure was quite a new experience. To emphasize this unique cooperation structure, the "Roodenburg-project" received separate mention in the Physics Lab's Annual Reports: an industry-university network based upon the idea of reciprocity (the sharing of ideas, knowledge, skills and means) was born.

Experiments with Different Light Sources

University of Wageningen published "Kunstlichtcultuur" [The Cultivation of Plants in Artificial Light], the first results of Roodenburg's research carried out between 1928 and 1930, in a series of scientific reports on agriculture. Roodenburg reviewed the scientific literature on which he based his own research activities; his main objective was to find the best light source for the cultivation of plants. He investigated the effects of light on plant growth using three kinds of Philips lamps and tubes: incandescent lamps, neon discharge tubes, and mercury vapor lamps. Philips delivered these lamps together with necessary accessories such as steel frames, coils, and transformers.

In new experiments, Roodenburg found the red light emitted by discharge tubes filled with neon gas proved most useful for plant irradiation. Roodenburg only encountered one disadvantage: the purchase price for neon tubes was much higher than that for incandescent lamps. After these first promising results, Roodenburg recommended neon tubes for practical use in horticulture.[33]

In order to extend his experiments, Roodenburg needed more space in the laboratory and in the Wageningen greenhouse. Because of space problems, Professor Sprenger planned a new building and sought funding from both the Dutch government and industry.[34] Sprenger and Roodenburg negotiated with Philips concerning payment for the new

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[33] R. van der Veen and Gerardus Meijer, *Light and Plant Growth* (Eindhoven, 1959), 121. The plants with which Roodenburg experimented showed much stronger growth, thanks to artificial light that facilitated an intensive assimilation of carbon dioxide. In addition, the plants' roots became stronger, the plants had a deeper green color, and more flowers. Roodenburg also found that plants could endure unbroken illumination during day and night periods. Greenhouse temperature was the most important external factor; it needed to be controlled by heaters and the heat derived from lamps limited as much as possible.

[34] Van der Haar, *Van school naar hogeschool*, 236.

greenhouse building where Roodenburg could carry out his experiments with artificial light. Sprenger knew government permission was needed to build this new greenhouse. Philips and other industrial firms were allowed to pay the cost of the greenhouse, but only under government supervision.[35] The minister of Domestic Affairs and Agriculture put forward a financial plan to Sprenger and Philips on the condition it be implemented without increasing personnel.[36] Philips then promised Roodenburg that it would finance the new greenhouse and building activities that had already begun.[37]

Once Roodenburg had the financial resources to extend his project, he tried to find additional expert knowledge. Since autumn 1930, Roodenburg had been in contact with government agricultural experimental stations, where agricultural researchers conducted government-aided work for the benefit of Dutch growers.[38] Roodenburg came into contact with Riemens, an engineer who was a government consultant and head of the agricultural experimental station in the Dutch village of Naaldwijk. Riemens had done research with artificial light in his greenhouse before 1930 as part of a national research program.[39]

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[35] Rijksarchief Gelderland, Arnhem. Deelarchief 0740 Landbouwhogeschool 1914-1958 te Wageningen. Nr. 1142 Stukken betreffende schenkingen, hoofdzakelijk in geld, aan Professor A. M. Sprenger t.b.v. proefnemingen op het gebied van tuinbouwplantenteelt 1926-1935. Letter from Sprenger to the Governing Body of the University of Wageningen, 22 May 1931.

[36] Rijksarchief Gelderland, Arnhem. Deelarchief 0740 Landbouwhogeschool 1914-1958 te Wageningen. Nr. 1142 Stukken betreffende schenkingen, hoofdzakelijk in geld, aan Professor A. M. Sprenger t.b.v. proefnemingen op het gebied van tuinbouwplantenteelt 1926-1935. Letter from the Permanent Secretary of the Minister to the Governing Body of the University of Wageningen, 17 June 1931.

[37] PCA/NL 546. Plantenbestraling. Letter from Roodenburg to Holst, 2 July 1931.

[38] D. J. Maltha, *Honderd jaar landbouwkundig onderzoek in Nederland 1876-1976* (Wageningen, 1976); *Gedenkboek uitgegeven bij het vijftigjarig bestaan der Rijkslandbouwproefstations 1927* ('s-Gravenhage, 1927). See also 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 "scientification" 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), 249-61, esp. 254. Indirectly, these stations influenced the Dutch consumer's food supply; 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), 237-47, especially pp. 242-5.

[39] 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. See also, *25 Jaar Tuinbouw—onderwijs—voorlichting—onderzoek in het Zuid-Hollands Glasdistrict 1924-1949: Jubileum-*

Similar government-financed experiments in horticulture and agriculture took place in several agricultural experimental stations in the Netherlands. In addition to Naaldwijk, the Dutch government supported experimental stations in places such as Aalsmeer, Horst, and Groningen. A consultant led each agricultural experimental station. The agricultural experimental stations contributed to crop problem solutions. Some of the research was done for individual growers who submitted special requests. Industry provided financial help, such as the free electricity contributed by the Dutch electricity group VDEN. Consultants shared their knowledge with researchers from interest groups and universities. Riemens, for example, worked with researchers from the University of Wageningen, and after face-to-face contact with Roodenburg, decided to begin further research into artificial light for growers in "Het Westland."[40]

Following Roodenburg's mediation, Philips indicated that it was willing to support Riemens' research and gave him several lamps, neon tubes, and devices such as reflectors.[41] Riemens carried out a research project in 1930 in which artificial light was used to grow cucumber plants. He was in close contact with growers, because the primary function of the Naaldwijk agricultural experimental station was to serve the public. In February 1931, Philips received a report from Riemens explaining his research activities.[42] He communicated some of the positive reactions to his research from individual growers. A grower who used artificial light had significantly better crop results than his direct competitors. His colleagues, to avoid lagging behind, would have to consider purchasing light bulbs or neon tubes. Riemens emphasized the reciprocity for Philips: the opening of a new market for Philips lamps. He used strong arguments in support of his request to Philips for financial assistance for his neon tube experiments. He argued his advantage over Roodenburg was his close contact with individual growers and greater familiarity with commercial growers' practical problems.

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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 agricultural innovation system in Harro Maat, "Het innovatiesysteem voor de Nederlandse landbouw," *NEHA Jaarboek* 66 (2003): 233-62.

[40] In English: "The Westland," a part of the province Zuid Holland (South Holland), in the Western part of the Netherlands, where there were and still are many greenhouses.

[41] 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.

[42] PCA/NL 545. Plantenbestraling. Report of Riemens, Proeftuin Westland Naaldwijk, 9 Feb. 1931, summarized by Mullens.

Other Research Institutes Involved: A Growing Network

As mentioned, VDEN provided financial aid to Sprenger's Wageningen Laboratory for Horticultural Botany and also contributed free electricity to government agricultural experimental stations. Professor Ir. J. C. van Staveren, director of VDEN, wrote asking Philips for further support of the experimental station artificial light experiments.[43] Van Staveren also asked Philips to provide some technical details on neon tubes and their installation, so that VDEN mechanics could implement such systems in customers' greenhouses.

In the 1920s and 1930s, VDEN promoted the use of electricity in all sectors of Netherlands society. Of course, VDEN had a good reason to stimulate agricultural networking activities with financial support for agriculture and horticulture: the creation of a promising new electricity market.[44] In an article about the possible applications of electricity in horticulture, Sprenger argued that the agricultural sector was a potential market.[45] Although his focus was on electric heating for greenhouses, Sprenger also referred to Roodenburg's research on electric lighting.

VDEN invited Holst and Sprenger to attend a meeting in March 1931 to discuss the benefit of artificial light experiments in agricultural experimental stations.[46] The meeting was decisive in bringing several partners together. From the minutes, it can be gathered that the participants had a fruitful discussion. They decided to visit Professor Sprenger's laboratory and greenhouse at Wageningen to further discuss their networking activities.

During the next year VDEN members, a spokesperson for the agricultural experimental stations, Sprenger, and Holst held other meetings to evaluate the experiments and preview the 1932 research program. In the following years, annual meetings were organized to discuss the results of research experiments with artificial light and to plan further research. This served to structure participants' communication

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[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.

[44] In the commemorative book published on the occasion of the 25-year VDEN jubilee, Sprenger clarified the application of electricity in horticulture: A. M. Sprenger, "De toepassing der electriciteit bij het beoefenen van den tuinbouw," in *De ontwikkeling onzer electriciteitsvoorziening 1880-1938: Uitgegeven naar aanleiding van het 25-jarig bestaan der Vereeniging van Directeuren van Electriciteitsbedrijvan in Nederland. 2e Deel Monografieën over de ontwikkeling van de Nederlandsche electriciteitsvoorziening* (Arnhem, 1948), 945-60.

[45] A. M. Sprenger, "Toepassingen van Electriciteit in den Tuinbouw," *Elektrotechniek* 17 (1939): 183-6; *Elektrotechniek* 17 (1939): 191-5, 203-5. This article was a version of an earlier lecture given by Sprenger for engineers and VDEN members.

[46] PCA/NL 544. Plantenbestraling. Letter from the VDEN to Holst, 12 and 16 March 1931.

such that each gradually found their place in the research network, and the network gathered momentum. It was during this period that an unexpected new participant from outside the industry appeared who was willing to cooperate with Holst and Roodenburg.

This non-commercial interest was from an informal subcommittee of the "Nederlandsche Verlichting Comité" [Dutch Lighting Committee] that wanted to strengthen interaction among physicists, physicians, and biologists. Two Dutch "system-builders," professors Gorter and Dorgelo, spoke on behalf of the committee, inviting Holst to attend a meeting with members from other interest groups. During the meeting of the "Nederlandsch Natuur-en Geneeskundig Congres" [Dutch Physical and Medical Congress], several physicists, physicians, and biologists decided to establish a new foundation to study research questions from these three disciplines. In April 1931, spokespersons for several parties discussed features of the new foundation and Holst was specifically invited to participate.[47]

The new association's statutes, which included the intention to cooperate, were formulated and circulated for comments among potential participants. In the 1931, the foundation was established under the name "Stichting voor Bio-Physica" [Foundation for Bio-Physics].[48] Holst, a prominent member of the first board, was willing to share his specialized knowledge during the new foundation's regular meetings.

The "Nederlandsch Genootschap voor Verlichtingskunde" (NGVV) [Dutch Society for Lighting] was another foundation with which Holst and Roodenburg shared knowledge about artificial light. Established in 1926, NGVV aimed to bring together several parties concerned with any scientific application of light. Prominent members of the committee were Professor L. S. Ornstein from the University of Utrecht, and Delft Polytechnic professors C. Zwikker and H. B. Dorgelo. Industry representatives also participated in the NGVV. By 1932, several new NGVV sub-committees had been set up to discuss specific light applications. One new sub-committee studied plant-irradiation, and, not surprisingly, Sprenger was a prominent member.[49] Roodenburg and Zecher later joined this committee.

Ornstein had a dominant position in several Dutch scientific foundations. He was also the leading man within the NGVV as a member of the Board of Directors and of several sub-committees, putting a

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[47] PCA/NL 327. Stichting Bio-Physica. Letter from Professor Dr. E. Gorter and Professor Dr. H. B. Dorgelo, 20 April 1931, and a letter from Dr. E. H. Reerink to Professor Dr. E. Gorter and Professor Dr. H. B. Dorgelo, 24 April 1931.
[48] 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.
[49] PCA/NL 514. Nederlandsch Genootschap voor Verlichtingskunde. Letter from A. H. O. W. Bats, secretary of the foundation to the m.s, 24 May 1932.

scientific stamp on the organization. During one of the first meetings of the NGVV, Ornstein presented a standardized way to determine objective scientific units of lighting. Zecher became acquainted with the details of the standard through his presence at this meeting and face-to-face discussions with Ornstein in Utrecht. Zecher, in turn, provided extensive information to Roodenburg. Ornstein's committee decided, for example, to change the scientific unit for lighting with neon tubes from "Lux" to "energy per second per square millimeter."[50] With his scientific knowledge, Zecher was able to tell Roodenburg how to apply these units in his papers.

Roodenburg's Output: Artifacts and Articles

In the Physics Lab building, Zecher developed installations for artificial lighting experiments. A 1932 issue of the journal "Philips Industry," included an article explaining the technical features of Philips neon tubes for plant irradiation with an illustration of the installation. Roodenburg had developed an idea of Zecher's, namely the use of a construction frame with a reflector above the neon tube.[51] The reflector was employed to direct light onto the plants that would otherwise be wasted. Roodenburg also developed so-called germination boxes in which the lamps' heat could be maintained at an appropriate temperature. In these boxes, seed plants were covered with glass to prevent too high an evaporation rate. Because the boxes were small, the seedlings could be left in them for only a short time. For a continued plant growth under artificial light, a big greenhouse was necessary.

We can divide Roodenburg's publications during the first years of research with Philips light sources into scientific and popular ones. His major scientific article, "Kunstlichtcultuur" [Artificial light], which appeared in a scientific series of the Wageningen University called "Mededeelingen van het Laboratorium voor Tuinbouwplantenteelt" (an issue of the Laboratory for Horticultural Botany) in which he described his research project and its outcomes in detail. Roodenburg concluded that his experiments had proved the possibility of using artificial light, and that it would be economically profitable if a grower used the lowest electric current possible. This conclusion was important for Philips; Roodenburg declared that a practical way to use artificial light would be a permanent installation for artificial illumination, which of course meant a big potential market for Philips.

Roodenburg's conclusions had important scientific implications, because he described the exact conditions under which he carried out his research experiments, giving such details as the environmental

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

[51] PCA/NL 546. Plantenbestraling. Letter from Zecher to Roodenburg, 19 Nov. 1930.

temperature, the distance of the light source from the plants, the intensity of the light, the working of reflectors, and, last but not least, the specific plant characteristics.

It was not only Dutch agricultural experimental stations and individual growers who showed an interest in this research. Philips' cooperation with Roodenburg, Sprenger, and Riemens got the attention of foreign researchers, too. A group of Scandinavian researchers was especially interested in the results. Artificial light was useful in the long, dark Scandinavian winters and a special committee was established in Sweden to study the possibilities of using artificial light in greenhouses. Just as in the Netherlands, the Swedish Electricity Companies were involved in research projects by delivering free electricity. Philips had contacts with the Swedish committee and Holst insisted on closer scientific cooperation with researchers from those countries, with the intention of sharing specific knowledge and experience.[52] Roodenburg, too, was convinced of the usefulness of international scientific contacts.

Although contacts within the world of agricultural science were important to him, Roodenburg also published for designers. One of the first issues of the "Philips Technisch Tijdschrif" (PTT, the Philips Technical Review) offered him a good opportunity to do that. He co-authored an article in the PTT in 1936 with Zecher.[53] They paid specific attention to the technical details of the tubes and to the electrical and mechanical installation, aspects that were useful for Philips constructors who were interested in the special applications and purposes of the tubes.

Apart from his scientific and technical papers, Roodenburg also published in popular magazines for a broader audience. In an issue of "Natuur en Techniek" (a popular Dutch journal called "Nature and Technology"), he wrote an article entitled "Als de zon ons in de steek laat" ("If the Sun Deserts Us"). Roodenburg explained the benefits of artificial light for plant growth in more practical terms.[54] Although he did not describe his experiments in detail, he did provide a detailed discussion of his ideas. Roodenburg presented the use of artificial lighting in greenhouses as very promising, but stressed that a lot of research remained to be done with a variety of plants. In his popular publications, he emphasized that the purchase of Philips technology was suitable for professional application and useful for individuals and hobbyists.[55]

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

[53] J.W.M Roodenburg and G. Zecher, "Plantenbestraling met Neonlicht," *Philips Technisch Tijdschrift* 1, 7 (1936): 193-99.

[54] J. W. M Roodenburg, "Als de zon ons in de steek laat," *Natuur en Techniek* 1 (Jan. 1931): 276-9.

[55] J. W. M Roodenburg, "Rood licht voor kasplanten," *Weekblad voor de Koninklijke Nederlandse Maatschappij voor Tuinbouw en Plantkunde* 28 (1934): esp. p. 8.

Users Involved in the Network

Due to their good communication with individual growers, agricultural experimental station directors were able to bring Philips into contact with potential customers in the Netherlands. Such contacts were necessary for Philips, because only a few growers in the “Westland” area were actually using artificial light sources. The increase in crop yields offset the extra energy costs only for selected plant species. Dutch horticulture proved to be the best branch for the Philips neon tubes.

In 1934, the Philips information office published an article on the results of the Philips Plant Irradiator. This report incorporated the technical details of several research projects with Philips neon tubes. Several agricultural experimental stations in Europe contributed to the publication. Pinkhof, a researcher and consultant, gave an account of experiments in Aalsmeer in the Netherlands. Other contributions came from Cortenberg in Belgium, from Oslo in Norway, from Cheshunt in the United Kingdom, and from an agricultural experimental station in Landskrona in Sweden. These research reports led to the unanimous conclusion that lighting with neon tubes produced the best results for plant growth. A recommendation was made that Philips develop an installation suitable for low voltage.

After 5 years of research and an international investigation, Roodenburg had made the case that providing artificial lighting for plants was a promising proposition. Philips plant irradiators had been developed for the public as well as the professional market. Several articles and brochures recommended Philips neon tubes suitable for plant irradiation in the living room. Architects became involved in the application of plant irradiation in living rooms, by designing windowsills suitable for small-scale nurseries with neon tubes.[56] Although non-professional customers received attention, the main customers were still the scientific researchers and professional growers. Small-scale irradiation was very expensive; it was most profitable to illuminate large numbers of young plants in a greenhouse. Using artificial light for the stimulation of plant growth at home proved to be sensible for hobbyists only. However, even this small market did not escape Philips’ attention.

Strikingly, even Philips’ dominant man during the 1930s, Anton Philips himself, became involved in the research project because of his own interests. Anton Philips’ hobby was gardening. In the winter of 1934/35 he and his grower experimented with neon tubes in his own greenhouse with houseplants and strawberries. The results of the experiments were presented in an official Philips report written by the

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[56] A windowsill design a 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, 38 (1936).

engineer, Schouwstra.[57] Pictures of the illuminated plants accompanied the report. Anton and his grower were only partly certain about the results; it was clear that the use of artificial light for the cultivation of plants needed careful and professional investigation. According to Anton, additional scientific research was necessary to achieve satisfactory results.[58]

Holst, too, showed his personal interest in the research on artificial light. During several meetings, he enthusiastically discussed Roodenburg's research, offered his own opinions, and even related details of his personal practical experience with the use of artificial light on plant growth. This enthusiasm resulted in the continued, expanded research. Philips tried to influence the market for neon tubes suitable for plant irradiation by, for example, having sales representatives display neon plant irradiators at exhibitions.[59]

Economic Crisis: A Difficult Period for the Physics Lab

In the early 1930s, the Dutch industry was confronted with major difficulties due to the economic crisis.[60] Holst's critical remarks were a direct reaction to poor financial results during the economic crisis. The crisis of the 1930s forced the company's management to think about more strictly controlling its activities. In the summer of 1928, the Dutch Professor of business economics, J. Goudriaan, became head of the Business Organization Department.[61] His first move was to set up a budgetary system to control the growth of the workforce and salaries. Philips established a Central Budget Committee that enabled the company's managers to strengthen their grip on the allocation of financial and workforce resources. The Physics Lab was part of this process.

Interested parties within the agricultural network, such as the experimental stations, used the crisis when asking Philips for extra support. The consultants argued that most individual growers were in financial trouble and could not immediately afford to purchase neon tubes, let alone do the experiments with artificial light.[62] To minimize risk,

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[57] PCA/NL 545. Plantenbestraling. Report of Ir. P. Schouwstra: Proeven met Plantenbestralingsbuizen, 5 April 1935.

[58] Unfortunately, I cannot deduce how much weight Anton Philips carried in this research program from documents left in the Philips Concern Archives. It is clear that he was not opposed to further scientific research on this topic.

[59] PCA/NL 544. Plantenbestraling. Letter from Professor Van Staveren of the VDEN, 22 June 1934.

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

[61] Blanken, *The History of Philips Electronics N.V.* vol. 3, 362-368.

[62] PCA/NL 545. Plantenbestraling. Report of H. J. Cortel after a visit made to several individual growers, 26-28 Sept. 1932.

growers wanted to know exactly what the effects of artificial light would be before investing in an expensive installation. Therefore, growers' interest in the results of the agricultural experimental stations increased, and the experimental stations became important intermediaries between Philips and the growers.

Roodenburg kept in touch with Riemens in Naaldwijk and with Zecher at the Physics Lab; Philips still gave him financial aid. Because of the financial problems, Philips was hesitant about continued participation in his research projects. However, for the time being decided to continue supporting projects carried out by Roodenburg, Riemens, and Pinkhof; in 1935, Philips supported research their projects and experiments in Aalsmeer, Naaldwijk, and Wageningen, providing incandescent lamps, neon tubes, and accessories free of charge.[63] Despite the financial problems, research continued and with the participation of several organizations, even gathered a certain momentum.

This positive attitude changed, however, when Holst made critical remarks about this part of his research program at the end of the 1930s. He doubted if Philips would benefit from the project financially, and after some years of disappointing sales, his attitude switched from enthusiasm to concern, wondering if further involvement would be fruitful.

A Period of Disappointment: Tensions within the Network

Some involved in the research network feared that Philips would discontinue its financial aid. In the summer of 1936, Roodenburg expressed his concern about Philips' commitment to further research. Despite promised intensification of sales efforts and the recording of favorable expectations in the Philips Annual Reports, the reality of Philips' promotional activities disappointed Roodenburg. After a conversation with some Philips sales representatives during a flower show, he had the impression that Philips' interest in this market was diminishing. As a result, he asked Holst if he could count on further help from Philips for his research projects or not. In his answer to Roodenburg, Holst was entirely clear. Because of disappointing sales results and poor expectations for the immediate future, Philips intended to withdraw its financial support.[64] Holst announced plans to end his participation in the project within three years; Roodenburg would get help only until 1939.

Roodenburg was not alone in having the impression that Philips' interest was waning; Riemens had noticed Philips' decreasing interest and during a NGVV meeting had heard about Philips' intention to cut back on further participation. The fact that Riemens' concern was not unfounded can be demonstrated from the foundation's annual reports. It appears

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63 PCA/NL 545. Plantenbestraling. Situatie der Proefnemingen met Plantenbestraling voor het seizoen 1934/'35 van Dr. Zecher, 22 June 1934.

64 PCA/NL 546. Plantenbestraling. Letter from Holst to Roodenburg, 10 Nov. 1936.

from these reports that the committee for plant irradiation had been inactive; the committee members had not met since 1936.[65]

From a business point of view, Philips' declining interest in further research was understandable, but Riemens was still disappointed about the decision to cut financial aid. Moreover, he was annoyed about how Holst had announced his diminishing interest. According to Riemens, Holst had failed to inform the NGVV committee at an earlier stage, although he had already expressed his concern to Roodenburg and Riemens in person. During discussions with Holst, Riemens understood that Philips' wish to increase its profit was based only on commercial considerations. Riemens could not deny the need for a good market for artificial lighting. For that reason, he had always emphasized that scientific publication was not enough. According to Riemens, well-educated sales representatives with special knowledge about gardening were indispensable when it came to sales success.

This argument was consistent with a remark made by Roodenburg who was, of course, disappointed about Philips' plan to end their support in 3 years. In a letter to Holst, he uttered a mixture of astonishment and indignation about the attitude shown by Philips' sales representatives.[66] Friction arose between Roodenburg and the sales representatives as a result of their different interests. A remark that Roodenburg made to Holst reveals the source of the friction. Roodenburg had provided growers with recommendations concerning the most advantageous illumination intensity for plant growth. He supported these recommendations with results derived from his scientific experiments. However, Philips' sales agents advised growers, in conjunction with their attempts to increase the sales of plant irradiators, to cut down on the intensity of illumination to save energy costs. Roodenburg's scientific findings showed that decreased intensity was unfavorable for plant growth, and he concluded that Philips' sales representatives gave growers inaccurate instructions as a result of biased sales motives.[67]

Holst had two responses to Roodenburg and Riemens. Consistent with the enthusiasm expressed during several meetings, he emphasized his personal interest and underlined his conviction concerning the importance of Roodenburg's research. Nevertheless, he had to take the benefit to

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[65] PCA 933.1. Nederlandsch Genootschap voor Verlichtingskunde. Verslag over het jaar 1936.

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

[67] Roodenburg's opinion that the Philips' sales representatives could not do justice to their promises was shared by Riemens' agricultural experimental station. See *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, esp. 140.

Philips into account. That was the obstacle to further participation: purchasing an installation for artificial lightening seemed too expensive for the individual grower. Thus, sales results and the speed of diffusion, national and international, of the installations were all too disappointing for Philips to consider further participation.

Various parties tried to encourage Philips and Holst to participate in further research. For example, Professor Miss. Johanna Westerdijk, who had recommended Roodenburg to Holst in 1928, wrote to Holst at the end of 1937 expressing her disappointment about Philips' intention to cut back their financial aid.[68] Westerdijk proposed consolidating and strengthening contacts with Sprenger. After all, she argued, it would be regrettable if the greenhouse built with Philips' assistance would have to be closed prematurely. Even after a pressing request by Sprenger himself in which he clarified his research projects and plans for the near future, Holst persisted in his expectant attitude. At the bottom of Sprenger's letter Holst wrote: "We will wait for Sprenger's next reaction."

In the meantime, Philips had already taken several measures to end further cooperation with Roodenburg's research. His contract with Philips ended in 1939; he left Wageningen and started a new research project at the Aalsmeer agricultural experimental station. In spite of Holst's interest in the project, Philips had ended its financial aid for business reasons; there was a possibility of renewing the contact in the future, however.[69]

Continuing Research after the Second World War

Philips was not involved in any botanical research program during the German occupation. Only informal contacts remained between Holst and Roodenburg; the latter sometimes contacted Holst to inform him about his research work in Aalsmeer. Because of the Physics Lab's membership on the NGVV committee for plant irradiation, Holst received information about research activities.[70] Dr. A. A. Kruithof, Zecher's successor after the outbreak of the Second World War, represented Philips on the committee.

It is striking, therefore, to observe that since 1949, the Physics Lab has a large horticultural greenhouse at its disposal. Various plants have been cultivated there in several small greenhouses equipped with artificial

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[68] PCA/NL 544. Plantenbestraling. Letter from Professor Dr. Johanna Westerdijk, 13 Dec. 1937. Johanna Westerdijk was one of Professor De Vries' students (De Vries had supervised the earlier mentioned Professor F.A.F.C. Went). In 1917 she became Professor extraordinaire of phytopathology and she was the first female Professor in the Netherlands, see Berkel, van Helden, and Palm, *A History of Science in the Netherlands*, 189.

[69] PCA 881. Contracten Archief. Letters from Mr. H. F. van Walsem to Roodenburg, 22 Dec. 1936 and from Dr. A. C. J. Mulder to Roodenburg, 15 March 1939.

[70] PCA/NL 515. Nederlands Genootschap voor Verlichtingskunde. Letter from NGVV to Holst, 6 Nov. 1943.

lighting installations, implying that research with Philips irradiators into plant growth began again after the Second World War. Moreover, from 1949 on, research experiments were not left to scientists outside the Physics Lab, but were carried out in a greenhouse in Eindhoven by Physics Lab researchers. Dr. Voogd, who had worked at the Physics Lab since 1934, was responsible for research into biological and medical problems carried out directly after the Second World War. In the aftermath of the war, the inter-war Physics Lab activities had been evaluated. Voogd evaluated the Physics Lab's research activities relating to plant irradiation and came to the conclusion that the research remained promising and that Philips should contact international scientists doing the leading research on this topic.[71] According to Voogd, close contacts with Scandinavian scientists would be especially useful. It would be interesting for Philips to re-start horticultural research activities only if it placed a new research program within this broader context. Voogd came into contact with the Dutch biologist, Dr. R. van der Veen, who Philips appointed to do research in a greenhouse at the Physics Lab. Around 1946, Roodenburg had re-started his research together with two researchers at the Bovenkarspel agricultural experimental station.[72] They were not involved in the renewed Physics Lab program, but carried out their experiments by other means.

Van der Veen started his research project in a big Physics Lab greenhouse with a laboratory in Eindhoven.[73] He had full permission from Hendrik Casimir, one of Holst's successors, to begin a research program on the use of artificial light in plant life. In a letter to a Philips' budget committee, Casimir himself explained why he was willing to support such research at Philips. According to Casimir, increased sales of Philips' light sources for this specific application would soon become a reality due to the promising market directly after the Second World War. In cooperation (again) with Wageningen University, the Physics Lab researchers investigated a physical method to measure the effects of artificial light on plant growth.[74]

Casimir was of course interested in possible practical applications, but as a theoretical physicist, he also promoted the theoretical outcomes of

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[71] PCA/NL 544. Plantenbestraling. Letter from Dr. J. Voogd to Ir. Oranje, 2 April 1947. The engineer Oranje worked at the Philips Lighting at that time.

[72] R. van der Veen, "Het forceren van tulpen met kunstlicht," in: *Philips Technisch Tijdschrift* 10, 9 (1948): 282-85, especially p. 283.

[73] PCA/NL 324. Bestralingslampen. Notitie naar aanleiding van de budgetaanvragen van het Lab. W. O. voor de "Bouw van Botanisch laboratorium" en voor "Inrichten van een botanisch laboratorium," Dr. Voogd, 16 Sept. 1948 and Notitie betreffende werkruimte voor biologisch en biophysisch onderzoek, Dr. Voogd, 22 Nov. 1948.

[74] PCA/NL 60. Casimir. Letter from Casimir to Van Dijkhuizen, 4 June 1948.

the renewed program.[75] This was consistent with Casimir's attitude on how scientific research should be conducted at the Physics Lab when he was the lab's main director.[76] Agricultural research work became one of the promising "fundamental" research activities carried out under his supervision. Van der Veen became the leader of a big biological research program, which would remain in the Physics Lab organization for many years. Thus, research ideas accumulated within the agricultural network during the 1930s were internalized by the Physics Lab organization in a period of scientific optimism after the war.

Discussion: Research at Philips as a Networking Activity

It is clear how Holst, as a research director became involved in the Dutch agricultural research network consisting of representatives from industry, university, government, and interest groups. Physics Lab researchers participated in research activities outside the laboratory by elaborating on Roodenburg's project. Roodenburg, an independent biologist, had used his personal, informal network to ask Anton Philips and Holst for financial aid and specific knowledge. At the Philips company, Holst was willing to share his technical knowledge about lighting. After careful investigation of Roodenburg's skills and the value of his research proposal, Philips decided to provide him with financial aid and technical consultation. Philips through Holst must have seen this project as a promising activity given that the company was searching for new markets at the end of the 1920s not only for new products such as radio, but also for the existing light bulb technology. Behind Roodenburg's request, there was an emerging market for Philips light bulbs.

Holst certainly did not anticipate that the first contribution to Roodenburg's project would develop into participation in a network of research institutes and foundations. Although Holst had not anticipated such involvement, he was willing to build a network that connected individual researchers. In choosing partners, he considered their network embeddedness. At the same time, Holst became an interesting partner for other firms and universities' research groups. After some years of cooperation with Roodenburg, Holst received a request to participate in an agricultural research foundation because of his (and his fellow researchers') knowledge. These contacts—the ties within the network–gradually evolved, resulting in technical and market opportunities for Philips. The Physics Lab's joint ventures with research institutes such as the Wageningen University served as a way for Holst to learn about others'

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[75] The same can be said about research into medical applications. See PCA/NL 77. Casimir. Letter from Dr. Voogd to Professor H. Berkelbach van de Sprenkel of the Laboratorium voor Embryologie en Histologie, 26 June 1947.

[76] See Marc de Vries (with contributions by Kees Boersma), *80 Years of Research at the Philips Natuurkundig Laboratorium (1914-1994): The Role of the Nat.Lab. at Philips* (Eindhoven, 2002).

skills and resources. This learning enabled him to determine which of the partners' resources were of interest and how to value these resources.

However, the story also shows the network's vulnerability. Although Philips and Holst were initially most interested in Roodenburg's scientific results, eventually extending product markets became their dominant interest. It is not surprising therefore that Holst cut back Philips' support to Roodenburg as soon as the sales results were disappointing. Holst's reaction was consistent with his vision that the Physics Lab research should support his company. Roodenburg's project results were too poor from a business point of view. However, in line with Philips' expansion policy and its search for new markets, Holst left open the possibility for renewed contact and further agricultural research. Just after the Second World War, in a renewed period of expansion at Philips, Casimir, Holst's successor, gave Philips' agricultural research department renewed impetus.

To understand how industrial research networks involving Physics Lab researchers changed over time, I have presented and analyzed individual actor attributes, motivations, cognitions, and behaviors in an in-depth case study of their agricultural research network. This reveals that innovation at Philips involved not only the internal institutionalization of R&D activities, but networking activities as well.