

Martinus Willem Beijerinck

(1851-1931)

Pioneer of general microbiology

KING-THOM CHUNG and DEAM HUNTER FERRIS

"Fortunate are those who now start."

Martinus W. Beijerinck

Late in 1995, microbiologist, historians, and dignitaries participated in a conference, "Beijerinck Centennial-Microbial Physiology and Gene Regulation: Emerging Principles and Application," in The Hague, The Netherlands, to commemorate the appointment of Martinus Willem Beijerinck, the great microbiologist, as a professor at Delft Polytechnic School. Despite his discovering the filterability of the infectious agent responsible for tobacco mosaic disease, identifying the first microbial sulfate reducer, and conducting pioneering research on nitrogen fixation, very few current students of biology are aware of Beijerinck's fundamental contributions to the development of microbiology.

One reason that Beijerinck is not better known is that his studies of plant- and soil-associated microorganisms were less dramatic than those of his contemporaries Louis Pasteur and Robert Koch. Moreover, their work related to familiar human and animal diseases.

Beijerinck, with his keen ability for observation, was a prime mover in establishing general microbiology as a major discipline. Well before most universities recognized microbiology as a distinct discipline, he established the Delft School of Microbiology, which set the cornerstone for developing many such departments and institutions worldwide. Soon this school attracted a steady stream of insightful researchers, including the botanist and microscopist Gijsebertus Van Iterson and N. L. Söngen, the first to describe microorganisms

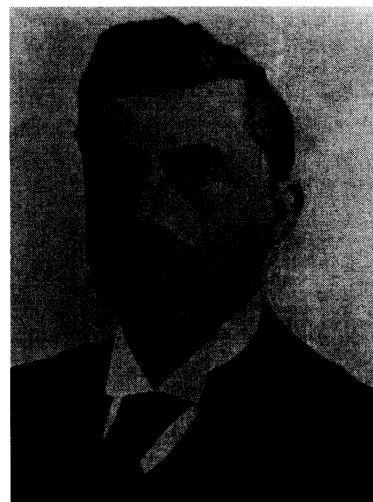
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that use methane as their sole source of carbon and energy. Albert Jan Kluyver, who inherited the chair of Beijerinck in 1921, developed the theory of metabolic unity and diversity for microorganisms. And C. B. Van Niel, one of Kluyver's students, migrated to the United States, where he influenced an entire generation of microbiologists with his enthusiasm for unusual biochemistry and physiology. Together with Pasteur, Koch, and the Russian Sergi N. Winogradsky, who specialized in soil microorganisms, Beijerinck is regarded as a founder of microbiology as a distinct discipline.

Beijerinck's Humble Family Origins

The family of Martinus Willem Beijerinck, who was born on 16 March 1851 in Amsterdam, The Netherlands, came from Twente in the province of Overijssel. His father, Derk Beijerinck (1805-1879), and mother, Jeanette Henriette van Slogteren (1811-1875), had one other son and two daughters.

When Derk Beijerinck's tobacco business in Amsterdam failed, he and his family moved to Naarden in 1851, where he found work as a clerk in the Haarlem booking office of the Holland Railway Company. Although the family was too poor to send Martinus to school, his father taught him not only



Beijerinck (from ASM Archives)

Scientific Highlights of Beijerinck's Career

- Demonstrated the filterability of the infectious agent of tobacco mosaic disease and coined the term "filterable virus." Described the intracellular reproduction of tobacco mosaic virus in 1898, a pioneering contribution in virology.
- Isolated *Bacillus radicola* and proved that it forms nodules on the roots of *Leguminosae* species. Later isolated *Rhizobium* species, studied nitrogen fixation, and demonstrated nitrogen fixation by free-living microorganisms, particularly *Azotobacter chroococcum*.
- Isolated and described in detail the denitrification process of *Bacillus sphaerosporus* and *Bacillus nitrous*.
- Isolated sulfate producing *Thiobacillus* species and demonstrated their chemotrophic nature. Also studied hydrogen sulfide production by *Aerobacter* species.
- Contributed to the understanding of lactic acid bacteria involved in producing kefir and yogurt. Demonstrated the significance of a catalase-negative reaction and proposed the generic name *Lactobacillus*.
- Introduced the generic name *Acetobacter*, described pigment-producing *Acetobacter melanogenum*, and studied butyric acid and butyl alcohol fermentation.
- Pioneered the study of luminescent bacteria and isolated *Photobacterium Zuminosum* (1889). Pioneered the study of yeast, isolated *Schizosaccharomyces octoporus* from raisins, and discovered the saccharolytic enzyme lactase of *Saccharomyces tyrocola*.
- Was the first to obtain pure cultures of algae, zoochlorellae, and gunidia of lichens.
- Studied urea decomposition, microbial variations (mutations), and oxygen relationships among bacteria.
- Observed *Sarcina ventriculi* in media of high acidity and under anaerobic conditions.
- Studied plant galls and did extensive morphological work on adventitious structures and regeneration phenomena in plants.
- Studied phyllotaxis, the arrangement of leaves on plant stems.
- Investigated the fungus *Clasterosporium carpophilum* (later named *C. beijerinckii*), the potent cause of gummosis.

all the subjects of elementary school but also French, English, a little German, artwork, and some astronomy and physics.

At the age of 12, Martinus went on to the elementary school of Master Knoop and, subsequently, the Hoogere Burgerschool (secondary school) at Haarlem. Despite an inferiority complex that undermined his self-confidence, intelligence and hard work led him to the top rank in his class. Moreover, during this time, Frederik Willem van Eeden, his science teacher in botany, greatly influenced Beijerinck. The two of them spent considerable time wandering the sand dunes near Haarlem nurturing a love of plant life. In 1866, at the age of 15, he won a contest on the basis of his collection of 150 species of plants.

With the help of his brother and uncle, Beijerinck entered the Delft Polytechnical School, where chemistry became his major subject but plants remained his major interest. While a student, he met J. H. Van't Hoff, who later won the first Nobel Prize in chemistry.

They undertook many experiments together, and Van't Hoff later became Beijerinck's lifelong adviser. Whenever a new opportunity arose for Beijerinck, he consulted with Van't Hoff before taking action.

Beijerinck graduated in 1872 and enrolled in the

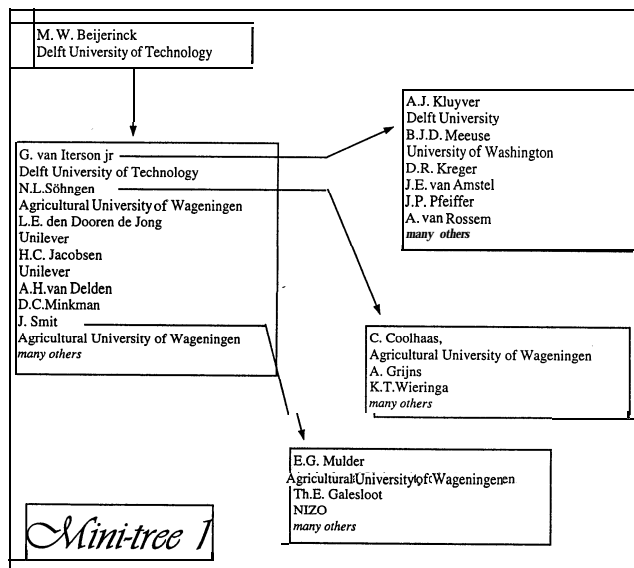
The Delft School of Microbiology Family Tree Project

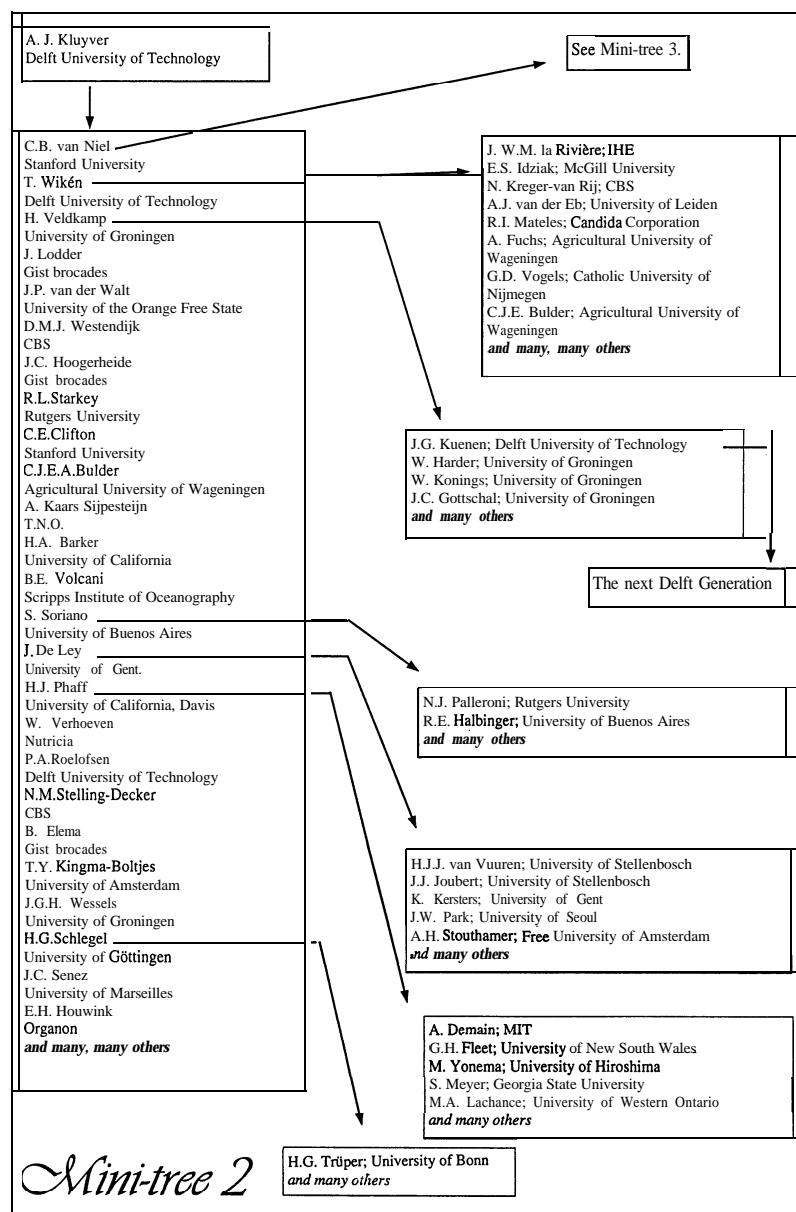
On a freezing evening outside the former Microbiology Laboratory in Delft late in 1995, the son of Albert Jan Kluyver unveiled a plaque commemorating the building, which is now an apartment complex. In that laboratory Beijerinck and Kluyver founded the Delft School of Microbiology a century ago. This year as we celebrate the Beijerinck centennial, we also recognize the five generations of microbiologists who descended from this school.

In marking the 100th anniversary of Beijerinck becoming a professor, we began to fill in the "family tree" of microbiologists who can trace part of their training to the Delft School. The tree began to grow as word of this effort spread. One of its most impressive aspects is its international spread. Members of this school are found on every major land block and in many countries,

Lesley A. Robertson

Lesley A. Robertson of the Kluyver Laboratory for Biotechnology at Delft University of Technology in Delft, Xhe Netherlands, began the Family Tree Project.





University of Leiden the same year. On 7 June 1873, he passed the candidate examination, magna cum laude, and was hired to teach at the Agricultural School in Warffum in the province of Groningen; however, his teaching was poor, and this job lasted for only a year. Meanwhile, he continued to study biology at the University of Leiden. In 1875, he became a part-time teacher at the State Secondary School at Warffum while continuing graduate school. When his mother died that same year, he was very upset.

Research and Teaching Become Beijerinck's Focus

In 1876, he took another teaching position at the Agricultural High School in Wageningen. This time, he liked his job greatly because he enjoyed teaching botany, a subject which really interested him. He contin-

ued research and in 1877 published his first paper on plant galls. In the same year he received his doctorate from the University of Leiden. His dissertation was dedicated to his father. He remained in Wageningen, teaching and studying plant galls. In 1883, one of his papers was accepted by the Amsterdam Academy, a great honor for him.

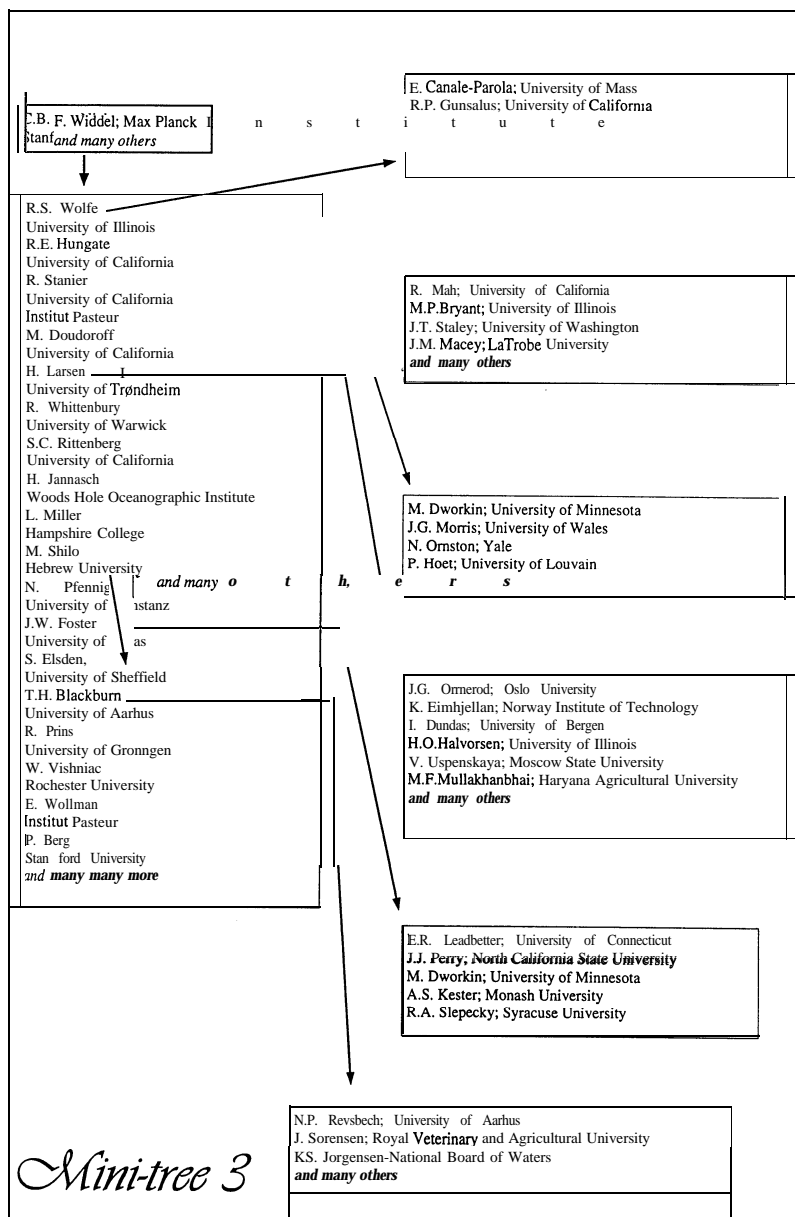
According to L. E. den Dooren de Jong, one of his students during this period, Beijerinck was a demanding and unpopular teacher who shouted his demands and often berated students for their mistakes. Their attitudes disappointed Beijerinck, who did not seem to understand the outlook on life of these "normal" students.

To Beijerinck, there was nothing more interesting than science. Botanical research was the love of his life. His work was increasingly recognized by the scientific establishment in The Netherlands, which in May 1884 elected him to the Royal Academy of Sciences in Amsterdam. During this period he also came into regular contact with many influential scholars, such as the botanist Hugo Marie De Vries (1848–1935), who rediscovered Mendel's rules of inheritance; the astronomer A. C. Oudemans (1827–1906); the ophthalmologist and optician F. C. Donders (1818–1889); and the German physiologist and microbiologist W. T. Engelmann (1843–1909). At Wageningen, with Adolf Mayer, who first discovered the transmissible nature of tobacco mosaic disease, he founded the Society for Encouragement of Natural Science.

Beijerinck Moves from Academic Life

In 1885, Beijerinck became a microbiologist at the Netherlands Yeast and Alcohol Manufactory in Delft at the invitation of its farsighted director, J. C. Van Marken. Paid an extraordinarily high salary and provided with excellent equipment to establish an outstanding laboratory for microbiology, Beijerinck really came into his own.

Just before the new laboratory was completed, Beijerinck visited several important researchers elsewhere in Europe, including the founder of mycology, Henrich Anton De Bary (1831–1888), at Strasbourg, France, and another expert on fungi, Emil Christian Hansen (1842–1909), whose specialty was the study of yeasts, at Copenhagen, Denmark. Although admired for his scientific enthusiasm, Beijerinck's fondness for dispute did not always make him welcome. For instance, his plans to visit Koch in Berlin were unfulfilled because of his reputation. From then Beijerinck developed a pronounced dislike for medical bacteriology. In contrast to most microbiologists at the time, who fol-



Despite such work-related successes, however, Beijerinck was deeply withdrawn and lived an extremely lonely life. Some of his writings reflect a concern that he might not live up to the expectations of the company. In addition, he did not get on well with colleagues. Fortunately, he enjoyed strong support from director Van Marken, who convinced him several times not to resign. He also formed a close friendship with a young technologist, F. G. Waller, a future chairman of the board of the Yeast and Spirit Work.

Beijerinck's Scientific Reputation Grows

In 1894, Beijerinck earned his place in history with his paper on *Spirillum desulfuricans*, a sulfate reducer. He showed that this bacterium extracts energy by metabolizing sulfur compounds. This interest in esoteric sulfate reduction arose from practical problems in the yeast factory, which used canal water for its steam boilers. Bacteria extracted minerals in the water and caused a buildup of calcium sulfate that fouled the boilers, he learned. Like that of Pasteur, Beijerinck's research led to solutions for industrial problems but also produced valuable insights into basic microbiology.

Recognizing Beijerinck's many achievements and realizing that the scope of his work could expand in better surroundings, in 1895 Dutch government officials created a special position for him at the Delft Polytechnic School. Because the school had no formal program in biology at that time, he was given a position in the chemistry department. Beijerinck was delighted with this new opportunity, which meant returning triumphantly to the school where his career started.

Although he was still unpopular, Beijerinck was a big inspiration to those who understood his vast knowledge and dedication to science. Most of his few doctoral students became eminent scientists and made significant contributions to science and industry.

Beijerinck appreciated quality scientific research, giving credit to his assistants and allowing them to publish important papers on their own. A. H. Van Delden, his assistant from 1895 to 1904, did important work on nitrogen fixation, on *Bacillus oligocarboophilus*, and on the retting of flax. He also helped work on sulfate reduction. G. Van Iterson, Jr., his assistant from 1902 to 1907, obtained a doctoral degree under Beijerinck's guidance in 1907. By far his most brilliant student, Van Iterson studied denitrification and decomposition of cellulose and later became an eminent

followed the lead of Pasteur and Koch by focusing on human and animal diseases, Beijerinck devoted his research to plant microbiology.

During this period in Delft, Beijerinck continued to work on plant galls and related microbiological problems. He made an important discovery, which later affected agriculture greatly, when he isolated nitrogen-fixing root nodule bacteria in pure culture. This work was but one of a multitude of projects. Increasingly absorbed in research, he spent long hours in the laboratory, sometimes spending entire nights without sleeping. Much of Beijerinck's research was relevant to production needs at the factory. For instance, he studied the butyl alcohol fermentation of *Schizosaccharomyces octoporus* and the nitrogen fixation of *Bacillus radicola*. He also studied luminous bacteria and green algae.

professor of botany. Yet another assistant, N. L. Söhn-gen, was the first to describe organisms that use methane as an energy and carbon source by demonstrating conversion of hydrogen to methane and obtaining the first enrichment cultures of methane-producing bacteria.

Beijerinck's persistence was amazing. According to den Dooren de Jong he would sometimes begin to examine inoculated plates in the morning and continue late into the evening on the same plates. His keen observations enabled him to discover many important microorganisms and their functions (see box).

Beijerinck developed the principles of enrichment culture. Through these techniques, he and others could more readily uncover the role of microorganisms in natural processes and better harness these activities to benefit agriculture and industry. His unusual application of these principles made him perhaps the first microbiologist to emphasize an ecological approach to microbiology. "In an experimental sense, the ecological approach to microbiology consists of two complementary phases which give rise to an endless number of experiments," he noted. "On the one hand, it leads us to investigate the conditions for the development of organisms that have for some reason or other, perhaps fortuitously, come to our attention; on the other hand, to the discovery of living organisms that appear under predetermined conditions, either because they alone can develop, or because they are the more fit and win out over their competitors. Especially this latter method, in reality nothing but the broadest application of the elective culture method, is fruitful and truly scientific, and it is no exaggeration to claim that the rapid and surprising advances in general microbiology are due to this methodology."

Beijerinck was awarded many honors, including the Leeuwenhoek Medal by the Royal Academy of Sciences at Amsterdam, honorary membership in the Royal Botanical Society of Edinburgh, candidacy for a Nobel Prize in chemistry, commandship in the Order of Oranje-Nassau, corresponding membership in the Czech-Slovakian Botanical Society, the Danish Emil Christian Hansen Medal, and election as a foreign member of the Royal Society of London.

Beijerinck never married. In fact, he never dated and had few, if any, female friends. He believed that marriage would interfere with his work. He was so reclusive that he even refused to have his picture taken. After his father's death, he lived in virtual seclusion with his sisters, Henriette and Johanna, except for socializing with the chemist Van't Hoff and his wife.

Although Beijerinck retired in 1921, he never gave up research. He died quietly on 1 January 1931 in Gorssel, The Netherlands. cl

Suggested Reading

- Van Iterson, G., L. E. den Dooren de Jong, and A. J. Kluyver. 1993. *Martinus Willem Beijerinck, his life and work*. A Publication Science Technology, Inc., Madison, Wis.
- Van Niel, C. B. 1949. The "Delft School" and the rise of general microbiology. *Bacteriol. Rev.* 13: 161-174.
- Waksman, S. A. 1931. Martinus Willem Beijerinck. *Sci. Mon.* 33:285-288.

Acknowledgment

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