Ferdinand Cohn, a Founder of Modern Microbiology

Cohn described several key physiological processes in microorganisms and developed principles leading to modern taxonomy

Gerhart Drews

By the middle of the 19th century, many bacteria, fungi, protozoa, and lower algae were known from microscopy studies. However, no pure cultures of any of these microorganisms were available, making it impossible to study their biochemistry, physiology, and genetics. Moreover, many scientists still believed that microorganisms could arise by spontaneous generation.

The obscure term "vital force" was replaced by an understanding that living things perform work. The strong influence of natural philosophy waned as biologists and other scientists looked toward empirical findings as well as principles developed within other disciplines to explain biological processes. For instance, the theory of heat conservation, the calculation of heat units, and the conservation of energy, proposed by Julius Robert Mayer (1845), J. P. Joule (1843), and Hermann L. Helmholtz (1846), provided a new basis for studying physiological processes.

Meanwhile, the idea that nature is not static, but is subject to constant change, developed slowly at first but soon accelerated. Jean Baptiste Chavalier de Lamarck (1809) helped to advance some of these ideas, but Charles R. Darwin subsequently formulated them as the theory of evolution and natural selection (1859). During this period, the important doctrine of cells as the building blocks of organisms also took shape, while valuable experimental instruments such as microscopes were being greatly improved.

Together, such developments ushered in a great period of cell and developmental biology. It was at this time that Ferdinand Cohn started his academic career in biology.

The Education of Ferdinand Cohn

Ferdinand Julius Cohn was born in Breslau, situated in Silesia in Prussia, Germany (now Wroclaw, Poland), on 24 January 1828. The Jewish Ghetto, where he was growing up, was situated in a southwestern neighborhood of Breslau and was not secluded from other parts of the town.

Ferdinand's father, Isaak Cohn, was known for his high intelligence, a strong interest in various cultural areas, and liberal views on politics. He became a successful merchant and manufacturer, who supported spiritually and financially the education and the sometimes rocky career path of his son.

Ferdinand was a precocious boy who finished his education at the Maria Magadalena Gymnasium by the age of 16. He began his professional studies in 1844, pursuing botany as his specialty under the guidance of H. Robert Göppert at the University of Breslau. He also devoted considerable attention to general sciences, history, literature, and languages.

When Cohn applied for admission to the doctoral program in Breslau, he was refused entry because of his Jewish background. His decision in 1846 to pursue a doctoral program in Berlin proved very wise. There, he came into contact with top scientists of the day, including chemist Eilhard Mitscherlich, botanist Karl S. Kunth, zoologist M. H. Carl Lichtenstein, physiologist Johannes Müller, protozoologist Christian Gottfried Ehrenberg, and many young scientists

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whose company proved very stimulating and thus contributed to his scientific work.

Cohn completed his doctoral work on the structure and germination of seeds, and received his degree on 13 November 1847 at the age of 19. For several years, he continued his studies in Berlin, where there was ready access to seminars, intellectual gatherings, and sessions of the Berlin Academy of Science and where he was welcomed into the homes of many intellectuals. His open-minded political interest led him to participate actively in the 1848 revolution.

Back in Breslau, Cohn Studies Cell Biology of Plants

In 1849 Cohn returned to Breslau, where his father obtained a large and expensive Plössl microscope for him–better than any then available at the university. The microscope was Ferdinand's major research tool, and he spent some time developing improved methods for its use.

In the first decade of his academic career, Cohn studied the growth and division of plant cells; described cellular structures and formation of the cuticula, epidermis, and plasma membrane; and analyzed plasma streaming and cell differentiation. For example, to fulfill his Habilitation (second dissertation), Cohn refuted a hypothesis developed by Matthias J. Schleiden that the cuticula is a secretion that forms at the surface of the cell. Cohn proposed that the cuticula is instead a separate layer upon the epidermis. In several other publications Cohn described the movement of leaves and contractile tissues of plants and animals. Based on comparative studies on lower plants and animals, he concluded that the protoplasm described by botanists and the sarcode or contractile substance described by zoologists are highly similar entities.

Cohn increasingly directed his attentions to unicellular algae and protozoa, lower fungi, and bacteria. For instance, he described the developmental and sexual cycles of the algae *Protococcus pluvialis*, *Stephanosphaera pluvialis*, *Sphaeroplea annulina*, and *Volvox globator* and of the lower fungi *Pilobolus crystallinus* and *Empusa* (*Entomophthora*) *muscae*. These early efforts are still considered important contributions to the cell biology and taxonomy of these eukaryotic microorganisms.

Early Contributions to Bacteriology

Meanwhile, Cohn's comprehensive studies on different groups of microorganisms led to a system for classifying bacteria. Louis Pasteur, Ernst Hallier, and other scientists from that era established that microorganisms cause fermentations or act as "contagions." However, no one then had isolated the microorganisms responsible for those activities in pure culture to characterize them more thoroughly.

Moreover, the nomenclature of bacteria during this era was chaotic. Almost every microscopist who observed bacteria gave them a new name without notice of whoever else might have observed and already named the creature under observation. Exceptions to this practice included Christian Gottfried Ehrenberg and Felix Dujardin, who arranged bacteria in several groups of genera and species. Many respected scientists of that time, including Wilhelm Zopf, Carl von Naegeli, and C. A. Theodor Billroth, believed that all bacteria were variations of one and the same organism. Thus, they thought that different stages of development, types of multiplication, the variety of size and form, and specific metabolic properties were not associated with distinct species types.

Cohn was aware that genera and species of bacteria have other meanings than for higher organisms, which reproduce sexually. He stated clearly that the "form-species" and the "form-genera" that he proposed for each microorganism would have to be further tested to determine whether they are related in terms of their development, chemical features, and descent. In 1875, he defined bacteria as chlorophyll-less cells of characteristic shape that multiply by cross division and live as single cells, filamentous cell chains, or cell aggregates.

After 20 years of extensive studies on shape, cellular structures, pigmentation, metabolic activities, and the variability of all these features, he confirmed and extended his hypothesis that bacteria can be divided into distinct species with typical characteristics, which are transmitted to the following generations when bacteria multiply. Cohn also proposed that varieties exist within species.

By comparing the chlorophyll- and phycocyan-containing *Oscillatoria* and the colorless *Beggiatoa*, Cohn learned that members of both genera have the same shape and cellular organi-

zation and the same type of movement, which is a combination of gliding forwards and backwards, a rotation around the longitudinal axis, and a vivid bending of the trichomes (Fig. 1). Waves of contraction along the surface of the filaments were later interpreted as a possible mechanism of movement.

In a comprehensive monograph published in 1867, Cohn deduced a relationship between groups of bacteria, phycochromaceae (Cyanophyceae), florideen (red algae), and lichen on the basis of pigments, type of cell division, movement, and mode of reproduction. The pigments chlorophyll, phycocyan, and phycoerythrin were detected by simple chromatographic and spectroscopic methods. On the basis of Darwin's evolutionary theory as well as his own observations, Cohn proposed that Phycochromaceae were early inhabitants of the earth because of their ability to adapt to extreme habitats, their simple way of reproduction, and the fossil records.

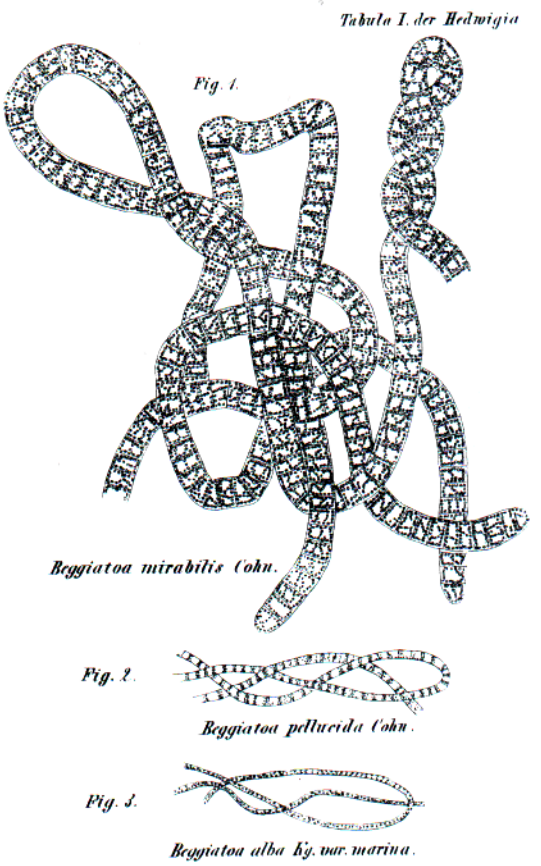
Cohn Believed All Bacteria Were Part of the Plant Kingdom

Cohn also was convinced that bacteria belong to the plant kingdom and that they are related to the algae. In this scheme, Schizophyceae (Cyanophyceae or cyanobacteria) and Schizomyceae (bacteria) were combined in the group of Schizophyta (fission plants).

Cohn studied bacterial growth using defined mineral solutions complemented with different organic carbon sources. He observed that some bacteria can decompose organic substances in the presence of inorganic sources of nitrogen. However, he denied that bacteria can assimilate carbon dioxide. Sergei N. Winogradsky discovered autotrophy (growth with CO_2 as the only carbon source) in 1890.

In Cohn's first system for classifying bacteria, he proposed a scheme with four groups: (I) Sphaerobacteria (sphere-shaped), *Micrococcus*; (II) Microbacteria (rod-like), *Bacterium*; (III) Desmobacteria (filamentous), including *Bacillus* and *Vibrio*; and (IV) *Spirobacteria* (screw-like bacteria), including *Spirillum* and *Spirochaeta*. He further divided the genera–for example, *Micrococcus* was subdivided into chromogen (pigmented), zymogen (fermenting), and pathogen (contagious).

FIGURE 1



Beggiatoa species, drawn by F. Cohn, from Hedwigia 5:161–166 (1866).

Cohn designated the genus *Bacillus*. In two thorough studies published in 1876 he outlined the entire life cycle of *B. subtilis*. He discovered that the vegetative cells but not the endospores are killed in boiling water. The discovery of heat resistance of endospores finally overthrew the old doctrine of spotaneous generation.

Cohn studied in detail the growth and development of such spores, describing their dependence on temperature, oxygen content, and various nutrients. These studies of *B. subtilis* were consistent with his earlier hypothesis that bacteria can be classified into different genera and that they have specific inheritable characteristics of metabolism, form, and development.

In another series of studies, Cohn correctly described the pigmented bacteria, which Wilhelm Engelmann had earlier named purple bacteria, in terms of their shape, pigments, gas

FIGURE 2

Ferdinand Cohn (from Cohn 1901)

vacuoles, and sulfur globules. Cohn took preparations from his own enrichment cultures of these microorganism to compare them with specimens obtained from specific habitats and from colleagues such as Eugen Warming.

On the basis of simple experiments, Cohn concluded correctly that the light-scattering granules in *Beggiatoa* species and purple sulfur bacteria contain elemental sulfur. But he was wrong in assuming that *Beggiatoa* species produce hydrogen sulfide, which in fact these microbes oxidize under low oxygen concentrations, according to Winogradsky. Several years later in 1895, M. W. Beijerinck correctly described formation of hydrogen sulfide by *Desulfovibrio desulfuricans*.

Cohn Was Active in Applied Microbiology

From the beginning of his career, Cohn gave lectures in agricultural botany and advised farmers on the diagnosis and treatment of plant diseases caused by fungal infections. He became a pioneer in the analysis of water as an important source of infectious diseases.

For example, during several cholera epidemics, he investigated the drinking water as a potential source of the infectious agent. Although Robert Koch and his coworkers identified the pathogenic agent of cholera, *Vibrio cholerae*, in 1883, Cohn described other pathogenic and nonpathogenic microorganisms in water. He also petitioned authorities to develop a system of microscopic and chemical analysis of drinking water not only during epidemics but also under normal conditions and when bodies of water were contaminated by industrial waste. His approach to water analysis proved practicable, even proving more sensitive than the chemical analysis then available.

In 1875 Cohn began and edited a comprehensive study of the flora of cryptogamae (lower plants, ferns, mosses, algae, characeae, and fungi) in Silesia, the results of which were subsequently compiled into three volumes, published in 1878, 1889, and 1908.

For more than 30 years, Cohn served as the secretary of the botanical section for the Schlesische Gesellschaft für vaterländische Kultur (the Silesian Society of National Culture), a type of scientific academy. From this post, he supervised studies on the distribution and development of about 90 plants, and he reported many of his own observations in the environment of Breslau and his experimental work. Cohn was also asked to give his expert opinion on biological material he received from participants of expeditions. For instance, he and his colleague Joseph Schroeter investigated a bulbous material from the West African coastal region that they identified as sclerotia of the new species *Lentinus woermannii*.

Cohn Heard by a Broad Public and Scientific Audience

Cohn became lecturer in 1857 and associate professor in 1859. His successful research and his carefully prepared and eloquently delivered lectures attracted many students and young scientists.

Cohn's comprehensive studies on different groups of microorganisms led to a system for classifying bacteria

However, during this early period, he had no rooms in which to conduct his research. After many unsuccessful petitions to the Minister of Culture, the university in 1866 allowed him to use an empty room in the old convent located in the center of the town.

In the same year, he received from the Minister of Agriculture 400 thaler to buy necessities. By the same order, he was obliged to give lectures for students of agriculture and to conduct agricultural studies at the request of the ministry without further recompense. Three weeks later Cohn reported to the Minister that the new laboratory was opened. Cohn received money from the Minister only in small portions, not sufficient for the first primitive equipment, repair of the rooms, and salary for a technician. Very often he laid out his own funds but was reimbursed many

Ferdinand Cohn Gravesite Restored, Rededicated in 1998

Several German microbiological societies provided funds for the restoration of the grave of Ferdinand Julius Cohn in Wroclaw, Poland (formerly Breslau, Germany), who is considered one of the founders of bacteriology. He was born in Breslau in 1828, received his Ph.D. from the University of Berlin when he was 19 years old, was granted professorship at the University of Breslau in 1857, and died in 1898.

A botanist and naturalist, Cohn began his study of bacteria in 1868. Four years later, he published his *Untersuchungen über Bakterien* (*Researches on Bacteria*), which is considered the starting point of modern bacteriology. His primary contributions included the classification of bacterial species on the basis of their morphology and physiological features and his description of the formation of endospores in *Bacillus subtilis*. Cohn also helped to establish the reputation of Robert Koch, who as an unheralded medical practitioner visited Breslau in 1876, seeking an appraisal of his anthrax studies. After Koch visited the Institute of Plant Physiology in Breslau to demonstrate his findings, their medical significance came to be widely recognized. Cohn remained a staunch supporter of Koch for years to come.

Cohn and his wife, Pauline, were buried in the Lohestrasse Jewish Cemetery in Breslau, which is now a component of the Historical Museum of Wroclaw (Stary Cmentarz Zydowski). The gravesite was in a state of disrepair (see photo) until three German microbiological societies (Vereinigung für Allgemeine und Angewandte Mikrobiologie, Deutsche Gesellschaft für Hygiene und Mikrobiologie, and the Gesellschaft für Virologie) joined forces with the Museum Historyczne we Wroclawin to reconstruct the Cohn monument with the placement of a memorial tablet. Polish and German inscriptions on the tablet translate as follows:

Ferdinand Julius Cohn
1828–1898
Botanist and Microbiologist, Pioneer in Modern Microbiology
and the Taxonomy of Microorganisms
Founder of the Institute of Plant Physiology of the
University of Breslau (1866)
Promoter of Robert Koch
On the 100th Anniversary of his Death on June 25, 1998 in Breslau.

During the commemorative gravesite rededication ceremony in 1998, several German and Polish microbiologists recalled Cohn's distinguished career and his many scientific and intellectual contributions. The leaders of the three German microbiological societies are planning a scientific symposium commemorating the achievements of Cohn in 2000.

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FIGURE 3

Institute of Plant Physiology and Museum of Botany, opened 29 April 1888 (photo taken 25 June 1998).

months later. By 1873, the institute received a regular budget.

In spite of these and other problems, Cohn was very productive in his scientific work and became an authority in bacteriology and systematics of lower plants. Many students and scientists from abroad came to Breslau to study with Cohn, and several of them later became leaders in their fields.

Cohn Lends Credence to Koch's Early Work

Cohn's reputation led Robert Koch to ask Cohn for his opinion on Koch's studies on the etiology of the anthrax bacillus. Koch was invited to the institute and discussed his results with Cohn and his colleagues, the pathologists Weigert and Cohnheim. Cohn recognized immediately the importance and scientific quality of Koch's work and encouraged and supported the further work and career of Koch. The article on the etiology of the anthrax bacillus was published in 1877 in *Beiträge zur Biologie der Pflanzen*, a journal that Cohn founded in 1875.

Cohn recognized immediately the importance and scientific quality of Koch's work and supported Koch's further work and career

In 1887, Cohn was appointed as full professor (Fig. 2). The inadequacy of rooms for research and teaching and the need for a museum of botany led after many years of planning to acceptance of a proposal for a new building. The new facility, containing the herbarium and the museum, a lecture room, the institute of plant physiology with laboratories, a library, and other rooms for the director of the botanical garden and apartments for employes, was opened in 1888. The building is still in use (Fig. 3).

The creative phase of Cohn's life continued from 1850 to about 1880. After that period, the years of hard work in research, teaching, and administration and increasing problems with hearing and failing eyesight began to interfere with Cohn's scientific productivity. Thereafter other scientists determined the speed and direction of research in microbiology. But Cohn remained active in the field of history, art, and in communicating science to a broad audience.

For example, during this period, he wrote, "I am convinced that the knowledge of the most important scientific problems, of the methods used for solving them, and the results which are obtained by their application, are necessary for general culture just as it is accepted for religion and philosophy, for history of culture and states and for art and literature." Cohn was deeply convinced that scientific ideas are important not only for scientists, but also for the general public.

Cohn impressed his audiences with his gifted, clear, and often brilliant speech. His description of a broad spectrum of botanical knowledge was combined in the collected lectures on plants (*Die Pflanze*), which was published in 1882 and in a second, revised edition in 1897. An article on the "Plants in the Fine Art" (1898) presents a retrospective on the description of plants in art and science during several epochs.

From the beginning of his career, Cohn communicated and cooperated with many of his contemporaries in Europe and America by letter and personal contact. He died suddenly on 25 June 1898 from a heart attack when he returned from his daily work to his home. The monument on his grave in the Jewish cemetery in Wroclaw was reconstructed in 1998 (see box on page 551).

Cohn was honored by numer-

ous distinctions during his life from academies, societies, universities, and his home town as an honorary citizen. His great personality and his important work has been detailed in several books. For instance, W. Bulloch remarked in his *History of Bacteriology* (1938) that "...[Cohn] is on new ground which in a way was the starting point of our modern ideas in bacteriology... [H]is work was entirely modern in its character and expression, and its perusal makes one feel like passing from ancient history to modern times."

SUGGESTED READING

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