The Academy and the Exact and Earth Sciences

One of the greatest services the Academy has rendered to the exact sciences – a term perhaps employed too narrowly in our times for astronomy, physics, chemistry and mathematics – has been to provide economic support. At first this was only slight in financial terms but often of decisive importance; for example, the support arranged by the tireless Academy Secretary H. C. ØRSTED (1777–1851), for the Danish discoverer of the law of conservation of energy, L. A. COLDING (1815–1888). The expression "Danish discoverer" is used because this was in fact an item of basic knowledge which was brought to light roughly simultaneously in several places in Europe.

Later on it was the *Carlsberg Foundation*, established by the brewer J. C. JACOBSEN (1811–1887), that was of invaluable importance for the development of the exact sciences in Denmark. Many of our most influential scientists have been members of the board of this Foundation, which is elected by the Academy, and have therefore been involved in the development of research in this country far beyond their own fields.

For chemistry and the associated biological sciences in particular, the *Carlsberg Laboratory*, also founded by J. C. Jacobsen in 1876, has been of great significance through the strongly interna-

tionally-orientated research that has been, and still is, carried on there. This also applies to the Foundation's *Institute of Biology* (1932).

Moreover, the Academy has been of importance in maintaining a *tradition* within the exact sciences in this country. This is exemplified by its publication of OLE RØMER's notebook, *Adversaria*, in 1910, edited by THYRA EIBE and KIRSTINE MEYER, the former being the Danish translator of Euclid. Another example is Kirstine Meyer's edition of the *Scientific Papers of H. C. Ørsted*, accompanied by two weighty treatises dealing, respectively, with Ørsted's sientific activities and his other contributions to Danish society – including his strenuous efforts as the Academy's Secretary.

Furthermore, the Academy has produced special publications to commemorate various scientifie events and taken other steps to maintain interest in earlier research and in great names in science, e.g., the Academy celebrated the 300th anniversary of the birth of OLE RØMER in 1944.

In addition, earlier publications have sometimes been re-issued with commentaries, after the realization that the work in question had been of greater significance than was apparent on its first appearance. This was the case with a treatise by the surveyor CASPAR WESSEL (1745–1818). He was the brother of the poet Johan Herman Wessel, who wrote of Caspar Wessel: "He reads the law and draws maps. Being as busy as I am lax". This treatise gave a definite geometric basis for calculations with complex numbers and contains ideas that point towards algebraic concepts conceived at a much later date. This was Caspar Wessel's only

known contribution to pure mathematics and it was without importance for later developments – particularly because it was written in Danish – but it is a captivating testimony of the rich intellect of an isolated mathematician.

The activities of the Academy and its members obviously reflect the most important aspects of the history of the exact sciences in Denmark. However, it should be noted in this connection that the Academy was first founded in 1742, by which time Danish scientists had already made their mark in several fields. In astronomy, physics and chemistry this applies to Tycho Brahe (1546–1601), Rasmus Bartholin (1625–1698), Ole Rømer (1644–1710) and Ole Borch (1626–1690), while the great Niels Stensen (Nicolaus Steno) (1638–1696) was also familiar with the exact sciences. Moreover, this list includes only the most famous names; almost two hundred years were to pass before Danish science was to achieve results even approaching the same importance.

The following is an attempt, in very brief glimpses, to describe some features of the development of the exact sciences in Denmark in terms of the efforts of the scientists involved, but shortage of space clearly only permits a very rough outline and thus precludes mention of much valuable research and many accomplished scientists. Furthermore, it is hardly possible for anyone to give an entirely impartial survey – for the unity of research has vanished with increasing specialisation and it is almost impossible, even within a circumscribed field to comprehend the whole subject.

The oldest of the exact sciences in Denmark is *astronomy*. After the unique work of Tycho Brahe and Ole Rømer in observational astronomy, a *tradition of astronomical research* was established that has remained intact in this country until the present day. Since these early years there has been a steady development of this subject but without results of comparable significance. No names will be mentioned in connection with this long tradition – its main feature is its continuity, which probably exceeds that of any other exact science in this country.

Two distinguished Danish astronomers in our century should be mentioned. EJNAR HERTZSPRUNG (1873–1967) carried out his work in Germany and Holland; it comprised a number of significant stellar-astronomical investigations. The so-called Hertzsprung-Russell diagram, which gives the relationship between the colours of the stars and their actual luminosity, proved to be of decisive importance in the development of astrophysics.

At the same time, the chair in Copenhagen was held by ELIS STRÖMGREN (1870–1949) whose sphere of research was celestial mechanics and who contributed much to practical international collaboration in astronomy.

With regard to *physics*, the first breakthrough after OLE RØMER was made by H. C. ØRSTED (1777–1851). His fame is based on his discovery of *electromagnetism* in 1820, among his other achievements in chemistry and physics, but it should not be forgotten that he was the first scientist to produce *aluminium*, which he termed the clay-soil

metal, or *Argillium*. To these successes should be added his very substantial contributions to society in general: the establishment of the *Polyteknisk Læreanstalt* (now the Technical University of Denmark), and of the *Selskab for Naturlærens Udbredelse* (Society for the Dissemination of Natural Science) and everything that followed in the wake of these initiatives. From 1815 to 1851 he was a very active and influential Secretary of the Academy.

Another great physicist was L. V. LORENZ (1829–1891). He distinguished himself both in experimental physics and in mathematical physics and made valuable contributions to, for example, the theory of light and the understanding of the relationship between the refractive index of a material and its specific gravity. He also studied the electrical- and thermal-conductivity of metals and their temperature dependence. The significance of his original and far-reaching research was only properly recognized after his death.

C. CHRISTIANSEN (1843–1917) acknowledged the debt he owed to Lorenz. As Professor at the of Copenhagen University and at the Technical University, he was the first physicist in Denmark to found an actual school of research. His work in widely differing fields had the character of rather isolated investigations (apart from the series of studies on *frictional electricity* in his later years) and was characterized by originality and a wealth of ideas. He is especially well-known as one of the first scientists to recognize the so-called *anomalous dispersion* of light.

One of Christiansen's pupils was KIRSTINE

MEYER (1861–1941), the most important historian of physics in this country, and an excellent and influential teacher. She never became a member of the Academy, but she performed valuable work under its auspices. MARTIN KNUDSEN (1871–1949) carried out a series of internationally renowned investigations on *gases under such low pressure*, that their properties – in theory, very easy to calculate – were experimentally very difficult to measure. He was a leading figure in Danish and international *physical oceanography* and Secretary of the Academy for thirty-two years (1917–1949), where he did much useful work in furthering international collaboration, which became of ever-increasing significance in his time. Other pupils of Christiansen should be mentioned: JULIUS HARTMANN (1881–1951), who became one of the forerunners of modern plasma physics through his *magneto-hydrodynamic investigations*; the spectroscopist and biophysicist H. M. HANSEN (1886–1956), who wielded considerable influence because of his broad physical insight and his collaboration with Niels Bohr; and P. O. PEDERSEN (1874–1941), Rector of the Technical University for many years, who made important contributions in different fields of electro technology (e.g., the propagation of radio waves). In a fruitful collaboration with VALDEMAR POULSEN (1869–1942), he further developed Poulsen's discovery of so-called continuous radio waves for radiotelegraphy and radiotelephony systems.

NIELS BOHR (1885–1962) was also a pupil of Christiansen, and his work provided the next, and uniquely important breakthrough in Danish phy-

Niels Bohr, president of the Academy 1939–1962. Painting by Henrik Sørensen.

sics. As early as 1906 Bohr and P. O. Pedersen were awarded the Academy's gold medal for their treatises on surface tension and waves. His significance for the development of *modern atomic* and *nuclear physics* is well known, as is his new and penetrating *insight into the epistemology of the physical world.*

He was President of the Academy from 1939 until his death, a term of office broken only by the years when he was forced to flee the country because of Nazi barbarism; it is no exaggeration to say that he cast a very special light over the work of the Academy. Through the work of Niels Bohr, Copenhagen became the centre of international research in atomic and nuclear physics – housed in the famed Blegdamsvej 17, now the *Niels Bohr*

Institute. All in all, he was the scientific world's most dedicated advocate of the value and importance of international collaboration in-research.

Among Niels Bohr's Danish colleagues were J. C. JACOBSEN (1895–1965), who worked especially on radioactivity; the above-mentioned H. M. Hansen; the spectroscopist EBBE RASMUSSEN (1901–59), who was secretary of the Academy for all too short a period in 1959; and CHRISTIAN MØLLER (1904–80), who took over this post and held it until his recent death. Møller's very broad-based work as a theoretical physicist was concentrated in his later years on the theory of relativity, where he held a leading international position.

Turning now to *chemistry*, the first notable contribution was made by the organic chemist WILLIAM ZEISE (1789–1847), who introduced accurate *quantitative chemistry* to Denmark. Thereafter, C. T. BARFOED (1815–1889) is known for his development of *methods of analytical chemistry*, particularly in organic chemistry. As a consultant to J. C. Jacobsen, the brewer, he had considerable influence on the founding of the Carlsberg Laboratory, where he became a board member. In this context mention should be made of J. KJELDAHL (1849–1909), who was the first head of the Department of Chemistry of the Carlsberg Laboratory, and who is now particularly remembered for his method of detecting nitrogen in organic materials: *"to kjeldahle"* is an international expression among chemists.

The two leading figures in chemistry in the last century and at the beginning of our own were, however, JULIUS THOMSEN (1826–1909) and S. M.

JØRGENSEN (1837–1914). The former is particularly famous for his unique, and extensive research in *thermochemistry* and for his prediction, through a new arrangement of the so-called *periodic system* (later used by Niels Bohr) of the existence of the *noble gases*. Jørgensen is remembered for his pioneering investigations of *complex metal compounds* and for his contributions to the *history of chemistry*. From 1888 until his death Julius Thomsen was an authoritative, and at times somewhat uncompromising, President of the Academy.

Because of S. M. Jørgensen's general attitude to chemistry and his interest in his pupils, it was he who started a research school. Of his pupils S. P. L. SØRENSEN (1868–1939) should be given first mention. He became head of the Department of Chemistry at the Carlsberg Laboratory, and was known for his studies of *enzymes and proteins*, as well as for his investigations of the importance of the *hydrogen ion concentration* in many fields. In 1938 he was elected President of the Academy, but died the following year.

NIELS BJERRUM (1879–1958) and J. N. BRØNSTED (1879–1947), both from the school of Julius Thomsen and S. M. Jørgensen, founded the modern tradition of *physical chemistry* in Denmark. They contributed much to the theory of *strong electrolytes*, in which they both were international leaders, but were also very active in other fields of physical chemistry. For example, Bjerrum pioneered the development of *molecular spectroscopy*, while Brønsted made a valuable contribution to the development of the third law of thermodynamics through his so-called *affinity studies*.

E. Biilmann (1873–1946) was a versatile organic chemist who for many years headed the research in organic chemistry at the University of Copenhagen. He played a large part in the work of the International Union of Chemistry.

Three of the following generation deserve mention: J. A. Christiansen (1888–1969), successor to J. N. Brønsted at the of Copenhagen University and internationally renowned for his research on the *kinetics of chemical reactions*; A. Langseth (1895–1967), who achieved unique results in *molecular spectroscopy* (the so-called Raman effect); and finally K. Linderstrøm-Lang (1896–1959), one of the most inspiring Danish scientists of our own times. Linderstrøm-Lang was head of the Department of Chemistry of the Carlsberg Laboratory, where he supervised an extensive and international research programme in a stimulating and versatile manner. At the same time he carried on his own very considerable research work, comprising *structure studies of proteins* and *enzymes*, as well as developing the *micromethods* that he had originated, which led to very important breakthroughs in biochemistry and other areas of biology.

H. G. Zeuthen (1839–1920) was the leading personality in Danish *mathematics*, although the far earlier C. F. Degen (1766–1825) and Zeuthen's contemporaries, the astronomer T. N. Thiele (1838–1910), Julius Petersen (1839–1910), J. P. Gram (1850–1916), C. Juel (1855–1935), J. L. W. V. Jensen (1859–1925) and Niels Nielsen (1865–1931) also contributed much to the development of the subject in this country. Earlier, we noted the single, unheeded contribution of Caspar Wessel.

Zeuthen's work particularly concerned *geometry* and the *history of mathematics*, and it is especially as a historian that his reputation has survived for posterity: he had a very highly developed ability in discovering the basic ideas and relationships in Greek mathematics. In this work he collaborated with the classical philologist J. L. Heiberg (1854–1928), whose editions of the Greek mathematicians have been very important for the history of mathematics. Zeuthen was, for as long as 39 years, Secretary of the Academy, a position he filled with great efficiency and sound judgement.

Four of the pupils of Zeuthen and of his contemporary university colleague Julius Petersen deserve mention:

Firstly, Johannes Hjelmslev (1873–1950), who dealt particularly with the *foundations of geometry* and the possibility of developing what he termed a "*realistic geometry*" able to reproduce the geometrical situations experienced in reality more satisfactorily than classical Euclidean geometry.

T. Bonnesen (1873–1933) was a schoolmaster for several years before becoming professor of geometry at the Technical University, at which time he energetically resumed the geometrical studies that had led in his youth to a doctorate in non-Euclidean geometry. He became particularly interested in so-called *isoperimetrical extremal problems*. His mathematical textbooks introduced a significant reform into the teaching of mathematics in Danish senior schools.

Finally, of Zeuthen's many pupils, mention must be made of Harald Bohr (1887–1951), brother of Niels Bohr and his strong supporter in

personal and administrative matters, as well as in the formulating of the epistemological questions in which both were keenly interested. Harald Bohr made significant and rapidly recognized contributions to the theory of numbers and to mathematical analysis, in particular relating to the theory he constructed for the so-called *almost periodic functions*. He was an excellent and inspiring teacher and, largely as a result of his work, exact methods in analysis finally became recognized in Denmark after introductory endeavours by NIELS NIELSEN.

Rather outside the general mathematical tradition lies the work of J. F. STEFFENSEN (1873–1961), who was a lawyer by training, but who had a great interest in mathematics from his early youth. He cultivated this interest in different ways, particularly in *actuarial mathematics* in which subject he was the first professor in Denmark (1923–1943), carrying on a tradition begun by T. N. THIELE and J. P. GRAM.

JAKOB NIELSEN (1890–1959) was educated in Germany and started a very promising academic career in that country, but being a pro-Danish Schleswiger he returned to Denmark in 1921. His fundamental and original mathematical works are concerned with *topology* and *group theory*. He acted as Secretary of the Academy from 1945 to 1959, and as one of the "founding fathers" of UNESCO he contributed much to international collaboration on research, e.g., in the establishment of the inter-European research organization for nuclear physics, CERN, in Geneva, a project in which he gave Niels Bohr strong support.

MOGENS PIHL

THE EARTH SCIENCES

Two classical figures in the history of the Earth sciences, NIELS STENSEN and RASMUS BARTHOLIN, are mentioned elsewhere in this booklet. F. L. NORDEN's unique expedition to Egypt and Nubia has also been discussed: his monumental work dealing with this journey is especially valued because of its significance for archaeology; but obviously it also contains contributions to geography and ethnology. Similarly, the Academy supported travels in Iceland: EGGERT OLAFSEN's and BIARNE POVELSEN's *Reise gennem Island* (Journey through Iceland) I–II, 1772 (mentioned above and re-issued in Iceland in the 1970's) has its place among the Academy's most important publications and touches upon all aspects of the nature and culture of this volcanic island. An early member of the Academy, ERIK PONTOPPIDAN (1698–1764), after having published works on a variety of Norwegian topics, planned and embarked upon the great topographical work of his century in Denmark, *Det Danske Atlas* (The Danish atlas), I–VII, 1763–1788. Against this background it was only natural that interest should be extended to include Iceland, which until 1944 belonged to the Danish monarchy.

By about the middle of the 19th century geology had become established as a separate subject and was dominated by J. G. FORCHHAMMER (1794–1865). Originally a chemist, he had been admitted to the Academy at an early age and was supported by H. C. Ørsted, whom he followed as head of the Technological University. The surface of Den-

mark is differentiated but, with the exception of the island of Bornholm, it is almost exclusively of quaternary age and at that time this interesting fact went unnoticed. However, Forchhammer applied himself to a number of questions and in 1835 he issued the first geology of Denmark. One of his excursions was made in the company of CHARLES LYELL, with whom he established a friendly association. For obvious reasons, Forchhammer was concerned with "chemical geology" and he produced important treatises on the disintegration of feldspar to kaolin and clay, on the importance of seaweed species for the production of alum slate and other minerals, as well as a large work on the constituents of seawater and their distribution in the oceans (1859). He was a scholarly, unassuming and practical scientist.

F. JOHNSTRUP (1818–1894), a pupil of Forchhammer, was of rather comparable, many-sided importance for his time. He wrote a number of treatises on subjects from different geological disciplines to the elucidation of glacial phenomena; with his recognition of the Ice Age he went beyond the stage reached by his teacher. The geology of the Faroe Islands, Iceland and Greenland was a natural subject for him and for other Danish scientists to tackle , and it was primarily Johnstrup who took the initiative in the establishment of the two institutions now known as the *Geological Survey of Greenland* (1876) and the *Geological Survey of Denmark* (1888). He was head of both these institutions, which have not only been and still are of vital importance for the training of Danish geologists, for their organization and for providing out-

lets for their publications in close collaboration with the *Geological Museum* of the University of Copenhagen, but also for international research.

The Greenlandic tradition in Danish research is of considerable interest, because Greenland possesses some of the oldest known rocks on Earth. Among older followers of this tradition are two generations of professors: the petrograph N. V. Ussing (1864–1911), who carried out studies, e.g., of the nephelin-syenites of Greenland; and the mineralogist O. B. Bøggild (1872–1956), whose chief work was *Mineralogia Groenlandica* (1905, an English version appeared in 1953). Furthermore, Ussing made studies of features of the geology of Jutland and Bøggild of the limits of the ice and of the volcanic moler sediment. During the same period J. P. Ravn (1866–1951) carried out epoch-making studies of the pre-quaternary fossils in Denmark. He was awarded both the silver and the gold medals of the Academy for works on Cretaceous and Tertiary mollusks. Ravn's efforts were all the more important because Danish fossils in the 19th century were so often subjected to sporadic or incomplete studies whereas the material very much deserved an overall survey.

Present-day research in this field has been carried out by Christian Poulsen (1896–1975), who in particular produced palaeontological descriptions of palaeozoic fossils in Greenland and Canada, as well as in Denmark, and by Alfred Rosenkrantz (1898–1974) who produced a series of works on Greenlandic Jurassic, Cretaceous and Tertiary and – earlier – on the Danien stage in Denmark – from which this era takes its name.

Surveying, cartography and geophysics are disciplines with long traditions in the Academy, not just in theory but also in the form of extensive practical undertakings. Surveying was the province of the Academy in the years 1761–1843, whereafter it was transferred to the General Staff, and subsequently to the Geodetic Institute. Well-deserved biographies of the pioneers Thomas Bugge (1740–1815) and H. C. Schumacher (1780–1850) have been written recently by their present-day successor Einar Andersen (1905), formerly professor at Copenhagen University and director of the Geodetic Institute.

Erik Dal