H. C. Ørsted and the Role of Science in Society

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6 November 1999

There is currently considerable discussion among natural scientists in general and physicists in particular regarding ways in which science more effectively can be brought to the attention of the public. This attention has been brought about both by the recognition of the need for a scientifically literate electorate and by the desire to encourage a larger number of young people to embark on a career in the natural sciences. It can thus be useful to recognize that similar concerns were raised and a variety of projects undertaken at the start of the nineteenth century. Here, I would like to consider these aspects of the scientific career of Hans Christian Ørsted. While most physicists are familiar with Ørsted's discovery of electromagnetism during a University lecture in 1820, few are aware of his many activities in bringing science to a wider public.

Hans Christian Ørsted was born in the provincial town of Rudkøbing. His father, the local apothecary, was engaged in a variety of business activities, including a monopoly on the distillation of spirits and the gathering of medicinal herbs for sale in Copenhagen. There was no local school and little time for instruction at home. As a consequence, Hans Christian and his brother Anders Sandøe, his junior by one year, were sent to a local German wigmaker for instruction. The boys proved to be bright, and the entire community was soon engaged in their education. As might be imagined, the result was less than systematic. Hans Christian was left with lifelong gaps in his knowledge which most modern physicists would find shocking — the pleasures of mathematics and even a working grasp of Newtonian mechanics were foreign to him. Nevertheless, the brothers managed to gain entrance to the University of Copenhagen in 1795.

Ørsted's interests were broad from the start, and his first academic success was the winning of a University prize in esthetics (1796) for an essay entitled "How Prosaic Language is Degraded by its Approach to the Poetic". It is perhaps no accident that this essay coincided with the start of Ørsted's friendship with the Danish poet Adam Oehlenschläger. The following year, Ørsted won a second prize competition in the Faculty of Medicine with his essay "On the Origin and Use of Amniotic Fluid". In the same year, he completed his pharmaceutical studies and began work on his doctoral thesis (successfully defended in 1799). The topic of this work, "Dissertation on the Structure of the Elementary Metaphysics of External Nature", was the philosophy of Immanuel Kant. The work was intended partly as an introduction to Kant's romantic philosophical views of nature for a Danish audience and partly as a reorganization of Kant's views. Ørsted was particularly taken by Kant's notion that there were only two fundamental forces

— attraction and repulsion — and that all the forces observed in nature were merely different manifestations of these two fundamental forces. In hindsight, it seems natural that a man with such convictions would anticipate and seek connections between specific forces. Indeed, there is little doubt that the lasting impact of Kant's ideas was crucial for Ørsted's later discovery of the connection between electricity and magnetism.

For present purposes, however, the most important observation regarding Ørsted's university years is that the breadth of his interests and enthusiasms was central to his effectiveness as a communicator of science. Indeed, 1798 marked Ørsted's first attempts in this direction. In a series of four articles[1] Ørsted attempted to introduce contemporary ideas in chemistry to a non-scientific audience. While these articles are far from comprehensive, they remain remarkably readable today.[2] They were also well-received at the time.

After some time spent working as an apothecary in Copenhagen and two years of travel in Germany and France, Ørsted was hired to teach chemistry at the University of Copenhagen. By all indications, he was a popular lecturer. Thus, in 1805 he wrote to Oehlenschläger that

> "My chemistry lectures have been so well attended this year that there are not enough seats for all. Five or six ladies also attended. You can readily imagine that I did not change my lectures on their account."

In the following year, Ørsted received his first University appointment as *Professor Extraordinarius* in Physics. In one of his first official acts, Ørsted wrote to University officials requesting a six-month salary advance "...to meet various necessary expenses occasioned by his new position including improvements to the lecture hall". At this time, neither chemistry nor physics were represented by separate departments at the University, and Ørsted's appointment represented the tentative start of an independent physics in Denmark.

When not busy teaching, Ørsted was engaged in an exhaustive study of the the acoustic figures (Chladni figures) created when a metal plate is stroked with a violin bow and revealed by powder strewn on the plate. While the experiments were relatively familiar, Ørsted's intentions were new. Consistent with his Kantian convictions, Ørsted wished to demonstrate that the mechanical vibrations of the plates could produce electrical effects. This meticulous and fully professional work was rewarded by membership in the Danish Royal Society (1808) and by the

[1] *Bibliothek for Physik, Medicin og Oeconomie*, vol. 14, pp. 152–60, Copenhagen, 1798; vol. 14, pp. 313–27; vol. 16, pp. 18–31; vol. 16, pp. 165–77,

[2] See, for example, "Selected Scientific Works of Hans Christian Ørsted", K. Jelved, A. D. Jackson, and O. Knudsen, Princeton University Press (1998) for an English language translation of these and Ørsted's other scientific writings.

Society's silver medal. It was also noted in other circles with specific references to acoustic figures appearing in Oehlenschläger's play *Aladdin* and later in Søren Kierkegaard's writing.

In 1813 Ørsted returned to Denmark after another trip to Germany. His experiences there had convinced him of the need for major reform of the study of physics in Denmark. His written proposals to the University emphasized the impact of experimental science on industry and the population in general. He suggested the immediate founding of a Faculty of Science at Copenhagen University. (Note that this was not done until 1850.) While the study of basic science rather than applied science was and remained Ørsted's interest, he was emphatic that "theorists are required only for the education of practical experimentalists". His personal preferences had been stated clearly in his "First introduction to General Physics"[3] (1811):

> "We now feel quite vividly how unworthy it would be to make utility the purpose of the study of this or any other science, for when we ask about the usefulness of an object, we thereby reveal that we do not attribute any worth to it in itself but only with regard to something else, which must then be higher. Consequently, if science were to be studied merely for its usefulness, there would have to be something that was more worthy of a rational being than the use of reason or a better part of man than the spiritual, but if this is impossible, *then insight is good in itself*, and no external justification is needed for wanting to acquire it. Science, then, must be studied for its own sake, as the vital manifestation of our innermost being, as the acknowledgement of the Divine."

In spite of Ørsted's feelings, the general public view of science at the time was not altogether positive. In 1814 the influential Danish clergyman and poet N. F. S. Grundtvig published his "World Commentary". He began mildly enough with the categorical assertion that history was the only true science and, warming to his task, contiinued with the charge that physics had "the denial of God as its first word, sorcery and alchemy its dearest occupations". Ørsted took up the challenge in an (anonymous) review of "World Commentary", and a long, often acrimonious exchange of open letters between Grundtvig and Ørsted followed. The general consensus is that Ørsted emerged victorious.

Recognition of Ørsted's abilities began to accumulate. In 1815 he became the Secretary of the Royal Danish Society and in 1817 he was appointed *professor ordinarius*. But there was nothing to anticipate the fame which followed his discovery of electromagnetism in 1820. During a lecture demonstration in the spring of 1820, Ørsted noted that a current carrying wire exerted a force on a compass

[3]See Jelved et al., pp. 282.

needle. This observation was followed (after an unaccountable delay of several months) by a thorough set of experiments which mapped out the detailed nature of this interaction. The results were described in a brief Latin publication and sent to leading centers of learning in the rest of Europe, England, and America. The reception was immediate and enthusiastic. By the first week in September Biot and Arago could report complete verification of Ørsted's results. On the first Monday in December, Ampére announced his theoretical description of the effect. As a consequence of his lack of mathematical training, Ørsted neither understood nor appreciated Ampére's contribution. With uncharacteristic sarcasm, he later wrote that

> "The ingenuity with which this clever French mathematician has gradually changed and developed his theory in such a way that it is consistent with a variety of contradictory facts is very remarkable."[4]

Ørsted's discovery was greeted by immediate acceptance, and there was universal agreement regarding its importance. The years 1822–23 thus saw Ørsted on a triumphal tour of Germany, France, and England. The visit to England was of particular importance, and Ørsted became aware of the existence of literally hundreds of local societies for the advancement of science. Upon returning home, Ørsted gathered support for the founding in 1824 of a Danish Society for the Advancement of Science (*Selskab for Naturlærens Udbredelse*) to promote the general welfare and to awaken general attention to science. The Society was to be (and remains) funded by private subscription. This decision resulted in a profound change of direction for Ørsted's career. Such public activities began to absorb an increasing share of his time and effort. The goals of SNU were divided. On the one hand, it was dedicated to providing basic science education (i.e., in physics and chemistry). On the other, it was concerned with a variety of practical issues including the manufacture of starch, fermentation, brewing, distillation, vinegar production, and tanning. The most visible of SNU's activities was an ambitious series of public lectures and courses given in Copenhagen and the provinces. During the initial season in Copenhagen, some 200 students studied chemistry and physics. At this time Ørsted delivered five evenings each week in addition to his normal University lectures. Lecturers — particularly those outside Copenhagen — were required to spend time each year in Copenhagen to learn of new developments in science and the latest from the industrial world. Ørsted's instructions to his lecturers were clear enough. They were requested to engaged in "a friendly exchange of information and advice rather than one-sided instruction from the scientist". In addition to its program of public lectures, SNU provided grants to artisans and craftsmen in areas including ceramics, dying, and gold and silver plating techniques. In spite of the fact that SNU was privately

[4]See Jelved et al., pp. 539.

funded, its principal problems were not economic. Ørsted's greatest difficulty was in finding qualified lecturers.

In spite of his demanding public schedule, Ørsted remained active in research. During the first half of the 1820s, he was engaged in a variety of electromagnetic experiments. He also began a long series of experiments aimed at an experimental determination of the compressibility of water and other fluids. The primary experimental obstacle to this determination lies in the fact that the compressibility of water is not markedly different from the compressibility of its container. Ørsted ingenious solution to this problem remains useful today.[5] His activities as a chemist continued as well, and in 1825 Ørsted succeeded in isolating metallic aluminum. While aluminum generates little excitement today, its discovery was met with excitement. In 1837 an elaborate aluminum parade helmet was fashioned for and presented to King Frederik VII.

Ørsted was not equally receptive to all new educational ideas. In 1829, N. F. S. Grundtvig returned from a stay in England with a proposal to found a series of popular high schools to be run by the people as "schools for life". A formal proposal was made to a faculty committee at the University of Copenhagen. Ørsted, serving on this committee, was played a central in its rejection.[6] In the same year, G. F. Ursin proposed the formation of a Polytechnic High School in order to provide practical training for artisans. Ørsted was not pleased by the narrow focus of the Ursin's ideas and was again central in the rejection of the proposal. Ørsted, still unhappy about the lack of a natural science faculty at the University, recognized that a Polytechnic High School could provide a suitable alternative. A new proposal for a more academic institution with entrance examinations and greater emphasis on basic science was soon produced, and the Polytechnic High School was quickly created with Ørsted as its first director. As mentioned above, SNU had encountered serious difficulties in coping with the heavy burden of popular education. The Polytechnic High School, with its paid staff of full time teaching, was now able to assume the bulk of these obligations.

Now free of its most time-consuming activities, SNU adopted a slightly different role (both independently and in collaboration with the Polytechnic High School) in bringing science to the public. A remarkably broad spectrum of studies was aimed at technical problems associated with, e.g., the salting of meat and butter, the working of platinum, and the study of building materials. In 1838 new diary techniques led to the production of Some 1800 kilograms of one-

[5]The fluid to be studied was placed in a vessel fitted with a narrow tube and sealed with a drop of mercury. This vessel was placed in a larger, water-filled container to which pressure could be applied by a piston. The volume of the water could be determined, from the height of the mercury drop, with confidence since its container was subject to equal internal and external pressures.

[6]Grundtvig's high schools were funded from other sources and continue to play a significant role in Danish society.

year-aged cheese. The cheese was auctioned off with great public attention and record prices. SNU also turned its attention to public lectures of a more popular character. There were Sunday lectures for SNU members (and their wives!), and there was a regular series of lectures on technological innovations "for the whole family". These included experimental demonstrations of new devices such as electric motors and steam engines. The 1839 demonstration of the telegraph was reviewed by H. C. Andersen.[7] Printed summaries of the lectures were always available. Attendance at these events was as high as 2000 per month, and their contents were frequently reported in the newspapers.

SNU produced a variety of publications including a book on "Beets and Beet Sugar" (*Runkelroer og runkelroesukker*) published in 1836. Although it met initial scorn from Danish farmers, it soon became clear that there was an economically exciting alternative to the dependence on West Indian cane sugar. A profitable production was not far behind. During the 1830s, SNU provided scientific equipment for schools and made the arrangements required to permit school pupils to attend physics and chemistry lectures at the University and the Polytechnic Institute. This presence in formal education ended in 1845 when science became an official part of the school curriculum. In 1834 SNU sponsored an exhibition of industrial products which enjoyed remarkable public success.

During the same period, the role of the Polytechnic High School grew dramatically both in its academic impact and its public visibility. These developments were not without a price for Ørsted, who found himself delivering an *additional* 10 hours of physics lectures per week![8] There were a number of attempts aimed at engaging the Polytechnic High School in the commercial exploitation of its new ideas and inventions. Such attempts were largely unsuccessful due in part to a endless stream of largely administrative problems. The most serious problem, however, would appear to be the fact that the Polytechnic High School attempted to maintain control of the details of product manufacture rather than spawn "spin-off" production companies or seek licensing arrangements. At the same time and with greater success, Ørsted sought to create a more academic environment and a more academic treatment of his faculty.

The growing popular reputation of the Polytechnic High School can be traced in large part to its active role (through Ørsted) in providing practical scientific advice on a variety of important public issues. Questions regarding the granting of patents and the establishment of monopolies were routinely forwarded to Ørsted.[9] Thus, he addressed a variety of specific questions including patents for

[7]Ørsted was one of the first to recognize the promise of H. C. Andersen, and their friendship was warm. Andersen's weekly visits to the Ørsted home continued throughout Ørsted's life.

[8]The intensity of Ørsted's teaching obligations is remarkable given his scientific accomplishments. It is no less remarkable for being "self-inflicted". By contrast, Niels Bohr was freed from all University teaching responsibilities in 1927.

[9]It should be emphasized that Ørsted held no formal government office and had no formal

the telegraph (1846), for asphalt-covered water pipes (1847), and for the creation of a railway line. Without legal or governmental guidance, Ørsted adopted several simple, common sense principles. Patents should be based on scientific priority, and they should cease if new ideas were not exploited by the patent holder. Ørsted demanded (and got) precise descriptions of new products and processes as a prerequisite for patents. He insisted that certain inventions were of such particular value to society (e.g., the telegraph) that patents should belong to the state. These were new and independently formed ideas of considerable value to Danish society.

Ørsted was also asked to produce a series of "white papers" regarding technical issues. Not infrequently, these concerned topics on which he had no special expertise. Let us consider one example. In the early 1830s, the bakers of Copenhagen discovered the value of adding 0.1% copper sulphate to bread flour. They were delighted by the lovely crust which resulted. Since bread was sold by weight, they were even more delighted by the fact that the dough absorbed some 10% more water. There was, however, the small matter that copper sulphate is poisonous. The police in Copenhagen thus put a stop to the practice, and Ørsted was asked in 1836 to prepare a new set of rules for the baking of bread. In the introductory notes which accompanied his general directives Ørsted wrote

> "If these suggestions are not adopted, it can only be due to the regulations of the bakers' guild which render it unnecessary for producers to respond to consumers and which contribute in so many ways to the ignorance if its members'."

Ørsted sounds remarkably likely a late twentieth century consumer advocate.

There were many other activities which kept Ørsted in the public eye. Let me mention only a few. In 1820 he suggested making systematic weather measurements. In 1824 SNU announced a prize for the best proposal for the creation of a "Danish meteorology". In 1827 Ørsted was part of a commission for the establishment of a laboratory for the collection of meteorological data for all of Denmark. Throughout his life Ørsted produced textbooks and popular writing (often of a "philosophical" nature).[10] Ørsted even introduced a scale of grades which was used in Danish schools until 1963.

Given Ørsted's involvement in so many spheres of public life, it is little wonder that literally thousands of Danes joined in a torchlight procession on the occasion of his death in 1851.

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power base. His success endeavors was due solely to the quality of his arguments and the general conviction that he was providing fair and unbiased advice.

[10]Ørsted's scientific writings constitute three volumes. By contrast, his non-scientific writings fill nine volumes including one volume of poetry. Reading his poetry today leaves the conviction that he would have been well advised to re-read his own 1796 essay on "How prosaic language is degraded by its approach to the poetic".

I think Ørsted's example can be of some value in our current discussion of the public role of science and scientists. The first and most obvious observation is that there is remarkably litle new content in the current debate. Whether our goal is to provide school children with an active experience of science or to exert influence in the corridors of political power, Ørsted was there ahead of us. Very few of our ideas are new or untried. Another lesson is equally obvious and generally ignored: There is no "quick fix" for problems related to the public awareness of science. Ørsted chose to make a lifelong commitment to education and to the communication of the ideas of science to the general public. There is no doubt that this activity took time away from his research. Indeed, there was a dramatic reduction in his scientific output after 1830 which can be related directly to his growing public presence. It is equally unrealistic to expect that a token public presence will have lasting effects now. If we want talented people to engage in similar activities today, we must make it clear that such an investment of time is valued. This will require a serious rethinking of institutional priorities. Just what is public presence worth in terms of research not performed and articles not published in *Physical Review Letters*? What criteria should we apply for the appointment and promotion of young faculty who wish to engage in such public activities? How do we identify those few scientists with have the talent for communicating the excitement and satisfaction they find in science, how should we measure the quality of these activities, and how should we reward them? To my mind there is currently little evidence of any institutional inclination to consider such a trade-off.

One could argue that times have changed and that there was a greater popular belief in "science as a force for progress" then (at the start of the industrialization of society) than there is today. I am not at all sure this is true. As indicated by Grundtvig's (admittedly extreme) views as stated above, there was no consensus regarding the beneficial nature of science then. Further, today's citizens need informed opinions on an even wider variety of problems with a technological or scientific character — pollution, nuclear weapons, information technology, and biotechnology. Scientific illiteracy is wide-spread and has never been more dangerous. We do have additional problems to deal with. For example, entertainment is increasingly passive. Most practicing scientists started by getting their hands dirty, but there is no longer much pleasure to be gained from taking old radios or clocks apart — computer chips do not provide much enlightenment. And there is undoubtedly a popular preference for the democracy of relative truths where every opinion counts as opposed to the monolithic, absolute truths of science. Nevertheless, I am convinced that we *can* make our case provided that we engage in "a friendly exchange of information and advice rather than one-sided instruction".

It is common among physicists to claim that we are superb problem solvers and, as such, a unique resource to society. (One need only think of the clarity and simplicity of Richard Feynman's very public explanation of the cause of the Challenger disaster.) Unfortunately, politicians and bureaucrats do not seem to share this view. Science is seen as being either "applied" (and linked to the needs of industry and national economies) or "basic" (and largely irrelevant). We must reestablish the view of scientists as active members of society with the inclination to use their considerable skills to define and solve tough problems wherever they appear. Again, this will require time, effort, and dedication from both individuals and institutions. I have little doubt that the result will benefit both society and science.