

**HISTORY OF SCIENCE IN EDUCATION:
AN INVESTIGATION INTO THE ROLE AND USE
OF HISTORICAL IDEAS AND MATERIAL IN EDUCATION
WITH PARTICULAR REFERENCE TO SCIENCE EDUCATION
IN THE ENGLISH SECONDARY SCHOOL
SINCE THE NINETEENTH CENTURY**

By

William Joseph Michael Sherratt

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of Leicester in the Faculty of Science
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LIST OF ABBREVIATIONS

A level	Advanced level
AO	Alternative Ordinary
<u>Ann Sci</u>	<u>Annals of Science</u>
ASE	Association for Science Education
AWST	Association of Women Science Teachers
BSCS	Biological Sciences Curriculum Study
B. Educ	Board of Education
BAAS	British Association for the Advancement of Science
BBC	British Broadcasting Corporation
<u>Brit. J. Hist. Sci.</u>	<u>British Journal for the History of Science</u>
<u>Brit. J. Phil. Sci.</u>	<u>British Journal for the Philosophy of Science</u>
CHEM Study	Chemical Education Material Study
Cd/Cmd/Cmnd	Command paper
GCE	General Certificate of Education
HMI	His (Her) Majesty's Inspector
JMB	Joint Matriculation Board
<u>J. Educ.</u>	<u>Journal of Education</u>
Mass.	Massachusetts
Min. Educ.	Ministry of Education
O level	Ordinary level
<u>Phil. Mag.</u>	<u>Philosophical Magazine</u>
PSSC	Physical Science Study Committee
SMA	Science Masters Association
TG	Teachers' Guide
UK	United Kingdom

Chapter 1

INTRODUCTION

1.1 The academic study History of Science

"It is the central business of the historian of science to reconstruct the story of the acquisition of this knowledge [of the physical and natural sciences] and the refinement of its method or methods, and - perhaps above all - to study science as a human activity and to learn how it arose, how it developed and expanded, and how it has influenced or been influenced by man's material, intellectual, and even spiritual aspirations".¹

The present-day study of History of Science involves the examination of scientific concepts and discoveries: it traces their origins, development and transmission; it gives consideration to the social and intellectual background of these concepts and discoveries; it examines possible interactions between these backgrounds and science. History of Science considers the changing nature, methodology and techniques of science; it looks at successes and failures; it is characterised by an attempt to evaluate the past not with the benefit of hindsight, but on its own terms.

Most historians of science see their study as independent of, and not centrally concerned with, the History of Technology, the History of Medicine, the History of Mathematics or the Philosophy of Science. They do however recognise that these cognate but independent disciplines may overlap; there may be a conscious examination of the interactions between the History of Science and one or more of these other studies. In the main they think of science in three related ways: as a body of knowledge; as the method of enquiry by which this body of knowledge has been built up; and as the human and social activity through which this knowledge has been acquired, refined and disseminated. Historians of science have in

1. H. Guerlac, Essays and papers in the history of modern science, Baltimore and London, 1977, p.20.

the past been primarily concerned with the natural sciences biology, chemistry, physics, astronomy, and geology. However, increasingly attention is being paid to the social and behavioural sciences; the present wide interest in the social history of science includes studies in education, patronage, and policy.

These present-day views about History of Science have gradually developed since the beginning of the twentieth century. Prior to this time history of science was largely histories of the individual sciences, frequently written as catalogues of past achievements and chronicles of the triumphant progress of science. The science discussed was not usually related to other branches of science or to a wider background of social and cultural history.

1.2 The scope of the investigation

The main purpose of this investigation is to examine the roles seen for history of science in education, and to trace its introduction into the curriculum of the English secondary school.

The term history of science has frequently been used in writings when expressions such as history and philosophy of science, or history of science and technology, or historical ideas and materials from the past would have been more appropriate. Also, with the gradual acceptance of History of Science as an academic discipline the implications of the term have changed. It is clearly impossible in this investigation to use the term in any rigorous and fixed sense, and undesirable to divorce it from simple philosophical notions about the nature and methods of science. The intention is to use the phrase in a fairly liberal way which may include aspects of philosophy and technology, and which may mean no more than historical ideas and material drawn from the history of science.

The expression secondary school came into general use in England in the second half of the nineteenth century. It was defined in 1904 as "a Day or Boarding School which offers to each of its scholars, up to and beyond the age of sixteen, a general education, physical, mental and moral, given through a complete graded course of instruction, of wider scope and more advanced degree than that given in Elementary Schools".² The schools considered in this investigation are those which in the nineteenth century came under the terms of reference of the Clarendon Report and the Taunton Report,³ and those schools subsequently established whose characteristics are in accord with the above definition; included are grammar, public, comprehensive, and other schools. Most of the discussion on history of science in school education has however, directly or indirectly, referred to pupils being prepared for GCE examinations, or for the precursors of these examinations. This investigation refers mainly to those pupils and to the schools, or forms within schools, containing such pupils. Phrases such as "those falling within the top ability range" will be used to refer to those pupils.

This study is primarily concerned with the English secondary school. However, since some background knowledge is essential to an understanding of events an account of the establishment of History of Science as an academic discipline in British universities is given first. Many scientists⁴ associated with the universities in the eighteenth and nineteenth centuries showed historical interests by their writings and by the inclusion of historical material in science courses. But it was only during the first half of the twentieth century that History of Science found some measure

2. B. Educ., Regulations for Secondary Schools, Cd. 2128, London, 1904, p.17.

3. See Chapter 3, notes 8 and 15.

4. The term "scientist" came into common use in the 1830s. It is used throughout this investigation to refer to those people who were considered in their own times as natural philosophers or scientists; their work is referred to as science. The history of the term is discussed by Sydney Ross in "Scientists. The Story of a Word", Ann. Sci., 18 (1962), 65-85.

of acceptance in British universities on a formal basis.⁵ This acceptance became more widespread from about mid-1960. Yet "History of Science" was introduced as a secondary school examination subject in the early 1950s. In view of the university influence on the school curriculum this may seem a surprising development. Would it be widely recognised by the universities as a valid "subject" for entry requirement? Could able and willing teachers be found for an examination subject in which the teachers themselves had received little or no formal training whilst at universities? This example of the schools leading the universities is perhaps resolved in terms of the particular demands of the period and the particular qualities of those who pioneered "History of Science" in the schools (see 4.2).

In Britain the period between the two world wars saw a noticeable amount of discussion on the role of history of science in secondary school science courses. But major concerns of those years were to increase the quantity of biology teaching, and to introduce General Science.⁶ At that time historical material was regarded by most science teachers as little more than an interesting and at times useful supplement to their courses. Only after World War II was there a more widespread acceptance of the claims of the discipline. The Nuffield reforms of the 1960s represented the first major opportunity of putting into practice this acceptance. Unique among the Nuffield science courses that emerged is O level physics. If followed as suggested, this contains a far greater quantity of history of science built in as a compulsory component and demands a good deal more historical knowledge on the part of the teacher than any of the other Nuffield courses. For this reason particular attention is focused on the physics programme. Some consideration is also given to the two other Nuffield O level courses and to the Nuffield

5. Throughout this study the word "formal" is intended to imply a recognition covered by regulations or statutes. It is not intended in any technical sense attributed by sociologists.

6. For a full discussion on the General Science movement see E.W. Jenkins, From Armstrong to Nuffield, London, 1979, Chapter 3.

History of Ideas Unit. Nuffield O level chemistry and biology certainly make use of historical material. However, not only is there less history than in the physics course, but most of the history of chemistry appears as an option, and the history of biology as an important, but slight and more incidental part of the programme. No discussion is given on the Nuffield A level schemes because of their lack of historical material.

Discussions on history of science in education have by no means been confined to Britain. In the late eighteenth century a practice of accompanying instruction in each science by lectures on its history emerged at the University of Göttingen. This resulted in several important treatises on the histories of the sciences including Gmelin's History of Chemistry, Fischer's History of Physics, and Kastner's History of Mathematics.⁷ In Russia the pedagogical aspect of history of science was seen as important in the nineteenth century; this led some people towards its study. The demand that teaching be based on the "logic of discovery" and on the disclosure of "the paths by which great discoveries in the study of Nature had been achieved" was the foundation of at least one secondary school physics textbook.⁸ Other examples abound. At the present time interest is shown as far afield as Europe, America and Australia. However, this investigation concentrates on the happenings within Britain. There are indications that in the past history of science in Britain has been subject to various external influences. Nevertheless, the work outside this country which had the most direct effect on history of science in English schools came after the Second World War in the USA. Thus a description is given of the case-history method of James Conant, and mention is made of the historical material in some of the American science curriculum reforms of the 1950s and early 1960s. History of science

7. See Guerlac, as in note 1 above, p.56 ff.

8. See V.P. Zubov, "Historiography of Science in Russia", A.C. Crombie (ed.), Scientific Change, London, 1963, pp.829-46. Also Y.I. Solovyev, "Teaching the History of Chemistry in Russia", G.B. Kauffman, (ed.), Teaching the History of Chemistry. A Symposium, Budapest, 1971, pp.217-22.

case-histories became a feature in the General studies programmes of the 1960s, and are currently being used in an attempt to stimulate interest in history of science among physics teachers.⁹ A good deal of this work owes its original inspiration to Conant. The American influence is also apparent in Nuffield. Reforms began in the United States several years before the corresponding British developments and did have some important bearing on what later appeared in this country.

In the past, and at present, history of science has found little place in school history courses. Accordingly, no detailed consideration is given to history teaching.

Since this thesis is not concerned with the development of the historiography of history of science, no attempt is made to give detailed and elaborate references to the literature.

9. See Chapter 8.

Chapter 2

THE ESTABLISHMENT OF HISTORY OF SCIENCE IN BRITISH UNIVERSITIES

2.1 Writings about the histories of the sciences: mainly eighteenth and nineteenth centuries.

Throughout the ages scholars often have shown an interest in the history of their studies. Their interest has arisen out of a variety of causes including natural curiosity, the belief that a knowledge of the past is helpful with present studies, and a recognition of the pedagogical value of history. Scientists have been no exception to this tradition and many have demonstrated their concern by writings on the histories of the sciences and by the use of historical material in science lecture courses.

Writings on the histories of the sciences go back at least as far as the Lyceum of Aristotle. A good deal of historical information is scattered about Aristotle's own writings; he frequently surveys the work of his predecessors, looking into their arguments for common trends he can develop, for a point of departure for his own treatment of a problem, and for support for his own ideas. "... let us avail ourselves of the evidence of those who have before us approached the investigation ... it will be of some assistance to our present enquiry if we study their teaching ...".¹ History of Geometry by Eudemos of Rhodes and Theophrastos's History of Philosophy, an account of Greek thought from Thales to Plato, are among the science histories produced by Aristotle's followers.²

In the sixteenth and seventeenth centuries it was not uncommon to find histories of medicine and chemistry given as introductions to the

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1. Aristotle, The Metaphysics, Books 1-9, trans. H. Tredennick, Loeb Classical Library, London, 1961 reprint, 983b.
 2. H. Guerlac, Essays and papers in the history of modern science, Baltimore and London, 1977, p.54.

technical treatises of the Paracelsians and iatrochemists.³ This possibly was to give some greater degree of authority and authenticity to studies which many regarded as speculative and even fraudulent. It is, however, only from about the mid-eighteenth century that histories of the sciences were written in appreciable quantities. Some evidence would suggest that there was an anti-historical element in that century. Jean d'Alembert, a leading figure in the French philosophe movement, wished that "all the record of past events whatever could be blotted out". J.S. Mill, looking back from the nineteenth century, commented that the eighteenth century did not value the past because it could not understand it and "anathematised all that had been going on in Europe from Constantine ... to Voltaire".⁴ However, in the century as a whole a belief in the power of science developed. It was forward-looking, anticipating the benefits that science would bring, an attitude more concerned with the future than with the past. Nevertheless, earlier and contemporary events did awaken or increase an historical consciousness. The overthrow and replacement of old traditions and texts in the Scientific Revolution emphasised the concept of progress in science, a concept with historical implications. The Enlightenment, with its belief in science as the source and pattern of progress and desire to spread the word of science, stimulated the writing of historical works. Speculation on the age of the earth and the evolution of nebulae brought an awareness of the past into scientific studies. Truly the mid-eighteenth century marks the beginning of a growing body of writing on science history.

With few exceptions the science histories of the eighteenth and nineteenth centuries were written by practising scientists and mathematicians usually working in or closely connected with the universities. The writings were mostly in the form of books devoted to the history of some

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3. See A.C. Debus, "An Elizabethan history of medical chemistry", Ann. Sci., 18 (1962), 1-29.
 4. C.A. Russell, "From Natural Philosopher to Scientist", Science and the Rise of Technology since 1800, Open University Press, Milton Keynes, 1973, Unit 2, p.65.

particular branch of science or mathematics;⁵ in addition science histories appeared as articles in journals and encyclopaedias, and as sections within technical scientific treatises. In technical treatises the historical material was usually confined to an introductory section. One example from early in the period is Herman Boerhaave's Elements Chemiae produced in 1732; here an historical introduction traces the art of chemistry back to Biblical times, discusses the ideas expounded in different ages, and gives details of the lives of notable figures in chemistry.⁶ Exceptionally the historical material would be spread throughout the whole of the technical treatise and closely integrated with the contemporary ideas. A splendid example of such treatment is provided by the 1820 edition of Thomas Thomson's System of Chemistry. This has a brief historical outline in the introductory chapter, but the detailed history is integrated with the contemporary science in the succeeding chapters. A topic is discussed by tracing its gradual progress from "its first rude dawnings as a science, to the improved state which it has now attained"; in Thomson's opinion by thus blending the history with the science "the facts will be more easily remembered, as well as better understood, and we shall at the same time pay that tribute of respect to which the illustrious

-
5. Many eighteenth and early nineteenth century histories of mathematics were really histories of mathematics and physical sciences, as in the case of Historie des Mathematiques (Paris, 1758) by J.E. Montucla. This work was enlarged and revised (1799-1802) after Montucla's death by J.J. Lalande, a celebrated astronomer, teacher, and populariser of astronomy who himself wrote several historical treatises. According to George Sarton, it was the best of the early histories of mathematics. (See G. Sarton, A Guide to the History of Science, Waltham, Mass., 1952, p.152).
 6. Hermann Boerhaave was one of the most widely known and most highly influential scientific figures of his day; his reputation rested on his skill as a physician, a teacher, and a writer of text-books. Elementa Chemiae was probably the chemistry text-book most widely used throughout Europe during the eighteenth century. Until at least the mid-eighteenth century most of the writings on the history of chemistry made some reference to Boerhaave's work. The debt of William Cullen and others to Boerhaave can be seen in Andrew Kent (ed.), An Eighteenth Century Lectureship in Chemistry, Glasgow, 1950. See also G.A. Lindeboom, Herman Boerhaave. The Man and his Work, London, 1968.

improvers of it are justly entitled".⁷

No single purpose lay behind the writing of the increasing quantities of science histories, and authors were not usually as explicit as Thomson or as Joseph Priestley in giving their motivations.

"The history of electricity is a field full of pleasing objects ... scenes like these, in which we see a gradual rise and progress in things, always exhibit a pleasing spectacle to the human mind ... histories are evidently much more necessary in an advanced state of science, than in the infancy of it. At present philosophical discoveries are so many, and the accounts of them are so dispersed, that it is not in the power of any man to come at the knowledge of all that has been done, as a foundation for his own enquiries. And this circumstance appears to me to have very much retarded the progress of discoveries ... Let histories be written of all that has been done in every particular branch of science ... [this] could not fail to give new life to philosophical enquiries. It would suggest an infinity of new experiments, and would undoubtedly greatly accelerate the progress of knowledge".⁸

It is evident that many authors shared with Priestley and Thomson these beliefs in the aesthetic appeal of historical works and in the cultural aspect of paying tribute to "illustrious improvers". But science histories were seen as having uses beyond suggesting "an infinity of new experiments" and helping to remember and understand "the facts ... more easily". They could be, and were exploited, to justify scientific, philosophical and even religious points of view. Thus both John Dalton and his opponents expounded Newton to support their respective views on chemical combination. Thomas Young sought to present his wave theory as a development of Newton's ideas while his opponent, Henry Brougham, attacked the theory not as bad

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7. T. Thomson, System of Chemistry, 6th edition, London, 1820, p 9 ff. This was a monumental and highly popular work that went through many editions. The first edition published in 1802 was drawn largely from earlier articles; by the sixth edition of 1820 this had grown into four volumes each of some six hundred pages or more. Its size is partly explained by the fact that chemical texts of that period frequently included a number of topics now considered outside the scope of chemistry; Thomson's work, for example, discussed light, heat, electricity, aspects of geology, and natural history. Thomson can be seen as a link in the chain of history of chemistry teaching. He studied at Edinburgh University from 1795 to 1799 and attended the chemistry lectures of Black; in 1818 he was appointed Professor of Chemistry at Glasgow University, and in the 1830s produced his two-volume History of Chemistry (London, 1830-31).
 8. J. Priestley, History of Electricity, 3rd edition, London, 1775, p. i ff. See Appendix 1.

physics but as a false exposition of Newton's views. When Darwinism was under debate the attack that it was little more than a reiteration of earlier ideas led Huxley to serious historical research. Huxley showed that the Schoolmen at least had not anticipated Darwin.⁹

Perhaps the justification of scientific standpoints was more of a general stimulus to historical research than a direct cause of many specific historical works. But the same cannot be said for religious and philosophical viewpoints. In the 1870s J.W. Draper, claiming to be the first to examine the historical relationship between science and religion, wrote "The history of science is not a mere record of isolated discoveries; it is a narrative of the conflict of two contending powers, the expansive force of the human intellect on one side, and the compression arising from traditionary faith and human interests on the other. No one has hitherto treated the subject from this point of view".¹⁰ Draper's History of the Conflict between Religion and Science, together with A.D. White's A History of the Warfare of Science with Theology in Christendom,¹¹ established a tradition which was to have a strong and lasting effect. The thesis of these works, that throughout history there has been an essential conflict between science and religion with each battling for dominance over the other, was uncritically accepted and taken into many later histories of science. Until well into the twentieth century these works were quoted as authoritative sources; a tradition of conflict was maintained even to the extent of appearing in 1966 in the Nuffield O level

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9. See D.M. Knight, Sources for the history of science 1660-1914, London, 1975, Chapter 2.
 10. J.W. Draper, History of the Conflict between Religion and Science, 14th edition, London 1880, pp.vi-vii.
 11. A.D. White, A History of the Warfare of Science with Theology in Christendom, 1st edition, 1896, Dover edition, 2 vols, New York, 1960

physics course.¹² But more importantly for the later developments of history of science and its use in schools was the research and writing that sprang from philosophical interests. Early in the seventeenth century Francis Bacon expressed a belief in the utility of the histories of learning for discovering the nature and proper use of human reason, but this gave little stimulus to science histories before the 1830s. In that decade however four notable works appeared: Herschel's Preliminary Discourse on the Study of Natural Philosophy, Comte's Course of Positivist Philosophy, and Whewell's History of the Inductive Sciences and The Philosophy of the Inductive Sciences.¹³ These set a pattern of determining and justifying a philosophy of science by appealing to its history. In the twentieth century employing history of science as a basis for philosophical beliefs has become a primary motive for research into the discipline; teaching about the nature and methods of science through its history has become a justification for its use in education.

The usefulness of history of science was a compelling motivation. But the desire to popularise and spread the word of science was probably responsible for more eighteenth and nineteenth century writings on science histories than any other cause. The popularisation of science had its beginnings in the eighteenth century and was stimulated by the spread of vernacular writing, the production of massive scientific dictionaries and encyclopaedias, and the formation of a number of local debating societies. Popularisation continued throughout the nineteenth century: a large

12. It can now be seen that a good deal of the writing in these works was lacking in objectivity; the history used was often highly selective and presented in a polemical way to support preconceived ideas. The validity of the conflict thesis is the theme of an Open University course Science and Belief: from Copernicus to Darwin, Open University Press, Milton Keynes, 1974. See also James R. Moore, The Post-Darwinian Controversies, Cambridge, 1979.

13. J. Herschel, Preliminary Discourse on the study of Natural Philosophy, London, 1830; A. Comte, Cours de philosophie positive, Paris 1830-42; W. Whewell, History of the Inductive Sciences, 3 vols, London, 1837; idem, The Philosophy of the Inductive Sciences founded upon their history, 2 vols., London, 1840.

quantity of scientific literature was produced for self-instruction, for the working-class population, for school use, and for other non-specialist consumption; in many cities throughout Britain and the rest of Europe popular lectures in science were given for the people. To a large extent this popularisation and diffusion of science was achieved through descriptions of existing scientific knowledge and explanations of everyday phenomena. But it was not unusual to find history used for this purpose. Many dictionaries and encyclopaedias carried accounts of historical ideas some of which were used subsequently by their authors as part of a book. In 1728 Ephraim Chambers published Cyclopaedia; or an Universal Dictionary of Arts and Sciences, Containing an Explication of the Terms, and an Account of the Things Signified Thereby, in the Several Arts, both Liberal and Mechanical, and the Several Sciences, Human and Divine ... the Whole Intended as a Course of Ancient and Modern Learning: among the history of science included were the opinions of twelve writers from Aristotle to Newton concerning the cause of gravity. Gianfrancesco Pivati, secretary of the Academy of Sciences at Venice, produced between 1746 and 1751 Nuovo dizionario scientifico e sacro-profano; this contained a lengthy discourse on the history of several sciences ranging from mathematics to geography. Early nineteenth-century editions of Encyclopaedia Britannica included accounts by John Playfair on the progress of mathematical and physical sciences since the Renaissance, a series of biographies of famous men of science written by Thomas Young, and historical articles by Thomas Thomson which formed the first outline of his System of Chemistry. Historical topics were included in popular science lectures. In the 1860s James Stuart of Trinity College, Cambridge gave the four lecture courses "which are usually regarded as the beginning of University Extension".¹⁴ His

14. T. Kelly, A History of Adult Education in Great Britain, Liverpool, 1962, p.219; see also D. Layton, "Diction and Dictionaries in the diffusion of scientific knowledge: an aspect of the history of the popularisation of science in Great Britain", Brit. J. Hist. Sci., 2.(1964-5), 221-34.

first courses, given to ladies' groups in four northern cities, were entitled "The History of Science". Popular books on science would occasionally include history, as in the case of Brewster's Letters on Natural Magic.¹⁵ And a large number of history of science texts were written for popular, non-specialist consumption. It is not always easy to decide which treatises should be classified as popular, even when the texts are so described by the authors themselves or by other eighteenth and nineteenth century authors. Works such as Grant's History of Physical Astronomy¹⁶ to take a British work self-described as popular, contained such a wealth of detail that they now appear far removed from popular reading. In many texts authors did not always seem to have a particular audience in mind; in other texts authors were not always consistent in maintaining what they apparently saw as the necessary quality and style of writing suitable for their chosen audience. Todhunter, who did not consider himself a populariser, criticised Whewell on these grounds.

"Mr. Whewell is perhaps open to the charge, which so frequently applies to authors of works on science, that he did not form, or at least did not always maintain, a steady conception of the class of readers whom he wished to address ... [Because there are] no mathematical formulae ... in a work of which a large portion is devoted to mixed mathematics, it might be supposed that the History is designed as a popular manual for the general reader: but it is on the whole far too difficult for the amount of knowledge and resolution [of such a reader]. On the other hand the references to the original authorities are not sufficiently numerous and precise to render the work adequate to the wants of the systematic student of science ... the position which it occupies is an unfavourable borderland ...".¹⁷

The Quarterly Review of February 1831 considered popular works as those "freed from mathematical symbols and technical terms, written in simple and perspicuous language, and illustrated by facts and experiments which are level to the capacity of ordinary minds".¹⁸ Works intended as scholarly usually included footnotes and cited references. Without doubt

15. D. Brewster, Letters on Natural Magic, London, 1838.

16. R. Grant, History of Physical Astronomy, London, 1852.

17. I. Todhunter, William Whewell. An account of his writings, London 1876, Vol. 1, p.106ff.

18. Quarterly Review, Vol.44 (Jan-Feb., 1831), Art. 6, p.476.

many science histories were written in the eighteenth and nineteenth century because their authors wanted to spread the word of science.

The nineteenth century has with justification been described as an age of nationalism. With one of the hallmarks of a nationalistic attitude the expounding of past achievements, and the wiping out of past failures, it would be surprising if this feeling was not reflected to some extent in the science histories of the period. Scientists perhaps were not the pure figures suggested by Merton in the 1940s.¹⁹ Scientific rivalry existed between countries; disputes between individuals on precedence of discovery were frequently within a national context; some scientific work was done in terms of national boundaries. Nationalism certainly did act as a spur to the compilation of some treatises. In 1790 Thomas Beddoes made a patriotic examination of some English chemical writings of the seventeenth century, and attempted to show that Lavoisier's theory of combustion had been anticipated in England.²⁰ Delambre's Rapport historique sur les progrès des sciences mathématiques depuis 1789 and Cuvier's Rapport sur les progrès des sciences naturelles depuis 1789 were sycophantic towards Napoleon and nationalistic in tone.²¹ Memoirs of the Distinguished Men of Science of Great Britain living in the years 1807-8, compiled and arranged by William Walker Junior and published in 1862 showed national pride in its introduction. "We have advanced to our present position in the scale of nations by the efforts of a few chosen minds ... The Discoverers are therefore deserving of that hero-worship".²² Nationalism certainly could and did lead to some claims of the type made by Wurtz. "Chemistry is a French science, it was founded by Lavoisier".²³

19. Robert K. Merton, The Sociology of Science, ed. by N.W. Storer, Chicago and London, 1973.

20. See D. Knight, as in note 9 above, p.49.

21. These works were published in Paris in 1810.

22. William Walker, Jnr., Memoirs of the Distinguished Men of Science of Great Britain living in the Years 1807-8, London, 1862 Introduction.

23. A. Wurtz, A history of chemical theory, trans. H. Watts, London, 1869, p.1.

But such examples are not typical of the majority of history of science texts of this century. When a book of biographies was compiled most commonly it included the lives and works of scientists of several nationalities. It was not uncommon to find a scientist from one country writing a biography of a scientist from another. When nationalistic sentiments were expressed it was the exception rather than the rule. Perhaps the key to this situation was the fact that most authors were practising scientists. While often quick to lay claim to their own achievements they were aware of the international character of the scientific activity, of their dependence on the work of others, on the need to collaborate with other scientists irrespective of nationality. From early on scientific societies had foreign members and associates. In the eighteenth and nineteenth centuries many scientific expeditions had an international character; ships engaged on scientific work were generally not considered fair prizes of war. In 1807 Humphry Davy was awarded a prize by Napoleon for his work on galvanic electricity. Despite Davy's anti-French sentiments and although Britain and France were at war, Davy received his prize in Paris. Scientists worked within a tradition of exchange of ideas by correspondence and travel, even in times of war. If their interest in politics matched their interest in science this was not reflected to any great extent in most of the science histories written in this period.

2.2 History of science in British universities; up to the late nineteenth century

Although history of science played no major role in British universities up to the end of the nineteenth century it was not completely neglected. There is evidence that historical material was used in science courses especially in the Scottish universities of Glasgow and Edinburgh; there is less direct evidence of its use in English universities.

In the eighteenth century William Cullen, referring to courses at Glasgow University, spoke of "the custom long established at this university ... [of beginning] with a History of chemistry".²⁴ Cullen himself, who from 1751 to 1789 held various professorships at Glasgow, then Edinburgh, university, introduced his own lectures on Chemistry, Materia Medica, and the Practice of Physic by a series of lectures devoted to their history. These lectures show Cullen's belief that the present could best be understood through a study of the past, and demonstrate his anxiety to establish that the traditions of chemical science were not exclusively ones of fraud and speculation. In the session 1774-5 John Robison, who was Professor of Natural Philosophy at Edinburgh University from 1774 to 1805, gave a course of lectures which embraced the sciences of mechanics, hydrodynamics, astronomy, optics, electricity, and magnetism. According to John Playfair's "Bibliographical Account of the late Professor Robison" published in the Transactions of the Royal Society of Edinburgh for 1815, his remarks on the history of science were said to have been particularly interesting and instructive. Playfair himself maintained this tradition and is credited, together with John Leslie his successor to the chair of mathematics at Edinburgh, with doing much "to revive an almost forgotten branch of learning, namely the History of Science".²⁵ Later in the century William Thomson, from 1846 to 1899 Professor of Natural Philosophy at Glasgow University, would in his lectures show "a generous admiration for the great thinkers and workers in science, and would pour forth his tribute to men like Newton, Laplace,

24. A. Kent (ed.), An Eighteenth-Century Lectureship in Chemistry, Glasgow, 1950, p.15. Cullen, a leading pioneer of chemistry teaching, must be credited with playing some part in the emergence of chemistry as an independent discipline. He viewed chemistry as more than merely an aid to medicine and initiated the teaching of chemistry at Glasgow University; from the beginning he lectured in English rather than Latin. See Owen Hannaway, "The teaching of the history of chemistry in Scotland - Past lessons for the future" in G.B. Kauffman, Teaching the History of Chemistry. A Symposium. Budapest, 1971, pp.163-9.

25. A. Grant, The Story of the University of Edinburgh, London, 1884, p.303.

Lagrange, Fresnel and Fourier ... forgetful ... of time, till in the last five or ten minutes of the hour he had to compress the scientific principles and maxims which should have formed the subject of his lecture".²⁶ At the end of the century John Ferguson, Regius Professor of Chemistry at Glasgow University from 1874 to 1915, insisted on the importance of an historical background and throughout most of his tenure of the Chair devoted himself largely to the study of the history and bibliography of chemistry.

It is likely that historical material was similarly used at Oxford and Cambridge, but seemingly to a lesser extent. In a work of 1783 Martin Wall, Public Reader in Chemistry at Oxford University, gave a syllabus of lectures which included the history of alchemy and the origins of chemistry. Between about 1830 and the 1850s some of the scientists and mathematicians most influential in the English university reforms produced history of science texts notable for their number, for their substance, and for showing at times a quality of scholarship far in excess of the majority of earlier such texts. George Peacock, one of the reformers of Cambridge mathematics, produced several popular treatments of science history; his history of arithmetic produced for Encyclopaedia Metropolitana in 1828 evoked much praise from Augustus de Morgan, first Professor of Mathematics at the newly created University College, London. Although not a history of science, Herschel's Preliminary Discourse on the Study of Natural Philosophy (see 2.1) made considerable use of historical material for philosophical purposes. In 1837 William Whewell, mathematician, classicist, and Master of Trinity College Cambridge, published his massive History of the Inductive Sciences. At Oxford the Savilian Professor of Geometry, Baden Powell, produced for the general reader a substantial History of Natural Philosophy in 1834. S.P. Rigaud,

26. J. Coutts, A History of the University of Glasgow, Glasgow 1909, pp.386-7.

Oxford mathematician, astronomer, and the most important antiquarian and bibliographer of his day, did much important research on the history of mathematics, astronomy, and the life and discoveries of Newton. No doubt Peacock, Whewell, Baden Powell, Rigaud and others made some use of their historical researches in their teaching, but there is little direct evidence of it. In their writings defending their institutions against contemporary criticism²⁷ and discussing university curricula they made little mention of science history. William Whewell did urge the introduction of questions from the history of science into the Tripos examinations.²⁸ Other brief mentions of history of science in educational reforms were made by people who were neither scientists nor writers on science history. The Rev. A.H. Wratislaw, a Slavonic scholar of Czech descent, made in 1848 a plea for a broader syllabus for university students; he suggested that before the Tripos students should have a general course of education to include "a popular knowledge of the History of Mathematics and of the Elements and History of Mixed Mathematics and Natural Sciences".²⁹ Hugh Wyatt, a Fellow of Trinity Hall, Cambridge, also wanted less narrow courses and advocated the inclusion of social sciences with history of science.³⁰ But neither Wratislaw nor Wyatt discussed in any way what they meant by history of science and history of mathematics, nor why they recommended it, nor what role it should play. This apparent lack of

27. For the first half of the nineteenth century Oxford and Cambridge were subjected to a good deal of ruthless criticism, partly because of the lack of science in their curricula and their methods of instruction. During the eighteenth century mathematical studies became a more important part of the total curriculum at Cambridge University; at both Oxford and Cambridge there were some lectures on natural philosophy, and chairs of astronomy, chemistry, botany, and geology were established. But there seems little doubt that during the eighteenth and first half of the nineteenth centuries there was considerably more science teaching at the Scottish universities than at Oxford and Cambridge and correspondingly more opportunities for the inclusion of history of science.

28. W. Whewell, Of a Liberal Education, London 1845. See Appendix 1.

29. A.H. Wratislaw, Further remarks on the University System of Education, Cambridge and London, 1848, p.14.

30. H.P. Wyatt, Thoughts on University Education, Cambridge and London, 1849.

history of science at the ancient universities is highlighted by Wratislaw's comment. "There is not even any attempt at encouraging the study of the History of Science, a subject which I wonder has never been pressed upon the University by the Author of the 'History and Philosophy of the Inductive Sciences'".³¹ It is reinforced by the Devonshire Commission which made a comparison between the science at the universities of Oxford and Cambridge and at the University of Berlin. At Berlin the 1872-73 session included lectures on "General History of Physics from Galileo to the Present Time", "The Recent History of Chemistry" and "The History of Chemistry". At Oxford and Cambridge there were no comparable lectures mentioned.³²

In London Augustus de Morgan produced a large range of historical writing at both the popular and more scholarly levels. But again there is little direct evidence to show what use he or his colleagues made of this material in their courses. In 1858 two of the witnesses called to give evidence before the committee set up to examine the proposed new BSc degree for the University of London made explicit mention of history of science as part of what they believed should be the required studies. But like Wratislaw and Wyatt before them they did not amplify their brief comments, gave no reason why they wanted it, and apparently saw no major role for the study. The fact that the investigating committee made no reference to history of science in their questioning of these witnesses or in their final report is a further indication of the general lack of

31. A.H. Wratislaw, Observations on the Cambridge System, Cambridge and London, 1850, p.15. This work is largely an attack on the ideas of Whewell. It is possible therefore that Whewell had "pressed upon the University" the case for History of Science.

32. Report of Royal Commission on Scientific Instruction and the Advancement of Science, (Devonshire Report) C868, Third Report London, 1873, p.xxii.

interest in such work in university education at this time.³³

Although Owens College, Manchester did not enjoy university status until 1880 the tradition of history of chemistry which began there in the second half of the nineteenth century was important for later developments. The Industrial Revolution had caused Manchester to become in the nineteenth century one of the foremost cities in Europe: a variety of local industries and processes heavily dependent on chemistry grew up; leading scientific and industrial figures were attracted to the city; and a tradition of interest in popular and higher education developed. Owens College, founded in 1851, was remarkable for the great chemists and educators associated with it. Its first Professor of Chemistry was Edward Frankland, a figure much concerned with popular education. The Chemistry Department however was really established by Henry Roscoe, a dominant figure at the College from 1857 to 1886. Roscoe was a devoted pupil of Bunsen, much influenced by him in his chemistry and his attitude towards teaching. According to J.J. Thomson, Roscoe campaigned for forty years "to make the public realise the importance of science, to get more science taught in schools, to make science play a larger part in our industries, and to persuade the Government to make grants to universities and colleges for teaching and research".³⁴ Although Roscoe believed that it was in the laboratory that chemistry was properly learned this did not stop him from beginning a tradition of history of chemistry. He collaborated with Carl Schorlemmer, Professor of Organic Chemistry from 1874 to 1892, to produce

33. University of London, Report of the committee appointed to consider the propriety of establishing a degree or degrees in science, and the conditions on which such degree, or degrees, should be conferred, London, 1858. The two witnesses who mentioned history of science were Joseph Hooker, then Assistant Director of the Royal Gardens at Kew, and William Benjamin Carpenter, then the Registrar of London University. For some reason the Athenaeum of 25 February 1860 regretted that the history of science was not included in the new syllabus.

34. J.J. Thomson, Recollections and Reflections, London, 1936, p.24. Thomson, who won a scholarship from Owens College to Cambridge in 1875, was chairman of the 1918 Government committee which looked into the state of science education; see Chapter 3.

a Treatise on Chemistry published in 1877. This important work, which held an outstanding place in chemical literature for over fifty years, often used an historical or semi-historical treatment. Schorlemmer himself composed the useful The rise and development of organic chemistry (1879). Roscoe also collaborated with Arthur Harden, one of the first graduates of the federal Victoria University, in historical studies which led to A new view of the origin of Dalton's atomic theory (1896) and other publications. Roscoe was succeeded as Professor of Chemistry and Metallurgy in 1886 by H.B. Dixon, who demonstrated a deep concern for his students and a tireless interest in experimental research. Dixon's background is interesting. He was a classics student at Oxford until, in the middle of his undergraduate course he turned to chemistry. His wide-ranging interests were reflected in his teaching which combined an historical approach with the art of showmanship.³⁵ The basis of his teaching of inorganic chemistry was made more vivid through critical accounts of the development of chemical thought and the way in which discoveries had been made. These were accompanied by demonstrations which reached high and at times spectacular levels. Although many of Dixon's students felt he spent too much time on the history of chemistry he did inspire some with a love of that subject. One such student was J.R. Partington who became renowned as a chemist, teacher, and author of a massive history of chemistry textbook.

As the majority of the eighteenth and nineteenth century authors of histories of the sciences were closely associated with the universities it is not surprising that historical material was used to some extent in university courses. But in England at least this usage was, up to the

35. The author is indebted to G. Norman Burkhardt, a pupil of Dixon and later a member of the staff of Manchester University. On his retirement in 1967 Burkhardt held the positions of Assistant to the Vice-Chancellor, Senior Tutor to the Faculty of Science and Senior Lecturer in Chemistry at the University of Manchester.

late nineteenth century, unregulated, spasmodic, and without official recognition. It relied on the interests and inclinations of individual scientists who had to battle against charges that historical studies were not useful, not experimental, and not true science. Baden Powell in 1830 commented that

"... history of science is hardly ever a matter of popular interest or attention ... Those who cultivate it have been regarded as a set of men isolated as it were from the rest of the world ... their speculations ... to be little applicable to any useful purpose".³⁶

In 1841 J.O. Halliwell, writing about scientific discoveries of the past, said

"... these discoveries seem to have attracted little attention from scientific men, either on account of that lamentable apathy towards matters of history which is too frequently characteristic of the lover of demonstration, or perhaps, let us hope, from a want of some general channel of communication such as the Historical Society of Science now affords".³⁷

It seems likely that more historical material was included in science courses in the Scottish universities than in England. In the eighteenth century a good deal more science was taught in Scotland than at Oxford and Cambridge; a succession of individuals like Cullen, Robison and Black had more opportunity than their English counterparts to build up a tradition within science teaching. Once a tradition is established within an institution or community the members of the community are not quite so "isolated from the rest of the world". Tradition brings justification. But by the end of the century science had become a good deal more highly specialised. In both Scotland and England it was not common to find many scientists with an active interest in historical research. At Glasgow University John Ferguson was not taken seriously as a chemist because of the time he spent on the history and bibliography of chemistry.³⁸ In 1894,

36. Baden Powell, An historical view of the progress of the physical and mathematical sciences, London, 1834, p.2.

37. J.O. Halliwell, A Collection of Letters, London, 1841, p.ix. See note 41.

38. See Robert Broom, "The Chemical Laboratory at Glasgow Sixty Years Ago", A. Kent (ed.), as in note 24 above, p.198.

according to Charles Singer, "... a few investigators of [William] Ramsay's calibre then took an interest in historical studies".³⁹

Before history of science received any widespread acceptance in British universities it had first to win recognition as an independent academic discipline with a professional status.

2.3 Recognition of history of science as an independent academic discipline

Certain of the events of the nineteenth century helped history of science to later become established as an independent academic discipline. Historical material was associated with university science courses in many European countries and in America, at times with distinct roles assigned to it. Eminent scientists had taken seriously research and writings of histories of the sciences. History of science was suggested as a separate university study⁴⁰ and a society devoted exclusively to history of science was founded.⁴¹ By the end of the nineteenth century a substantial body of

39. See Charles Singer, "Presidential address", Bulletin of the British Society for the History of Science, 1 (1949-54), 59-63.

40. Auguste Comte, recognised as the first scholar to conceive of History of Science as an independent discipline, pressed for the creation of a chair devoted to *Histoire générale des sciences* as early as the 1830s. Both Tannery and Sarton readily admitted the influence of Comte on them and the history of science movement. A useful summary of Comte's ideas about history of science is to be found in A.C. Crombie, (ed.), Scientific Change, London, 1963, pp.805-6.

41. Founded in 1840, J.O. Halliwell's Historical Society of Science listed among its members most of the contemporary English scholars and scientists interested in history of science; William Whewell was a notable exception. The society failed to provide a forum and did nothing in its day to promote the claims of history of science as a serious study. Its sole achievement was the production of two books (T. Wright, Popular treatise of science written during the middle ages, London, 1841; and J.O. Halliwell, Collection of Letters, London, 1841) neither of which showed any real degree of original research or scholarship. The society went out of existence after about one year. The most detailed account of the Historical Society of Science is to be found in A.N.L. Munby, History and bibliography of science in England 1833-1845, Berkeley and Los Angeles, 1968; this work also contains details of the life of Halliwell.

literature on the histories of the sciences had been built up. Although some of this was dismissed by George Sarton as superficial and discursive,⁴² it did provide a body of knowledge to use, modify, and build upon. Some of this literature showed a high degree of scholarship: the use of carefully searched out primary sources; meticulous citation of references; careful presentation and evaluation of representative available evidence. Despite a nineteenth-century tendency to chart a triumphant progress of science and to make historical judgements with the benefit of hindsight, there were examples of writings which evaluated a period from within and on its own terms. Such events and traditions gave some degree of respectability to history of science and made it easier for future arguments in its favour. Suggestions for change always seem less radical if it can be shown that such suggestions are not new.

The decisive steps which led to History of Science becoming recognised and accepted on a wide basis as an independent, international academic discipline with a truly professional status were taken in the years spanning the end of the nineteenth and the middle of the twentieth centuries. During these years history of science was formally recognised by some universities as part of their curriculum, with university chairs and departments for history of science being established; recognised academic qualifications in the subject became available; specialised societies and journals sprang up; national and international congresses and meetings were held; and a small but increasing number of scholars had the opportunity to spend a large proportion of their time on that study.

The first university chair in the History of Science was created in Paris in 1892; its first incumbent, Pierre Laffitte, taught history of science from then until 1903, according to George Sarton "with dignity but without distinction".⁴³ In the USA there was a particularly rapid and

42. G. Sarton, A Guide to the History of Science, Waltham, Mass., 1952, p.48.

43. Quoted in H. Guerlac, see note 2 above, p.54.

widespread introduction of the subject in courses around the turn of the century; by 1915 there were 162 courses in the history of some particular science and 14 general courses in the history of science in 113 institutions.⁴⁴ Such university activity was paralleled by the formation of societies and journals and the holding of meetings and congresses devoted to the history of science. Academies and scientific societies had for many years taken some interest in history, especially where it concerned achievements linked with their own organisations and members. However, this historical interest was usually quite subservient to the main interests of the society. From early in the twentieth century many special societies devoted to the study of history of science sprang up.⁴⁵ At first these were created as national institutions although some listed as members scholars from other countries. In 1928 Aldo Mieli and others founded in Oslo the Académie internationale d'histoire des sciences. Britain lagged behind other countries in forming such societies: the Newcomen Society for the study of the History of Engineering and Technology was formed in the early 1920s; a Society for the Study of Alchemy and Early Chemistry was formed in 1936; but the British Society for the History of Science came into existence only in 1947.

Although one of the important roles played by these societies was the production of journals, not all such publications grew out of societies.

Isis, still a foremost periodical, was founded by George Sarton in 1913

44. These figures were given in Science, 42 (1915), 746-60 by Frederick E. Brasch. Some years later Sarton, writing in Isis 4 (1921), 225-249, argued that such lists of courses were misleading and that history of science was much neglected in the universities of America and Europe. He based his arguments on the courses offered year after year by specialists and placed on the same academic footing as other fundamental studies, and on the number of chairs devoted to history of science. On these criteria Sarton was correct in saying that history of science was not taken seriously in most universities at that time. But there were few specialists available to teach history of science year after year, although as an academic subject it had neither the literature, nor the scholarship, nor the tradition of other fundamental studies.

45. For information about such societies see G. Sarton, as in note 42 above.

and only became linked with a society after David Eugene Smith and others had in 1924 founded in Boston the History of Science Society. Annals of Science, founded as an international journal by Douglas McKie in 1936, grew out of his activities at University College, London.⁴⁶ But besides publishing works on the history of science the specialist societies provided an organisation for regular meetings of interested scholars. Early in the twentieth century such meetings were mainly national in character. In 1929 however the first International Congress of the History of Science was held in Paris. Two years later the Second International Congress was held in London and became a milestone in the historiography of science. The amateur status of the study at that time is well brought out by J.G. Crowther's description of the participants.

"A number ... were elderly scientists, who had taken up the history of their subject as a pleasant diversion during their retirement, while others had worked at some historical aspect of science in their spare time; some were wealthy amateurs amusing themselves with studies in the history of science. The President of the Congress, Dr. Charles Singer, who was the most eminent British historian of science, was one of the few devoting the whole of his efforts to the subject".⁴⁷

But the importance of the Congress lay in the stimulus it gave to the study of history of science. The meeting was attended by a large delegation from the USSR who presented to Western historians a sustained Marxist treatment of social and economic factors as elements in scientific and technological development. The occasion gave impetus to a movement that already was stressing the relationship between science and society, an impetus later articulated by Crowther

"... the problems of society cannot be solved rationally without a thorough understanding of the role of science in modern civilization, and ... this was impossible without a knowledge of the history of science".⁴⁸

46. See section 2.4.2.

47. J.G. Crowther, Fifty years with science, London, 1970, p.77. See also the Foreword (by J. Needham) and Introduction (by P.G. Weskey) to P.G. Weskey, (ed.) Science at the Cross Roads, London, 1971.

48. J.G. Crowther, as note 47 above, p.173.

The Congress was held during a period of depression and massive unemployment in Britain and elsewhere, when fascism and nazism were emerging in Europe, but when there were euphoric reports of progress and success from the Soviet Union. Several prominent left-wing scientists were drawn towards a study of history of science. At Cambridge, the location for the most militant of the anti-war scientist, an interest developed in the history of science as an academic study.⁴⁹ Much debate about history of science in education developed, for example, at the 1932 Conference of Educational Associations and at several of the annual meetings of the British Association, with corresponding calls for its inclusion in the school curriculum.

By the 1950s history of science had won international recognition as an independent academic discipline, and a degree of acceptance in many universities. In the years following the Second World War chairs in the history of science were established at the universities of Amsterdam, Leiden, Utrecht, Frankfurt, Hamburg, Moscow, the Hebrew University of Jerusalem, as well as at about a dozen major universities in the USA. The contrast between the USA and Britain (and the rest of Europe) became most marked. By 1960 the majority of American universities had established teaching posts in history of science, over 40 had undergraduate examination courses in the subject, about 10 provided for post-graduate training, and general historians were showing a good deal of interest in history of science. In Britain in 1960 history of science was not accepted on anything like the same scale.⁵⁰

This acceptance of history of science was due in no small measure to the earlier strivings of Paul Tannery and George Sarton. Both made their own notable researches. They extended the scope and significance of the study urging that it should not be a study of the histories of the

49. See section 2.4.2.

50. See section 2.4.3.

individual sciences but a treatment of science as a whole; all of science should be included as indeed should all of history, an overall and comprehensive view of science was needed. Here was the example for the argument that history of science could counter too narrow and restricted science courses.⁵¹ Both Tannery and Sarton acted as propagandists for history of science and took early steps in its organisation. At the 1900 international congress of historians held in Paris, Tannery organised a separate history of science section, the first of its kind. Tannery who died in 1904, was anything but a professional historian of science. By profession he was a technical civil servant; his prodigious scholarship was produced in his leisure hours. Sarton on the other hand could be considered one of the first professional historians of science. Trained in science and philosophy at the University of Ghent he was employed on a full-time, paid basis from 1916 to 1951 to work in history of science at Harvard University.

2.4 History of science in British universities: from the late nineteenth century

2.4.1 Developments in the universities: from the late nineteenth century

"Higher education has not been planned as a whole or developed within a framework consciously devised to promote harmonious evolution. What system there is has come about as the result of a series of particular initiatives, concerned with particular needs and situations, and there is no way of dealing conveniently with all the problems common to higher education as a whole".⁵²

Since the late nineteenth century there has been very considerable and well documented changes in British universities. At the beginning of 1880 there were only four universities in England: Oxford, Cambridge, London and Durham. By the early twentieth century this number had more

51. See section 3.2.2.

52. Report of the Committee on Higher Education appointed by the Prime Minister (the Robbins Report) Cmd 2154, London, 1963, para.18.

than doubled with the creation of six new civic universities.⁵³ With the widespread development of secondary education and the rapid growth of the great northern cities, these new Redbrick universities were located mainly in the centres of the large industrial and manufacturing populations. Their foundation was due to local initiative. To some extent they represented a reaction against the Oxbridge commitment to a non-vocational, liberal university education. They were seen by their founders as a means of improving the position of British industries, then facing severe competition from Germany and America.⁵⁴ They also grew out of the Victorian ideal of betterment; it was believed that their very presence "is to do something to leaven the whole mass with higher aims and higher intellectual ambitions" even though the mass of the people engaged in trading and commerce would not necessarily attend them.⁵⁵ Initially the majority of their students were drawn from local areas, from the new secondary schools, and were non-residential.

In Britain as a whole there were some 20,000 university students in 1900, and some 50,000 by the beginning of the Second World War. During the war however, there was considerable pressure for expansion of university places as a part of the proposed social reconstruction. In 1944 the British Association for the Advancement of Science produced a report which suggested doubling the post-war Treasury grant to universities and increasing the number of students.⁵⁶ Two years later the Barlow

53. Manchester (1903), Liverpool (1903), Leeds (1904), Birmingham (1900), Sheffield (1905) and Bristol (1909). Also within the group of "civic" universities come Reading (1926) and Nottingham (1948); University Colleges at Southampton, Exeter, Hull and Leicester also taught to degree standard but presented their students for London external degrees (they attained university status between 1952 and 1957). There was also the federal university of Wales (1893).

54. See W.H. Brock and A.J. Meadows "Physics, Chemistry and Higher Education in the UK", Studies in Higher Education 2 (1977), 109-24.

55. Quoted in Asa Briggs "Development in Higher Education in the United Kingdom", W.R. Niblett (ed.), Higher Education Demand and Response, London 1969, pp.95-116.

56. British Association for the Advancement of Science, Report of the Committee on Post-War University Education, 1944

Committee, set up to examine the problems of scientific manpower and its use, spoke strongly of the need to double the output of graduates in science and technology (as well as urging an increase in the number of graduates in the arts and social studies) in the national interest. It reported a willingness of the civic universities to expand, and it recommended the foundation of at least one new university and several university colleges.⁵⁷ The widened terms of reference of the University Grants Committee in 1946 saw what has been described as the first open recognition that national needs should be a factor in university development. In 1947 the Vice-Chancellors' Committee also recognised that universities must take regard of the national interest, although it has been questioned whether most academics at that time would have subscribed to the notion.⁵⁸ The decade that followed the war saw a substantial increase in the number of places available for university students in Britain, the number of students doubling to over 100,000 between 1945 and the end of the 1950s; government expenditure on the recurrent grants to universities rose substantially; and full university status was granted to the University Colleges at Southampton, Hull, Exeter and Leicester. In 1949 the University College of North Staffordshire (later to become Keele University) was founded. This College, which was subjected to a period of tutelage, deliberately set out to innovate and look at university education in a new way. Created out of a tradition of adult education it designed a four-year pattern of studies which attempted to broaden the curriculum of the older universities and reduce the insistent demands of specialisation.

The decade 1958 to 1968 probably saw bigger changes in British university education than at any previous time during the century. In

57. Report of a Committee appointed by the Lord President of the Council entitled "Scientific Manpower" (the Barlow Report), London, 1946.

58. See Briggs, as in note 55 above, for a discussion on the University Grants Committee and the Vice-Chancellors' Committee.

the late 1950s arguments based on demographic and socio-educational factors - the "bulge", the "trend", and "English sense of fairness" over insufficient places for those qualified and wanting to go to university - led to an awareness that the existing universities could not, or would not, meet the likely demand for additional university places by the 1970s. In 1958 the University Grants Committee decided to sponsor seven new autonomous and free universities. The "Plateglass Universities" were to start as new institutions without any previous traditions, favourably situated for experimentation, and with an avowed policy of innovation and diversity. The criteria for the choice of sites was to include academic plans, local initiatives, and competitive bidding to the University Grants Committee. The sites eventually selected were at Brighton, York, Norwich, Essex, Kent, Warwick and Lancaster; charters were granted between 1961 and 1965. Each new university appointed its own faculty, devised its own curriculum and its own approach to teaching methods. From the start these new institutions, although facing common problems and sometimes producing common solutions, developed on separate lines and often produced unconventional courses. Meanwhile, the Robbins Committee, appointed in 1961 to look at Higher Education in the light of national needs and resources, reported on the desirability of new institutions and some change in the pattern of Higher Education. Accepting that social factors had deprived poor children of adequate educational opportunities it believed that there should be sufficient expansion of numbers to permit courses in higher education to be available to all who wished and were qualified to pursue them. From 1964 onwards the base of the universities was widened. Several existing institutions were upgraded and granted charters as full universities; Newcastle University became independent; the Open University was created; the Polytechnics were formed as institutions to teach up to and beyond degree level.

From the late nineteenth century onwards, in parallel with this expansion, were various often inter-related changes within the universities

themselves, and between these institutions and society as a whole. From 1889, when the government decided to distribute money from Treasury funds to the civic universities and appointed a committee to advise on its disbursement, the state became involved in financing the universities. This led to the formal establishment in 1919 (the year when Oxford and Cambridge accepted government grants for the first time) of the University Grants Committee. The social composition of university students changed. This was stimulated by a system of state scholarships, which began to operate in 1920, and by the financial assistance given to university students by Local Authorities. There were greater opportunities for women to attend universities. There were changes from a liberal to a more applied curriculum. Early in the twentieth century some interest was shown in various forms of professional training; in 1904, for example, Liverpool University founded a school of social science to train social workers. There was a growth of university involvement in extra-mural activities and adult education in general. Cambridge, Oxford and London universities had been involved in adult education from the 1870s with some of their teachers giving lectures to artisans in the industrial areas. The University Colleges of Bristol and Reading arose directly out of the University Extension Movement. However, university involvement in such work was especially noticeable in the period between the two World Wars. Greater emphasis was given to research, an emphasis encouraged by the introduction in 1912 of the PhD degree.⁵⁹ There was a marked trend in teaching and organisation towards specialisation: subjects were separated, new departments and chairs were created. Of these and other changes the trend towards specialisation, with its related arts/science division, was of particular significance for history of science in the British universities.

59. See Brock and Meadows, as in note 54 above.

2.4.2 First formal recognition of history of science in British Universities

In Britain the first formal recognition of history of science by the universities occurred about the turn of the century. The Calendars of University College, London, show that William Ramsay formally introduced some lectures on the history of chemistry into his Advanced Chemistry courses in the session 1898-99; these took place only on some Saturday mornings of the third term and clearly played no major role in the total course. At King's College, London, the "chief stages of the History of Astronomy" were formally introduced under Professor S.A.F. White in the session 1906-7; again the history was only a small part of the total course. Sir William Tilden was also noted for giving some lectures on the history of science in London about the same time. In Manchester the history of science tradition associated with Roscoe and Dixon continued; early in the twentieth century the regulations for the Honours School of Chemistry gave history of chemistry as a small part of the prescribed course: about the same time some history of science was stipulated for degrees in philosophy in the Faculty of Arts, although apparently the historians in that Faculty took little notice. But it was only in the 1920s that the first major steps were taken by history of science in the British universities. In 1924 Thomas Stewart Paterson introduced a course in the History and Philosophy of Science as a compulsory component of the Glasgow University BSc Degree in Chemistry. Several years prior to this, in 1921, the first British university department for the history of science was instituted at University College, London.

The first professor at University College, a philosopher, Abraham Wolf, had attempted to get history of science introduced into the university curriculum before the 1914-18 War, but had failed. After the war the university instituted a Diploma in Journalism as a small part of a scheme to provide professional training for men who had been deprived of the opportunity for higher education because of the war. It was suggested,

apparently by Sir William Bragg and Percy Nunn, that a general acquaintance with the history of science would be helpful to those who intended to take up scientific and technical journalism. Resulting from these lectures grew the belief that such courses would be useful to science teachers in schools. The Department in the History and Method of Science was instituted in 1921 to develop the work in this direction, and in 1924 an MSc Degree in the Principles, Methods, and History of Science was instituted for science graduates.⁶⁰ Although this department provided a full and thorough history of science course leading to a recognised academic qualification from the early 1920s it remained the only university department of its kind in Britain for the first half of the twentieth century. The only appointments made in the history of science at other British universities before about the middle of the twentieth century were at Oxford and Leeds. At Oxford early in the century there was some interest in the history of science. In 1919 Charles Singer was appointed lecturer in the history of biological sciences, with the duties of giving not less than six lectures in each of at least two terms of each academic year. But his stay was brief and he soon took up an appointment at University College, London. Then in 1923 a scheme was proposed for a new combined honour school with a combination of science and philosophy, including the history and philosophy of science; nothing came of this proposal at the time.⁶¹ Later, in 1933, the Vice-Chancellor of Oxford University spoke of the desirability of bringing some acquaintance with the history of scientific thought into the curriculum of science students,⁶²

60. See A. Wolf, "The Teaching of the History of Science in the University of London", Science Progress, 26 (1931), 275-9; and A. Armitage, "The Teaching of the History of Science in the University of London", Lychnos (1936), pp.302-7.

61. A.C. Crombie, (ed.), Scientific Change, London, 1963, p.763.

62. A.E. Gunther, Robert T. Gunther. A pioneer in the history of science, Oxford, 1967, p.471. This book gives full details of the life and work of Gunther but, surprisingly in view of the title, makes little mention of Gunther's interest in history of science apart from his work at the museum.

and in 1934 R.T. Gunther was appointed Reader in the History of Science. Gunther's first appointment at Oxford, to lecture in natural science, was in 1894. After the First World War he spent much of his time collecting and preserving scientific instruments and writings related to the history of science; also he wrote on various history of science topics. Much of his energy in later life was devoted to the founding of the Oxford Museum of History of Science of which he was the first curator. Gunther was aged sixty-five when he was offered the appointment of University Reader in the History of Science "without emoluments". Although he did give a series of lectures in the Oxford Colleges dealing with their men of science his appointment hardly increased in any significant way science students' acquaintance with the history of scientific thought; nor did the appointment help to introduce history of science into the programme of undergraduate courses. By far the majority of his time up to his death in 1940 was spent on the work of the museum.

At the University of Leeds, Joshua Craven Gregory⁶³ was appointed Honorary Lecturer in the History of Science in 1936; he held this title until his death in 1964. Honorary lectureships were courtesy titles and were not uncommon at Leeds at this time, such lectureships existing in several areas other than history of science. Gregory's appointment was made when he retired at the age of sixty-one from his lectureship in chemistry. There is no record of, nor in 1978 did anyone at Leeds recall, him giving any lectures in the School of History or in the Division of the History and Philosophy of Science. Gregory had shown his interest in history of science from about 1930 with his publications, but his appointment, like that of Gunther, had no practical effect in bringing history of science

63. Gregory had conferred upon him the title and status of Lecturer in Chemistry at Leeds University in 1926. His special field is recorded as analytical chemistry, but seemingly he wrote more on the history of chemistry than on any other aspect of that subject. The scope of his historical writings was restricted, but they do show an awareness of contemporary writing in history of science and make use of primary source material.

into the curriculum of that university at the time.

At Cambridge University the growing interest in the history of science in the 1930s has been noted. Several nineteenth-century Cambridge scholars had written on aspects of history of science, as had Sir William Dampier in the 1920s. But in the 1930s certain individuals, notably Joseph Needham,⁶⁴ held a belief that the lack of formal organisation for the study of history of science constituted a serious gap. In 1936 two efforts were made towards remedying this situation. An exhibition was arranged of scientific apparatus of historical interest collected from the Cambridge colleges; this loan exhibition was organised by Hamshaw Thomas and the apparatus catalogued by Robert Gunther. Apparently it aroused great interest although the collection was not kept together at the end of the exhibition time. More important was the setting up, with the blessing of the university authorities, of an informal committee to arrange courses of public lectures on the history of science. Here was the beginning of the History of Science Department at Cambridge. The History of Science Lecture Scheme seemingly owed its existence to Needham, who had for some time been urging on the Cambridge authorities his view that something should be done about history of science at the university. The public courses on history of science ran from 1936 to 1939, then again from 1942.⁶⁵ In 1946 the first official recognition was given to these

64. Needham was educated at Oundle School and Cambridge University. His interest in the history of science must owe some debt to F.W. Sanderson, Headmaster of Oundle, H.G. Wells, a close friend of Sanderson, and Sir Frederick Gowland Hopkins, a biochemist who advocated the use of history of science in British secondary schools and universities. In 1931 Needham gained a high reputation for his studies on the history of embryology, and was asked to help organise and participate in the Second International Congress of the History of Science and Technology to be held in London. At this congress he was much influenced by the Russian contribution and impressed by their application of Marxist principles to problems in the history of science. Subsequently he was prominent in the 1930s movement which attempted to exploit history of science for social and political ends.

65. Details of the setting up of the committee and of the early lectures can be found in the following: N.J.T.M. Needham and W. Pagel, Background to modern science, Cambridge, 1938; Isis, 46 (1955), 285-6.

efforts when the informal committee was reconstituted as a University Committee. But it was not until 1950 that an Assistant Lecturer in the History of Science was appointed at Cambridge. A full lectureship was created in 1953 about the same time as history and philosophy of science was incorporated into the tripos examinations. Subsequently a History of Science Department was formed.

Especially noteworthy amongst these developments was the creation of the Department of the History and Method of Science at University College, London. This, the first university department for the subject in the English-speaking world, provided what was for a long period the only academic centre for teaching and research in History of Science in Britain. It was of major importance in fostering this interest, in building up a tradition, and in leading to studies in this field in other universities. The post-World War I social responsibility felt towards ex-servicemen created a particular situation that was ultimately to lead to the formation of this department. With the return of large numbers of demobilised men to civilian life, University College was called upon to play its part in devising schemes which would give suitable professional training for those in need of it. Hence the Diploma in Journalism. Intertwined with this particular situation were several additional factors: a conception then existing that History of Science could be exploited in popularising science, a growing interest in relating History of Science to the school curriculum, a reaction against a prevailing trend in universities towards specialisation, perhaps even an element of "empire building". The use made during the previous century of history of science as a means of popularising and presenting science to non-specialists has already been noted. There were many examples of this both in books, and in lectures given in the University Extension Movement and to other adult audiences. It seems reasonable to speculate that such earlier examples played some part in the thinking of Sir William Bragg and Percy Nunn when they suggested history of science for intending scientific and technical journalists.

The growing interest in history of science in the school curriculum, well illustrated in the relative prominence it received in the 1917 British Association's Science Teaching in Secondary Schools and the 1918 Thomson report Natural Science in Education, is discussed later.⁶⁶

However, it can be noted that it was well in keeping with a mood of the time, and with Percy Nunn's own interests, to see that the journalists' history of science lectures would be useful to school science teachers. It is perhaps of interest to speculate whether an element of "empire building" may also have been present here. What would happen to the lecture series after all the demobilised servicemen had received their professional training? If the lectures were to be maintained a different source of students would have to be found; school teachers could provide a potentially unlimited supply. Furthermore, the creation of the new department at the College must be taken as part of the changes at that institution towards greater specialisation. In the period up to World War I a number of departments had been reorganised, a department of applied statistics was formed, the department of botany grew in size and became much more complex and highly specialised, engineering was separated from the faculty of science, a separate chair in organic chemistry was created, the Galton chair of Eugenics was founded, and the chair in geology was made a full-time appointment. After the war, besides the Department of the History and Method of Science, a chair in chemical engineering was created.⁶⁷

66. See Chapter 3.

67. See H. Hale Bellot, University College London, 1826-1926, London 1929, pp.403-4.

2.4.3 The spread of history of science in the universities

Marked changes in the position of history of science in the British universities came only in the second half of the twentieth century, especially from about the mid-1960s onwards. From that time the study has moved from being principally a postgraduate concern to figuring in both postgraduate and undergraduate programmes. There has been a dramatic increase in the number of academic appointments made in the discipline, with a change of emphasis in their background and training.

The 1950s saw most of the university activity in the history of science centred around London, Cambridge, Oxford and Aberdeen. In London University College continued to offer courses and to supervise students for various research degrees. At the London School of Economics a new department tenuously concerned with history and philosophy of science, the Department of Philosophy, Logic and Science, was created together with a chair; in fact, the work at this institution was mainly concerned with philosophy. At Oxbridge history and philosophy of science became more firmly established with several academic appointments made. At Cambridge a Certificate in History and Philosophy of Science was created, at Oxford a Diploma in History and Philosophy of Science; although some elements of these courses were available to undergraduates they were mostly taken by postgraduate students. Some undergraduate teaching was done in the history and philosophy of science at these two universities, especially at Cambridge, but the development of this was inhibited by the respective examination systems.⁶⁸ One notable exception to the postgraduate activity at London, Cambridge and Oxford occurred at Aberdeen University: there a Department of History and Philosophy of Science was created in 1951, the first in the UK to be chiefly concerned with undergraduate teaching.⁶⁹ By the late 1950s other universities apparently "were aware of the

68. A.C. Crombie, as in note 61 above, p.761ff.

69. A.C. Crombie, as in note 61 above, p.780.

importance of the history and philosophy of science"; but their teaching of it was described as "stop-gap".⁷⁰ This general lack of serious interest is indicated by the fact that, apart from the above four universities, only Leeds, Leicester and Belfast had made any academic appointments in this field by the end of the decade.

The 1960s and early 1970s saw a continuation and slight increase in the postgraduate activity in the history of science. But far more notable was the growth in the opportunities for undergraduates to study the subject as part of a first degree. In the early 1960s it was possible to study history and philosophy of science as part of a course leading to a first degree in less than half of the British universities, but in no case could it form a main part of the course. By the early 1970s the percentage of universities making it available in first degree courses had risen to some 66% and in nearly 15% of these it could form a main part of the course.⁷¹ This increase was recognised in the 1971 Royal Society Survey which concluded that "compared to ten years ago, the establishment of teaching in the subject has increased most markedly" and that history of science was "firmly established as an academic discipline".⁷² At present although it is unusual to specialise in history of science for a first degree there are many joint honours courses with history and/or philosophy of science as one component together with an increasing number of short one or two-year courses taken either as part of a general or general honours degree or as a subsidiary course in honours. In courses such as these it is possible to specialise in the history of a particular science, in particular periods of time, or in the work of particular scientists. It

70. W. Mays, "History and Philosophy of Science in British Commonwealth Universities", Brit. J. Phil. Sci., 11 (1960-1), 192-211.

71. These figures are based on the information given in Commonwealth Universities Yearbook for the years 1963 and 1973.

72. Royal Society, Report on the teaching of the history of science, medicine and technology in universities and technical colleges in the United Kingdom, London, 1971.

is possible to link the history of science with a wide range of other disciplines both scientific and non-scientific.

Among the conclusions of a 1958 Leeds conference⁷³ was a recognition of the need for more university teachers in the history and philosophy of science. This rising demand had some official recognition when both the Ministry of Education and the Department of Scientific and Industrial Research recognised History and Philosophy of Science as a subject among those for which grants for postgraduate study were made. In terms of overall numbers there was something of the order of a four-fold increase in the number of academic appointments in the field between the early 1960s and early 1970s.⁷⁴ But perhaps of greater importance, because of the influence on future policy, was the increase in the number of appointments made at a senior level. At both the professorial and the reader/senior lecturer levels there were also significant increases. In 1963 the only chair in the History and Philosophy of Science remained the one created in 1922 at University College, London.⁷⁵ By 1973 three new chairs had been created, at Imperial College, at Oxford, and at Chelsea College; further chairs were later created at the University of Manchester Institute of Technology and at the University of Kent, and a personal chair at Edinburgh. An increase can also be noted in the number of institutions with more than one member of the staff appointed in history of science. The importance of universities creating at least a small band of teachers with complementary interests was discussed at the 1961 Symposium on the History of Science held at Oxford.⁷⁶ There Buchdahl had pointed out the difficulties for a single lecturer in covering the wide field

73 See Brit. J. Phil. Sci., 11 (1960-1), 192-3.

74. These figures are based on the academic staff assigned History of Science, History and Philosophy of Science, or History of Science and Technology in the Commonwealth Universities Yearbook for the years 1963 and 1973.

75. The chair at LSE can hardly be considered as History of Science.

76. This symposium was held under the auspices of the International Union of the History and Philosophy of Science. The papers presented are edited by A.C. Crombie and published as Scientific Change, London, 1963.

provided by the study; he also pointed out the benefits to be gained in the way of exchange of ideas and mutual stimulation.⁷⁷ The 1971 Royal Society survey listed seventeen university colleges with two or more full-time posts or equivalents for the history of science, technology or medicine. This was in contrast with the position found by Mays in 1959 when, ignoring the London School of Economics, only Cambridge and University College, London had two or more posts in the history and philosophy of science.

Up to World War II the British figures most prominent in the field of history of science were mainly scholars who had done their initial research in some other field, had gained a degree of prominence for their work, and had then turned at least part of their attention to research in the history of science. As there were few opportunities in these decades for full-time employment in work related to history of science, it is not surprising that such scholars usually continued to work in their original field carrying their historical interests in parallel. The great majority of these scholars were scientists, as typified by Singer, Needham, Hogben, Bernal, Dingle and Partington.⁷⁸ Abraham Wolf, with a training and background in philosophy, was untypical. General historians usually ignored history of science. The second half of the twentieth century saw the slow emergence in Britain of the professional historian of science. Such a person is likely to be employed to devote a large proportion of his working time to teaching or research in history of science, his initial research interest is most likely to have been in that discipline, he may have academic qualifications in this field, and he will usually be associated with some society whose main purpose is the study of history of science. The first half of the century had in fact seen several

77. A.C. Crombie, as in note 61 above, p.783.

78. One quite untypical figure was T.L. Heath. Educated at Cambridge, taking the classical and mathematics tripos, Heath spent his working life in the civil service. Yet his leisure time studies and writings gained him the reputation of a world authority on Greek mathematics.

forerunners of this type of personnel,⁷⁹ but the opportunities for such to emerge were severely restricted until the expansion of university history of science posts in the 1960s. When the British professional historians of science did then emerge in significant numbers they emerged mainly from scholars whose initial training and background had largely been concerned with either philosophy or the natural sciences. With some notable exceptions general historians were still conspicuously absent.

The relatively widespread establishment of history of science in British universities in the 1960s can be seen as part of the contemporary wave of university expansion and the widely-held opinion then existing that new types of undergraduate courses were needed. The original mandate under which the "Plateglass Universities" were brought into being was to innovate. In 1963 the University Grants Committee reported that there was a need "... for more experiment in the structure of degree courses, in the content of the curriculum, in the method of teaching ...".⁸⁰ That same year the Robbins Report pointed out the need for much broader undergraduate courses. Not only in the "Plateglass" institutions but also in the existing and upgraded institutions was there a feeling that the years ahead were an opportunity to re-examine the aims and purposes of university education. What emerged from within the universities were attempts to inter-relate subjects. Undergraduates were increasingly offered a range

79. Douglas McKie and Frank Sherwood-Taylor serve as examples. McKie who trained as a chemist, worked from the 1920s in the Department of History and Method of Science at University College, London, finally succeeding Dingle as Professor in 1958. Sherwood-Taylor was educated in science at Oxford, made a study of Greek alchemy and alchemists for a London PhD, taught chemistry at various public schools, was appointed assistant lecturer in inorganic chemistry at Queen Mary College, London in 1933, and in 1940 succeeded Gunther as curator of the Museum of History of Science in Oxford. He was actively instrumental in founding Ambix and edited it from 1937. Both McKie and Sherwood-Taylor found employment in some aspect of history of science; both had an initial research interest in the history of science; both were actively involved with history of science societies.

80. University Grants Committee, University Development 1957-1962, London, 1964, p.104.

of "major and minor studies", "combinative studies", "cross-fertilised courses", "integrated courses" and "interdisciplinary courses".

Frequently built into such combinations were elements to provide humanising and liberalising influences and to balance the separate specialisms. It was as these elements that history of science chiefly came to light; as the meeting place of the disciplines, as the counter to excessive specialisation, as the way of presenting a broad, humane and liberal face of science. But these 1960s developments in history of science must be seen as more than a part of the contemporary expansion and innovation. They were a further episode in a development which stretched back to World War II and beyond, and clearly demonstrate the continuities that exist in certain educational issues. From the end of the Second World War history of science has been widely and frequently discussed within the context of the inter-related, perennial issues of the human face of science, worries about excessive specialisation, and the arts/science division.

As had happened during the First World War, history of science came sharply into focus after World War II. The British Society for the History of Science was formed. Greatly increased attention was given to history of science in the school curriculum.⁸¹ At the university level the changes at Oxbridge and Aberdeen have already been noted.

Universities Quarterly, founded in 1946, thought the subject sufficiently important and topical to devote four articles to it in an issue of 1952.⁸² War situations highlight the importance of science and technology both for national security and power, and for peace-time national welfare, growth and prestige. However, the war-time horrors caused by the products of science and technology, in particular the atomic bomb, emphasised the need to show that science was not the depersonalised, dehumanised and

81. See Chapter 4 for a discussion on both of these developments.

82. Universities Quarterly, 6 (1951-2), 332-60. Earlier in the same volume Douglas McKie had written an article entitled "The History and Philosophy of Science"; pp.169-74.

destructive outcome of a group of white-coated, semi-literate automatons. Science had to be presented as a cultural and humane study, a stimulating and rewarding intellectual pursuit; it had to be demonstrated that science was the product of people of other times and other places, a product which in the past has benefited society and had the potential to offer future benefits. Thus, when the universities were being asked to increase the output of scientists and technologists in the national interests, powerful voices such as Jacob Bronowski were urging the need to present science as a humanising study. Furthermore, in this period of pressure on the universities to turn out trained manpower, concern about excessive specialisation and the related arts/science issue was never far from the surface. As had happened in earlier times history of science was frequently pressed as a way of meeting the needs of the situation: it could counter overspecialisation; it could bridge the arts/science gap; it could show science as a beneficial product of human activity.

During the late 1940s and the 1950s such points of view were pressed, directly and indirectly, by many individuals both within and outside the universities. Jacob Bronowski,⁸³ who wrote the classical British report The Effects of the Atomic Bombs at Hiroshima and Nagasaki, lost no opportunity to press for a liberal and humane education which made use of history of science. In The Common Sense of Science, in which he attempts with the help of a good deal of historical material to give an interpretation of the development of scientific ideas meaningful to scientists and non-scientists alike, he states that

83. Bronowski read and researched in mathematics at the University of Cambridge from 1927 to 1933; he was a Senior Lecturer at the University of Hull from 1934 to 1942. He then left university teaching and held a series of administrative posts including, in 1945, Scientific Deputy to the British Chiefs of Staff Mission in Japan. Bronowski, who was accused of abandoning scholarship for popularisation, combined scientific and literary interests. He has been described as a leader in the "modern movement of scientific humanism" (The Times obituary 23 Aug. 1974).

"A knowledge of history ... gives us the backbone in the growth of science ... It throws a bridge into science from whatever humanist interest we happen to stand on ... it asserts the unity ... of knowledge. The layman ... will understand science as culture when he tries to trace it in his own culture ... it is the business of each of us to try to remake that one universal language which alone can unite art and science, and layman and scientist, in a common understanding".⁸⁴

During his stay as Visiting Professor at the Massachusetts Institute of Technology in 1953 he delivered a series of lectures "Science and Human Values" which initiated a good deal of discussion on the two-cultures. In 1955 in his address "The Educated Man in 1984", delivered to Section L of the British Association, he rejected the arts/science division, called for changes in school science, and wanted among those changes, science to be taught as an "evolution of knowledge".⁸⁵ History of science again came up at the British Association Annual Meeting the following year. In a paper "Can science courses educate?" J.A. Ratcliffe, then a lecturer in physics at the University of Cambridge, clearly showed his belief that history of science had a part to play in general education at the universities. His views were strongly supported in a subsequent paper at the same meeting by his Cambridge historian colleague R.C. Smail.⁸⁶ In 1957 Frank Greenaway, then a science teacher and later to move into museum work, in an essay "The historical approach to science" expressed his belief that it was a lack of understanding of science which divided intellectual society; he called for history of science as a way of helping to understand science and to act as a bridge between the two-cultures.⁸⁷ There is an abundance of further such examples. Clearly, as C.P. Snow freely admitted, the "two-cultures debate" was very much alive well before his vivid depiction of the chasm was given an importance in the intellectual

84. J. Bronowski, The Common Sense of Science, London, 1951, pp.3-11.

85. J. Bronowski, "The Educated Man in 1984", The Advancement of Science, 12 (1955-6), 301-6.

86. J.A. Ratcliffe, "Can science courses educate?" and R.C. Smail, "The Combination of Arts with science courses in higher education", The Advancement of Science, 13 (1956-7), 421-31.

87. F. Greenaway, "The historical approach to science", Universities Quarterly, 12 (1957-8), 130-40.

press out of all proportion with its merit. Nevertheless, the controversy which followed Snow's 1959 Rede Lecture⁸⁸ was another manifestation of a concern that had been worrying academic teachers for many years and did help to focus further attention on history of science as a potential solution to the divide.

One of the direct attempts to press more history of science on the universities came in 1956 from Stephen Toulmin, then Professor of Philosophy at the University of Leeds. Toulmin was involved in 1952 in writing the first GCE "History and Philosophy of Science" examination paper for the Cambridge Local Examination Syndicate,⁸⁹ and later became Director of the Nuffield History of Ideas Unit.⁹⁰ Writing in Universities Quarterly he argued for more history of science in the universities on the grounds that such work was capable of providing in itself a liberal education. His article was to provoke interest in the national press and a good deal of anger at University College, London. In a leading article of 11 August, 1956 "Science Has Its History Also" The Times supported Toulmin's views. This leader was followed during the next two weeks by extensive correspondence which did not really come up with any new ideas or set out the issues more explicitly. Within University College, however, there was a good deal of resentment at what was seen as a deliberate snub in Toulmin's neglect of any reference to the Department of the History and Philosophy of Science.⁹¹ Even The Times, which "thundered" "In England ... [no university] provides more than an appendix to a degree course" had forgotten or knew nothing about the department. Herbert Dingle, Professor of the History and Philosophy of Science at the College, immediately fired off a letter to the editor pointing out apparent inaccuracies in Toulmin's article and The Times leader. The editor however, was "unable to find room" for Dingle's reply. After a good

88. This lecture was published under the title C.P. Snow, The Two Cultures and the Scientific Revolution, Cambridge, 1959

89. See section 4.2.

90. See section 5.4.1.

91. By 1956 the title of the department had been changed: see Chapter 3, note 59.

deal of activity within the college, its point of view appeared in a letter from Ifor Evans, the Provost, on 21 August. (Dingle subsequently had a further letter published on 24 August). This episode does perhaps serve to illustrate some of the rivalries, tensions and jealousies that existed.⁹² More importantly however, that The Times should devote a leading article to such an issue is in itself a clear indication that the editorial staff felt the issue was highly topical and reflected current concern.

Thus the 1960s developments in history of science can be seen as resulting not only from a series of particular initiatives concerned with the particular 1960s situation and needs of expansion and innovation in broader undergraduate courses. They could also be described as the culmination of two decades and more of persistent pressure from individuals, the outcome of a cumulative, almost self-generating process. And perhaps involved in this self-generating process was more than a trace of institution begetting institution, of more people receiving an academic and professional training in history of science consequently seeking to use this training and expertise in a professional capacity. But two ironies are apparent. It is ironical to note that after this period of expansion in 1969 the Department of the History and Philosophy of Science at University College, the oldest university department for the subject in the English-speaking world, was seriously threatened with closure as part of financial economies.⁹³ The successful resistance to this closure - resistance from sections within the college itself, from the British Society for the History of Science, and from many distinguished academics throughout the world - illustrates both the power of a professional pressure group and that History of Science had by that time achieved a sufficient and powerful voice inside and outside the College.

92. This information is taken from memoranda, correspondence and other records kept at University College, London.

93. Press notices of the proposed closure appeared in The Guardian of 5 March 1969 and on the following day in the Daily Telegraph.

The second irony concerns specialisation. In 1961 Asa Briggs spoke of a contemporary vociferous demand from university students for the inclusion of more history of science into the university curriculum. This demand he saw was not for further specialisation but as an antidote to the excessive specialisation that already existed.⁹⁴ Yet in keeping with the tradition that had existed since at least the late nineteenth century, history of science only found a place in the university curriculum after it had become a highly specialised and professional discipline. Once that had happened the subject had acquired an intrinsic legitimacy; to suggest its use as a liberalising agent presented a possible conflict of loyalties. As Sir Alec Cairncross has reported

"there is some evidence that, with the emergence of the history and philosophy of science as a discipline in its own right, those who launched courses in this field of study are increasingly absorbed in it without any particular regard to its relevance for science education".⁹⁵

94. See A.C. Crombie, as in note 61 above, p.756.

95. Unpublished draft of a report to the Nuffield Foundation, "Liberal Studies in Science" by Sir Alec Cairncross. This has been published as Nuffield Foundation, Science Studies, London, 1980.

Chapter 3

HISTORY OF SCIENCE AND THE ENGLISH

SECONDARY SCHOOL: UP TO WORLD WAR II

3.1 Awakening of interest

"It is desirable ... to introduce into the teaching some account of the main achievements of science and of the methods by which they have been attained ... There should be more of the spirit, and less of the valley of dry bones ... Everyone should be given the opportunity of knowing something on the lives and work of such men as Galileo and Newton, Faraday and Kelvin, Pasteur and Lister, Darwin and Mendel, and many other pioneers of science. One way of doing this is by lessons on the history of science, biographies of discoverers, with studies of their successes and failures, and outlines of the main road along which natural knowledge has advanced ... History and biography enable a comprehensive view of science to be constructed which cannot be obtained by laboratory work. They supply a solvent of that artificial barrier between literary studies and science ... ".¹

The British Association's Report of 1917, Science Teaching in Secondary Schools, was one of several investigations into school science teaching during the first two decades of the twentieth century. This report, which attached particular importance to teaching science as "a body of inspiring principles" and as "a truly humanising influence", is a landmark for history of science in school education. It is the first major British report to give prominence to history of science in the school curriculum. It clearly showed distinct roles for the history suggested. And it marked a peak in a growing interest in the use of historical material in school science courses.

Up to the closing years of the nineteenth century mention is hardly ever made of history of science in the secondary school curriculum. Herbert Spencer, Thomas Huxley, John Tyndall, Canon Wilson and other supporters of

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1. British Association for the Advancement of Science, Science Teaching in Secondary Schools, London, 1917, pp.18-19. This report was drawn up by a committee chaired by Richard Gregory and consisted almost entirely of teachers with experience in secondary schools. The report concerned itself chiefly with a brief consideration of the existing methods and scope of science teaching in secondary schools, and gave as specimen courses seven schemes of work suitable for various types of schools.

science education frequently showed interest in, and knowledge of historical matters. Huxley wrote several essays which showed his familiarity with the histories of the physical and especially the biological sciences. These included "Errors regarding the structure of the heart attributed to Aristotle", "Evolution in Biology" and "Joseph Priestley".² Spencer's main work on education Education. Intellectual, Moral, Physical contained at least two historical thoughts which later were to become important. His belief that the "education of the child must accord both in mode and arrangement with the education of mankind, considered historically"³ became a common argument during the first half of the twentieth century for advocates of the historical method of teaching science.⁴ His approval of the historians who were beginning to occupy themselves with the phenomenon of social progress foreshadowed an externalist approach to the study of the history of science and technology.⁵ Wilson was noted as a leading antiquarian of his day. However, perhaps it is not surprising that they made no sustained calls to introduce history of science into the schools. The 1850s and 1860s champions of science teaching needed to establish the validity of science as a part of the school curriculum and this they did mainly by stressing its utilitarian and educational values. As science had an obvious utility and would benefit the country economically and politically science teaching, they argued, was essential in the schools; in addition the mental training that science gave was at least as good as that given by the classics. Of necessity they placed the emphasis on the contemporary body of scientific knowledge and on its methods. They were not all in agreement about what should be taught. Huxley argued for school science

2. These were published in Nature of 6 Nov. 1879; Encyclopaedia Britannica, 9th edition, 1878; MacMillan's Magazine, 1874 respectively.

3. H. Spencer, Education. Intellectual, Moral, Physical, London, 1861, pp.81ff.

4. See 3.2.3.

5. See Chapter 4, note 1.

courses to be wide in content and include physics, chemistry and especially biology. He believed that biology contained the subject matter most suitable for developing powers of observation and most important for the pupils' own welfare; he also believed that a study of biology would show the beauty of God's creation, would provide a belief in the living law and order, and would help to overcome the despair caused by the contemporary social problems. In contrast at the 1862 British Association meeting in Cambridge Edwin Chadwick found a "gratifying unanimity" among the educationalists assembled that studies should be "narrower and deeper".⁶ In his writings Wilson reasoned for narrower and deeper courses:

"... the scientific habit of mind, which is the principal benefit resulting from scientific training, ... can better be attained by a thorough knowledge of the facts and principles of one science, than by a general acquaintance with ... many".⁷

In taking evidence on what science should be taught the Clarendon Commissioners were faced with a contradictory mass of opinions: biological sciences were variously dismissed as less scientific than physics and chemistry; botany was only suitable for young ladies; the physical sciences laid the foundation for the study of the biological sciences. Apparently the nature of the scientific enterprise, the historical development of scientific ideas, the part played by science in providing the nation's cultural heritage all seemed less relevant to what was seen as the purpose of science education during the third quarter of the nineteenth century, and did not appear as frequently in the debates as did the facts of science and the experimental method. Likewise nineteenth-century schemes of work, school science syllabuses and reports had little or no place for history of science. Where mention was made the comments were

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6. Quoted in D.S.L. Cardwell, The Organisation of Science in England, London 1972, p.107.
 7. J.M. Wilson "On teaching natural science in schools", published in F.W. Farrar (ed.), Essays on a Liberal Education, London 1867, p.262.

usually tenuous and undeveloped, as in the case of William Johnson's evidence to the Clarendon Commissioners. Johnson, a classics master at Eton, suggested two ways of approaching science: one was to study science so as to master it; the other was to "be content with a sort of literary appreciation of its leading theory, its history, its relationship to other departments of knowledge".⁸ That this view was not developed or commented on by either the commissioners or Johnson himself, seems to exemplify the attitude prevailing at that time.

From the closing years of the nineteenth century onwards allusions to history of science in the school curriculum are to be found with a steadily increasing frequency, and by the turn of the century it seems that some science teachers were using historical material in their courses. In 1903 the Rev. A.H. Fish, of Arnold House School, Chester, described his science course which had "evolved over the last fifteen years of teaching". The lessons, which he described as "very successful", closely followed the history of physical science and were accompanied by a good deal of biographical matter. Each lesson was grouped around one or two historical experiments "... surrounded as far as possible with the historical conditions under which they were originally performed".⁹ Four years earlier Florian Cajori's A History of Physics had been reviewed with the recommendation that

"every teacher of physics and every library in schools should possess a copy ... nothing is more stimulating to students of science than familiarity with the methods and results of great investigators".¹⁰

In his preface Cajori himself agreed with the sentiment that

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8. Report of Her Majesty's Commissioners appointed to enquire into the revenues and management of certain colleges and schools, and studies therein, (Clarendon Report), London, 1864, Vol.3, para 4750. This report inquired into the nine public schools: Eton, Winchester, Westminster, Charterhouse, St. Paul's, Merchant Taylors', Harrow, Rugby and Shrewsbury. It will be referred to as the Clarendon Report.
 9. A.H. Fish, "Science in a liberal education", School World, 5 (1903), 354ff.
 10. School World, 1 (1899), 157.

"eminent and far-sighted men ... have repeatedly been obliged to point out a defect which too often attaches to the present scientific education of our youth. It is the absence of the historical sense and the want of knowledge of the great researches upon which the edifice of science rests".¹¹

Although Cajori's work was intended mainly for the use of students and teachers of physics in the USA, during the first decade of the twentieth century eminent and far-sighted men in England were also pointing to the same defect. Oliver Lodge, physicist and first Principal of the new Birmingham University, in lectures given to secondary school teachers and teachers in training¹² included history of science in his proposals. He believed that throughout physics teaching it was desirable to intermingle the facts of science with some human interest, to trace the steps of discovery, to point out what was thought at one time and how it was gradually corrected, to elicit admiration for the "Pioneers of Science". Lodge believed that the early ideas of men of the past were sure to be something like the early ideas of the child today

"... the steps of evolution should be borne in mind by the teacher and may to some extent be followed".

He thought that insufficient attention was paid by science teachers to the scientific classics and commended teachers to

"study the early parts of Newton's Optics ... Young, Fresnel, Carnot ... the accumulated information of the race must be handed down among teachers".

(It is of interest to note that Professor Eric Rogers recalls first getting the idea of using the history of science to teach about scientific theories from reading Lodge's Pioneers of Science¹³: see Chapter 6). In School World, a monthly magazine for use in secondary schools edited by Richard Gregory, various references were made to possible uses of historical

11. F. Cajori, A History of Physics, Dover Edition, New York, 1962, Preface to the first edition.

12. Published as O. Lodge, School teaching and school reform, London 1905.

13. Published as O. Lodge, Pioneers of Science, London 1893.

material in school science courses. Authors of articles and books on pedagogy increasingly referred to its potentialities. Especially prominent in this increasing awareness were Gregory and T. Percy Nunn, both of whose earlier writings were clearly reflected in the 1917 report Science Teaching in Secondary Schools.

3.2 Factors behind the upsurge of interest

The steps being taken in the late nineteenth and early twentieth centuries towards acquiring for history of science an independent and professional status have already been noted. History of science was being taken seriously by a significant number of scholars and was becoming fashionable in certain quarters. It is easy to underestimate the part played by fashion in attracting people to a cause. Also, it is interesting to speculate on the part played by classics masters in its early promotion. When science was finding a place in the school curriculum in the closing decades of the nineteenth century much science teaching was done by classics masters. These masters with a background of classical studies and a probable awareness of Matthew Arnold's views on history of science in education¹⁴ may well have been attracted by science histories. However, other more technical factors lay behind the upsurge of interest in history of science in education. The most important of these were the attacks on science made from without, the unease of teachers about the type of science taught, and the contemporary interest in the intellectual development of the individual.

14. See section 3.3.1.

3.2.1 Attacks on science

The position of science in the English secondary school in the 1860s and 1870s is well documented in the reports of that period;¹⁵ the natural sciences were practically excluded from the education of the higher classes in England. It was only because of the influence of these reports and because of the work of Spencer, Huxley, Tyndall, Wilson and others that science was gradually introduced. By the end of the nineteenth century there was some kind of science teaching in most of the English schools. By 1917 the British Association's Report showed that, with the exception of the classical sides of the boys' Public Schools, science had a significant place in the secondary school curriculum even though the time allowance was usually unsatisfactory; a year later the Thomson Committee¹⁶ broadly agreed with this finding.

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15. Three nineteenth-century reports are particularly relevant to the schools considered in this investigation. The Clarendon Report has already been mentioned. The Schools Inquiry Commission of 1868 was a government commission which looked at endowed, propriety, and private schools; this will be referred to as the Taunton Report. The Royal Commission on Scientific Instruction and the Advancement of Science of 1872-75 was a detailed survey of science education at the higher levels; this will be referred to as the Devonshire Report (see Chapter 2, note 32).
 16. B. Educ., Report of the Committee on the Position of Natural Science in the Educational System of Great Britain (Natural Science in Education) Cd 9011, London, 1918; this will be referred to as the Thomson Report. This report was produced by a government committee chaired by the physicist J.J. Thomson. According to the British Association report of 1917 the committee included "only three or four members familiar with the science work carried on in secondary schools". Its terms of reference were wider than those of Gregory's committee, but they did lay special emphasis on the position of science in secondary schools and universities.

From early in the nineteenth century supporters of science education had argued for its inclusion into the school curriculum on the grounds of its utility, on account of its ever-increasing influence on everyday life, and because it gave a mental training at least as good as that given by the classics. The Clarendon Commissioners saw the value of science

"as a means of opening the mind and training the faculties ... cultivating directly the faculty of observation ... the power of accurate and rapid generalisation and the mental habit of method and arrangement ... accustoms the tracing of cause and effect ... familiarizes with reasoning ...".¹⁷

The seemingly self-evident arguments of the usefulness and everyday importance of science were strengthened in contemporary eyes by such events as the trade depressions of the 1880s, the inefficient conduct of the Boer War, and the trauma of the First World War. But these arguments were not accepted uncritically. It was widely recognized that the goods upon which Britain's prosperity depended relied increasingly upon the application of scientific principles, that these principles should be diffused throughout the community, and that science must play a part in education if Great Britain was to maintain her position in the world. It was widely agreed that without physical science civilisation would collapse, and that the community needed a sufficient number of trained men of science. But the opponents of science education were quick to point out that it did not follow that every citizen need be a trained scientist; the well-being of the community also depended on other specialists, farmers, shipwrights, and teachers, yet it did not follow that "we must all study agriculture, naval architecture and pedagogics".¹⁸ It was argued by many that science did not give a good general training to the mental faculties; the training was in a restricted area and suitable only as training for scientists. Science itself was bitterly attacked. It was criticised as being no more

17. Clarendon Report, as in note 8 above, p.32.

18. R.W. Livingstone, A defence of classical education, London, 1917, p.29.

than a cold-blooded depersonalised and dehumanised intellectual feat, concerned only with things and not with people. The progress of science was seen by some as having no beneficial, or even detrimental effect on the character, as destroying the mystery of the universe, as making the rainbow cold, even as being harmful to civilisation. Many people rejected science as a means of learning about human nature, human society, and culture. Some people rejected science as a valid part of the secondary school curriculum.¹⁹

The obvious counter to such attacks was to assert that science was truly a cultural and humanistic study, and to emphasise those aspects of science which supported this assertion. Hence the importance attached in Science Teaching in Secondary Schools to the humanising influence of science. The Thomson Committee expressed similar sentiments.

"The humanising influence of the subject has too often been obscured ... the teaching of science must be vivified by a development of its human interest side by side with its material and mechanical aspects ... it must never be divorced from those literary and historical studies which touch most naturally the hearts and hopes of mankind".²⁰

Many people saw history of science as a prime means of demonstrating the humanistic and cultural aspects of science. The calls for the inclusion of history of science into the school curriculum came therefore partly as a response to the attacks made on science and its place in the schools.

3.2.2 Disquiet within

In 1918 the Thomson Report summed up feelings that had been steadily increasing among science teachers during the previous decade. It asserted that secondary school science courses needed urgent reform in respect of the choice of subject to be included, and in the manner of teaching those subjects. The committee pointed out that the choice of subjects had resulted in the work being too restricted. Boys' schools concentrated

19. For a fuller discussion see E.W. Jenkins, From Armstrong to Nuffield, London, 1979, pp.49-57.

20. Thomson Report, as in note 16 above, p.5.

almost exclusively on physics and chemistry and girls' schools on biology. At the pre-matriculation stage the sciences were restricted in their scope. Physics frequently consisted only of practical measurement and heat; chemistry often concentrated on quantitative experiments and laboratory exercises which were little more than pieces of drill, with the theoretical foundations largely ignored; biology was chiefly simple botany. At the post-matriculation stage it was common for pupils to select from within a narrow grouping of subjects: the Sciences could be studied to the total exclusion of the Arts, and vice versa; the gap between the Arts and the Sciences was a reality. In addition there could be a concentration on certain science subjects to the exclusion of other science subjects. In all of this the Thomson committee was echoing the views of those teachers who regretted that no overall and comprehensive view of science was being given to their pupils.

In the way that science was taught the committee believed that there was too much emphasis given to laboratory work to the detriment of other aspects. Laboratory work they considered was an essential part of science teaching; but the insistence that individual pupil experiments were always preferable to teacher demonstrations led to a great waste of time and this they deplored. Again the committee was in accord with the sentiments of a great number of teachers. From the time science was first established in the schools many teachers wished to emphasise the experimental side of science and to give in their lessons some understanding of its nature and methods. The *heurism* of Armstrong²¹ which naturally focused attention on scientific method rather than on scientific knowledge achieved both of these desires. But from the early years of the twentieth century there was some reaction from science teachers against the type of experimental work that had developed and against the over-emphasis placed on the laboratory. The reaction was against the measurement studies

21. See W.H. Brock, H.E. Armstrong and the Teaching of Science, Cambridge, 1973; and E.W. Jenkins, as in note 19 above.

which prevailed in practical work and against the excessive use of heurism. It was not exceptional to find teachers who no longer wished to rely purely on experimental work for their pupils to learn about the methods of science.

This mood of unease within science teachers was paralleled by changes within history of science itself.²² There it was being argued that the study of History of Science should not be a study of the histories of the individual sciences but a treatment of science as a whole; all of science should be included, an overall and comprehensive view was needed. This attitude was transferred to school science courses where, it was argued, histories of science could "enable a comprehensive view of science to be constructed" and "do much to counteract the narrowness of view which sometimes accompanies specialisation".²³ At the same time the startling new discoveries made in physics were forcing upon scientists new conceptions of the meaning of laws and theories of science, of the nature of science, and of its methodology. These discoveries were helping to arouse a new interest in examining the philosophical basis of science. From the 1830s until the turn of the century history of science had been largely ignored by philosophers. But the writings of Mach and Duhem²⁴ marked the beginning of a new and sustained interest in historical analysis by philosophers. Thus school teachers were now provided with the example and an abundance of historical material for descriptive teaching of the nature of science and its methods.

It is reasonable to suppose that not a few teachers came to see history of science as a possible solution to their problems by the changes then occurring in that study.

22. See 2.3.

23. Thomson Report, as in note 8 above, p.78.

24. See, for example, Ernst Mach, Die Mechanik, Leipzig, 1883 and Pierre Duhem, La théorie physique, son objet et sa structure, Paris, 1906. In Die Mechanik Mach states "The historical investigation of the development of a science is most needful ... [it] promotes the understanding of that which is now ... brings new possibilities before us ...". (English edition, 1960, p.316).

3.2.3 Parallelism between intellectual and historical development

Early in the twentieth century, with faculty psychology increasingly under attack, there was a good deal of interest in the intellectual development of the individual; a belief that the history of culture at large was indicative of the several stages through which every child passed to maturity was prevalent. This belief that the mental development of mankind is repeated in the mental history of the individual was discussed in some detail in 1907 in Adamson's The practice of instruction. There the belief was traced back to Pestalozzi, Froebel, and Comte; Froebel is quoted as saying that "every human being who is attentive to his own development may thus recognise and study in himself the history of the development of the race ...": Herbert Spencer's idea that the education of the child must accord both in mode and arrangement with the education of mankind, considered historically, was noted; and Ziller's attempts in the 1880s to apply the doctrine to the teaching situation was discussed.²⁵

Parallelism was taken up early in the twentieth century by Benchara Branford who stated that the development of mathematical knowledge in the individual parallels the historical development of mathematics itself.²⁶ This idea was repeated by Percy Nunn who wrote "... the student in training must think his way afresh through the mathematical curriculum from the genetic standpoint; logic, psychology, and the history of the science being his

25. J.W. Adamson (ed.), The practice of instruction, London, 1907, pp.107-14. In the same work Percy Nunn wrote about the "value of the history of a science as the source of correct views upon the general method of development of the subject in teaching" (p.381).

26. B. Branford, A Study of Mathematical Education, Oxford, 1908. In the Preface Branford made a plea "... for a greater appreciation of the value ... of historical study in scientific education ..." and commented that it had not been "... sufficiently remembered that the history of mathematical science is part of the history of human education". See Appendix 1 for Branford's ideas about the parallel development of mathematical experience in the race and in the individual. The recapitulation idea was also pressed by Stanley Hall and influential in the USA; see Granville Stanley Hall, Adolescence, New York, 1904.

guides".²⁷ Interestingly even heurism suggested history; the origin of the term was associated with this parallelism, and Armstrong had said that his system "was necessarily historical".²⁸ All of this naturally focused attention on the history of science, and during the succeeding decades the supposed parallel between individual and historical development was frequently used to justify the use of the historical method and the inclusion of historical material in school courses.

In 1917 Science Teaching in Secondary Schools clearly reflected Nunn's earlier writings. In suggesting how to select what might be taught the committee recognised three especially conspicuous motives which had prompted men to understand nature. These they called the wonder, the utility, and the systematising motive, and related them to children of various ages. At about the age of eleven children responded "most surely and actively to the direct appeal of striking and beautiful phenomena" (the wonder motive) according to the committee; from about twelve to sixteen the utility motive assumed mastery; while the full advent of adolescence was necessary for the systematising motive to have the first opportunity of predominance.²⁹ Some twenty years later, again influenced by Nunn, the Spens Report described these motives as rhythms or successions of phases which were exhibited in the history of science as a whole, were constantly repeated in its smaller parts, and were exhibited in the changing interest a child had in a subject. Using history of science to illustrate these phases the report described how the history of electricity began in the eighteenth century

"with a period of wonderment and delight in marvellous and bizarre phenomena for the first time brought to light ... it passed to the exploitation of electricity in the service of

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27. T.P. Nunn, "The training of teachers of mathematics", B. Educ., The teaching of mathematics in the United Kingdom, Part 2, London, 1912, p.292. Both Branford and Nunn were talking in these cases about mathematics, but the same principle applied to the teaching of science.
28. W.H. Brock, as in note 21 above, pp.19 and 72.
29. Science Teaching in Secondary Schools, as in note 1 above, pp.13-15.

man ... and was completed by the contemporary phase - initiated by the great work of Clerk Maxwell - in which the physicist seeks to construct a picture of the whole material world in terms of electrical entities".³⁰

In between Science Teaching in Secondary Schools and the Spens Report several books on pedagogy discussed the same theme.

Discussion on the parallelism between intellectual and historical development played a part in the upsurge of interest in history of science in the early part of the twentieth century. During the succeeding decades it was frequently used to justify the use of the historical method and the inclusion of historical material in school courses.

3.3 Roles seen for history of science in the school curriculum

Many roles and uses, some highly idiosyncratic, were suggested for history of science in school courses during the first half of the twentieth century. History of science was seen as a source of simple experiments for illustrating fundamental scientific principles; it was a means of understanding modern complexity by teaching from the simple to the complicated; it was useful for subjects that did not lend themselves to an experimental treatment; it was thought valuable when the time was limited (and criticised as too time consuming); it was able to provide a moral training; it could even supply the teacher "with a possible method for presenting the subject [science] when all other is lacking".³¹ At times history of science was all things to all men. But from the early years of the century three roles were argued most frequently for history of science. History of science was a means of demonstrating the cultural

30. B. Educ., Report of the Consultative Committee on Secondary Education with Special Reference to Grammar Schools and Technical High Schools (Spens Report), London, 1938, p.162. This will be referred to as the Spens Report. The quoted section is clearly taken from Nunn's paper "The Significance of Science in Education" published in T.F. Coade (ed.), Harrow Lectures on education, Cambridge, 1931, pp.117-29.

31. H.H. Cawthorne, Science in Education, London, 1930, p.69.

and humanistic aspects of science; it was highly suitable for teaching about the nature and methods of science; it could counter over-specialisation. These roles dominated the debates about history of science in education throughout the first half of the twentieth century.

3.3.1 To demonstrate the humanistic and cultural aspect of science

"Of all the claims made for the inclusion of science into a school curriculum, the strongest undoubtedly is that which stresses the cultural value which the subject possess".³² The statement that science possessed a cultural value and exerted a truly humanising influence became the argument used most commonly to promote the claims of science in the school curriculum during the first half of the twentieth century. For many decades there had been widespread agreement among science teachers that their courses needed humanising and needed to emphasise the cultural aspect of science. But there was no consensus of opinion on how this should be achieved. Nor was there precise agreement on the meanings of the terms cultural and humanistic. Consequently the use of history of science was only one of the several ways suggested of meeting the humanising and cultural requirements.

The words humanistic and cultural were very closely linked and often considered synonymous in the minds of people in the nineteenth and early twentieth centuries. For a good deal of the nineteenth century the narrow classical interpretation of humanism (pertaining to classical studies, Latin and Greek language and literature) dominated the secondary schools and universities. In the second half of the century the work of Darwin, Spencer, and Huxley profoundly influenced this prevailing concept and helped to develop scientific humanism, a humanism based on scientific discovery, the empirical approach, and rational evaluation of human relations. Increasingly this scientific humanism took on implications

32. SMA, The teaching of general science, London, 1936, pp.14-15.

far wider than the natural sciences themselves: it became a movement aimed at the total reform of the educational process; scientific ways of thinking and acting became extended over a field wider than science itself; science was seen as one aspect of a total cultural or social system leading to man's progress.

The classic nineteenth-century debate between traditional and scientific humanism came in the writings of T.H. Huxley and Matthew Arnold over the relative importance to education of the natural sciences and the more traditional humanities. Both Huxley and Arnold agreed that humanism, whether classical or scientific, was concerned with promoting human culture, and that culture meant knowing the best that has been thought and said in the world. Their writings in this debate, especially those of Arnold, clearly show that humanism and culture involved history of science, and that history of science had a definite place in education.

"... by knowing ancient Greece, I understand knowing her as the giver of ... the guide to a free and right use of reason and to scientific method, and the founder of our mathematics and physics and astronomy and biology ... By knowing modern nations, I mean ... knowing also what has been done by such men as Copernicus, Galileo, Newton, Darwin".³³

Here lay the seed for the later advocates of history of science to counter the criticisms that science was inhuman and lacked a cultural value.

The most common and basic historical interpretation placed on the humanistic aspect of science was little more than a truism. Science was an activity carried out by human beings, thus by including in science courses something of the lives and works of past scientists courses would become humanised. A consequence of this interpretation was that scientific biographies became the most common type of historical material associated with school science courses during the first half of the twentieth century. F.W. Westaway, in his monumental and highly influential Science Teaching, talks about how the imagination of the young may be kindled by a knowledge

33. Matthew Arnold, "Literature and Science", Discourses in America, London, 1885, pp.91-2. This paper was originally given as the Rede Lecture at Cambridge in 1882.

of the long and patient struggle associated with the great names in science, "the series of lucky accidents, bold hypotheses, painstaking studies, the failures, disappointments and the successes", of how boys like to read of the quarrels of the great men of science, and of how biographies show that science has transcended national boundaries.³⁴

Percy Nunn in The New Teaching says

"The prime contribution of the heroes of science to the world's cultural wealth is not the scientific method but the scientific life ... Our proper aim, then, is to make our pupils feel ... what it is to be ... inside the skin of the man of science, looking out through his eyes as well as using his tools, experiencing not only something of his labours, but also something of his sense of joyous intellectual adventure".³⁵

An important aspect of many such writings was the appeal to make biographical detail more than a narrow description of the lives and works of scientists. There were suggestions of setting the historical facts into the wider context of their contemporary intellectual and social background, and an emphasis on evaluating a period from within. Nunn had spoken of getting inside the skin of the man and looking out through his eyes.

H.H. Cawthorne, a science teacher in the 1930s, reiterated this approach.

"The boy should project himself into the life of the scientist ... He may be Gilbert of Colchester ... he must be made to feel that he is living in the age following Columbus; he must be conscious of the spirit of discovery which surrounds him ..."

34. F.W. Westaway, Science Teaching, London and Glasgow, 1929, pp.11-12. Westaway, teacher, Headmaster, and HMI, was the author of several books of which Science Teaching was perhaps the most influential. In this work he was quite explicit that whether or not science was taught on an historical basis, some definite instruction in the history of science should be included in every science course (p.378). During the Second World War Westaway was much concerned about the apparent indifference of scientists towards the world's urgent problems. This he attributed to the high degree of specialisation in the schools which had forced scientists away from the humanities. He expressed the fear that "during my professional career, I advocated the claims of science teaching much too strongly and I am now quite sure that the time often devoted to laboratory practice and to the purely mathematical side of science, more especially chemistry and physics, was far too great" (quoted in E.W. Jenkins, as in note 19 above, p.140).

35. T.P. Nunn, "Science", John Adams (ed.), The New Teaching, 2nd edition, London, 1919, p.160.

Cawthorne had no time for mere details of lives and encyclopaedic sequences of facts.

"If a study of the life and work of Davy [is as below], then the subject were better left alone: 'Davy Sir Humphry (1778-1829) - while at Bristol he respired 20 quarts of nitrous oxide - he electrolysed gypsum in solution, and solid potash (isolating potassium for the first time) - he predicted Ba, Sr, Ca, Mg, Si, Al and Zr - he explained the nature of chlorine and ... and ... lamp' ".³⁶

A survey of school science text books of the period reveals a good deal of the type of material that Cawthorne would have wished left alone; if they contained any biographical material most frequently it was little more than a series of names, dates, pictures, and a few historical achievements. Occasionally some school science texts appeared with historical material that provided more genuinely a cultural background. Such a work is R.G. Mitton's Mechanics and Hydrostatics. Nearly one quarter of the chapter on the motion of falling bodies is devoted to science from the Middle Ages through to Newton. The following chapter, on Newton's laws of motion, begins with a brief outline of the life and work of Newton. This material includes comments on the state of science during the Dark Ages, the preservation of Greek learning in the libraries of cloisters, the telescopic discoveries of Galileo, and Newton's discoveries in mathematics and optics. None of this material is immediately relevant or necessary for an understanding of the motion of falling bodies or Newton's laws of motion. The tone and width of the writing suggest that the author placed some value on the cultural aspect of the background material. Significantly, Mitton was at the time a master at Clifton College and acknowledged a debt to E.J. Holmyard, the General Editor of the series.³⁷

Away from the school science text books the picture was brighter: as well as the increasing number of specialised history of science journals, educational journals such as School Science Review carried at regular

36. H.H. Cawthorne, as in note 31 above, pp.78-9.

37. R.G. Mitton, Mechanics and Hydrostatics, London, 1936.
See Appendix 1 for some details of Holmyard.

intervals biographical articles more in keeping with the sentiments of Cawthorne; additionally there was a spate of books of scientific biographies, often addressed to the general reader and young student, many of which were highly readable and authoritative. It can fairly be said that if any science teacher wished to humanise his courses by including scientific biographies suitable and adequate material was available, especially if he went outside school science text books.

A wider interpretation of humanistic embraced phrases such as the romance of science and the cultural aspect of science. Notable for his suggested use of historical material to bring out the romance of science was F.W. Sanderson, Headmaster of Oundle School from 1892 to 1922.

Sanderson, who put into practice many of his suggestions, believed that the function of the science teacher was to open out ideals and inspire pupils with a love of the natural world. He believed that groups of pupils should prepare historical exhibitions with experiments and demonstrations to illustrate the lives and works of great investigators. The basis of these exhibitions, which would be left in working order and used for teaching purposes, would be books from the classics of science together with original papers. Sanderson was particularly keen that pupils should read original papers.

"Read Archimedes ... Read Faraday's papers ... mark the long procession of experiments ... the diversity of methods, the trials and failures, uncertainties, doubts and suggestiveness, the atmosphere of discovery ... ".³⁸

But the success of Sanderson's methods was not universally agreed. Shortly after his death in 1922, Armstrong commented that although the boys from Sanderson's school were full of enthusiasm they had insufficient knowledge of the fundamentals of science and were undisciplined thinkers. In 1944 the Fleming Report stated that although Sanderson had introduced the first really drastic changes in the curriculum that the Public Schools had ever

38. H.G. Wells (ed.), Sanderson of Oundle, London, 1926, p.242.

witnessed, they had little effect on the other Public Schools.³⁹

The relationship of science to modern culture was seen in the twentieth century as profound and important with science playing a significant and active part in shaping both the intellectual and material changes that were occurring in contemporary society. Moreover modern culture was recognised as the accumulation and synthesis of varying contributions made by preceding civilisations, with some of the most significant contributions made by science and technology. As discussed in Chapter 2 this had a particular relevance to the educational value of the history of science; people argued that to appreciate and understand how and why modern culture and society came to their existing state it was necessary to know and understand the ideas and achievements of the past. Attempts seem to have been made, especially in the 1930s, to encourage science teachers to consider the social consequences of scientific discoveries and to use history of science to do so. F.W. Westaway was one of several people to attempt this. But there were few practical results. In 1942 Humby and James pointed out that schools had failed to demonstrate to future citizens that scientific discoveries were social activities with social consequences;

"... science is taught as a collection of laws and facts rather than as a constantly growing body of knowledge with social implications of vital importance ... pupils too rarely realise ... that the pursuit of scientific knowledge is a social activity, that science has the power to affect society and society the power to direct science. The relation between science and history is taught, if at all, in the most uninteresting and irrelevant way. The social repercussions of science are relegated to a few isolated industrial applications".⁴⁰

In the inter-war period most science teachers did not see a consideration of the relationship between science and society as part of their function. If such teaching was valid they believed that it fell within the domain of the history teacher.

39. B. Educ., Report of the Committee on Public Schools appointed by the President of the B. Educ. (Fleming Report), London, 1944, p.30.

40. S.R. Humby and E.J.F. James, Science and Education, Cambridge, 1942, p.49.

3.3.2 To teach about the nature and methods of science

The late nineteenth-century resurgence of interest in the philosophy of science has already been noted. This resurgence was reflected throughout the succeeding decades in the many suggestions made for using historical material to teach about the nature, methods, and philosophy of science. When authors wrote of the nature and methods of science they frequently had quite specific goals in mind. They believed that pupils needed to see that scientific enquiry involved the forming of inferences and hypotheses, with their testing and possible overthrow; they should understand the transient nature of scientific laws, theories, and truths; they should appreciate how a scientific truth differed from a religious truth; they should be aware of some of the theories which dominated contemporary scientific thought, and realise how these theories and theories in general grew; they should be conscious of how theories unified apparently disconnected facts and often suggested fresh problems to attack; they should note the paradoxical aspect of some of the great men of science, radical in the introduction of their own new ideas yet frequently conservative in later resisting new "truths"; they should be presented with science not as a collection of facts, but as a method. History of science frequently provided the material to achieve these goals.

Archer Vassall wanted pupils to be familiar with "typical instances of the overthrow of generally accepted theories". He cited as an example Galileo's disproof of Aristotle, but he described in more detail how this could be achieved by using the problem of combustion and phlogistic theory. His method was to let the pupils perform relevant experiments, watch demonstrations, then hear a lecture on the history and overthrow of phlogistic theory.

"It is important that typical instances of the overthrow of a generally accepted theory, as well as the work of some of the great pioneers, should be familiar. The elementary chemistry affords excellent material for this, as well as for experimental investigation. For example, in the consideration of combustion and the phlogistic theory, let the boys perform

the six following experiments:

1. Does magnesium really lose weight when burnt? Gain in weight may be due to crucible, therefore
2. Does crucible gain in weight? Perhaps the air is concerned in the increase, therefore
3. Burn phosphorus in bell-jar over water. One-fifth of air active; rest; inactive. What has become of the phosphorus and the active constituent?
4. Test water with litmus. Dissolve some phosphorus pentoxide in water and add litmus.
5. Burn phosphorus in a weighed round-bottomed flask with stopper and valve. (a) Heat has no weight, (b) conservation of mass, (c) gain in weight on opening valve shows that air has been used.
6. Burn candle and catch products; determine gain in weight.
7. Demonstration with oxygen and nitrogen to show properties of active and inactive constituents.
8. Lecture on history and overthrow of phlogistic theory."⁴¹

I.M. Drummond saw the ages of twelve and thirteen as an appropriate time for the pupils to make a continuous piece of investigation necessitating the framing of tentative inferences and hypotheses, and testing these by further experimentation; such work she believed would help "greatly to deepen the understanding of the methods and development of scientific knowledge". She describes how combustion is suitable for such work and like Vassall makes partial use of historical material in her treatment. Pupils perform experiments similar to those given by Vassall, consider various questions, and are given details of Priestley's and Lavoisier's experiments with red calx; implicit is some historical discussion of the changing ideas on the theory of combustion. Then at the ages of fifteen and sixteen pupils should realise how great theories grew and unified apparently disconnected facts, with "an historical treatment of the molecular and atomic theories helping towards such a realisation".⁴² Some years later Eric Holmyard argued that not only was the historical method an appropriate way to teach the nature of science, but it was the only way in which a clear understanding of the nature of a scientific truth could

41. Science Teaching in Secondary Schools, as in note 1 above, p.31. This does seem to be a development of heurism.

42. Science Teaching in Secondary Schools, as in note 1 above, p.58ff.

be successfully achieved. Holmyard believed that the average boy had difficulty in understanding that the word of science was not final and absolute, that the "truth" of science and the "truth" of religion were totally different conceptions. Perhaps Holmyard had his tongue in his cheek when he argued that to allow a boy to believe that the word of science was final could affect his whole character, but he was quite explicit in his statement that the historical method was not one of several equally good schemes of teaching chemistry. It was the only method.⁴³

Charles Singer believed that a major defect in science education in the 1920s was that science teaching did not give a true understanding of the nature of science; this needed, he believed, some knowledge of the history of science. Singer wrote that science was taught as though the present men of science were repositories of a system of absolute knowledge, capable of expansion, but of correction only in minor details. He saw the body of scientific knowledge as a living and growing thing, and believed it impossible to obtain an educationally valuable knowledge of science without a knowledge of how the body of scientific thought came to be what it is. He shared Goethe's views that to some extent history of science was science itself. In giving some practical suggestions Singer laid more stress on the introduction of science into general history than the introduction of history into formal science teaching. Yet he did emphasise that

"we must recognise the important place that historical considerations can take in the formal teaching of science. One function fulfilled by such history teaching within the science curriculum ... is the removal or avoidance of the absolute attitude towards scientific knowledge ... Another aspect often fondly imagined is that scientific discoveries are the result of extreme cleverness ... the result of specially bright ideas by specially bright individuals ... history of science does not confirm this ... very seldom has an effective advance been made

43. E.J. Holmyard, "The historical method of teaching chemistry", School Science Review 5 (1923-4), 227-33.

by one not learned in his particular department ... to succeed in science it is necessary to receive the tradition of those who have gone before".⁴⁴

Several examination syllabuses of the inter-war period did ask for some understanding of the nature and methods of science. But a sample of the corresponding science examination papers shows that it was rare for questions to be set on this theme.

3.3.3 To counter over-specialisation

The British Association's Science Teaching in Secondary Schools asserted that

"History and biography enable a comprehensive view of science to be constructed ... (and) -supply a solvent to that artificial barrier between literary studies and science which a school timetable usually sets up".

A year later the Thomson Report stated that a knowledge of historical matters could overcome the unfortunate situation

"that many of the ablest boys who enter the Public Schools pass on to the Universities ignorant of Science and with little or no idea of its importance as a factor in the progress of civilisation or of its influence on human thought";

it believed that courses with an historical content would be profitable to both science and non-science specialists and

"... would do much to counteract the narrowness of view which sometimes accompanies specialisation".

On the numerous other occasions during the first half of the twentieth century history of science was suggested as a means of providing an overall and comprehensive view of science, and as a way of countering the related issues of excessive specialisation and the division between the arts and the sciences in the Advanced Stage of schooling.

In the pre-matriculation studies the problem was seen more as a lack of width in the science courses rather than scientific subjects being

44. Singer's Introduction to D. Turner, Makers of Science. Magnetism and Electricity, London, 1927. Singer encouraged Dorothy Turner to write a History of Science Teaching in England, (London, 1927).

studied to the total exclusion of the arts subjects. In the early years of the century boys' schools concentrated very largely on physics and chemistry and girls' schools on biology, all in a very restricted form. Physics frequently consisted of little more than practical measurement and heat; chemistry often concentrated on quantitative experiments and routine laboratory exercises, often ignoring the theoretical foundations; biology was mainly simple botany. A criticism of courses was that they seemed to be planned as if the sole object was to lay the foundation for a specialised study of science at a later period even though most pupils would never make such a study. It may be that the calls to use history of science as a means of providing the desired overall and comprehensive view sprang from the type of history of science advocated by Tannery and later Sarton. Both urged that the study should not be of the histories of the individual sciences but a treatment of science as a whole; all of science should be included as indeed should all history; an overall and comprehensive view was needed. But to talk in such general terms was a good deal more simple than to construct science courses on such a basis. If such a construction was ever attempted it was not widely publicised. Although all seven of the suggested schemes of work in Science Teaching in Secondary Schools made some reference to history none used it to give an overall and comprehensive view; comprehensiveness came from including some astronomy, physics, chemistry and biological science within their own separate compartments. And as the time progressed calls for such a use of history of science seemed to die away. During the inter-war period the main responses to wider pre-matriculation science courses were the establishment of General Science, and for botany to be replaced by biology and taught increasingly to both girls and boys.⁴⁵ In contrast, calls for history of science to counter post-matriculation over-specialisation and and act as a bridge between the arts and the sciences persisted throughout

45. See E.W. Jenkins, as in note 19 above, Chapters 3 and 4.

the whole of the period under consideration.

Prior to World War I sixth-form work and advanced courses were largely uncertain or non-existent in a great many of the grammar schools. Financial support for advanced courses was poor. Although the 1907 Board of Education Regulations allowed grants for pupils over the age of sixteen, no provision was made for the special expenses of advanced work, such as extra teachers, equipment and books. A variety of demands for special work within the schools, arising out of the chaos of the then available examinations, inhibited the development of advanced courses and together with the small numbers of pupils made class teaching difficult. With matriculation and immediate entry to some universities possible at sixteen there was a degree of competition between the schools and these universities for the sixteen to eighteen or nineteen-year-old age-group of pupils. It was only after the war with the increase in the number of grammar school pupils, the changes in the examinations available, and the establishment of special grants that sixth-form work and advanced courses were increased and strengthened in many of the grammar schools.

At the beginning of the twentieth century the schools were faced with a variety of examinations devised by different bodies, each with their own lists of compulsory subjects and peculiarities of syllabuses, and each designed to meet particular needs and situations. Many had an extremely restricted value. Few universities accepted the examinations of others unconditionally; some professional organisations set their own examinations and made them compulsory; other organisations laid down strict conditions about the acceptability of certain examinations. In 1911 a Board of Education Consultative Committee, deploring this situation because of its interference with school work, recommended a more simple system of school leaving certificate acceptable to all interested parties. Delayed by the First World War the new system of School Certificate and Higher School Certificate was introduced in 1917. School Certificate, designed to test the attainments of an average pupil and provide evidence

of a good general education, required candidates to pass in five or more subjects, including at least one from each of three compulsory groups. The certificate was to be taken at sixteen, an age set to encourage more pupils to stay on at school. (The school leaving age was then fourteen). The Higher School Certificate, to be taken at eighteen, was based on a more concentrated study of fewer subjects from a connected group, with some subsidiary work to broaden and balance the work. The examinations were not new, but the system was very much more simple. Special grants for six-form courses so planned as to lead up to a standard required for entering upon an honours course at a university were announced in 1917 by H.A.L. Fisher, President of the Board of Education. A recognised Advanced Course had to offer continuous and systematic instruction in a group of subjects which had an "organic unity" - Classical Studies, Mathematics and Science, and Modern Studies being suggested as such groups. All schools with a sixth-form were to aim at providing one of these courses, which had to be taken by sufficient numbers to make class teaching possible. A mutual exchange of pupils between schools was envisaged. The new grants were warmly welcomed by the Times Educational Supplement of 3 May 1917, which hoped that they would "secure a regular flow of the most competent to the universities and other places of higher humanistic and technical education" and bring many schools "for the first time into the full curriculum of university life". The growth in the number of advanced courses recognised for grant purposes under the 1917 Regulations, which were introduced to encourage the development of sixth-form courses in secondary schools, is indicated by the data given in the tables of Appendix 2.

The intention in both the Higher School Certificate and the new grant regulations had been for some degree of specialisation supplemented by more general studies. However, some people feared that the hopes of a balanced curriculum catering for the differing needs of sixth-form pupils would not be fulfilled, and developments appear to show that such fears

had justification. Higher School Certificate imposed on many schools a heavy burden on academic work often quite unsuitable for those pupils not going on to some form of higher education. Standards demanded in main courses seemed to be driven steadily upwards, partly because of university requirements and competition between schools. Many teachers valued and defended a high degree of specialisation, seeing it as the best means of maintaining standards and ensuring the intellectual development of their pupils (and perhaps also a means of providing greater interest, stimulation and status for themselves). In many cases the sciences were studied to the total exclusion of the arts, and vice versa. In addition, there was often a narrow concentration within the science subjects themselves. It was against such a background that calls were made for history of science to be used as a possible way of countering excessive specialisation and bridging the gap between the sciences and the humanities.

As a field of knowledge history of science could be seen as both a science and a humanity, a means of giving a literary appreciation to scientists, scientific knowledge to non-scientists, and demonstrating the cultural aspect of science to both sides. The Thomson Report in 1918 suggested details for the contents of such courses.⁴⁶ At the Third Annual Meeting of the Science Masters' Association history of science figured in a discussion on post-certificate science for non-specialists.⁴⁷ In the opening paper given to a 1923 conference on science teaching in schools and colleges Sir William Tilden regretted the specialisation in modern courses and urged that time be found for history of science.⁴⁸

46. As these suggestions were in some respects the precursors of General Studies courses (see Chapter 4) they are quoted in full as Appendix 3.

47. 'Post-Certificate Science for non-specialists', School Science Review, 3, (1921-2), 119-25.

48. "Conference on Science Teaching in Schools and Colleges", School Science Review, 4 (1922-3), 158. Tilden had written A short history of the progress of scientific chemistry (London 1899) and Famous Chemists (London, 1921), as well as several other popular historical works.

There were calls for history of science to be used in a similar role in the universities. At the Second Congress of the Universities of the Empire,⁴⁹ held in 1921, Cecil H. Desch spoke of the place of humanities in the education of men of science and saw the role of history of science in education as a link between the sciences and the humanities, a theme he repeated at the 1926 British Association Meeting at Oxford. A.E. Heath, a university teacher, believed that honours degrees caused many science teachers to become too highly specialised at the expense of wider issues, and called for a sound knowledge of both the physical and biological sciences together with a knowledge of history and philosophy of science.⁵⁰ Further such examples abound. Perhaps it is true to say that during the inter-war period the role advocated most frequently for history of science in education was that it could act as a bridge between the two cultures and counter over-specialisation.

It has been argued⁵¹ that during this period women teachers, who dealt with a smaller proportion of university entrants than did men, expressed more serious doubts about intensive specialisation than did their male counterparts. Those doubts may well have been one of the factors underlying their interests in the history of science, an interest which on the basis of reports of annual meetings of the Association of Women Science Teachers was possibly greater than the interest shown by science masters. This is an area which may well be worth further investigation.⁵²

49. C.H. Desch, "The place of the humanities in the education of men of science", Alex Hill (ed.), Second Congress of the Universities of the Empire, 1921, Report of Proceedings, London, 1921, pp.25-30.

50. A.E. Heath, "The philosophy of science as a school subject", School Science Review, 1 (1919-20), 131-4.

51. A.D. Edwards, "The Changing Sixth Form in the Twentieth Century", London, 1970, p.35.

52. See 8.3.

3.4 History of science and the teacher

Whether or not history of science was to be taught in the schools, many people believed that science teachers themselves would benefit from some knowledge of it. Percy Nunn believed that history of science was a most useful guide to a teacher in choosing his exposition and for seeing the child's point of view.⁵³ The Thomson Report stated that

"... some knowledge of the history and philosophy of science should form part of the intellectual equipment of every science teacher in a secondary school".⁵⁴

Westaway believed that some knowledge of the history and philosophy of science enabled teachers to assess more correctly the true value of science as an educational instrument, as well as making them more critical of loose reasoning and more insistent on accuracy of thought in their pupils.

According to Westaway the successful science teacher

"... knows his own subject ... is widely read in other branches of science ... knows how to teach ... is able to express himself lucidly ... is skilful in manipulation ... is resourceful both at the demonstration table and in the laboratory ... is a logician ... is something of a philosopher ... is so far an historian that he can sit down with a crowd of boys and talk to them about the personal equations, the lives, and the work of such geniuses as Galileo, Newton, Faraday, and Darwin".⁵⁵

It is possible that science teachers could obtain such historical knowledge informally by private reading and study. But if history of science was to become established as part of the secondary school curriculum clearly science teachers or history teachers needed the opportunity for some formal training in it.

Up to World War II science teachers in the schools under discussion were mostly science graduates, sometimes with additional training for a teaching qualification.⁵⁶ In 1918 the Thomson Committee reported that although most science teachers in secondary schools had a university degree

53. T.P. Nunn, "Natural Science", J.W. Adamson, as in note 25 above, pp.381-2.

54. Thomson Report, as in note 16 above, p.93.

55. F.W. Westaway, Science Teaching, London and Glasgow, 1929, p.3.

56. See E.W. Jenkins, as in note 19 above, Chapter 6.

in science they had no training in the art of teaching, nor the opportunity of seeing science teachers at work in other schools. By 1938 however the Spens Report showed that of the 25,000 full-time teachers (of all subjects) in grant-earning secondary schools, 78% were graduates of whom 60% were professionally trained, with 50% of the non-graduates also having a professional training. A few secondary school science teachers had attended the teacher training colleges. As already discussed some universities did provide history of science courses as part of the normal science degree; but where this occurred it was usually very much an incidental part of the course. In the mid-1930s instruction in history of science was available as part of the course of training for schoolteachers in the Education Department of the University of Liverpool and in the Institute of Education in London.⁵⁷ Little information is available to judge the success or popularity of these courses. At the London Institute of Education there were some twenty-five voluntary lectures on the history and methods of science in the session 1935-36 with "some 30 or 40 students attending".⁵⁸ Apparently the teaching was linked with University College and the students were encouraged to pursue the subject further; some read for the London University MSc degree in the History and Philosophy of Science at University College under Professor Wolf. Up to (and beyond) World War II Wolf's department at University College provided the only opportunity for teachers in England to obtain a full and formal training in the history of science.

3.4.1 The Department of the History and Method of Science⁵⁹
at University College, London: its pre-war students
and some recollections

As noted, this department developed very much with school teachers in mind. In the inter-war period the majority of those attending lectures

57. A. Armitage, "The teaching of the history of science in the University of London", Lychnos, (1936), 302-7.

58. University of London Institute of Education, Annual Report 1935-6.

59. The original title of the department was "History and Method of Science". From the session 1938-9 onwards the title was changed to "History and Philosophy of Science".

as part-time students were school masters and mistresses teaching in schools in or near London. Prior to the war the College was the only institution in Britain to offer a formal academic qualification in the history of science.

3.4.1.1 College records

To get some indication of the strength of the department in terms of student numbers, and the proportion of men to women, college lists of post-graduate and research students were examined for the sessions 1925-6, 1930-1 and 1935-6. These three sessions were chosen to cover the inter-war period, beginning with the first session which attracted a substantial number of history of science students (in 1924-5 only 4 students registered in the department) and ending before the impending war might affect student numbers (the department was closed during the war). The lists show that for the selected years there were respectively 57, 38 and 34 post-graduate and research students registered for either an MSc or PhD degree in the department. This represented 11%, 8% and 6% of all such students in the college. In these sessions 39%, 26% and 6% of the history of science students were women compared with 26%, 27% and 17% for the college as a whole.

An examination of the names listed showed that several of the students subsequently achieved a degree of prominence in the field of History of Science. F.H.C. Butler (1925-6), who read for the Natural Sciences Tripos at Cambridge, studied for the MSc degree whilst a science master at Dulwich College. He later became an Inspector of Schools for the London County Council and Secretary of the History of Science Lecture Committee at Cambridge during the war.⁶⁰ Francis Butler was the Foundation Secretary of the British Society for the History of Science and did nearly all of the Society's administrative and clerical work in the early years. F.S. Taylor (1925-6), who read science at Oxford, received his PhD degree for

60. See 2.4.2.

a thesis on Greek alchemy and alchemists. He taught chemistry at various public schools and at Queen Mary College, London. In 1940 he turned to museum work, first as Curator of the Oxford Museum of History of Science and later as Director of the London Science Museum. Sherwood-Taylor was instrumental in founding Ambix, a journal devoted to the history of alchemy and early chemistry, and acted as its editor from its inception in 1937 until his death in 1956. His An Illustrated History of Science⁶¹ proved popular in schools. D. Turner (1925-6) and A. Armitage (1930-1) were among those who were both registered as post-graduate students and staff members in the department. Dorothy Turner (Feyer) was appointed as one of the first two Honorary Research Assistants to Charles Singer at the college. Her career included school science teaching, lecturing in the history of science at the University College department and in English at the University of Bratislava, and for some twenty years work in educational psychology and the physical sciences at Maria Grey Teacher Training College London. She was a founder member of the British Society for the History of Science and a member of the original council. Dorothy Turner received her PhD degree for her published book The History of Science Teaching in England together with some subsidiary papers. Among her other publications The Book of Scientific Discovery⁶² was intended for schools and non-technical readers. Angus Armitage, who graduated with first-class honours in astronomy from University College London, taught in the Department of the History and Method of Science from 1927 until his retirement in 1969. As well as acquiring an international reputation for his publications on the history of astronomy he too was a founder member of the British Society for the History of Science, and subsequently served as a council member and as Vice-President. F.W. Gibbs (1935-6) studied chemistry at the

61. F. Sherwood-Taylor, An Illustrated History of Science, London 1955. This has now been reprinted, presumably with the younger reader in mind.

62. D. Turner, The History of Science Teaching in England, London 1927 and The Book of Scientific Discovery, London 1933.

college before registering as a research student in the History and Philosophy of Science. Between 1936 and 1949, apart from the war years, he taught science in schools before being appointed Specialist Officer for Science at the British Council. In 1951 he became Assistant Secretary (Scientific) at the Royal Institute of Chemistry and worked as an administrator and editor for the next fifteen years. Gibbs' many historical writings earned him an international reputation as a distinguished scholar and an historian of chemistry.⁶³

Several other such examples can be found in the names listed. Quite clearly many of the students of the department helped to advance History of Science as an international academic discipline, and furthermore were in strong positions to encourage its use in the secondary school curriculum.

To see what further information was held at the College an examination was made of all the College records of the 1935-6 post-graduate and research history of science students. The student records at University College consist of a record card, First Entry Forms and Re-entry Forms, reports on progress, and miscellaneous correspondence. The information on each of the student record cards is basic: date of birth; dates of first entry and, when appropriate, re-entry; date of leaving; dates and titles of academic qualifications; home and term addresses; college department of the student. Occasionally extra information is to be found: this may be a post held, a reference to the Directory of British Scientists,⁶⁴ or a notice of death; there is no ongoing process of updating these record cards. The First Entry Forms and the Re-Entry Forms generally add little to this information. Some students do give the subjects of their first degree, but this is not usually the case; no details of previous or existing occupations, if any, are given. The miscellaneous correspondence

63. For obituaries of Butler, Turner and Armitage see British Journal for the History of Science, 5 (1971), 319; 7 (1974), 304; 11 (1978), 99 respectively: for Sherwood-Taylor see Ambix, 5 (1953-6), 57: for Gibbs see Chemistry in Britain 2 (1966), 285.

64. Directory of British Scientists 1966-7, 2 vol., London 1966.

is sparse and usually concerned with financial arrangements. In 1935-6 of the thirty-four registered students there were thirty-two men and two women. With one exception all held a first degree in science: where the main subject was specified it was most commonly either physics or chemistry. At least sixteen of the thirty-four were involved at some stage of their professional career with schools: ten were shown to hold some form of teaching qualification such as a Teachers' Diploma, a Diploma in Education, or a Teachers' Certificate; eight were shown to have done some secondary school teaching, and three others had taught in post-school institutions. Others may have taught in schools or held a teaching qualification but not recorded it on the forms. As the average age of the students was thirty-one the most that can be inferred from this information is that at least half of the students were probably experienced science teachers. As many of the students remained registered with the department for up to four or five years the student numbers alone for a given year do not indicate how many new students were attracted to history of science each year. Only on one occasion was there some indication as to why a student was following the course: one letter showed that a particular student was studying for the MSc degree to improve his promotion chances within the teaching profession.

Clearly the College records themselves give no real information about how and why the students became interested in the history of science, or about the influence and impact of the department on history of science teaching in the schools during the inter-war period.

3.4.1.2 Some recollections from former students

As one other possible way of throwing some light on history of science in the school curriculum during the inter-war years, contact was made with six former students of the department who had taught in secondary schools during this period. These former students were either known to the author by word of mouth or traced via addresses shown on the College

records. Initial contact with the six suggested that they had a preference for answering specific written questions rather than being interviewed. Accordingly the following questionnaire was devised and sent to the group.

1. What first aroused your interest in history of science?
2. Did you attempt to develop this interest in any way prior to attending the UCL Department? If so, please give details.
3. Did you receive any encouragement, either as a pupil at school or as a university undergraduate, to study any aspect of history of science? If so, please give details.
4. How did you become aware of the UCL Department?
5. What were your principal reasons for wanting to obtain a higher degree in history of science?
6. Did you attempt to introduce any history of science into your school (or other) teaching? If so, please give details.
7. How successful were any attempts made by you or others to introduce history of science into school courses? What difficulties were encountered?
8. What was the attitude of other science teachers to using historical material in science courses?
9. What was the reaction of history teachers to using history of science in history courses?
10. What was the reaction of pupils to history of science?
11. What was the impact of the UCL Department on history of science in the schools between the 1920s and 1940s?
12. Please give brief details of your school or other teaching experience, and educational background.

The items in the questionnaire do overlap to some extent but could be used as guidelines.

Replies came from three of the group in written form and from the others orally, hence the comments below represent a mixture of evidence.

Interest in the history of science had usually been first aroused and then developed through private reading. In the majority of cases there had been little or no encouragement at school ("perhaps the odd anecdote") or university to read up on historical aspects of the science. One

exception to this was the chemistry teaching at Imperial College during the early 1920s. One respondent recalls a course at the Royal College of Science in the 1920-2 period with the comment "a chemist ignorant of the lives of the great personalities and of the main trends and problems would in 1923 have been (rightly?) regarded as a barbarian". All became aware of the University College department through notices in the national press. Clearly one strong factor in wanting to obtain a higher degree was to improve their qualifications and possibly increase promotion prospects - "my interest in History of Science was because it provided a convenient way of obtaining a Higher Degree by part-time work" was one reply. All six did attempt to include some historical material into their science courses and most used it to teach science to non-scientists in the sixth form. It was generally valued as a means of giving a cultural background and as providing a link between arts and science pupils. One found "a biographical approach of special value in the attempt to arouse interest in science among the weaker pupils". On the reaction of colleagues there were differences. On the one hand there was the reply "my colleagues also included elementary historical material in their science courses ... I always had the full support of my non-science colleagues in my efforts to teach history of science to non-scientists". In contrast, others reported "few science teachers were sufficiently enthusiastic or knowledgeable to include historical aspects" and "I think it is fair to say that we have not time for frills attitude was normal and widespread" and "on the whole the predominant factor was the examination paper and a review over the years shows that little attention was paid to historical matters". In general pupils were thought to have responded favourably to the introduction of some historical detail. No one was able (or willing) to offer a clear opinion on the impact of the department on history of science teaching in the schools. However, one did comment "UCL was rightly criticized for its too traditional ('internal') approach, but most unfairly given no credit for the excellent

and almost unique pioneering without which there would have been no teachers when the History and Philosophy of Science fashion emerged. What it lacked in the necessary 'transvaluation of values' it made up for in breadth".

3.4.2 Interest in history of science as indicated
by School Science Review

In May 1900 four masters at Eton College - T.C. Porter, W.D. Eggar, M.D. Hill and H. de Havilland - wrote to science masters at fifty-seven other schools suggesting a conference on science education. This led directly to the formation of the Association of Public Schools Science Masters (APSSM) with membership initially confined to graduates teaching in Public Schools. In 1919 the membership was extended to other secondary school science teachers and the association changed its name to the Science Masters' Association. In June of that year the first issue of the Journal School Science Review appeared, seemingly in answer to the plea from the Thomson Committee that

"it is well worth considering whether some organisation might not undertake the task of issuing a journal ... in which teachers who have devised new lecture or laboratory experiments or new methods of dealing with particular problems in connection with their work might bring them to the notice of their colleagues."⁶⁵

The School Science Review to some extent achieved this with descriptions of new apparatus and experiments, reviews of books, and by answering queries and discussing difficulties. In addition each issue carried major articles; although some of these were directly concerned with educational aspects and the teaching of science, in the main they concentrated on more purely scientific matters. As the School Science Review was the journal of an organisation whose members were mostly schoolmasters and whose purpose was to promote science education in schools, the type and tone of comment made in its pages does give an indication of the feeling of science teachers

65. Thomson Report, as in note 16 above, pp.96-7.

in the public and grammar schools towards science teaching in general and towards the history of science in school education in particular.

Historical biographies and articles on the development of scientific concepts appeared with some regularity. Most frequently they were concerned with aspects of chemistry, but other branches of science were also represented. "Wollaston", "Gregor Mendel", "Early theories of heat" and "Some early work bearing on specific heat"⁶⁶ serve as examples. Significantly such articles were usually written by teachers in schools. Frequently other articles, as exemplified by "Manufacture of sulphuric acid" and "Metallurgy and the uses of zinc", started with an historical introduction.⁶⁷ The book reviews usually contained at least one new book connected with the history of science, often written for the general reader and considered suitable for use in schools. One early review, of Rose Stern's Short History of Chemistry,⁶⁸ would seem to indicate the relative newness of the school interest in the history of science.

"We do not know of any History of Chemistry written expressly for use in schools; there is room, therefore, for such a work ... it is a desirable book [for schools] ... we are a little uncertain as to where we should 'place' it".⁶⁹

But, as Cochrane's School History of Science⁷⁰ illustrates, such texts were increasingly being written with the school in mind. Noteworthy amongst these was a series published by G. Bell and Sons as Classics of Scientific Method, intended for sixth forms and favourably commented upon

66. W.H. Barrett, "Wollaston": S.A. McDowall "Gregor Mendel": J.R. Morgan "Early theories of heat": P.A. Wells "Some early work bearing on Specific Heat": School Science Review; 12 (1930-1) 124-34; 14 (1932-3), 154-61; 12 (1930-1), 166-70; 16 (1934-5), 356-59 respectively.

67. Stanley I. Levy, "The Manufacture of Sulphuric Acid" and Stanley Robson, "Metallurgy and the uses of zinc": School Science Review 13 (1931-2), 33 and 16 (1934-5), 21 respectively.

68. R. Stern, Short History of Chemistry, London, 1924.

69. School Science Review, 6 (1924-5), 141.

70. J.A. Cochrane School History of Science, London, 1925. This was reviewed in School Science Review of 7 (1925-6), 142.

in School Science Review.⁷¹ Further evidence of the school interest comes from the requests made by teachers to the journal for recommendations of suitable history of science texts. One reply, by W.J.R. Calvert of Harrow School, implied that he used several.⁷² On one occasion there was a request about the availability of pictures of famous scientists for hanging on the walls.⁷³ When Annals of Science was first published in 1936 there was the enthusiastic comment

"Schoolmasters in particular will welcome its appearance ... they know from experience the value of historical details in arousing and maintaining interest and in meeting the criticism that science is unhuman ... ought to be placed in every school library".⁷⁴

All of this would seem to indicate quite conclusively that at least some science teachers wished to, and did, exploit historical material in their science courses. But, on the evidence of the pages of School Science Review, history of science in the school curriculum never became a burning issue during the inter-war period. Arguments about General Science and concern over the biology taught litter the pages and aroused strong feelings. In contrast, the only major articles which were concerned with the educational aspects of history of science⁷⁵ and which clearly and specifically called for its inclusion in school science courses aroused no reaction whatsoever; no letters or comments followed. Perhaps this could be interpreted as a lack of interest on the part of the readers, although this does not accord with the foregoing. It may be more likely that the suggestions were not seen as being so radical and threatening as

71. The titles included C. Singer, The Discovery of the Circulation of the Blood, 1922; Clara M. Taylor, The Discovery of the Nature of the Air, 1923; Alex Wood, Joule and the Study of Energy, 1925; J.R. Partington, The Composition of Water, 1928; Michael Roberts and E.R. Thomas, Newton and the Origin of Colours, 1934. All were published by Bell and Sons, London. E.R. Thomas was the general editor.

72. School Science Review 4 (1922-3), 40.

73. School Science Review 4 (1922-3), 214.

74. School Science Review 17 (1935-6), 631-2.

75. These were the articles by Heath and Holmyard. See notes 50 and 43 above.

to be controversial. Those science teachers who favoured using historical material could quietly get on with it; any who opposed the suggestions could afford to ignore them.

3.4.3 History of science in history courses

Although the calls for history of science usually came from people who saw it as an integral part of school science courses, it was also suggested as part of wider history courses and as an independent study. Notable for such suggestions were F.S. Marvin and Charles Singer.

Marvin (1863-1943) studied classics and modern history at Oxford, taught for a time in an elementary school, then joined the Board of Education as one of His Majesty's Inspectors of Schools in 1890. He remained in the Inspectorate until his retirement in 1924. Marvin, whose chief interest was in history, did much to improve its teaching in English schools. He arranged courses for history teachers and others interested in the subject. He was a prime mover in the committee which produced in 1923 the Report on the Teaching of History,⁷⁶ a report which commented on the movement to introduce the historical spirit into the study of science. After his retirement he spent part of his time furthering the work of the Historical Association by organising branches and speaking at their meetings.

Marvin's interest in history of science was stimulated by his membership of a small "Positivist Group", which was concerned with applying Comte's teaching to social and political questions. Several of the group were Oxford men trained in the classical tradition and, not unnaturally in view of Comte's inspiration, some interest was shown by the members in history of science. At least one serious history of science text was produced from within the group.⁷⁷ Between 1893 and 1925 Marvin

76. B.Ed., Report on the Teaching of History, Pamphlet No.37, London, 1923.

77. J.H. Bridges, Opus Major of Roger Bacon, London 1897.
See Isis 36 (1945), 7-9.

contributed over 100 articles to the group's journal, Positivist Review. On various occasions, in these and in other writings, he spoke strongly for the inclusion of the development of science into the study and presentation of history, urged that history should be included as part of science teaching, and supported the recommendations made by the 1917 British Association Report for lessons on history of science for Advanced Pupils.

Marvin's support for history of science was closely related to his views on the study of history. This, he believed, should be studied as a continuing record of man's progress; due place should be given in such learning to scientific thoughts and developments because of their great influence on this progress and on the growth of society. Furthermore, Marvin had a strong conception of a unity of mankind, thus a unity of history. He was a man whose views included a belief in the ultimate triumph of right over wrong and a conviction of "Humanity" as an ideal. In 1914 he was deeply concerned about the prospect of impending world cataclysm, which he thought had been made more likely by the lack of conception of world history as a unity. Writing in 1921 he spoke of the "unparalleled devastation" of World War I, a war which "seemed for the moment the heaviest blow which the cause of unity had ever borne".⁷⁸ His belief that nations had always worked together most easily on the field of science led him to see history of science as a means of deepening the intellectual basis of unity. Marvin's views on unity in history led to the setting up of the "Unity History Schools", which grew out of an idea he first mooted on the day of the outbreak of World War I. The schools, which consisted of short annual seminars planned and directed by Marvin, met most years from 1915 until the outbreak of World War II. Two of these meetings dealt specifically with science. In 1922, with a theme

78. F.S. Marvin, "Science and the unity of mankind" in Charles Singer, Studies in the History and Methods of Science, Vol.2, Oxford, 1917-21, p.344.

of "Science and Civilization", several of the speakers, including Charles Singer and J.L.E. Dreyer (noted for his studies into the history of astronomy), gave papers on the history of science. The 1935 meeting, which took as its theme "Science in the Modern World", was held in Rome jointly with the History of Science Department of Rome University.

Not surprisingly Marvin also had definite views on the role of history of science in science courses - to humanise the work. Marvin believed that the essence of humanism was an "understanding of, and sympathy with, the growth of the great from the small, the complicated from the simple". To receive a general humane education a pupil "should learn to regard everything as part of the great heritage into which he is to be introduced by education". Writing in 1925 Marvin noted the "little co-operation, or even community of feeling, between the science and the literary, or classical, sides of our big schools and colleges"; the science man usually knew little and often disparaged literary and historical studies; the man of letters was ignorant of physical science, which he usually regarded as a material and mechanical thing serving lower ends than poetry and philosophy. Marvin believed that there was no division in the nature of things which corresponded with the division of interest in men's minds, a division which he attributed mainly "to the want of the wide and general views in teaching which might put the details in their place and give a human purpose to the whole". To introduce more humanism into the teaching of science Marvin called for "some history work, choosing especially parts of history which illustrate the reactions of science on social progress". Furthermore, he believed that there was room on the science side for lessons on the history of science to follow from the preliminary science course. He noted with some regret that the recommendations for such lessons, made in Science Teaching in Secondary Schools, had only been followed by a few schools.⁷⁹ Thus incorporated into the role of

79. F.S. Marvin, "Humanism in Science Teaching", The Journal of Education and School World, July 1921, pp.488-90.

humanising science courses Marvin clearly believed that history of science could help to provide a knowledge of man's cultural heritage, had the advantage of presenting a highly differentiated and complex thing in its simplest form, and could provide a bridge between the arts and the science division which then prevailed in education.

Charles Singer, widely acknowledged by his contemporaries as the foremost British historian of science in the inter-war period, shared many of Marvin's views and lost no opportunity to press for the inclusion of history of science into the school curriculum. Singer attributed the lack of a true understanding of the nature of science to the neglect of historical material in science courses and believed that historical considerations had an important place in the formal teaching of science. Nevertheless, he did believe that

"the present circumstances of laboratory and experimental instruction do not lend themselves readily to historical exposition ... it is undesirable to disturb from the pupils' minds the essential truth that science has primarily to deal with direct evidence, and not with discussion about evidence".⁸⁰

He saw the place for history of science as part of wider history courses, and pressed for a history of civilization as a central topic in school training. Singer wanted his history of civilization, which resembled Marvin's conception of history as a unity, to be wider than the "History of English Politics" which was then the most usual type of school history course. History of civilization was intended to cover all sides of man's life and activity, with history of science having its appropriate place. However, Singer was not at all optimistic about his "ideal remedy". In the 1920s he saw his suggestions as so drastic that he believed their early introduction was unlikely.⁸¹

80. D. Turner, The Book of Scientific Discovery, London, 1933; Singer's Foreword.

81. D. Turner, Makers of Science. Electricity and Magnetism, London, 1927. Singer's Introduction. George Sarton also pressed for a history of civilization.

Despite such pleas it seems that very little history of science was prescribed to be taught in the secondary school history courses during the inter-war period. A sample of examination syllabuses, examination papers, and history textbooks - which in general tend to reflect and respond to school courses - reveals virtually no mention of science or technology. The focus of attention was on political and economic issues within a mainly English and European context. To some small extent social issues were considered; where this happened technology could be brought in, but usually as an incidental. Very seldom was any mention made of cultural issues or a range of human activities such as science, art or religion. This general picture is reinforced by the Spens Report which commented that the "... teaching of History loses a great deal because it neglects the contribution teachers of Science and Art could make". The Report believed that one of the chief functions of secondary teaching was to make the pupils conscious of "the Western European tradition, derived mainly from the Greco-Roman civilisation as it was transformed by Christianity" and that science teaching should aim, among other things, to complement historical studies in revealing "the influence of scientific thought and achievement in the evolution of our present-day civilisation".⁸²

The formal provisions of a syllabus cannot fully reflect the work that actually was carried out in the classroom. Nevertheless, on the basis of a sample of syllabuses, examination papers, textbooks, Reports, articles in journals and personal reminiscences it does seem that few school history teachers were willing or able to include scientific aspects into their crowded periods. As with all school curricula problems, the inclusion of the new means excluding some of the old. It is probable that most history teachers (if they ever gave consideration to the matter) felt that they knew insufficient about history of science to judge the soundness of replacing tried and tested material with something innovatory.

82. Spens Report, as in note 30 above, pp.160 and 245.

Moreover, not only would history teachers have received little or no training in history of science, it is likely that few would have had sufficient training in science itself to make them confident enough to deal with scientific concepts and developments. Although written after the period under discussion, the comments of A.J.P. Taylor, when explaining why he ignored scientific developments in his English History 1914-1945, would seem to fairly reflect the attitude of history teachers at both the school and university level during the inter-war period. "I do not understand the internal-combustion engine, let alone the atomic bomb, and any discussion of scientific topics was beyond me".⁸³ Thus the lack of recognition of history of science by general historians in both the schools and universities probably stemmed from the arts/sciences division.

3.4.4 Some conclusions

On the evidence presented it would be unwise to draw too firm a conclusion about the position of history of science in the English secondary school prior to World War II. Certainly there existed criticisms about the quality and quantity. Lancelot Hogben, for example, in an address to the 1936 Annual Meeting of the British Association, apparently "excited comment by his witty onslaught on the average method of teaching history of science" with "lantern slides of bearded and very much superannuated scientists or their birthplaces" producing the impression that science "progressed by a succession of miraculous divinations of the exceptionally gifted to be born at any convenient time with much the same results".⁸⁴ H.J.J. Winter, then a science teacher at Newton Abbott Grammar School, was one of many teachers who believed that more historical

83. Quoted in Brian Harrison, "History at the Universities 1968, A Commentary", History, 53 (Oct. 1968) 375.

84. Journal of Education, Oct. 1936, p.657ff. It is interesting to note that this journal represents Hogben's attack as the main theme of his address. Reports given in the British Association's Report of Annual Meeting, 1936 and Education of 2 Oct. 1936 give a somewhat different impression. This highlights some of the historiographical problems.

material should be included.

"At the present time, the historical approach to science - confined to brief incidental remarks made now and again by the teacher or excluded from the classroom altogether, is in danger of becoming a stranger in our schools ... Does not such an elevating and humanistic study demand a fairer treatment ..."⁸⁵

However, such utterances must be treated with caution. Hogben's criticism of the quality of the work may say more about his own personality than about the true state of the teaching. Moreover, to sum up what was going on in the schools into an "average method" almost certainly was a gross oversimplification. Likewise with Winter's remarks. In his youth Winter's interests on the arts side were as strong as those in science, and he always considered himself a better historian than scientist. As he came from a strong science school he took a physics degree initially, feeling that physics was the most fundamental and philosophical of the sciences. When he began teaching in 1935 he attempted to place science in the context of the history of science after the manner of George Sarton. This approach he believes was not common because "most science teachers in those days (and today) were inhibited by the rigidity of their training".⁸⁶ Nevertheless, his comments in School Science Review may well have deliberately understated the case in an attempt to promote a greater use of history of science in the school curriculum.

To draw some conclusions it would seem worthwhile to distinguish between what was prescribed to be taught and what actually went on in the classroom. On the basis of such evidence as science examination syllabuses, School Certificate and Higher School Certificate examination papers, schemes of work and school science text books only a little historical material seems to have been prescribed. The General Science syllabus, providing as it does an example of a pre-matriculation syllabus developed during the

85. H.J.J. Winter, "Humanism in science teaching", School Science Review, 22 (1940-1), 177-9.

86. Correspondence between Dr. Winter and the author.

inter-war period, should give some reflection of contemporary thought. The 1936 Science Masters' Report The teaching of general science⁸⁷ did give special consideration to whether there should be direct instruction in the history of science. It believed that a study of history of science was highly important for the teacher. However, it believed that initially boys were more concerned with scientific phenomena and only later became receptive to historical ideas. Thus it came to the conclusion that to appreciate the significance of an historical study the pupils needed to have amassed a multitude of facts which history could place in an appropriate setting. Accordingly, although it did recommend biographical details to introduce the human element - less as a matter of formal teaching, more one of occasional treatment - it decided not to specify what could be taught historically. Therefore the history of chemistry was something which "might serve as a basis for revision". Apart from general science other specialist science syllabuses at both pre- and post-matriculation levels did at times mention the names of famous scientists and other historical detail, but as with school science text books the history was usually little more than some useful incidental.

In view of the undoubted interest that existed it is valid to question why history of science did not force itself more strongly into the prescribed school curriculum. Perhaps it was because people recognised the limitations and dangers in an historical approach to science teaching. It was said that history had many unhelpful sidetracks which needed to be avoided, that the historical method was slow, that it was difficult to repeat early experiments, that fundamental principles were apt to be obscured by details not worth remembering. History of Science was seen by some as too vast an area for the school.

"There can be but few positions more difficult to fill than that of Lecturer in the History of Science. Such a post implies not only a knowledge of the history of each branch

87. SMA, The teaching of general science, London 1936.

of science, but also the principles of each and all. At the present day such a knowledge is only possible for a superman".⁸⁸

(At the same time History of Science was attacked as an easy option).

Perhaps the comment in the Thomson Report that "... teachers ... tend to go on teaching as they were taught themselves, and thus the work becomes stereotyped ..." ⁸⁹ provides a clue. As has been seen, very few science teachers received an appreciable amount of training in the history of science, and the opportunities for such training were restricted. Thus the majority had little background knowledge of such material. Perhaps it was because the universities at that time paid little attention to the history of science. J.A. Lauwerys, a lecturer at the University of London Institute of Education, was one who pointed out how the universities dominated school science courses. He asserted that the principal reason for the intensive specialisation characteristic of science courses was the "all pervading influence of the Universities on our school system", and that school teachers, whose promotion and reputation depended on the examination results of their pupils, were continually faced by the demands of examinations largely controlled by university teachers.⁹⁰ However, if it is accepted that during the first half of the twentieth century the shaping of the school curriculum was dominated by professional groups (although, as will be seen in Chapter 4, this was not the case with GCE "History of Science"⁹¹) perhaps the answer lies within the Science Masters' Association. This was probably the pressure group with the greatest potential for altering school science curricula. As a group they did give some consideration to history of science in education but, for one reason or another, did not seem to believe (perhaps rightly) that

88. School Science Review, 13 (1931-2), 78. This is clearly reflecting Sarton's view.

89. Thomson Report, as in note 18 above, p.57.

90. J.A. Lauwerys, "The teaching of physical science", School Science Review, 17 (1935-6), 161-70.

91. See 4.2.

historical material should be anything more than an important, although relatively minor part of specialist science courses; something to be occasionally exploited in the teaching of present-day science.⁹² Notwithstanding the lack of prescribed history of science, on the evidence of what was advocated, of the interest shown in the School Science Review and of personal recollections it does seem clear that more than a few science teachers included historical material in their regular science courses, and used it to teach science to non-specialists in the sixth form. Although it is not possible to quantify the position, H. Haywood was not alone when he said

"I believe in it [the historical method] and spend much valuable time dealing with historical development, knowing full well that my pupils will benefit hardly a single mark in their examinations".⁹³

92. See 8.3.

93. H. Haywood, "Fundamental laws of chemistry", School Science Review, 9 (1927-8), 92.

Chapter 4

HISTORY OF SCIENCE IN ENGLISH SECONDARY SCHOOLS

POST WORLD WAR II

4.1 History of Science Finds a Place

In the years immediately following the war there was in Britain a climate of opinion and sufficiently important happenings to give encouragement to those who believed that history of science had some rightful place in the school curriculum.

The favourable atmosphere was partly a legacy from the pre-war interest in history of science, an interest stimulated by the science/society issue. The cold-war backlash against this issue did affect history of science as an academic discipline, changing its emphasis towards an internalist study,¹ but it did not deflect interest from it. More responsible for creating the favourable climate of opinion was the Second World War. The horrors of war inevitably seem to lead to some re-examination of the values and traditions of society. Even before the fighting was over voices were heard urging a rethinking of the purpose of education and the contents of the curriculum; the words cultural and humanistic were frequently central to proposed reviews. The awareness that World War II was a physicists' war while strengthening the place of science in the school led some people to argue for modified science courses. The recognition that a knowledge of science was necessary for the survival and well-being of the country was balanced by a revulsion many people felt towards science for apparently providing the means of suffering and destruction. Anything that could help to demonstrate the human and beneficial side of science was a thing to be exploited. This attitude was of course an echo of the

1. In essence an internalist approach to history of science focuses attention primarily on changes within science itself, its theory and practice; an externalist approach considers factors outside the science itself which may have played a part in the development of the theory and practice. It is a gross oversimplification to equate an externalist approach with a Marxist approach.

original response made to the assertions that science was cold-blooded, depersonalised, and dehumanised. As had happened in the early part of the century some people again turned to history of science.

In this supportive climate there were several hopeful occurrences. The British Society for the History of Science founded in 1947 "to promote and further the study of the history and philosophy of science in all its branches and by any and every means" did not exclude the school from its orbit. It provided for its schoolteacher members both a natural forum and a potential pressure group. In 1948 representatives of the Society met with representatives from the Science Masters' Association, the Association of Women Science Teachers and the Historical Association to consider the place of history of science in education.² This meeting brought together the main professional associations that were in a position to influence developments in the schools. Two years later an evening meeting of the British Society for the History of Science which discussed history of science in education attracted about fifty teachers including many concerned with teacher training. At this meeting Herbert Dingle commented on a satisfactory feature of the History and Philosophy of Science Courses at University College, London; a high proportion of the students, he said, were teachers and instructors in Training Colleges.³ At both the 1948 and 1950 discussions there was a wide measure of agreement that history of science should have some place in the normal school science courses and in the regular school history courses. The publication in 1949 of Herbert Butterfield's The Origin of Modern Science gave further encouragement to history teachers. Butterfield, then professor of modern history at the University of Cambridge, wrote that the scientific revolution of the seventeenth century "outshines everything since the rise of Christianity

2. Accounts of this meeting are to be found in Bulletin of the British Society for the History of Science, 1 (1949-54), 11-16 and School Science Review, 31 (1949-50), 2-6.
3. H. Dingle, "History of Science in Education", Bulletin of the British Society for the History of Science, 1 (1949-54), 89-93; also see School Science Review, 31 (1949-50), 329-35.

and reduces the Renaissance and Reformation to the ranks of mere episodes"; reinforcing what had by then become a major role he saw a value in history of science "both in its own right and as a bridge which has so long been needed between the Arts and the Sciences".⁴ The Origins of Modern Science has been described as the first significant gesture in Britain "from the side of general history" towards the study of history of science.⁵ The BBC was also playing a promoting role. During the Autumn and Spring terms of 1949-50 a series of broadcasts on History of Science, given by Herbert Butterfield and others, were transmitted to the schools aimed at the sixth form;⁶ in addition biographies of famous scientists were included in science programmes for secondary-modern schools. By 1950 two School Certificate examination boards were actively considering History of Science as a school examination subject.

But developments from this early post-war interest were slight, the promise was largely unfulfilled. Over the following thirty years discussions and writings on the place of history of science in the school curriculum became spasmodic and the quantity of history of science taught in the schools has been slight. In the early years of this period many people stressed that teaching history of science away from a wider context could cause it to degenerate into a collection of anecdotes. It was commonly believed that the great scientific achievements and the major

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4. H. Butterfield, The Origins of Modern Science 1300-1800, London, 1949, Introduction. In 1960 Butterfield was invited to join the controlling committee of the Nuffield Foundation History of Ideas Unit (see 5.4.1). He declined with the comment "The truth is, that I was concerned with the History of Science only at a certain point in my career, and only to meet an immediate need ... [I have now lost touch] with that interesting study".
 5. C.A. Russell, "Some Approaches to the History of Science", Science and Belief: from Copernicus to Darwin, Open University Press, Milton Keynes, 1974, Unit 1, p.16.
 6. These broadcasts were published as H. Butterfield, The History of Science: origin and results of the scientific revolution. A symposium, London, 1951.

landmarks in man's progress had to be viewed "in their proper perspective, in the social, economic and political environment in which they arose and which often conditioned their development".⁷ The history teacher was seen as a person with the necessary extensive background of knowledge to correlate all the facets of history and to achieve this perspective. But, just as nothing had become of Singer's history of civilisation, in the succeeding years history teachers and their associations did little to introduce history of science into their courses. There are examples of history syllabuses which do include some science. At the 1948 Meeting S.M. Toyne, Chairman of the Historical Association, gave details of one such syllabus. In the early 1970s the Joint Association of Classical Teachers produced an A level Ancient History syllabus which emphasised culture and society rather than simply political and military history. Two books written in conjunction with this were Early Greek Science and Greek Science after Aristotle.⁸ Between 1972 and 1977 the Schools Council developed History Project 13-16 which included some history of medicine. The present (1980) A level History syllabus of the Oxford and Cambridge Schools Examination Board includes as a special option "Growth of the Scientific World View, c. 1500 - c. 1640: Copernicus, Kepler, Galileo". However, such examples are exceptions rather than the rule. In general history syllabuses, school history textbooks and history teachers ignore science. A symposium on the teaching of history of science in schools and colleges held at Loughborough University of Technology in 1968⁹ did not attract representatives from the Historical Association. An economic historian, Margaret Gowing, in her 1975 inaugural address as a professor of history of science at Oxford University, felt the need to

7. G. Fowles, "The place of history of science in education", School Science Review, 31 (1949-50), 6.

8. G.E.R. Lloyd, Early Greek Science: Thales to Aristotle, London, 1970; idem, Greek Science after Aristotle, London, 1973.

9. See Brit. J. Hist. Sci., 4 (1968-69), 199.

challenge the omission of science from the teaching of history as well as the omission of history from the teaching of science.¹⁰ A recent study of current school history text books, by Janet Maw of the University of London Institute of Education, revealed that they contained very few references to science and technology. Such references as did exist were usually confined to the presentation of names and dates, with little or no explanation of the effects of developments.¹¹ But the resistance of history teachers was understandable and their arguments echoed the attitude of the inter-war period.¹² They argued that if there were to be wider history courses more time had to be found for teaching the subject; few other subject specialists willingly agreed to surrender part of their own teaching time. Perhaps more importantly they reasoned that a full knowledge of present-day science was essential for teaching its history, and few felt themselves equipped with this. Furthermore, it was the exception for a history teacher to have studied history of science either as part of a history degree or as part of a training course. There seems to be a good deal of truth in the assertion made in the Thomson Report that "teachers ... tend to go on teaching as they were taught themselves".¹³

Individual science teachers and their professional organisations did show more interest in history of science than their historian counterparts, and did to some extent, promote its claims for inclusion into the school curriculum. As during the inter-war years articles, notes and comments concerned with historical matters appeared from time to time in School Science Review and in other science education journals. As will be seen, GCE "History of Science" resulted from initiatives made by certain science teachers. Various examples exist of the official recognition given by professional organisations to the use of historical material. In 1945

10. Margaret Gowing, What's Science to History or History to Science?, Oxford, 1975.

11. An unpublished 1980 discussion paper made available to the ASE and the British Society for the History of Science. "Science and Technology in History Textbooks: Attitudes and Images".

12. See 3.4.3.

13. See Chapter 3.

a sub-committee of the Science Masters' Association suggested a science syllabus for sixth-form non science specialists which contained a good deal of historical material.¹⁴ About the same time the policy of the Association of Women Science Teachers was that history of science should have a definite place in the General Science syllabus during the first five years of secondary education and should be introduced into the sixth form.¹⁵ The 1961 policy statement of the SMA and AWST, Science and Education,¹⁶ together with its accompanying documents acknowledged the claims of history of science and specified some use in the proposed syllabuses.¹⁷ When the Nuffield O level science programmes emerged they all contained some historical material.¹⁸ Other such examples of official recognition occur. Nevertheless, these professional organisations seem to have made little or no attempt to initiate a debate amongst their members on the merits of history of science in education. It was not usual to find the topic discussed at the annual meetings of the SMA or the ASE (formed in 1963 by the amalgamation of the SMA and the AWST). Nor did these organisations seem to act as pressure groups to ensure that science teachers had some training in the history of science, or to ensure

14. This syllabus was published in School Science Review, 26 (1944-5), 229-35.

15. See AWST, Science in Post-Primary Education, London, 2 parts, 1944 and 1946.

16. SMA and AWST, Science and Education, London, 1961.

17. Two years earlier the SMA had produced an interim report with specific recommendations for a course in the History and Philosophy of Science for all Sixth-Formers. This report was considered at a five-week evening course on "Science in Sixth Form General Education" held at the University of Manchester School of Education (Course No.59/06, October 1959); the course was attended by over fifty science teachers from local grammar schools. The final report, produced by the course organiser Dr. L.H. Shave (see 4.2.3), showed that there was little support among the teachers for the SMA recommendations, seemingly because in the past such studies "had rarely been found effective". (Records held at the University of Manchester School of Education).

18. See Chapters 5 and 6.

that historical questions appeared in science examination question papers - two factors which would seem important if history of science was to establish some firm and widespread place in the school curriculum.

More disappointingly for its advocates, however, was the lack of initiative shown by the British Society for the History of Science. The Loughborough Symposium of 1968 was held under the auspices of the Society and did speak of the desirability of setting up short courses for teachers, but these did not materialise. On the basis of articles appearing in its journal and topics discussed at its annual meetings, the Society has concentrated its energies mainly on promoting research in history of science; encouraging the teaching of that subject in the schools, or even in the universities, seems to have come low in its priorities. There are several probable causes for this blind spot. Like any learned society the reputation of the British Society for the History of Science was going to depend largely on the degree of scholarship shown by its members, and by its success in advancing the frontiers of knowledge in its own discipline. Pure research in the history of science was vital to the survival of the Society and to its establishment as an august and academic body. However, a great number of the founder members had spent at least part of their career in school teaching. Not unnaturally they were anxious not only to promote research but to advance the claims of history of science in education. But as the years progressed and they retired from age or death the type of personnel prominent in the Society changed. The officers were chosen more for their eminence and visibility as publishing historians of science than for their largely unknown ability as teachers. There was greater glamour attached to research than to pedagogy. Professional historians of science were well aware that their promotion prospects and status depended to a very great extent upon their publications. They perhaps even felt the need to justify their existence by the quantity (and quality) of the papers they could produce.

Clearly more than a favourable climate of opinion and some promising

events was needed for the widespread introduction of history of science into the school curriculum. Although not widespread the subject has gained some established and regulated place in three areas of the school curriculum since the end of the Second World War. The Nuffield reforms of the 1960s saw some history built into the new O level science courses and saw certain materials produced for teachers; this is discussed in Chapters 5 and 6. History of science has become established as a separate GCE examination subject. General Studies courses, especially in the 1960s, have made use of the subject.

4.2 "History of Science" as a GCE examination subject¹⁹

4.2.1 The early examinations

"History of Science" was first introduced as a separate school examination subject in 1952 by the Cambridge Local Examination Syndicate and by the Oxford and Cambridge Schools Examination Board. The Cambridge Syndicate used the title "History and Philosophy of Science" although the syllabus concentrated mainly on the history; the Oxford and Cambridge Board used the title "History of Science". The examinations were offered at GCE O level standard and intended mainly for sixth form pupils, the equivalent of the then recently abolished Higher School Certificate Subsidiary examinations.

An attempt to list the schools which entered candidates for the 1952 examination immediately illustrates the problems which may be encountered

19. The information in this section was drawn mainly from the following sources: correspondence and interviews with (a) people involved in setting up and teaching the early courses, (b) the colleagues and friends of the deceased pioneers of GCE "History of Science", (c) pupils from some of the schools concerned; records and archives held at the two examination bodies; records and archives held at some of the schools concerned, in particular Whitgift School; various obituaries. Unless the context indicates differently the term "History of Science" will be used to indicate both the "History and Philosophy of Science" and the "History of Science" GCE examinations.

in this type of research. The Oxford and Cambridge Board has no records of entries; all that can be checked at the Board, and that with great difficulty, is from the record of passes. These records indicate that in 1952 there were six passes at Frensham Heights School and fifteen at Tonbridge School, Kent; as thirty-one candidates were awarded a pass at least one other school made entries. By 1955 Monkton Combe School, King Edward VII School Sheffield, Becket School and Watford Grammar School had also entered candidates for the Oxford and Cambridge examination, although none of these are shown as having any successful candidates in 1952. One significant and initially surprising feature is that there is no record amongst the 1952 passes of any candidates from the four schools which had members on the syllabus drafting committee - King Edward VII School Sheffield, Nottingham High School, the City of London School, and Christ's Hospital - or from Leys School Cambridge, which also had an involvement in the syllabus construction. At the Cambridge Syndicate the only way to determine which schools entered candidates for the first examination is to check through each of the entry forms for 1952, an equally difficult and laborious process. Whitgift School, South Croydon certainly entered candidates in 1952; King Edward VI Grammar School Nuneaton first entered candidates in 1953. An attempt to find such information through likely schools was even more difficult. No school was found which could trace records of examination entries for the early 1950s. Even when staff members who taught GCE "History of Science" in the early years were traced they were not usually able to remember the precise date of its introduction into the school.

4.2.2 The origins and construction of the syllabuses

On 29 October 1949 the Secretary of the Cambridge Local Examinations Syndicate, J.L. Brereton, explained to a meeting of the Science Committee that enquiries had been made by teachers in two schools about the possibility of including the subject History and Philosophy of Science in the GCE

examination. (One of these schools was Whitgift. No record has been traced at the Syndicate Buildings of the name of the other school; nobody at Whitgift or at the Cambridge Syndicate could recall anything about the second school. From the documentary evidence available and from the recollections of individuals it can be inferred that this unknown school played little or no part in the subsequent development of GCE "History and Philosophy of Science"). These schools had conferred and drawn up a draft syllabus which was presented to the meeting. This draft was later circulated to schools but was criticised as being too ambitious; it was thought to be pitched at too high a level for the sixth form schoolboy, with many of the topics appropriate only to the undergraduate level. A further draft syllabus was then prepared by masters at Whitgift School.²⁰ This was presented at a meeting of 27 May 1950 to the Science Committee and considered much more suitable for use in schools. Accordingly the Science Committee appointed a special committee which included Professor Herbert Butterfield, the Cambridge historian, and two members from Whitgift School to consider (a) if the subject should be included in the list of examination subjects, and (b) if so, to draw up a draft syllabus. This special committee, which met in June 1950, agreed that the subject should be included and adopted with small amendments the Whitgift draft. This syllabus was then approved by the Science Committee at a meeting on 28 October 1950 and appeared as the Syndicate's first "History and Philosophy of Science" syllabus.²¹

Whitgift School had first adopted a general course in the History and Philosophy of Science for all Advanced Sixth form pupils in 1947. The originators of this course were three men, then all in their late forties: Dr. C.T. Prime, a biologist and botanist, A.H. Ewen, a classicist, and H.E. Parr, a mathematician. The immediate post-war period saw a greatly increased pressure of specialisation in the sixth-forms of schools to

20. This is given as Appendix 4.

21. This is given as Appendix 5.

ensure success in obtaining University places and awards from the final school examinations. This tended to narrow the general education of all advanced pupils, who were unwilling to take much interest in subjects which would not help them in their applications to Universities. There was as a result an almost total lack of contact at Whitgift School between the various specialised sixth forms, Classics, History, Modern Languages, Mathematics and Sciences. This development was caused by the selection policy of the older universities, and did not operate in the 1930s.

In the 1930s a pupil's university career was largely determined by the parent's financial resources. Unless a candidate was capable of reaching the very high standard needed for success in Open Scholarship or Exhibition examinations, finance determined the choice of university; selection by the individual colleges often depended on athletic prowess as much as on academic ability. This system permitted Schools to have a general course in a range of subjects for all pupils including the sixth forms. The situation was radically changed after 1945 by the establishment of Local Education Authority grants to supplement the parents' resources. The field of candidates was greatly widened, and competition for entry to Oxford and Cambridge intensified. At the same time changes in the University Degree courses tended to eliminate the Pass Degree and to transfer the syllabus of the first year Honours Course to the sixth forms. To adapt to these changes schools were forced to introduce more specialised courses at an earlier age, and to narrow the general education of the more gifted pupils in order to enable them to compete for university places. Athletic prowess, though retained by some Colleges as a qualification, yielded pride of place to academic distinction. The result of this process of change was a sharpening of the divisions between the different sixth-form courses and a decline in general education. Classics pupils did no Science, Science pupils did no History and had little Language instruction. At Whitgift the study of history of science seemed a useful method of creating some common ground between the various Advanced

courses, to get the pupils out of the straight-jackets of their rigidly confined and specialised courses, to break down intellectual barriers, and to learn something of the history of ideas. Prime, Ewen and Parr all believed that history of science might, with careful teaching, enable the Classics Sixth to appreciate the contribution made by the Greeks to the history of mathematics and science, Plato could lead to Archimedes; the Modern Sixth to see the part played in the development of science by men such as Descartes and Voltaire, with Voltaire leading to Newton; the Science Sixth and the Maths Sixth to understand that their subjects had long histories during which they had developed, in different nations and civilisations, step by step as mankind progressed. As noted, Whitgift School adopted such a course in 1947.

The Advanced pupils at Whitgift however, were interested mainly in examination work and were reluctant to spend time on non-examinable subjects. Because the introduction of an examination paper was seen as a means of countering this reluctance and helping to ensure the interest of the pupils Prime made an approach to the Cambridge Syndicate. Both Prime and Parr had good contacts and were well known at the Syndicate Buildings. Through their work as Syndicate examiners they were on very friendly terms with the Secretary, Brereton. Prime, a Cambridge graduate, had examined for the Syndicate since 1936. Parr, who had examined since 1933, was appointed Chief Examiner in Mathematics in 1949 and was on the Mathematics Committee. Whitgift was perhaps the most important school taking the Syndicate's examinations. Not surprisingly an approach for a new examination coming from such a school, which probably would enter a fair number of candidates, and backed by three such senior masters, received very careful consideration. It seems that all the major points were settled during informal talks between Prime and members of the University Syndicate.

It can thus be seen that the Cambridge Local "History and Philosophy of Science" examination evolved mainly from the Whitgift course. This

course was based, not on any existing conceptions about what a history of science course should contain, not on any formal training in history of science received by the masters concerned, and certainly not on any pre-war arguments about using history of science to examine the science/society relationship: it was based on purely empirical factors - the masters available for the purpose, and the need to balance the interests of the pupils in the several advanced courses. As a background for the whole subject Ewen was giving a general historical course from the earliest civilisations to the present time: Prime was teaching the history of medicine and the biological sciences: Parr the histories of mathematics and the physical sciences. The resulting Cambridge Syndicate examination paper was divided into sections which permitted the pupils to concentrate on the material most appropriate to their interests and needs; students of the classics, for example, could spend much time on Greek science, science pupils could concentrate on the later periods.²²

Whereas the Whitgift masters certainly had in mind history of science as a meeting place between the science and non-science pupils in the sixth form, the Oxford and Cambridge Board examination grew more out of a wish to teach science to non-scientists and out of the personal belief of one of the Board's Secretaries, A.E.E. McKenzie, that history of science was the best way to do this. At a Meeting of 24 February 1949 the Board, concerned about the degree of specialisation in the sixth forms, agreed that

"sixth form Humanists, who wished to discontinue formal mathematics and science, might welcome an opportunity of examining the implications of science, and offering the subject for university examination purposes".

They proposed that a committee be set up to devise an O level science syllabus, suitable for non-science specialists in the sixth form, together with a general paper. This was a period in which Alternative Ordinary

22. For a published account of the setting up of this examination see A.H. Ewen, "A Sixth-Form Course in the History and Philosophy of Science", History of Science, 2 (1963), 84-90.

syllabuses for the new GCE examinations were being developed in a number of areas (some of which proved to be very unsuccessful in attracting entries). At the February meeting the Board, which was against the extinction of Subsidiary subjects, also resolved that application be made to the Secondary School Examination Council for the inclusion for the first GCE examinations in 1951 of AO syllabuses in all the existing Higher Certificate Subsidiary subjects. From the records available and the recollections of individuals the implication is that the move towards a new science syllabus for non-scientists was initiated by the two Secretaries of the Board. At that time both were scientists. The Oxford Secretary was G.J.R. Potter, formerly Headmaster of Nottingham Pavement School, who had before that taught physics at Oundle. In Potter's own words "I personally had no particular interest in History of Science".²³ At Cambridge the Secretary was A.E.E. McKenzie, a man with a deep personal interest in the history of science. McKenzie entered Trinity College, Cambridge as an Open Scholar in Natural Science in 1923. After graduating he taught physics at Haileybury for three years, was Head of Physics at Repton for fourteen years, and in 1944 was appointed Cambridge Secretary to the Oxford and Cambridge Examination Board. His interests extended well beyond science into history, literature, music and art. During his time at Repton he gave courses on the history of science to sixth form arts pupils. In 1964 he wrote that he was conscious of not doing this well partly because of a lack of suitable books and articles on the subject. His interest in history of science is further shown in the several physics textbooks he wrote, in which he attempted to make the subject more alive by putting it into an historical and human perspective. It is McKenzie who seems to have been mainly responsible for the proposed new science syllabus becoming a "History of Science" syllabus.

Following the February Board Meeting a committee, formed by the two Secretaries, met on 14 May 1949 to discuss the general paper and the

23. Correspondence between Mr. Potter and the author.

science syllabus. This committee, prompted by McKenzie, agreed that the science syllabus should consist of a series of topics selected from the physical and biological sciences and treated historically on the lines of Conant's case histories, as described in On Understanding Science²⁴. The topics were intended to bring out the aims, methods and influences of science. Following this meeting a sub-committee of six met on 7 July 1949 to draw up the new science syllabus. This sub-committee, selected by the Secretaries, consisted of Dr. A.W. Barton, Headmaster of King Edward VII School, Sheffield, C.L. Reynolds, Headmaster of Nottingham High School, R.H. Dyball of the City of London School, Dr. G. Van Praagh of Christ's Hospital, and the two Secretaries, McKenzie and Potter. All were highly experienced science teachers and prominent in science education. Each of the three major scientific disciplines were covered: Barton and Reynolds were physicists, Dyball a biologist, and Van Praagh a chemist. No member of the sub-committee had any formal qualification in the history of science.

The July meeting was chaired by Dr. Arthur Barton, a dominant character with high academic qualifications, wide-ranging interests, and fame in the world of sport as an association football referee. The younger son of a Professor of Physics at the then University College of Nottingham, Barton was educated at Nottingham High School. He later went up to Trinity College, Cambridge where he obtained First Class Honours in both parts of the Natural Sciences Tripos in Physics. To this he added First Class Honours in the London BSc examination, and a London PhD for a thesis on Radioactivity. After several year's work under Rutherford at the Cavendish Laboratory in Cambridge he took up an appointment as Senior Science Master at Repton, where he had as a colleague Arthur McKenzie. Whilst at Repton he wrote textbooks on Heat and Light which were widely used in schools for many years. According to a Profile

24. See 4.4.

written in New Scientist²⁵ it was during his time at Repton that Barton's ideas about the teaching of science really developed and he "set out to teach it as it evolved historically". Between 1939 and 1950 he was Headmaster of King Edward VII School Sheffield, and between 1950 and 1965 Headmaster of the City of London School, the School's first scientist Headmaster. Like others on the sub-committee Barton, with no formal training in history of science, acquired his knowledge of the subject from private reading. An important aspect of Barton's thinking was his concern about overspecialisation in the schools. One of his tasks as Headmaster of the City of London School was to postpone specialisation for as long as possible and for as many boys as possible: this he did by a reorganisation of the curriculum. The New Scientist Profile shows him as a teacher who typified the broad approach to education.

Prior to this meeting three draft syllabuses had been submitted; by Dr. G. Van Praagh, by Mr. R.P. Ayres, Head of Chemistry at the Leys School, Cambridge, and by McKenzie.²⁶ Gordon Van Praagh, a science master at Christ's Hospital and prominent in the Science Masters' Association, was well known for following Armstrong's heuristic methods at the school and for his membership of the Chemistry Syllabus Committee. As an undergraduate he had studied chemistry at University College, London in the late 1920s. It is of interest to note that whilst an undergraduate at the College Van Praagh was not aware of the existence of the department of the History and Method of Science - perhaps an indication of the department's

25. "Dr. Arthur Willoughby Barton. Profile", New Scientist, Vol.5 (1959), 128-9. It is of interest to note that two years earlier Barton had written for New Scientist an article "On teaching science in the schools" (Vol.1 (1956-7), 9-11); in this he gives as justification for using historical material the parallelism between intellectual and historical development "... there is also evidence that the emotional and mental development of a boy reproduces the emotional and mental development of the human race. So it follows that the subject matter will be most closely in harmony with the boy's state of mind if it is presented as it developed historically". (See 3.2.3).

26. These are given as Appendix 6.

lack of influence at that time. After taking his PhD at Cambridge, where he was a contemporary of C.T. Prime ("we all stood in awe of Prime"). he spent nearly thirty years teaching at Christ's Hospital. He received no formal training in history of science but acquired his knowledge of the subject through private reading. However, several factors did influence his historical interests. Teaching in the tradition of Armstrong and being familiar with his writings, he was aware of how Armstrong, although not using history as a vehicle, made frequent references to historical matters and was constantly looking back to the beginnings. (This can be clearly seen in Armstrong's Essays on the Art and Principles²⁷). A further stimulation came from the Christ's Hospital school library which contained many books on the history of science. However, the largest influence came from F.W. Wagner, a colleague who later became Professor of Education at the University of Southampton and who was especially interested in the subject. It was from Wagner, that Van Praagh, who had earlier tried without success to use history of science as a means of teaching science to arts pupils, got the idea of using Conant's case history methods. Van Praagh drew up his draft syllabus by selecting and simplifying what he considered to be important topics in chemistry and biology. He then traced the historical development of these by using material from available history of science text books and from Conant's case histories.

R.P. Ayres submitted his draft syllabus at the instigation of his Headmaster, Dr. W.G. Humphrey, a member of the Committee which had met in May. In 1980 Ayres had no recollection of how he had drawn up his draft. His academic qualifications were two London BSc degrees (1925 and 1932) and the Cambridge University Part 2 Chemistry Tripos (1932). He had trained in chemistry, physics and mathematics, but had received no training in history of science. The brevity of his draft is in contrast with the two

27. H.E. Armstrong, Essays on the Art and Principles of Chemistry, London, 1927.

other submissions and seems to have played little part in the final proposals. McKenzie's submissions appear to have come from ideas he had developed during his years of school teaching. As already noted, McKenzie had given history of science courses to sixth form arts pupils at Repton. In 1943, writing in School Science Review on science for arts specialists, he suggested a syllabus on the history, methods and social effects of science.²⁸ These suggestions show some resemblance to his draft of 1949.

After considering the draft syllabuses the meeting submitted to the Oxford and Chambridge Board a syllabus and specimen examination paper for approval.²⁹ As can be seen, this was a combination of McKenzie's and Van Praagh suggestions. Apart from the "influence of Descartes and Bacon, induction and deduction" and the "Foundation of Geology" all McKenzie's proposals were included in some form. Likewise with the majority of Van Praagh's recommendations. With a few minor alterations, agreed between Barton, F.M. Brewer, a university lecturer in chemistry, and the Secretaries, this appeared as the first Oxford and Cambridge Board "History of Science" syllabus.³⁰

At the instigation of McKenzie the first examination paper was set and marked by H. Hamshaw Thomas, who had shown an interest in history of science at Cambridge in the 1930s³¹ and Stephen Toulmin of Leeds University, who was later to organise the Nuffield Foundation History of Ideas Unit.³² J.R. Partington, an eminent scientist and writer on the history of chemistry, who had then retired to Cambridge, was one of the first Awarders. It is of considerable interest and significance that there is no record at the Oxford and Cambridge Board amongst the 1952 passes of any candidates from the four schools which had members on the drafting committee. This

28. A.E.E. McKenzie, "Science for Arts Specialists", School Science Review, 25 (1943-4), 13-20.

29. This is given as Appendix 7.

30. This is given as Appendix 8.

31. See 2.4.2.

32. See 5.4.1.

would appear to reinforce the notion that the pressure for the new "History of Science" syllabus did not come from those particular schools, which seemingly only became involved because of the prominence of certain members on their staffs. It also supports the notion that McKenzie was the main driving force for the new History of Science examination.

As can be seen, both the Cambridge Syndicate's "History and Philosophy of Science" and the Oxford and Cambridge Board's "History of Science" are heavily internalist. The 1930s interest in the history of science by certain English Marxists has already been noted. Any ascendancy that these Marxists may have then possessed in the way that the discipline was developing did not carry through the war years; they had neither the journals to maintain their position and establish a tradition, nor the opportunities to train future historians of science. After 1945 history of science emerged under scholars who were particularly conscious both of the cold-war climate of opinion and of the Marxist neglect of science as a body of ideas. The paradigm for histories of science in the early post-war period became Herbert Butterfield's Origins of Modern Science and the writings of the Frenchman, Alexander Koyré. This approach to history of science was reflected in the internalist orientated history of science advocated in the USA for general education. In so far as the Oxford and Cambridge Board syllabus was influenced by Conant the cold-war backlash may have had some indirect influence on developments. However, the internalist orientation of the Cambridge Syndicate's "History and Philosophy of Science" syllabus certainly seems more of a reflection of the personal interests and beliefs of the Whitgift masters than any conscious knowledge of developments in history of science as an academic discipline.³³ In the words of Parr:

33. Butterfield only became involved after the Whitgift draft syllabus had been submitted. His presence helped to ensure that the draft was accepted, but he did not assist in preparing it.

"I think I was in favour of helping to evaluate the relation between science and society, so I suppose I am an externalist. Neither Ewen nor I was likely to be put off by American hostility to Russia! However, looking back after nearly thirty years, I would say that the teaching of the History and Philosophy of Science at Whitgift was partly cultural for its own sake, an attempt to interest sixth-formers in a subject we were keenly interested in ourselves, and a desperate (only partially successful) effort to break down intellectual barriers ...". (see note 44).

4.2.3 The pioneers' knowledge of history of science

As seen, none of the people most directly concerned with setting up the two "History of Science" syllabuses had any formal qualifications in the subject, or had attended the Department of the History and Philosophy of Science at University College, London. With the notable exception of Ewen all were, or had been for some part of their career, science teachers (Parr was a mathematics teacher). At the time they were undergraduates history of science was not usually included in a science degree. All these pioneers of history of science in the schools had acquired their knowledge of the subject from private reading and could be said to be self-taught in the work. On the basis of two further schools investigated, one from each of the examination boards, the same was probably the case with the staffs of other schools entering candidates in the early years.

In choosing schools for further investigation certain criteria were adopted. The person responsible for introducing the examination into the school was to be available, willing and able to discuss his experiences; thus the status of the information would be higher than if less direct evidence was used. This was considered to be of primary importance and the major criterion. The school was to have entered candidates for several consecutive years; this would increase the likelihood of a pattern being set and any typical problems being encountered. A school from each of the two examining bodies should be chosen. The two schools selected which met these requirements were Tonbridge School, Kent and King Edward VI Grammar School, Nuneaton.

Tonbridge School first entered candidates for the Oxford and Cambridge Board "History of Science" examination in 1952 at the initiative of J.N.F. Morris, then head of the Science Department. Morris studied at Cambridge University (Mathematical Exhibitioner 1915, Part 1 Natural Science), where he was a contemporary and friend of F.H.C. Butler, later to become Foundation Secretary to the British Society for the History of Science. He taught physics at Tonbridge from 1921 to 1960, accepting the appointment Head of Science Department in September 1951. Although Morris regarded his Cambridge supervisor, Edward Appleton, as a humane man with wide-ranging interests, he received no encouragement to read up on history of science from either Appleton or his tutors at University. However, historical interests were aroused while an undergraduate by private reading, in particular Lodge's Pioneers of Science and Sacha Guitry's Pasteur.³⁴ These interests were further stimulated at a brief vacation teachers' training course at Oxford in 1921 when, as he recalls, occasional allusions were made to history of science. Prior to his appointment as Head of Science Morris's full teaching and extra-curricula duties left him with few opportunities to develop his historical interests. However, when he became aware of the Oxford and Cambridge "History of Science" syllabus (by looking through the Board's published Syllabuses and Regulations) he saw this as an excellent means of overcoming the rigid division between scientists and non-scientists, countering the excessive sixth-form specialisation, and teaching some science to the non-scientists. At that time there was no compulsory O level (or its precursor, School Certificate) science for the Tonbridge pupils but it was thought proper that they should have some science in their education. It was realised that in the sixth form what might be called "formal" science would almost certainly have been rejected. Various attempts were therefore made to give them something more digestible. Current affairs science was one

34. O. Lodge, Pioneers of Science, London, 1893.
Sacha Guitry, Pasteur, Paris, 1919.

attempt, History of Science was another. With the approval of the Headmaster and the willing co-operation of the Rev. J.M. Stanton, B.E. Day and J.A.D. Healey, colleagues in the Science Department, Morris was able to initiate the entry. The examination was taken by Lower Sixth non-science pupils (later science pupils would on very rare occasions enter) purely as a stimulus and not because it was needed as a qualification. None of the Tonbridge science staff had received any training in the history of science; they acquired their knowledge of the subject by reading and private study. Day, who recalled approaching historically the then exciting developments in DNA RNA through classification, evolution and heredity with a good deal of interest and success, suspected his teaching was unscholarly. But he was quite certain that it was full of enthusiasm. Interest in the history of science increased markedly for all the masters involved in teaching it.

GCE "History and Philosophy of Science" was introduced into King Edward VI Grammar School, Nuneaton by the Headmaster, T.C. Sumner. Candidates first entered for the examination in 1953. Sumner, a physicist, had studied at King's College, London in the 1930s. Coincidentally, like J.N.F. Morris his tutor was Edward Appleton. After graduating Sumner remained at the College a further year to take a post-graduate teaching qualification. Although his post-graduate course included some history of education he received no encouragement, either then or as an undergraduate, to read up on history of science. Sumner, unable to isolate what initially aroused his historical interests, believes it goes back to his-school days and continued during his time at university. During the late 1940s he taught at Hull Grammar School under a Headmaster, Dr. H.L. Shave, who had studied history of science at the University College, London department prior to World War II. With some encouragement from Shave, Sumner taught a little history of science to the sixth-form as a means of bringing together the arts and science pupils. When he was appointed Headmaster of King Edward VI Grammar School in 1951 he decided

to continue to use the same means in the sixth form to bring together the arts and the science pupils, thus teaching some science to the arts pupils and widening the knowledge of the science pupils. However, the pupils themselves regarded this as an unnecessary chore and the Cambridge Syndicate "History and Philosophy of Science" examination was introduced to provide them with some kind of motivation. As none of the science staff or historians at the school had any knowledge or real interest in the subject Sumner was the only person to teach the course. Like the other pioneers in History of Science teaching he was self-taught in the subject and acquired his knowledge by private reading.

4.2.4 Difficulties encountered

4.2.4.1 Suitably interested and qualified teachers

As would be expected, in the early years of the examinations the schools who entered candidates had one or more teachers with a particular sympathy towards history of science. As the years progressed, however, and the pioneer teachers retired or left for other positions, the schools encountered the difficulty of finding suitably interested and qualified replacements. At Whitgift, for example, enquiries to new staff appointments during the early period always produced a totally negative response. When Sumner left King Edward VI Grammar School in 1960 the subject was dropped. None of the science staff at that school had taken part in teaching the course during the 1950s; nor, according to the then Head of Science, S. Herbert, did they have any interest in the work. On the departure of Sumner their lack of interest and their very full teaching commitments precluded any possibility or desire to make any study of history of science. It is clear that this difficulty of finding suitably qualified teachers persisted at least into the 1960s. In October 1964 Michael Hoskin, a lecturer in history of science at the University of Cambridge, wrote to McKenzie informing him that there was the possibility of the BBC undertaking television programmes on the history of science,

either for senior forms in schools or for teachers themselves. His letter was to sound out McKenzie on the feasibility and value of the proposals.³⁵ McKenzie was enthusiastic in his reply, commented on the great value such programmes would have, and spoke with feeling of the problem of finding teachers with a sufficient knowledge to teach History of Science.

On the face of it the History and Philosophy of Science course offered at University College, London, which was known about in at least some of the schools, offered a potential solution to the problem. Douglas McKie, who became head of the department in 1954, certainly showed an interest in history of science at the school level.³⁶ In 1958 he arranged the series of articles, written by members of his department, on important scientific papers. They appeared in the Times Educational Supplement and were intended to be read by teachers in schools;³⁷ two were contributed by McKie. In 1960 he organised a series of evening lectures covering various topics in the history of science at Reading University; the audience was mainly teachers and sixth formers. Soon afterwards, on the invitation of Dr. C.A. Russell, then of Harris College later of the Open University, he organised a similar course at the Harris College, Preston (now Preston Polytechnic). Again the lectures were in the evenings and the audience came from the local schools. One of McKie's last publications was in Physics Education and again intended for school teachers.³⁸ However, it seems that the schools involved in the "History of Science" examinations in the 1950s made no attempts either to seek out

35. The programmes were eventually transmitted on television and were a notable success. They were published as M. Hoskin, The Mind of the Scientist, London, 1971.

36. I am grateful to Dr. W.A. Smeaton of University College, London for his most useful information and comments on Professor McKie.

37. There were ten articles published in successive weeks between 25 April and 27 June 1958. The general title of the series was "Great Scientific Papers".

38. Douglas McKie, "The rise of scientific societies and periodicals", Physics Education, Vol.1 (Nov.1966), pp.213-22.

graduates from the University College department or to encourage members from their staffs to attend the course. The indications are that the masters involved in the examinations at their inception saw little point in attending such a course. They believed that they possessed the knowledge and skills necessary to cope with the demands of the work; any deficiencies could be overcome by their own private reading or attendance at short vacation courses. When these pioneer teachers had to be replaced it required a combination of suitable school location, flexible time-tabling arrangements, and sufficient interest, energy and time on the part of the staff to attend evening lectures on a part-time basis. Such a combination was rarely to be found. One notable exception did occur at Winchester College where the Headmaster, Sir Desmond Lee, apparently believed that it would be of value to have a trained historian of science on his staff. In 1961 Lee arranged with McKie for one of the College chemistry teachers, D.M. Steele, to leave Winchester early on several afternoons a week to attend the MSc course.³⁹ In general however, outside a few members of the science staffs there seems to have been a marked lack of interested teachers for the subject. Those science teachers who had some interest but little knowledge of history of science seem to have had such heavy teaching commitments together with many out-of-school interests and obligations that intensive study for post-graduate qualifications in the subject was out of the question.

4.2.4.2 Suitable text books

A further difficulty immediately encountered by the pioneer teachers of "History of Science" was the lack of suitable books. This is evidenced by the recollections of many of the teachers involved, and by the correspondence between the schools and the Oxford and Cambridge Examination Board. In the early years few available history of science texts were considered to meet the requirements of suitable contents,

39. Steele was later to become involved in the Nuffield History of Ideas Unit. See 5.4.1.

convenient size and low price. At Whitgift the books first used were Farrington's Greek Science and texts of Bernal. At Tonbridge Farrington's and Bernal's works were used by the staff as references; Reason's Roads to Modern Science, which was considered as no more than a very simple skeleton on which to hang the teaching, was made available to the pupils. At the Oxford and Cambridge Board on several occasions in 1952 and 1953 McKenzie answered requests from schools by saying that no really suitable books existed. His recommendations to Finchley Catholic Grammar School in 1953 were Butterfield's The History of Science, Turner's The Book of Scientific Discovery, Toulmin's The Philosophy of Science, Sherwood Taylor's Science Past and Present and, to show how to teach the subject, Conant's On Understanding Science.⁴⁰

The first attempt to overcome this lack of texts came from within the schools themselves. At several schools the staff concerned prepared and circulated typed summaries of the work. A selection of the summaries used at Whitgift is given as Appendix 9. At Tonbridge these summaries became so full that one of the staff, the Rev. Stanton, made considerable progress on the draft of a book. This unfortunately was never completed as Stanton soon left the school to take up the post of Headmaster of Blundell's School. One book which did however, result from this concern over lack of suitable texts was written by McKenzie himself. In 1960 he published his two volume The Major Achievements of Science,⁴¹ a work intended for both non-science and science specialists in the sixth form. The production of two separate volumes may have been influenced by Morris who discussed the work with McKenzie. Morris, while recognising the value of including primary source material believed that it could disturb the

40. B. Farrington, Greek Science, 2 vols. New York 1944 and 1949;
Hazel A. Reason, The Road to Modern Science, London, 1935;
H. Butterfield, The History of Science, London, 1951;
D. Turner, The Book of Scientific Discovery, London, 1933;
S. Toulmin, The Philosophy of Science, London, 1953;
F. Sherwood Taylor, Science Past and Present, London, 1945;
J.B. Conant, On Understanding Science, London, 1947.

41. A.E.E. McKenzie, The Major achievements of Science, 2 vols., Cambridge, 1960.

sequence of thought. Accordingly he was much in favour of keeping the original writings separate from the descriptive account. McKenzie's main object was to record the history of scientific ideas and to present science "as an intellectual adventure". In Volume 1 he gave an account of the historical development of the main generalisations of science, their philosophical implications, and their influence on the climate of western thought. Because he believed that there was more interest in people than in ideas, he devoted considerable space to the lives and personalities of the outstanding scientific investigators. Volume 2 contained ninety-one extracts from original writings, arranged under the same chapter headings as in the first volume. The way in which he intended the book to be used was for pupils to read a chapter to provide the historical, biographical and sociological background, while the teacher expounded the science rather more fully with experimental demonstrations. There was a very close correspondence between the contents of the book and the Oxford and Cambridge Board syllabus.

4.2.5 Entries for the examinations

The GCE "History of Science" examinations have never succeeded in attracting a large number of candidates. In 1952 the total number of candidates for both examinations was sixty-seven. During the 1960s this total averaged about 250 per year, with a peak of 432 candidates in 1965. During the 1970s the average fell to some 140 candidates per year with the 1979 entry at ninety-eight.⁴² Small numbers in the early years are not surprising. Only a few schools had pressed for the new examinations. Where all sixth form pupils followed the course, as at Whitgift, entry to the examination was entirely voluntary and no pressure was exerted on pupils to sit the paper. But even during the growth period, when compared with the increased entries in other GCE science and arts subjects little

42. Full figures are given as Appendix 10.

interest was shown in the examinations. Entries for the Alternative Ordinary examinations are usually quite small, but the "History of Science" entries are smaller than average.

Several reasons can be postulated for the relative lack of interest in the subject in the schools. The difficulty in finding suitably qualified and interested teachers would have inhibited the growth. As seen, in the 1950s history of science had not yet been accepted into the British universities on any significant scale. It was too early for many former candidates of the examination to have emerged as potential teachers of the course. Neither the British Society for the History of Science nor the Department of the History and Philosophy of Science at University College seem to have attempted to act as a potential pressure group to promote the subject in the schools. It is possible too that there was some pupil resistance to an examination offered at A0 level. The objection of pupils to spending time on non-examinable subjects has already been noted. It is only a short step from this to argue that an O level subject in the sixth form had relatively little value when it came to university entrance; more could seemingly be gained from concentrating on A level subjects. One of the reasons that the course at Whitgift was eventually abandoned was the overpowering pressure to get high A level grades in subjects which in complexity compared with actual university courses in other countries. A further possible reason for the lack of growth may be found in the width and complexity of the syllabuses, which could have appeared as excessively demanding to potential teachers and pupils alike. The syllabuses covered a period of time from the Greeks up to the twentieth century (the Cambridge Syndicate syllabus even contained some pre-Greek "science" and technology), and included histories of the physical and biological sciences, history of astronomy and some history of medicine. Even though a complete coverage was not expected the demands were formidable. Few teachers would be prepared to introduce such work without an adequate background. Many might quite happily

introduce some history of science as a non-examinable part of a course. But most teachers would feel that their own lack of knowledge would unfairly disadvantage their pupils, as well as being conscious that they themselves would be judged by their pupils' examination results. Furthermore, within a very short period of time GCE "History of Science" was overtaken by events. An original intention was to use the subject as a bridge between the arts and the sciences, as a counter to over-specialisation. Perhaps the irony of attempting this by introducing a new subject which at the time was itself becoming increasingly more highly specialised did not pass unnoticed. Within a few years of the introduction of the examinations the growth of General Studies offered a more logical means of bridging the gap. It also made less formidable demands on teachers who wished to teach some history of science, but whose knowledge of that subject was limited.

4.2.6 Particular initiatives

It seems clear that "History of Science" was introduced as a GCE subject in 1952 as the result of the particular initiatives of certain individuals, notably the three Whitgift masters and McKenzie. But for individual initiatives to succeed they must be made at an appropriate time and place, and usually by individuals with qualities and opportunities somehow different from the ordinary. The time was appropriate in the immediate post-war period. The horrors of war and the desire to present science as a human, humane, and beneficial study had created a favourable climate of opinion; in some schools at least the worry about excessive specialisation and the competition for university places and prizes was felt to be greater than ever before; the changed selection policy of the older universities had created a new situation; and the post-war social commitment to greatly increase the numbers of scientists and technologists emphasised to some people the necessity of scientific knowledge for the educated non-scientist. The individuals concerned were in appropriate

places. Their close links with the examination boards allowed them direct opportunities to press for the introduction of new examinations. And all were well qualified, highly experienced, successful and respected teachers, with a keen interest in history of science.

In the opinion of several of their former colleagues and pupils all three of the Whitgift masters were men of such academic distinction, profound learning and wide culture as are seldom found together in schools today. Ewen, Second Master from 1947 to 1962, although a classicist by training, had interested himself in politics, economics (two subjects on which he lectured the Whitgift sixth forms as far back as the 1920s), literature and social history; he was a local historian of some fame, specialising in the Channel Islands. Although he had no training as a scientist, and probably very little practical knowledge of any of the experimental sciences, his interests probably developed like those of an eighteenth or nineteenth century amateur. It seems most likely that his interest in the development of scientific theory and method came through his interest in social history. Ewen was a member of the Royal Institution and lectured there of occasion, and joined Prime in the production of one learned work. Prime, the youngest of the three and Chief Science Master from 1964 to 1969, was the practical scientist. On his retirement he devoted the major part of his time to field work and writing. He travelled on botanical excursions to many countries including Turkey, Sicily, Romania, Austria and the Dolomites, the Spanish Pyrenees, the Greek Islands and Canada; on several such excursions he acted as leader of tours for botanists arranged by a specialist travel firm. His writings included Trees and Shrubs, Investigations in Woodland Ecology, Experiments for Young Botanists (dedicated to the Whitgift Biological Sixth), and Ray's Flora of Cambridgeshire, translated from the Latin and edited in collaboration with Ewen, Plant Life, and Wild Flowers

of Europe⁴³. Parr, who succeeded Ewen as Second Master on the latter's retirement, also compiled and edited many text books. As a mathematician he had some practical knowledge of physics; like Ewen, he has been described as a polymath, devoted to all kinds of search for knowledge. His historical interests were of long standing. In his own words

"I have always been deeply interested in the history of mathematics, as almost every Cambridge graduate in the subject is bound to be, and man's control over nature and scientific knowledge always advanced parri passu with maths. I found at Whitgift in the 1930s a treasure-house of books on the history of mathematics in the mathematical departmental library".⁴⁴

Likewise with McKenzie. In a tribute in The Times Bryan Thwaites, Principal of Westfield College, London wrote

"It was McKenzie through whom a whole generation's-worth of curriculum reform was made feasible, and English education must remain ever thankful that there was that great man in the right place at the right time".⁴⁵

Although Thwaites had the Schools Mathematics Project in mind, McKenzie was also in the right place at the right time to help the introduction of "History of Science" as a GCE examination subject.

At the present time (1980) the Cambridge Syndicate and the Oxford and Cambridge Board are negotiating with a view to setting a joint syllabus and examination paper in 1982.

43. A recently-published obituary of Prime (who died in 1969) is to be found in Watsonia, Vol.13 (1980), 67-70. It is written by one of his former pupils at Whitgift, Dr. J.F.M. Cannon, Keeper of Botany at the British Museum (Natural History). There is also an obituary in The Whitgiftian.

44. Correspondence with the author.

45. The Times, 27 September 1969.

4.3 History of Science in General Studies⁴⁶

"[Between 1962 and 1964 History and Philosophy of Science]... has gained an established place in the curriculum of Grammar schools in this country ... something like a quarter ... are teaching the subject, mainly as a part of some General Studies programme in the sixth form".⁴⁷

General Studies became an important feature in the curriculum of the English secondary school in the 1960s, initially as a sixth-form study and later as a study extending from the middle school upwards. Although many teachers have supported the view that General Studies courses should not be examinable, its development as a GCE examination subject gives a good indication of its growth in the schools. In 1959 the Northern Universities Joint Matriculation Board (JMB) introduced a General Studies A level examination.⁴⁸ In the first year this attracted 1,537 candidates; this number more than doubled two years later, and increased to such an extent that by 1977 General Studies became the subject with the largest entry at A level for the JMB examinations; in 1976 it was taken by

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46. The term "General Studies" has been used in a variety of senses and is often considered synonymous with terms such as liberal studies, humanities, complementary studies, and foundation studies. The General Studies courses considered in this investigation are those programmes of work devised, among other things, to mitigate the effects of specialisation by giving pupils some knowledge of achievements in spheres other than those studied for A level, and by setting specialist subjects in a wider context. Many schools have long included such a liberalising element in their curriculum. The present section, however, is mainly concerned with happenings in the sixth forms since the late 1950s.
47. T.F. Wheatley, The History and Philosophy of Science Newsletter, No.4, 1964, p.2.
48. 1951 saw the replacement of School Certificate and Higher School Certificate examinations, which "grouped" subjects, by the new GCE examination, with no grouping requirement of any kind; it also saw the abolition of the subsidiary level examination, described as "a sort of half-way house" between School Certificate and Higher School Certificate. In that same year the Joint Matriculation Board introduced an

24,268 candidates out of a total of 52,050 for the JMB examination as a whole. By 1977 General Studies was offered at A level by three of the eight GCE examination boards, with two other boards planning future General Studies A level syllabuses; as an Alternative O level subject it was offered by five of the boards. Its growth as a GCE examination subject is in marked contrast to the "History of Science" subjects.

Strangely enough impetus was given to the General Studies movement in the late 1950s and 1960s not only by the "two-cultures debate" of that time, but also by both supporters and opponents of specialisation in education. The Crowther Report,⁴⁹ while supporting the principle of specialisation referred to "minority time", a portion of the school week given to non-specialist subjects. One of the purposes of this minority time was "to ensure the literacy of science specialists and the numeracy of arts specialists". On the other hand, a Secondary Schools Examinations Council report of 1960⁵⁰ spoke of a situation in the schools where "specialisation [was being] carried to a point at which general education [was] in jeopardy" and brought out the "urgency of the need for remedial action". Thus from the onset General Studies programmes were aimed at broadening general education and countering excessive specialisation. Specialist studies were to be set in a wider context; science specialists

48. Cont. Alternative Ordinary level General Paper as an attempt to bridge the gaps of the new examination. It was intended to provide a sixth-form examination at O level which would complement the main studies of the post-16 year old pupils. It was the success of this General Paper which eventually led in 1959 to the JMB General Studies A level examination (see General Studies Association, General Education, No.28 (1977), p.155ff).

49. Report of the Central Advisory Council for Education (England) entitled '15 to 18' (Crowther Report), 1959.

50. Min. Educ., Secondary Schools Examination Council, The general certificate of education and sixth-form studies, London, 1960.

were to be given an overall and cultural view of science; arts students were to learn something about science.

There is little doubt that history of science courses frequently appeared in the General Studies programmes of the 1960s. Some schools used the GCE "History of Science" examinations as a component of General Studies courses.⁵¹ A Schools Council publication of 1969, categorizing the main approaches used by teachers, stated "Most common are courses based on familiar disciplines, sometimes extending them on to unfamiliar ground, e.g. ... history of science ...".⁵² More detailed evidence for the frequency of history of science courses comes from several surveys carried out during that decade. One survey of thirty-eight schools with "well developed General Studies courses" showed that history of science courses were by far the most frequently occurring of the general education courses.

History of Science courses in 16 schools
Survey of Science courses in 8 schools
Basic Principles of Science courses in 8 schools
Methods of Science courses in 7 schools
Science and ... courses in 6 schools
Philosophy of Science courses in 4 schools
Depth Studies in 3 schools
Project work in 1 school
'O' level course in 1 school
Practical course in 1 school

Some schools, as will be apparent from the figures, offer more than one of these alternatives. Some of the courses are run for all sixth-formers, others are limited to the arts sixth and yet others are run as optional courses for all or part of the sixth form.⁵³

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51. See, for example, Desmond Lee, "General Studies at Winchester College", J. Brierley (ed.), Science in its context, London, 1964, p.31ff.
52. Schools Council, General Studies 16-18, Working Paper, No.25, London, 1969, p.9.
53. J. Baker, Science in Sixth-Form General Studies. A General Studies Association Occasional Publication, Reference No. L/13/67, 1967, pp.6-7.

A more detailed survey carried out in 1969 again placed history of science high on the list.⁵⁴ An analysis of the recommendations from senior staff in the same survey concluded "The most favoured courses are history of science, survey of present-day science ..."

<i>Types of course</i>					
	<i>Physicists (73)</i>	<i>Biologists (76)</i>	<i>Chemists (71)</i>	<i>Unclassified (34)</i>	<i>% of total mentions</i>
Survey of science	32	29	29	15	15
Recent discoveries	7	15	9	6	6
Basic science	2	6	3	2	2
Depth study	9	5	5	6	4
Science and . . .	12	19	16	8	8
Bridge study	8	10	6	6	4
Projects	29	23	27	13	13
Methods of science	20	30	21	13	12
Philosophy of science	26	28	25	14	13
History of science	41	29	29	12	16
Science in everyday life	3	9	9	1	3
Others	7	7	7	2	4
Different courses for arts and science sixth-forms	28	23	25	11	—
<i>Topics</i>					
	<i>Physicists (73)</i>	<i>Biologists (76)</i>	<i>Chemists (71)</i>	<i>Unclassified (34)</i>	<i>Totals (254)</i>
Energy	14	10	9	4	37
Cosmology	9	5	2	1	17
Space	8	10	5	1	24
Astronomy	7	2	6	3	18
Relativity	4	0	0	0	4
Nuclear physics	18	8	7	4	37
Communications	8	3	5	2	18
Technology	10	9	5	3	27
Case studies in history	7	4	4	1	16
Hist. and phil. of science	11	6	10	8	35
Methods of science	5	7	5	9	26
Nature of matter	6	1	5	0	12
Synthetic materials	4	6	17	0	27
Medicine and drugs	3	13	9	3	28
Genetics and evolution	12	38	11	6	67
Social biology	8	36	8	5	57
Psychology	0	5	2	2	9
Human biology	1	10	6	4	21
Bacteriology	0	10	5	0	15
Science and ethics, etc.	6	5	6	2	19
Engineering projects	3	0	4	0	7
Others	17	27	20	10	74

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54. J. Baker, "A Survey of the position of general studies science", Bulletin of the General Studies Association, No.15 (Summer 1970), pp.22-38.
55. J. Baker, "Survey of attitudes to general studies science", School Science Review, 51 (1969), 176-83.

A survey by D.E. Newbold⁵⁶ concluded that history of science was extensively taught in the sixth-forms of English schools, especially in the north of England and closely associated with the JMB General Studies examination. By "extensively" Newbold specified 25% of the schools.

The quantity of history of science taught in General Studies in the 1960s gave some satisfaction to its advocates. However, evidence seems to suggest that on the whole history of science was not well taught, and that it did not help pupils to understand science. Evidence on the help history of science gave in pupils' understanding of science comes from Newbold's investigation into general scientific education in sixth forms. Newbold claimed that there was "an advance in 'scientific understanding' gained by non-scientist sixth form students in schools associated with the A level examination in general studies ...".⁵⁷ But when it came to examining the success of history of science in meeting this end he tentatively concluded that such courses did not achieve very much. He did point out however that the lack of success might be due to the limited number of teachers qualified and available to teach history of science in the schools. It does seem self-evident that if history of science was not well taught, and this surely is related to the number of teachers qualified and available to teach history of science in the schools, its chances of fulfilling assigned roles would not be great. An analysis, made in 1963 by R.A.C. Oliver, of candidates' answers to history and philosophy of science questions in the 1963 JMB General Studies examination, gave little cause for satisfaction in the quality of the teaching. Professor Oliver reported that there was "ample evidence that few candidates have studied the history of science as a human endeavour". Historians had a sense of chronology but knew insufficient science to fit it in to their periods. Non-historians lacked this sense of chronology; they had "difficulty in

56. D.A. Newbold, Student Understanding of Science and Scientists. Unpublished thesis for the degree of B. Letters, University of Oxford, March 1969.

57. As in note 56 above, p:160.

distinguishing the seventeenth century from earlier and later periods ... Newton, when mentioned, was usually assigned to the period, but so might almost anyone be, from Aristotle to Darwin". Oliver showed that the teaching was uncritical with gross oversimplification and with the perpetuation of myths.

"One of the examiners hardly parodies the answers when he writes: 'Galileo invented the telescope (and/or microscope) and so proved that the earth goes round the sun. For this he was burnt by the Inquisition and so started the Reformation (and/or Renaissance)'. ... Darwin and evolution ... (were) greatly oversimplified; men were descended from apes and Genesis was therefore disproved or alternatively remained firm as an acceptable parable: as in the seventeenth century, black reaction was opposed to martyred enlightenment".

Candidates had little understanding of the philosophy of science.

"Whatever may be meant [by philosophy of science]... science ... consisted of an assortment of established answers, of 'facts' ... The facts and theories of science are unrelated to their historical and cultural setting ... If one thinks that the history and philosophy of science or both should be learnt by Sixth Form pupils, one must be disappointed ... except in a few schools these subjects have not been taught, and in fewer schools has the teaching achieved much".⁵⁸

A sample of the JMB General Studies A level history of science questions and examiners' reports, taken from more recent years, reveals that the situation has changed little since Oliver's analysis. In some schools there is an interest in the history of science and apparently the teaching is good, but in many more schools seemingly it is neglected or badly taught. The lack of widespread teaching in that subject is typified by the comments on the 1976 and 1973 examinations. "Although the history and methods of science might be expected to feature in many general studies courses question 2.6 was largely avoided" (1976). "Question 6 (scientific methods) was more rarely attempted and answers tended to be poor" (1973). Yet both questions mentioned were quite predictable and even generous for pupils

58. R.A.C. Oliver, "History and Philosophy of Science in the Joint Matriculation Board General Studies Examination", Bulletin of the General Studies Association, No.6 (Autumn 1965), pp.30-33. Oliver was Professor of Education at Manchester University from 1938 to 1970. During the same period he was Dean of various faculties. On his retirement he was appointed Emeritus Professor.

well taught in history of science:

1976 Paper 1, Question 2.6

Choose one of the following scientists and assess his contribution to knowledge in the stated field, paying particular attention to previous work in the field connected with his own contribution.

- a) Newton and cosmology; b) Faraday and electricity;
- c) Lavoisier and Chemistry; d) Harvey and human physiology;
- e) James Watt and mechanical engineering.

1973 Paper 2, Section 3, Question 6

What are the characteristics of those methods of enquiry which you would consider to be scientific?

Choose one of the following or any other normal scientist and assess the extent to which his research was in this sense scientific.

- a) Aristotle; b) Lawrence Bragg; c) Darwin; d) Faraday;
- d) Galileo; f) Lavoisier; g) Pasteur.

The lack of sense of chronology was still obvious. "... some uncertainty on the relative positions on the historic time scale of well-known inventions and inventors" (1974). "Some good answers ... but many failed to provide an adequate historical perspective ..." (1975). The variable quality of the teaching comes over time and time again, typified in the 1971 report. "There were a few good accounts ... There were, however, many disappointing answers amounting to little more than assorted items from the history of science".⁵⁹

The 1970s have seen the character of many General Studies courses change. This is partly because of the emergence of a more "comprehensive" sixth form with a significant number of those pupils repeating O level subjects, and partly because of the concern over the environment, pollution, and the social responsibility and impact of science. History of science is still mentioned in General Studies syllabuses and history of science questions still appear on examination papers. But the indications are

59. Joint Matriculation Board, Examiners' Reports: General Studies A level, 1969-79.

that the history of science taught as part of general studies programmes is not widespread, and probably the overall quality of the teaching is still open to considerable improvement.

4.4 The American influence

"... a man who has been a successful investigator in any field of experimental science approaches a problem in pure or applied science ... with a special point of view. We may designate this ... 'understanding science' ... [a convenient and practical way of giving the layman this understanding of science is to take him] ... back to certain events in scientific history ...".⁶⁰

It has been argued that in the nineteenth century and in the first half of the twentieth century developments in the UK and the USA have paralleled, but been largely independent of each other. There can be little doubt however that in the post-war period work in America did influence the thinking and some of the changes that came into the British schools. The efforts of J.B. Conant and those at Harvard University in the decade following the war was of particular importance both in America and in Britain to the subsequent reforms of the science curricula and for the use of history of science in general education.

Teaching for understanding, perhaps the major feature of the Nuffield science reforms, was a key component in Conant's philosophy; in this he was neither original nor unique. But more obvious and certain was Conant's influence on the Oxford and Cambridge Board "History of Science" examination, and on the history of science included in the General Studies courses in Britain, which frequently made use of the case history method. British teachers were quick to acknowledge as their inspiration James Conant, who gave the first detailed discussion on the use of historical case histories in the teaching of science,⁶¹ who acted as general editor

60. J.B. Conant, Science and common sense, London, 1951, pp.3-5.

61. See J.B. Conant, On understanding science: an historical approach, Yale University Press, New Haven, 1947.

for Harvard Case Histories, and who stimulated Klopfer's History of Science Case Histories for High Schools.⁶²

J.B. Conant, by turn a research chemist, university teacher, administrator, and in later life a diplomat, was President of Harvard University from 1933 to 1953. There, deprecating too narrow a specialisation, he introduced measures to bring greater flexibility into the curriculum and more collaboration between the departments. Conant came to believe that to be well informed about the facts and findings of science was not necessarily the same thing as understanding science. To understand science he believed that students should have a feel for, and an appreciation of certain principles and aspects of what he called the tactics and strategy of science. These aspects included the complex interplay between experiment, observation, and the development of new concepts; the difficulties attending new advances in science, and the importance and influence of new techniques; the difficulties of experimentation and the significance of controlled experiment; the role of accidental discovery in science; the necessary fumbblings of intellectual giants at the frontier of knowledge; and the interactions between science and society. To achieve this understanding Conant recognised the existence of what he called the logical approach in which the current products of scientific activities are dissected "with the hope of revealing the structural pattern and exposing the logical relations of the component parts". But the approach he favoured for the layman at college level was a detailed study of a few relatively simple historical case histories as examples of the development of science. Although he knew that the case history method was used in law schools and in the Harvard Business School, he freely admitted that he had no first-hand experience with this type of teaching and no awareness of its use in scientific education elsewhere. Conant came out in favour of historical case histories because he believed

62. J.B. Conant, (ed.) Harvard Case Histories in experimental science, Cambridge, Mass., 1957; and Leopold E. Klopfer, History of Science Case Histories for High Schools, Chicago, 1964.

that the phenomenal material of the earlier centuries was relatively simple and that the students would require relatively little factual knowledge of the sciences. He also believed that the early days of a science show most clearly the necessary fumbblings of the intellectual giants; a knowledge of these fumbblings should he thought dispel the notion that science can be reduced to following glib precepts and set procedures. When writing case histories Conant advocated that they should have a restricted time base and almost all be chosen from the early days in the evolution of the particular discipline; by early days Conant specified the seventeenth and eighteenth centuries for physics, the eighteenth and nineteenth centuries for chemistry, the early nineteenth century for geology, and the eighteenth and nineteenth centuries for biology. The case histories, Conant believed, should be chosen from as many areas in the whole field of accumulated knowledge as possible provided that they met certain criteria. These were that the field in question was one where there had been substantial progress over the previous century or so, the progress should be in terms of changing concepts and evolving conceptual schemes, and one or more principles of the tactics and strategy of science must be conveniently illustrated.

Conant's case history method was not accepted by all. One critic, Michael Yudkin, attacked the method as being incomplete in the most vital part of science. "The moments of discovery are the most important in science ... An undergraduate whose understanding of sciences lacks any experience of discovery will have only a skeleton in his grasp".⁶³ Yudkin also correctly made the point that published papers were composed with the benefit of hindsight, usually ignored inconclusive experiments, false starts and wrong turnings, and tended to rationalize the discoveries of science and the progress of scientific investigation. As we have seen,

63. M. Yudkin (ed.), General Education. A symposium on the teaching of non-specialists, Harmondsworth, 1969, p.147. See also George Basalla, "Science, Society and Science Education" in Bulletin of Atomic Scientists, (June 1968), 45-8 for another attack.

Conant himself had pointed out that case histories show that science is far from a routine and mechanical activity. But the type of criticism made by Yudkin raises an absolutely fundamental question about school science courses. Can they, indeed should they, really ever be more than simulation exercises?

Notwithstanding the doubts and criticisms, it can safely be asserted that Conant's writings on the case history method were well known and discussed in Britain, and used in the general studies programmes. The Association for Science Education publication Science in sixth form general education⁶⁴ stressed that the use of case histories from the history of science was an important method for the study of the growth and influence of science and for giving humanity to courses. The document gave, as detailed suggestions for courses, eight themes in which considerable use was made of history of science. A theme considered of primary importance, "The nature of scientific thought", listed ten possible case histories and named Conant as a source of material. When Harvard Case Histories were reviewed in School Science Review they were recommended as highly suitable for general studies programmes. Several case histories were written for that journal. Batley Grammar School was among many schools who used the case history method.⁶⁵ In 1972 three case histories intended for use in sixth forms were published.⁶⁶ Their editor, W.H. Brock, was very much alert to the writings of Conant and to Klopfer's case histories. Perhaps one great attraction of the case history method was that it made fewer historical demands on the teacher. The limited time-base, a feature of case histories, meant that a teacher who had an interest in history of science but relatively little knowledge could more readily acquaint himself with the necessary teaching material.

64. ASE, Science in sixth-form general education, London, 1963.

65. A.J. Flintham, "Scientific general studies at Batley Grammar School", Bulletin of the General Studies Association, No.14 (1969-70) pp.42-6.

66. W.H. Brock (ed.), Case histories in science, 3 vols, Amersham, Bucks, 1972. (W.H. Brock, M. Chapple, M.A. Hewson, Studies in Physics; N.G. Coley, Studies in Chemistry; Dale L. Ross, Studies in Biology).

Chapter 5

HISTORY OF SCIENCE IN THE REFORMED CURRICULA

5.1 Towards the Nuffield Reforms

"I am pleased to announce that the Nuffield Foundation has decided to make available £250,000 towards the cost of a long-term development programme to improve teaching in these [science and mathematics] subjects ... the detailed work will be carried out by practising teachers under the guidance of specially appointed full-time Nuffield Fellows ...".¹

This statement, given in April 1962, by the Minister of Education to the House of Commons, publicly announced the setting up of the Nuffield Foundation Science Teaching Project.

In Britain the decades leading up to the 1950s had seen a large growth in the number of pupils studying General Science, and had seen the position of biology enhanced in relation to physics and chemistry. But by and large these decades had been a period of stability for science curricula in the grammar school. Science courses were mainly academic and self-contained; they did occasionally contain some "useful" science, but generally gave little or no consideration to social problems and the responsibility of science to society. By the early 1950s however many people were critically examining such syllabuses and making suggestions for reform. Despite such suggestions at that time there was more concern in Britain over the shortage of science teachers than over curriculum reform. The National Advisory Council on the Training and Supply of Teachers commented several times in the early 1950s both on the shortage and on the quality of science teachers. The Committee on Scientific Manpower, appointed by the Advisory Council on Scientific Policy, published in 1952, a report which stated "The inadequate supply of good science teachers is giving serious concern".² Letters from university education

1. M. Waring, Social Pressures and Curriculum Innovation, London, 1979, p.2.

2. Quoted in E.M. Williams and N.M. Brown, "Reflections on some problems of training science teachers", School Science Review, 36 (1954-5), 164.

departments to the Times Educational Supplement reported on the difficulty in recruiting intending science teachers. Such concern had led the General Committee of the SMA, at a meeting in March 1953, to institute an enquiry into the general conditions affecting science teaching in the grammar schools.³ At the 1954 Annual Meeting of the Scottish branch of the SMA, Professor A. Rex Knight noted that several influential people had suggested that the abolition of science from the secondary school was a possible way of dealing with the shortage of science teachers.⁴ Clearly, faced with such an extreme solution, there was more preoccupation with preserving the position of science in the schools than with curriculum development.

By the late 1950s, however, attention in Britain had become focused on reforms of the curriculum. The Advisory Council on Science Policy said in its 1959-60 report.

"We have no doubt that school science curricula are in need of a thorough re-examination. They tend at present to be unimaginative and to be overloaded with factual material (in part as a result of the tendency to keep adding new material without removing the old). It has been suggested to us that up to 20 or 30 per cent of the curricula in physics, chemistry and biology could be removed without harm - and indeed with benefit".⁵

In November 1957 the SMA and AWST⁶ had published a preliminary Policy Statement on science and education which was widely distributed and discussed. This resulted in a modified full report, Science and Education, appearing in 1961 together with syllabuses for biology, chemistry, and physics. Science and Education, which interpreted contemporary "scientific illiteracy" mainly as the result of a lack of understanding of the basic nature and aims of science, made a strong plea for the cultural claims of science.

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3. K.M.H. Chapman and E.H. Coulson, "An enquiry into the conditions affecting science teaching in grammar schools", School Science Review, 35 (1953-4), 168-77.
 4. A. Rex Knight, "Recent Researches into the Teaching of Science", School Science Review, 36 (1954-5), 112.
 5. Advisory Council on Scientific Policy, Annual Report 1959-60 London, 1960, para.46.
 6. The Association for Science Education, at present the most significant association for science education in schools, was formed in 1963 by the merger of the Science Masters' Association and the Association of Women Science Teachers.

"Science should be recognised - and taught - as a major human activity ... schools have the duty of presenting science as part of our cultural and humanistic heritage ... we stress the cultural aim here because science has not yet been given its proper place in general education".⁷

The report recommended that up to the end of their fifth-form year all pupils should follow a balanced course of science subjects. In the sixth form there should be two types of science courses; a broad science course designed for all pupils, and the traditional specialist science courses. Details of the suggested courses were given in accompanying documents for physics, biology, chemistry, physical science and general education. While the proposed specialist science courses were not quite as revolutionary as suggested by their authors, and hardly presented science as a major cultural activity, they did make some use of history of science. For example, among the historical suggestions for the physics courses were an historical approach to heat, some history of astronomy, and historical ideas relating to atomic structure.

Science and Education formed the basis of a proposal to the Nuffield Foundation which at that time was actively considering support for research in education. The outcome was the formation of the Nuffield Foundation Science Teaching Project.⁸ By this time the science curriculum reforms in the USA were well underway.

5.2 Reforms of science curricula in the USA

"If, like that extraordinary bird, the Phoenix, the American School system could consume itself in flames and emerge anew, cleansed and perfect, there would have been no need for this Conference ... What concerns us here is that one of the areas of pending failure, at a time when success is most vital, is secondary school science teaching".⁹

7. SMA and AWST, Science and Education, London, 1961, p.5.

8. Full details of the background to this project are given in Mary Waring, as in note 1 above.

9. Conference on Nationwide Problems of Science Teaching in the Secondary Schools, Critical Years Ahead in Science Teaching, Harvard University Printing Office, Harvard, Mass., 1953, p.7.

So opened the Report of the Conference on Nation-wide Problems of Science Teaching in the Secondary Schools. This conference, proposed by James Conant and held at Harvard University in 1953, included as its members science supervisors of states and large cities, professors responsible for training and aiding science teachers, and a representative of the US Office of Education. Clearly there was a reaction against the prevailing science teaching well before the 1957 launching of the Soviet Sputnik.

The American curriculum reformers of the 1950s had many objections to the contents of their existing courses and the way they were taught. They believed that traditional courses presented science as a body of static, certain and verified information; the probabilities, incertitudes and revisionary characteristics of science were largely ignored. They saw an emphasis on describing what was known, rather than on how it was known; upon answering questions rather than on deciding what questions to ask; upon presenting an anthology of achievements rather than on presenting a human activity. The reformers believed that school science did not reflect science as science was known to scientists, that it did not provide students with a valid understanding of the true nature of science. The laboratory work associated with the established science courses was criticised for being little more than a series of exercises recording uninterpreted observations, verifying the known, and producing a right answer if the directions had been followed correctly; although it could develop manipulatory skills it neither helped in understanding the underlying scientific concepts nor in encouraging systematic thinking. The factual content of the courses was criticised for frequently being out of date and trivial, and for being made up of an unconnected conglomeration of scientific facts lacking in overall themes and conceptual unity.

The response made by the reformers to such criticisms was to develop courses which had more conceptual unity; they contained modern ideas and discoveries; more concern was shown for the procedures of science with

attempts made to give an understanding of the nature and processes of science; emphasis was placed on learning by doing with pupils expected to act and think in the way of practical scientists by doing experiments and testing theories. The humanistic, cultural and social aspects of science were often mentioned among the specific objectives of the courses. Thus students were expected to learn the substance of science, the mature concepts, theories and facts, at the same time as learning the nature, processes and procedures of science. The courses that emerged in the first phase of the reform¹⁰ presented the sciences as self-contained disciplines, studied largely as ends in themselves, with the practical applications of science and their relevance to social problems and everyday life largely ignored.

The first American venture was PSSC Physics, which began in 1956. This was followed by a plethora of other courses.¹¹

5.3* History of science in selected American courses

The courses considered in this investigation which received publicity in Britain were devised for students in the USA corresponding roughly in age to British GCE O level pupils, and had a potential influence on the later British reforms. They are Physical Science Study Committee (PSSC Physics), Chemical Education Material Study (CHEM Study), and Biological Sciences Curriculum Study (BSCS).¹² No exact parallel can be made between

10. In the USA a second phase of curriculum development began about the mid-1960s. The criticisms of the new first phase science courses that were emerging and some of the responses made are discussed in Paul DeHart Hurd, New Directions in Teaching Secondary School Science, Chicago, 1969, (Third Printing, 1971), p.47 ff. See also George Basalla, "Science, society, and science education", Bulletin of Atomic Scientists, 24 (1968), 45-8.

11. Details are given in Hurd, as in note 10 above.

12. By 1970 these courses existed in several different versions and editions. In 1968, for example, three revised versions of the original CHEM Study were produced. The history of science discussed is based on the original versions.

these three courses and the Nuffield O level physics, chemistry, and biology schemes. The British courses were designed for the top 15-20% of academic ability, the American for a much wider ability range; the Nuffield courses were intended to be taught over the full five years of the secondary school (or exceptionally three years), the American over one or two years; the courses were structured differently. Nevertheless in several respects they can be regarded as equivalent: they were designed as basic introductory courses in these disciplines for secondary school pupils; there was a good deal of similarity between the selection and presentation of many of the topics; the underlying educational rationale was to all intents and purposes identical.

5.3.1 PSCC Physics Project

The PSCC Physics project started in 1956 with a grant from the National Science Foundation. Under the leadership of a steering committee research physicists and physics teachers outlined, drafted and discussed many ideas. This led to material which was tried out in schools from 1957 onwards. A final version of the course was submitted to the publishers in 1960.

The heart of the course is a text book which presents physics not as a mere body of facts but basically as a continuing process by which men seek to understand the nature of the physical world. It attempts to provide, at the introductory level, a conceptual framework of contemporary physics showing how physical knowledge is acquired experimentally and woven into physical theory. The conceptual unity comes from four closely interconnected parts: the universe, optics and waves, mechanics, and electricity and atomic structure. It was hoped that the students would be led to realise that physics is a single subject of study, and to learn the "qualities of physics as they are known to physicists".

Specific objectives inherent in the PSCC course are the recognition of "physics as a cultural element", the understanding of "physics as a human activity", and the appreciation of the "historical background of

physics".¹³ The text book Physics¹⁴ briefly mentions some historical matters in its opening chapter and has a short look back on the history of the idea that heat is energy. But the only part of the book with any significant quantity of historical material is the chapter on "Universal gravitation and the solar system". In this man's solution to the problem of planetary motion is developed in an historical context. It begins with the ideas of the ancient Greeks, leads to a discussion of how Kepler built on the work of Copernicus and Tycho Brahe, and considers Newton's many contributions to this field of study. The historical writing throughout this chapter is "internalist". Perhaps this is not surprising in view of the post-war American attitude towards Communism and the simplistic association between the externalist approach and Marxism. In the main the writing is completely descriptive, relating what was done and suggested by various figures in the past. No attempt is made to set the description into its contemporary social, political or economic background; even the contemporary intellectual background is scarcely mentioned. An historian of science, Bernard Cohen, is acknowledged as having "read successive drafts and supplied historical material". Clearly the influence of James Conant was being felt in this first of the science reforms for Cohen, who was the first person in the USA to receive a PhD in the history of science, had worked for his doctorate under the direction of Conant.

Outside this "heart of the course" a series of books, The Science Study Series, was published as supplementary reading. Some of these books, including The Birth of a new Physics, Michelson and the speed of light, and Pasteur and modern science¹⁵ contained much historical matter. But the series as a whole did not attempt to give a complete background

13. Hurd, as in note 10 above, pp.188-9.

14. Physical Science Study Committee, Physics, D.C. Heath and Company, Boston, 1960.

15. I.B. Cohen, The Birth of a new Physics; Bernard Jaffe, Michelson and the speed of light; René Dubos, Pasteur and Modern Science. All were first published in Great Britain in 1961 by Heineman Educational Books Ltd.

to the history of physics.

The authors of Physics do assert that a study of science cannot be divorced from a study of history of science, and believe that an historical study can help in the perception of scientific principles. But they give no reason why the history of astronomy is considered especially relevant to the course.

5.3.2 Chemical Education Material Study (CHEM Study)

CHEM Study was devised as a one-year High School introductory chemistry course aimed at about eleventh grade students (about sixteen/seventeen year olds). The basic ideas for the project were outlined by a Committee established in 1959 by the American Chemical Society; this committee was composed of College and High School chemistry teachers. The approach recommended by CHEM Study was that important concepts and generalisations in chemistry should be developed inductively, and based on data gathered as far as possible by the student in the laboratory. The emphasis was to be on the experimental nature of chemistry. The first drafts of the scheme were written in 1960. These were followed by school based trials and revisions with a final version appearing in 1963.

The Steering Committee of the project objected to the existing chemistry courses on several counts. These included the preoccupation "with having students memorize a great deal of chemical history, descriptive detail, and technology, much of which was out of date and/or relatively unimportant".¹⁶ As a deliberate policy little history of science was included in the course. The opening chapter of the text book discussed the nature of science: here it was felt that the student would be more aware that he was preparing for the problems of today rather than of Dalton's time if history was excluded. In the second chapter the atomic theory was used

16. R.J. Merrill, The CHEM Study Story, San Francisco, 1969, p.26. Merrill's book gives an account of the history of the project. In it little mention is made of the use of historical material; no comment is made on the discussions which led to the deliberate policy of disregarding historical material.

as an example of a scientific model, but it was believed to be unhelpful to drag the student through "half a century of confusion", and stated that there were better ways of teaching this material. "Freeing the development of the atomic hypothesis from chronology makes it possible to use the simplest and most easily grasped presentation of the logic by which chemical evidence supports the atomic theory".¹⁷ The Bohr planetary model of the atom was omitted from the development of atomic theory "because it is primarily of historical interest and is no longer useful to chemists".¹⁸ The only use made of history of science is to show the transient nature of scientific laws. In a short section (in Chapter 15) history is deliberately used to show the development of our understanding of energy.

The project team showed that they were aware of the arguments in favour of the case history and historical presentation methods of teaching chemistry.¹⁹ They accept these methods as valid and use an apologetic tone to explain the exclusion of history of science from the course. The CHEM Study project seems to have been dominated however by university professors and research chemists who built a course on what they saw as the requirements for a professional chemist; and apparently they believed that a professional chemist requires no knowledge of history for his work. Interestingly in the project "No attempt was made to include professors of education or curriculum specialists" and one high school contributor was "not sure how much experience our college people had had with high schools and high school students".²⁰ This is the one project that makes little mention of the humanistic, cultural and social aspects of science.

17. CHEM Study, Teacher's Guide for Chemistry, An Experimental Science, San Francisco, 1963, p.77.

18. R.J. Merrill, as in note 16 above, p.31.

19. CHEM Study, as in note 15 above, p.77.

20. R.J. Merrill, as in note 16 above, p.10.

5.3.3 Biological Sciences Curriculum Study (BSCS)

BSCS began its activities in 1959 under the sponsorship of the American Institute of Biological Sciences. As it was believed that there was no one point of view about biology as a science it was decided to prepare three courses in high school biology; each would have a different emphasis and approach, but each would represent a valid interpretation of the science of biology. Following the pattern of the other courses material was written, tried out in schools, and rewritten to produce text books by 1963. The Yellow Version Biological Science and Inquiry Into Life was the classical approach to biology with its emphasis at the cellular level; the Green Version High School Biology placed the emphasis at the community level with an ecological-evolutionary approach; the Blue Version Biological Science: Molecules to Man had the emphasis at the molecular level with a physiological-biochemical approach.

Each of the three versions had the same goals and objectives and not unnaturally a considerable degree of overlap in topics. Among the specific objectives was to provide the student with an "understanding of the historical development of biology with examples of concepts to show how these are related to contemporary techniques, technology, and the nature of society".²¹ To achieve this, frequent references are made to historical figures and ideas throughout the text books. Taking the Blue Version as a sample, out of a total of 669 pages, something historical is mentioned on nearly ninety pages (13%). The mention is usually brief but tries to give four things. (1) A realistic view of scientists and science; (2) that scientific knowledge is built upon the work of many men and over long periods of time; (3) the development of biological concepts; (4) the part played by chance and intuition in research.²²

21. Hurd, as in note 10 above, p.155.

22. BSCS, Biological Science: Molecules to Man. Teacher's Guide, Boston, 1963, p.249.

The course team does not define what it means by "a realistic view of scientists and science" and makes no strong links between this and "the part played by chance and intuition". Most of the historical examples used are quite straightforward descriptions of experimental work carried out by various people. One interesting and unusual (for British audiences) example quoted is of Alexis St. Martin's stomach. Apparently in 1822 Alexis St. Martin, a trapper, had part of his ribs and stomach wall torn away by the accidental discharge of a shotgun. A doctor in the United States Army, William Beaumont, attended to the man but the wound did not close properly. As a result, there was a hole in the side that led to the interior of the stomach. Bandages had to be left over the hole to prevent food from falling out. Beaumont persuaded St. Martin to remain with him and for about eleven years studied the interior of his patient's stomach.²³ It is not history of science, but it is an anecdote that pupils will remember; properly used such material can motivate and stimulate interest. To show that "scientific knowledge is built upon the work of many men and over long periods of time" the development of concepts fairly frequently starts with the Greeks. The biological concepts considered historically include biogenesis, cell theory, and evolution. Books on the history of biology and scientific biographies are often mentioned as supplementary reading.

5.4 Nuffield Projects

The Nuffield Foundation, set up in 1943, was the last of a series of gifts to public causes given by Lord Nuffield. With an initial endowment of £10m and wide terms of reference, the Foundation had quite considerable freedom in the projects it could choose to support. Its support for the History of Ideas Unit came after an approach from Professor Stephen Toulmin,

23. BSCS, Biological Science: Molecules to Man, Boston, 1963, pp.499-501.

support for the Science Teaching Project after an approach from the ASE. The Science Teaching Project was to be aimed at every science subject at school level, and have a coherent overall pattern and coordinated objectives. It was decided, however, to concentrate in the first instance on O level courses in physics, chemistry, and biology. Following the 1957 and 1961 Policy Statements the science teachers' associations had carried out a good deal of work in developing syllabuses for these areas. As they were generally agreed to be satisfactory these syllabuses were to form the basis of the Nuffield courses. Accordingly teams were set up in 1962. Following the American pattern the next several years saw discussions, drafts produced, and trials in schools. The first materials for the O level courses were published in 1966. The History of Ideas Unit however operated on a far smaller scale.

5.4.1 The Nuffield Foundation Unit for the History of Ideas²⁴

The Nuffield Foundation Unit for the History of Ideas was set up by the Trustees for an experimental period of three years beginning on 1 July 1960 with a grant of £60,000. Its aim was to produce a basic collection of teaching films and text books for use in sixth forms and introductory university courses in the history and philosophy of science: the collection was to consist of four linked volumes on The Ancestry of Science, together with a Teaching Guide and a sequence of eight to ten 16 mm films. The general idea was that the Unit should work under the aegis of the Foundation with the hope that before the end of the three-year period it would be taken over by some University.

In May 1957 Professor Stephen Toulmin, then Professor of Philosophy at Leeds University, wrote to the Director of the Nuffield Foundation. In his letter he spoke of his wish to help establish in the schools and

24. I am grateful to the Director of the Nuffield Foundation for providing access to the files of the History of Ideas Unit.

universities of Britain a recognised place for the history of science and related topics, and gave details of four projects which he believed would stimulate a greater demand. The projects were a major bibliographical index of the literature on the subject, the production of satisfactory modern editions of many of the great classics in the history of science, secondary source books suitable for use in schools and universities, and the production of history of science films. As a result of Toulmin's approach the Foundation made, in June 1957, a grant of £1000 towards the expenses of producing certain films. The first in the series was entitled "Earth and Sky" and had as its basis the solar system from Babylonian times to Newton. This film, despite some technical crudities, was well received and resulted in the Foundation making further and substantially larger grants and setting up the Unit. The plans were drawn up early in 1960. The Unit was to consist of Dr. Toulmin, Miss June Goodfield (later to become Mrs. Toulmin), a secretary-administrator and a young science graduate, and was to be under the control of a small Steering Committee. 1 July 1960 was agreed as the formal starting date.

From the outset concern was expressed that the Unit had set itself too ambitious a programme. So it proved to be. By March 1963, three months before its expiry date, the work of the Unit was so far from completion that Dr. Toulmin was looking for an extension of two to three years. Two volumes, The Fabric of the Heavens and The Architecture of Matter,²⁵ of the central text book had been issued together with three advanced monographs;²⁶ the teaching guide and the third central text were part-written; one film, "The God Within" was ready. Some practical contact had been made with the schools. In April 1962, Dr. and Mrs. Toulmin gave a Ministry of Education teachers' vacation course on the

25. S. Toulmin and J. Goodfield, The Fabric of the Heavens, London, 1961; S. Toulmin and J. Goodfield, The Architecture of Matter, London, 1962.

26. J. Goodfield, The Growth of Scientific Physiology, London 1961; S. Toulmin, Foresight and Understanding, London, 1961; D. Bohm (et al.), Quanta and Reality, London, 1962.

history and philosophy of science. According to the Ministry this was "a most notable success". In addition, the Unit was backing a newsletter for schools, The History and Philosophy of Science, edited by the senior physics master at St. Paul's School, T.F. Wheatley; the Unit had organised experimental showings of its film to schoolchildren, and had corresponded with schools about its work. However, prospects of links with a university were not promising, and no links were sought with the British Society for the History of Science. Despite a good deal of canvassing, Dr. and Mrs. Toulmin had not found any institution whose financial position allowed it to take over the Unit. There were, however, indications from the University of Sussex, where the Leeds historian Asa Briggs had become in 1961 Pro Vice-Chancellor, that at some future time it might be in a position to do this. Faced with the prospect of closing down the Unit, its work only partially completed, the Trustees of the Nuffield Foundation agreed to a further grant to keep the History of Ideas Unit in being for another year.

By mid-1964 the initial programme of books and films "was three-quarters completed". Three further films - "Time Is", "The Perfection of Matter", and "The Perception of Life" - had been completed and released; The Discovery of Time (1965), the third volume of the text book, had been written and sent to press; more monographs had been produced. What remained was the final volume of The Ancestry of Science ("Science and its Environment"), a final batch of four or five films, and several monographs. On the university front it appeared that there were prospects for absorbing the work and staff of the Unit into the University of Sussex, although the grants of that institution were not sufficient to permit it to accept full financial responsibility at that stage. Accordingly, at their July meeting, the Trustees agreed to make a final grant over two years to allow the Unit to complete its programme. The grant was made with the provision that the Vice-Chancellor of Sussex, Sir John Fulton, expressed positive interest in the proposals. During the following weeks however it became apparent that Fulton was not willing to pursue the application

to the Nuffield Foundation. As other prospects for an academic attachment for the Unit were remote, in August 1964 Stephen Toulmin accepted, as from the end of January 1965, an offer of a post at Harvard University.

The following eighteen months saw many discussions and proposals regarding the winding up of the Unit and the disposal of the balance of its grant. The most important decision for history of science in the schools however, was made when the Trustees decided to allow completion of the teachers' guide. They were quite correct in believing that

"a completed guide would greatly enhance the value of the Unit's whole output of books and films in schools, and would play a most useful part in promoting the main aim of the Unit's work - namely to make material in this field of study readily available in a form suitable for incorporation in the regular curriculum".

A certain amount of draft material had been prepared over the years and early in 1966 David Steele,²⁷ Assistant Master at Winchester College, was appointed general editor to complete the work. With the help of A.J. Joyce of Magdalen College School, D.E. Newbold of Henbury Comprehensive School, and D. Hughes-Evans of Farnborough Technical College, Steele produced a guide²⁸ which in the opinion of many school teachers was the most useful of all the History of Ideas products.

What finally appeared from the Unit was far removed from Toulmin's ideas of May 1957. Like many before him, Stephen Toulmin believed that the Arts and Sciences overlap in the history of science; this was the subject to bridge the gap for sixth-form pupils and university undergraduates. But his basic qualification was "given the requisite teaching material". The Unit certainly produced some good quality material, but it was not completely of the type he had in mind in 1957. Then he had in mind "source-books" with a commentary; in these passages from original scientific authors would be linked together by explanatory discussions to

27. Prior to 1966 Steele had worked with Mrs. Toulmin on material for the teachers' guide. His appointment as editor was on the recommendation of Dr. Toulmin.

28. D. Steele, (ed.) The History of Scientific Ideas, London, 1970.
See 4.2.4.1 and note 39.

help students to see the way ideas developed during the transition from each author to the next.²⁹ At that time he described his thoughts about films as "the most tentative and in some ways the most promising". It does seem with hindsight that, for one reason or another, too much emphasis came to be placed on the production of films. Many teachers find well-made films a great help to their teaching. But in the classroom they are passive, time-consuming if used too often, and essentially a supplement to other teaching material. Films are costly in both time and money to produce, yet here apparently was the major effort of the Unit. Moreover, it does not need hindsight to see not only that films have a limited educational value, but that resource material alone is insufficient to establish a new subject in the schools. Evidence of what teachers feel as a further requirement comes from the success of the vacation course of April 1962. Furthermore it is a pity that the final volume of The Ancestry of Science never appeared. Its plan was to deal with the relations of science to the social and cultural environment; it could possibly have become the most appropriate volume of the series in the light of present-day thinking on the role of history of science in education. But this could not have been foreseen. Nevertheless, especially after Steele's book appeared in 1970, useful source material was available for schools. But clearly having material available does not mean that teachers will use it, or even know about it. In 1972 a Royal Society investigation into the training of teachers of science and mathematics reported:

"Many teachers who have advised us feel that the history and philosophy of science, particularly its impact on society, is an essential part of the training of science teachers (indeed desirable for all teachers) and that new resource material is vital".³⁰

Did the teachers who thought "new resource material vital" know about the

29. This is effectively Conant's case histories again (see 4.4).

30. The Royal Society, The Training of Teachers of Science and Mathematics, London, 1972, p.15.

Toulmin output? Or did they think of it as inadequate? (Or, to be fair to the Unit, were they not representative of teachers interested in the history and philosophy of science?).

The Nuffield Foundation Science Teaching Project began its work some two years after the History of Ideas Unit. The three Organizers of the O level projects were all sympathetic towards the history of science. W.H. Dowdeswell had in fact been offered, and declined, a place on the Steering Committee of the Ideas Unit. H.F. Halliwell expressed a hope for "forging a close link with the work of the Nuffield Unit in the History of Ideas".³¹ Both Donald McGill and Eric Rogers were well aware of the potentialities of history of science in science courses. On the face of it there was a strong case for some form of co-operation, even at the expense of extending or modifying the aims of the Ideas Unit. Yet for some reason it seems that the Unit worked in isolation from these other projects. Perhaps it is unhelpful to speculate on reasons. But surely a lesson for the future is the desirability of seeking close co-operation between teams during periods of curriculum development.

The Ideas Unit probably gave a boost to history of science courses in the General Studies programmes in the 1960s. To a very large extent it did fulfil its original aims. But it does seem that its aims were too narrow.

5.4.2 History of Science in the Nuffield O Level Chemistry Course

Like the other Nuffield science courses, O level chemistry was concerned that teachers should encourage in their pupils the spirit of enquiry, an understanding of what science is, and an ability to interpret evidence; in short the pupils were to "be scientific". The course that emerged was one in which it was assumed that the teacher would make considerable use of a laboratory-based discovery approach. Nevertheless,

31. M. Waring, as in note 1 above, p.123.

the course team took as their starting point the assumptions contained in Science and Education. The team wanted to provide for their pupils' a general education, Chemistry was to be recognised as a product of people's activity and was to be set in its human and social context. The appointment of Organizer of the Chemistry Project went to H.F. Halliwell, a former pupil of Percy Nunn and a teacher who had made "excursions into the history of science".³² Material for the course first became generally available in 1966. Revision began in 1970/71 with R.B. Ingle appointed as General Editor; the first material for the revised version appeared in 1974. Although there are new features in Revised Nuffield Chemistry the original philosophy of a laboratory-based discovery approach with chemistry set in its human and social context was retained. One change that many teachers will welcome is the restructuring of the publications with a reduction in the number of titles from fifty to eighteen. Of especial importance to history of science is the new book Chemists in the world, half of which is historical. It replaces the series of background books.

Nuffield O level chemistry provides teachers with opportunities to introduce historical matters at various points of the course. The main occasion comes in Stage 3, the final stage. In this stage, intended to allow pupils to use and apply skills and ideas learned in the earlier stages, two options out of a possible eleven (thirteen in the original version) are studied. One of these options is Historical Topics: its

32. M. Waring, as in note 1 above, p.115.

According to Professor Halliwell he was never much interested in history of science as a school subject, but very committed to the idea of science as the outcome of personal curiosity and argument, human in origin and therefore fallible. In his schoolteaching days he "always had an anecdote or a paragraph from a diary or a comment or two about the origin of a word - perhaps a picture - (to use incidentally) ... it was an approach based on the fact that people other than themselves, in other countries or in other times have been involved...". The nearest he came to an historical treatment was to deal specifically with the development of a few ideas in the sixth form. In his thinking he was influenced by Percy Nunn and his chemistry professor, J.R. Partington, who both handled topics in a way that showed how the topics had developed throughout the activity of people over the years. (Personal correspondence between Professor Halliwell and the author).

purposes are to review the historical development of a field of chemistry with special reference to its applications and social aspects; to study the life and work of one or more famous scientists; to create an interest in the original writings of scientists; and to carry out laboratory reconstructions of key historical experiments and practical techniques. To achieve these purposes pupils may develop a topic of their own choice. Alternatively, they may study either "Humphry Davy, Michael Faraday and the history of electrochemistry" or "The history of dyeing"; both of these topics are given in great detail in the course material.³³ Pupils can spend up to a full term on their chosen topic. It is of interest to note that a professional historian of science, Dr. F. Greenaway, Keeper of Chemistry at the London Science Museum, helped in the preparation of material for this option.

Other opportunities for introducing historical material into the course come from the suggested approach to several topics and from the pupils' book Chemists in the world. It is suggested that certain topics such as atomic theory, the periodic table, gases, may be introduced through their history: in the atomic theory the "first to give a satisfactory answer [was] Dalton ... discussion of theories of particulate and continuous matter ... brief account of the history of the atomic theory up to Dalton"; for the periodic table "start with an outline of the discovery of the Periodic Table by Meyer and Mendeleev ... early attempts at the relationship between atomic masses and chemical properties ... Newlands and Dobereiner should be mentioned"; the work on oxygen includes "discussion about the discovery of oxygen ... how some significant discoveries were made ... [pupils] repeat some famous experiments".³⁴ The pupils' book Chemists in the world, which is intended for use in Stages 2 and 3 of the course, draws mainly on material from the background books

33. Nuffield Foundation, Revised Nuffield Chemistry Options. Option 10 Historical Topics, York, 1976.

34. Nuffield Foundation, Nuffield Chemistry. The Sample Scheme, Stages I and II, London, 1966, pp.222, 253, 57 respectively.

written for the original version of the course. The first half of the book covers a history of chemistry from the time of Dalton up to the present; it emphasises the part that individuals have played in making chemical discoveries. In his researches preparatory to the revised version, R.B. Ingle found that the background books were seldom used, and when used there was "little interest in the historical material".³⁵ Apparently factors against their use was their cost and their designation as "background". One of the intentions of Chemists in the world was to bring to the fore the history, applications, and social aspects of chemistry making it less likely that teachers would neglect these considerations.

Revised Nuffield Chemistry certainly provides more historical material than any other O level or equivalent English chemistry course. In the revised version there are perhaps slightly fewer words written about historical matters than in the original. But the history has been brought more to the attention of the pupils and become more of an integral part of the course. Chemists in the world is seemingly receiving a very favourable reception from teachers. The revised option "Historical Topics" contains excellent and detailed material which should provide great support for science teachers. In the original version it seems that very few teachers took the opportunity to use historical material in their work. Besides a lack of interest in the history in the background books, Ingle found that in his sample schools "Historical Topics" was the least used of all the options. One reason for this appears to be that the option was teacher assessed, and teachers do not like to make their own assessment.³⁶ But the fact remains that at present history of chemistry remains as something that teachers have the opportunity to include rather than something that they must include. Perhaps because of the pressures they face, not least of all pressures from external examinations, the

35. M. Waring, as in note 1 above, p.213.

36. M. Waring, as in note 1 above, pp.213-4.

evidence suggests that many teachers need more than opportunities. Mary Waring wrote

"The overwhelming impression that emerges from this research is that many of this particular sample of teachers wanted a detailed course, a package ... rather than a flexible set of resources. They ... welcomed more and more spelling out ...".³⁷

This view is well in accord with the experience of the author. The Nuffield course provides some excellent historical resource material. However this is not a package. Moreover, a sample of Nuffield GCE O level examination questions shows that teachers need fear no pressure from this source to use the resource material.

5.4.3 History of science in Nuffield O level biology

The O level biology project had as its Organizer a person sympathetic towards history of science. W.H. Dowdeswell was, in 1960, Senior Science Master at Winchester College and a member of the SMA panel working on a proposed sixth-form history and philosophy of science curriculum. When, in that same year, he was invited to join the controlling committee of the History of Ideas Unit he indicated that it was a project that would greatly interest him. However, he refused the offer because he was in the process of writing a book covering heredity and evolution in precisely the way the Unit intended to do it and with the same general purposes in mind. Seemingly he wanted to avoid a possible clash of interests. The prospects for historical material to appear in the biology course were promising.

The year after publication of the first materials Dowdeswell wrote of his course team's belief

"... it should be possible to integrate first- and second-hand evidence and to adopt the same attitude of enquiry to each ... Historical experiments too (their imperfections may well be an advantage in providing material for discussion), also provide splendid second-hand evidence.... we quote the famous experiment of Van Helmont which provides an admirable lead-in to the study of starch production by leaves".³⁸

37. M. Waring, as in note 1 above, p.215.

38. W.H. Dowdeswell, "The Nuffield Project 1: Biology 11-16", School Science Review, 48 (1966-7), 326-7.

Specified among the original aims of the course was the development of certain ideas about biology as part of human endeavour. These included the notions that the pursuit of biological knowledge is international, it is based on communication between people, and that "Biology has been developing over many centuries: there are many unanswered questions about life; our ideas of life may change as new knowledge is obtained".³⁹

Clearly the course team believed that historical material should play some part in the scheme as a humanising influence, as a means of bringing out the nature of biological ideas, and as a source of teaching material.

When Revised Nuffield Biology appeared in 1974 the format was a good deal more attractive. The original aims however remained the same, as did the majority of the subject matter including the historical material.

The material for Revised Nuffield Biology includes four Texts intended for pupils, and four Teachers' Guides. Historical material, frequently in the form of background reading, is scattered throughout the Texts, with corresponding sections of further and more detailed historical information in the Teachers' Guides. Text 1 Introducing Living Things contains a generous amount of accurate and well-written history including the development of the microscope, the discovery of small organisms, spontaneous generation, disease, plagues, and classification. Included in Text 4 The perpetuation of life is an account of Darwin's work on the Beagle and some of Lamarck's ideas. In many ways this is reminiscent of the type of writing that Holmyard encouraged (see section 3.3.1). It provides a general cultural background and brings out, though perhaps somewhat too gently, that scientific truths and theories are not absolute.

Overall Nuffield O level biology uses only a little historical material. It selects few historical experiments to provide "second-hand evidence". Nevertheless there is more history than in most other contemporary and equivalent biological texts, and the material provided is clear and accurate.

39. Nuffield Foundation, Nuffield Biology Teachers' Guide 1, Glasgow, reprinted 1967, p.x.

Chapter 6

NUFFIELD O LEVEL PHYSICS

In a study of history of science in English secondary school science education Nuffield O level physics deserves especial attention. This course has built in as an integral and compulsory part more history than any other comparable scheme recently devised for, and widely used in, English schools. The width and complexity of some of the historical material can make historical demands on the pupil and teacher far in excess of any other similar science course. If, as the author believes, one of the values of an historical study is to provide some insight for future developments a detailed consideration of this course is highly appropriate.

Throughout Chapter 6 the abbreviation TG for Nuffield Physics Teachers' Guides is used in the references.

6.1 The Course

The Nuffield O level physics programme developed between 1962 and 1965, growing out of plans of the ASE and Scottish Education Department. The books for the first edition were published in 1966. Preparation for a second edition, with a similar structure and content began in 1975. At the time of writing, the revised material for planetary astronomy has not been published. The programme was designed as a five-year course from eleven plus to O level "for all who do physics in a grammar school", meaning the top 15% to 20% of the whole ability range. There was to be less emphasis on rote learning and more on pupils doing and thinking, aiming to give better understanding. The syllabus was to be less crowded, was to include some modern topics, and was chosen to show physics as a connected scheme of knowledge. It was hoped that the pupils would experience "wonder and delight" and get intellectual satisfaction. No options were built into the scheme, but there was the possibility of

individual extensions; compression into a shorter course was not recommended although Year 1 and Year 3 were seen as possible starting points.

Years 1 and 2 are considered as the stage of seeing, doing, and making acquaintance with phenomena in the physical world, although without expressing results in formal statements. This is done by giving the pupils acquaintance with the concepts of forces, atoms and molecules, energy, and electric currents: pupils are encouraged to observe, classify, estimate and measure: a tradition of independent experimentation is established, with pupils encouraged to design their own experiments, not necessarily seeking one "right answer", certainly not simply following routine instructions. Pupils are encouraged to work on their own, to think critically, and to discuss.

From Year 3 the investigation and learning becomes more formal and organised. Certain topics are introduced early to give a preparation for later work. Thus, Year 3 sees an informal preparation for Newtonian dynamics; general ideas are given, partly by asking questions and partly from pupils' experiments, ideas of velocity and acceleration, of free fall and diluted gravity, of inertia and Newton's laws of motion: a more serious and detailed study of these topics is made in Year 4: then, Year 5 sees Newton's laws of motion and gravitation applied to planetary astronomy. From Year 3 more theory is gradually introduced, but with the aim of soundly basing the theory on experiment. The whole programme becomes more closely knit with the course ultimately leading to four end points: a quantitative molecular-kinetic theory, atomic theory, planetary theory, and wave-particle duality.

6.2 Historical material in the course

The physics course contains a good deal more historical material than either of the other Nuffield O level science courses. Frequent references are made to people and ideas of the past, often with great enthusiasm.

The importance of including something of the history of science, especially for future arts students is clearly stated. Historical material is brought into the work on radioactivity, atomic structure, and theories of light. The largest quantity of history however comes in two important sections, one of which is totally based on an historical development, the other making considerable and necessary use of history. The growth of planetary astronomy, from its empirical beginnings with early man to its culmination with Newton's gravitational theory, is one of the four end points of the course; the suggested time allowance of twenty-one periods represents seven weeks work, much of it on the history of astronomy. Universal conservation of energy contains a lesser amount of historical material. With a recommended time of ten periods for the whole section and the urging that the core of the work is the "great discussion of Conservation", there is an implication that at least five or six periods, that is about two weeks, could usefully be spent on the historical aspects.

6.2.1 Planetary astronomy

The growth of planetary astronomy from its empirical beginnings with early man to its culmination with Newton's gravitational theory is one of the four end points of the course. The authors of the Nuffield scheme believe that the pupils need to see how a successful scientific theory develops and to have their understanding of theory strengthened. They use the history of astronomy to provide an example of the building of a successful physical theory, Newton's gravitational theory. But in addition, the authors regret that in the past the astronomical problems that called for Newton's work and received his solution were crowded out of the syllabus, resulting in a lack of appreciation of the magnitude of Newton's achievement and a lack of awareness of the drive felt by Newton's contemporaries and successors. The historical studies are intended to allow pupils to feel the force of a great body of knowledge awaiting a concerted explanation, a

clear history of need leading up to Newton's theory.¹ So Nuffield has chosen Newton's theory both in its own right and as a model for scientific theories in general. However, it can be argued that the success of the section in achieving its purpose is only partial.

6.2.1.1 Fulfilment of aims

The material of planetary astronomy is well structured with a logical and orderly development. After a description of the observed facts (the apparent movement of the stars, moon, sun and planets) early explanations and models are given (Thales and the Pythagoreans). The need to modify these models and explanations as more precision was demanded allows consideration of the work of philosophers from Eudoxos down to Ptolemy. The fundamental change made by Copernicus is described followed by modifications to his new structure, again resulting from demands for greater accuracy. Finally acceptance of the new system, because of its success in explaining the known facts and in making predictions, is shown.

The work does not trace explicitly the development of the concept of universal gravitation and is little more than a chronology of ideas and discoveries. Nevertheless Nuffield believes that the main work is to describe the great list of things Newton extracted from his theory, aiming more at piling up a great record of successes than teaching the details of each item fully.² With the tremendous catalogue of explanations and predictions - including Kepler's laws, satellites of a planet, comets, the relative masses of the heavenly bodies, the shape of the earth, the differences in g , the ocean tides, the mass of the moon, the precession of the equinoxes, the irregularities of the moon's motion, the perturbation of planetary orbits - there is a wealth of material to allow an appreciation of the magnitude of Newton's work. But on scientific theories in general the material is less convincing.

It shows that from the time of the Greeks men have devised theories

1. TG4, pp.11-12.

2. TG5, p.184.

and models as explanations of natural phenomena and that to some extent these theories have been able to predict further or future phenomena; that as further phenomena are discovered and as measurements are made with an increasing degree of accuracy these theories and models can undergo slight or fundamental changes. In essence, the section shows that theories have changed in accordance with the requirements of the ages. But the very considerable emphasis given to Newton's gravitational theory and the stress on the building and development of a successful physical theory suggests a false picture: it suggests that Greek theories were not successful, it almost implies that they were components of the final Newtonian theory and it could be seen as representing Newton's theory as an ultimate, unalterable truth. It is positivistic and could almost be teaching a philosophy of the seventeenth century.

Surely the required concept of a scientific theory is of a reasonable explanation of known phenomena, possibly with the powers to predict, with some wide measure of acceptance, perhaps with some experimental justification, but with no pretence as an ultimate truth. It must be allowed that Greek theories were successful in their time. Eudoxos' theory gave an explanation of the observations better than anything previous. At some stage its limitations and inaccuracies were recognised as greater precision was demanded and new phenomena were discovered; so it was modified and other models were introduced. The same can be said of the work of Ptolemy, which certainly stood the test of time - admittedly not in particularly vital circumstances. It ought to be recognised that Newton's work was not immediately acknowledged as successful throughout Europe; some explanations were lacking, he was accused of having a "God of the gaps" to account for apparent inconsistencies and many thought he was bringing the occult back into science. As is admitted, we now consider that in certain cases Newton's laws are only correct subject to some relativistic modification.³

To generalise about theories and models in science perhaps there needs to be a change in aim and emphasis. The aim of the work could be to consider changing theories used in planetary astronomy throughout the ages and to emphasise that each was to some degree successful to its contemporary eyes. Newton's work could still be shown to be of very considerable magnitude and of especial significance, and the nature of scientific theories would be brought out more clearly.

6.2.1.2 Accuracy, reliability and adequacy

Some science teachers will have received little or no training in history of science and will have had little experience of teaching such material. To what extent do the Teachers' Guides meet their needs? Is the material given correct in facts and implications? Does it reflect currently accepted thinking in history of science? Does it allow the teacher of physics to consider the wider education of his pupils?

The writing on Greek science contains a great deal of valuable material with some very clear explanations. But it blurs the character of the Greeks' work, gives a poor treatment of Eudoxos' highly important contributions and fails to bring out several significant points. It is asserted that "Pythagoras and others who followed him imagined a scheme of concentric spheres like shells of an onion" and later that "Eudoxos devised a tremendous system of spheres to match the facts very closely".⁴ Perhaps it is relatively unimportant that Eudoxos' scheme was excellent for Jupiter and Saturn, reasonable for Mercury, unsatisfactory for Venus and a complete failure for Mars.⁵ Perhaps the omission of any mention of Plato, while strange, is not of great significance. It does seem a pity, however, not to bring out very clearly the fundamental change in Greek astronomy and the completely new character it assumed from the time of Plato. An opportunity has been missed of drawing out the conceptual development

4. TG5, pp.112-3 and 118 respectively.

5. J.E.L. Dreyer, A History of Astronomy from Thales to Kepler, Dover publications, New York, 1953, pp.99-103.

involved in moving from purely descriptive models to models containing mathematical analysis.

Little contrast is drawn between the "scientific" activities of the Greeks with their desire to understand nature and the "scientific" activities of the earlier civilisations whose desire was more to control nature: again a missed opportunity for helping the pupils to understand the nature of science and for drawing out some distinction between science and technology. There are suggestions that Greek astronomers were practical men of science, making observations and measurements, doing experiments: "As Greek civilisation grew up, philosophers gathered astronomical knowledge from Egypt and from their own observations"; "Greek astronomers at the university at Alexandria ... [made] real measurements of distances ... the size of the earth ... the distance, and therefore the size, of the moon ... the distance of the sun".⁶

Certainly some observations and measurements are described by Greek astronomers. But a description of Eratosthenes' determination of the circumference of the earth reads to many as a textbook example of how the measurement could be made rather than how it was made. The choice of 5000 stadia made by both Eratosthenes and Posidonios is curious and coincidental, particularly as in the case of Posidonios the distance was between Alexandria and Rhodes and a measurement across the sea was difficult. Whether or not the Greeks actually carried out such real measurements is at least open to debate, as is whether a significant part of Greek science and astronomy was practical and experimental. The point at issue is that historians, like physical scientists, are attempting to evaluate evidence before them, and to ignore that various possible interpretations exist (as indeed they do in the question of the extent of Greek experimental science) could not only misrepresent the historical position but also unnecessarily restrict the critical attitude desired in the pupils.

6. TG5, p.132.

Copernician revolution

The Copernician revolution over-simplifies to the point of distortion, dogmatically presenting a position of conflict contrary to much contemporary thinking. Copernicus's total motivation in seeking a more simple scheme is described in Nuffield as a desire to glorify God. He is portrayed as spending a lifetime perfecting his scheme; he is shown as unwilling to publish until near the end of his life; although no reason is given for this reluctance, conflict with the Church is implied.

Supposedly De Revolutionibus had an explosive effect although

"when it first appeared, the book was read by astronomers but in its formal Latin it was not read by educated people in general ... Galileo ... expounded the scheme and put forth winning arguments for it in popular, rolling Italian. That was a bombshell, because educated readers far and wide enjoyed it, understood it and realised that the Copernican system had made the earth common and ordinary ... with no place for Heaven. That was disturbing, both to man's picture of Heaven and to the teaching of Church authorities. No wonder Galileo got into trouble for insisting so loudly and clearly that the Copernican system is true".⁷

Copernicus "moved the earth out of its grand central position and made it an 'ordinary' planet like the rest. That was a tremendous change of viewpoint which horrified people ...".⁸

Such a presentation of Copernicus and his work gives a far from true picture and seems to presuppose a conflict between Copernicanism and the Church, a battle between science and religion. This presupposition was expounded and popularised about one hundred years ago in books such as J.W. Draper's History of the Conflict between Religion and Science (1875) and A.D. White's A History of the Warfare of Science and Theology in Christendom (1895). But surely it is a presupposition that has not stood up to modern historical research.

Copernicus was born into a world where astronomers were groping for reform, a reform that seemingly could be achieved by the Renaissance desire to seek out the perfection of classical Greek authors. After an unusually

7. TG5, p.151.

8. TG5, p.141.

long period of study, which included mathematics, astronomy, law and medicine, Copernicus returned to Poland in 1506. There he settled to an extremely busy life, dividing his time between his various duties and interests. His interest in astronomy was shared by a Church anxious for calendar reform. In 1514 Copernicus declined an invitation to advise the Lateran Council on such reform, believing that planetary motion was insufficiently understood to provide the necessary basis. De Revolutionibus was certainly the result of many years' labour but he probably had a clear idea of it by 1506. The most likely reason for the delay in publishing was his attempts to replace the Ptolemaic system with a system that was just as complete. De Revolutionibus was written as a careful parallel to Ptolemy's Almagist: whatever had been treated in one was to be treated in the other. Copernicus's insistence was to be judged on the same basis as Ptolemy. It has also been argued that reluctance to publish was well in keeping with the Pythagorean tradition of retaining knowledge within the initiates; Copernicus had in fact circulated to his friends a sketch of his ideas in Commentariolus well before 1543.

De Revolutionibus was initially well received by the Church, and if "it was not read by educated people in general" this was more likely because of the complexity of the mathematics than because it was written in Latin. While the problems raised by the dethronement of man must not be ignored, this aspect should not be overstated. Copernicus himself had been at pains to point out that man's displacement was relatively trivial. The Church had traditionally taught that this earth is a vale of tears, a temporary dwelling place. Aristotle's terrestrial region was imperfect, subject to change and quite different from the perfection of the rest of the planets. When Galileo became involved, some fifty years later, his main battle was against Aristotle. His "winning arguments in rolling Italian" gave as much support to the anti-Copernican Tychonic scheme as they did to the heliocentric system. Tycho Brahe, an opponent of the Copernican system, had proposed a system in which all the planets revolved around the sun, while the sun revolved around a fixed and

central earth. Such a scheme was both mathematically and observationally equivalent to the Copernician system, so retained the advantages of the latter while avoiding the difficulties introduced by assuming that the earth moves. It was a scheme which was to receive a good deal of support.

Traho Brahe to Newton

References to Tycho, Kepler, Galileo and Newton maintain the loose and misleading writing that characterises much of this section. To say that "Tycho realised that the old practice of collecting and using chance observations did not suffice. Systematic observations and records were essential",⁹ ignores the systematic observations of the heavens going back at least as far as the Babylonians. To present Tycho as "a magnificent observer but not a strong theorist"¹⁰ ignores the paradoxical situation that he perhaps more than any other sixteenth century astronomer influenced theoretical developments with his removal of crystalline spheres, his calculations on the motions of the moon and his highly influential geocentric scheme. To present Kepler as "struggling as a Protestant in a largely Roman Catholic world"¹¹ and to state that Galileo, "probably in an attempt to please the Pope when he sought permission to publish his book, suggested that the tides were due to a breathing motion of the earth"¹² continues with the apparent bias against the Roman Catholic Church.

To say that Kepler's laws were the talk of the day in the scientific world¹³ is simplistic and misleading, and to talk of Kepler announcing his laws¹⁴ gives a wrong emphasis and impression. The first two laws of Kepler were published in Astronomia Nova (1609) and the third in The Harmonies of the World (1619). As Professor A.R. Hall says "... Kepler's discoveries were displayed in extremely difficult books, published far from the main foci of scientific activity in France and Italy, and so were

9. TG5, pp.152-3.

10. TG5, p.153.

11. TG5, p.154.

12. TG5, p.215.

13. TG5, p.172.

14. TG4, p.11.

passed over by a generation that ignored their true importance".¹⁵ The history of the third law is obscure between 1619 and 1665, and Kepler's work aroused no excessive interest in this period. To say that Newton was discouraged by his initial test on the moon's motion and put the calculation away to avoid controversy¹⁶ ignores the development of Newton's own ideas. In 1666 Newton was by no means sure that Cartesian cosmology was false nor that the mathematical method in science was the only one leading to truth.¹⁷ To assert that Newton and the apple story is true¹⁸ seems to demonstrate a lack of awareness in the problem of interpreting historical documents and is contrary to the opinions of some historians of science.¹⁹ To present the Newtonian synthesis as an example of a successful scientific theory ignores the fact that over a quarter of a century passed before the Newtonian system was finally accepted on the continent of Europe.

It is recognised that the authors of Nuffield physics believe the main target in planetary astronomy should be Newton's work, the earlier history being taught without detailed accounts. Nevertheless many details of this earlier period are given in the Teachers' Guides, details of which are questionable, misinform, and distort the historical position.

6.2.2 The conservation of energy

The historical survey of the nineteenth-century experiments of Joule and others is not "... an arbitrarily chosen chapter in the history of science".²⁰ The programme emphasises that theory should be firmly based on experimental evidence and maintains that energy conservation has especially strong claims for an experimental discussion.²¹ This

15. A.R. Hall, The Scientific Revolution 1500-1800, London, 1967, p.126.

16. TG5, p.172.

17. A.R. Hall, From Galileo to Newton 1630-1720, London, 1963, pp.280-86.

18. TG5, p.181.

19. A.R. Hall, 1967, pp.247-8.

20. TG1, p.32.

21. TG1, pp.28-33.

experimental basis is provided by descriptive accounts of experiments which measured energy exchanges and determined the mechanical equivalent, "J"; discussion is accompanied by charts and "token models".

The possible lines of attack given in Teachers' Guide 1 are not the only ways of providing this experimental basis; it could have been achieved quite successfully without any reference to history. The programme does not say why the historical treatment is more appropriate for energy conservation than for equally important concepts in the course, concepts with equally strong claims for experimental justification. In addition, it must be remembered that much theory in science was not and is not based on experiment. "The scientific revolution was not affected by empirical methods only ... it embraced ideas ... which were not and could not be proved experimentally ...".²² A great deal of present-day theory in physics does not come from an experimental basis but is awaiting some experimental confirmation. However, the historical review does show that nineteenth century scientists did experiments to justify their belief that heat was a form of energy and gave support to the theoretical principle of energy conservation. The historical treatment does succeed in its aim. It is a pity, however, that the experimental evidence is presented in a totally descriptive rather than a more practical way.

Although the notes on the conservation of energy are in the main little more than a series of dates, names and experiments, they are generally reliable and accurate. It is questionable whether statements like "Scientists believed that heat was ... rather uninteresting" and "in the 1840s electric circuits were being investigated for the first time"²³ are true. To picture Joule as a brewer and amateur scientist who latched on to the idea that heat was a form of energy and spent all his spare time proving it is perhaps misleading both about Joule and how scientists develop their ideas. Joule was a practical engineer who

22. A.R. Hall, 1963, p.104. 23. TG4, pp.285-7.

began his researches with no new ideas on heat in mind but with a desire to improve the electric motor. Initially he became interested in the theories of electricity and the atomic nature of things, only later becoming involved in measuring the mechanical equivalent of heat. But such points are few. The major defect seems to be inadequacy. No detailed explanations of the experiments are given nor are any satisfactory references.

6.3 Sources of the historical material

Two of the people who were to play an especially significant part in the development of the course were Donald McGill and Professor Eric Rogers. McGill was seconded from the Scottish Education Department and appointed as full-time organiser of the physics project; Rogers, who taught at Charterhouse before being appointed Professor of Physics at Princeton University, soon became involved with the project team as a consultant. In the PSSC Physics course (see Chapter 5) Eric Rogers is named as one "among the major creators and selectors of material at every point". In 1960 he produced a major text book Physics for the Inquiring Mind; this was based on a one-year course given at Princeton to undergraduates whose chief field of study lay outside technical physics.

Prior to his Nuffield appointment McGill had had experience of curriculum development and had prepared a course for the Scottish Certificate of Education. The syllabus for this course, issued in April 1962 and soon widely adopted in Scotland, stated that "teachers should gain insight into the spirit and method of presentation envisaged from selected passages and examples in two works relevant to the main theme: PSSC Physics Text and Physics for the Inquiring Mind".²⁴ In Circular 490 some history is mentioned in connection with radioactivity, and with

24. Scottish Education Department, Circular 490: Alternative "O" grade syllabus in Physics, Edinburgh, 1962.

Joule's work on mechanical and thermal energy, although in the latter there is no suggestion of using nineteenth-century history to provide an experimental basis for the universal conservation of energy; no mention is made of historical astronomy. On his Nuffield appointment McGill himself wrote the theme of the course as "Physics for all", and with the help of his consultative committee and regional teams, produced in February 1963, his first attempt at an overall syllabus. This draft contained a section on historical astronomy, presented as an option in Year 5, and with contents and an objective - to show the making of a physical theory - substantially the same as was to appear in the final scheme.²⁵ No other suggestion for historical material were made explicitly: there was no suggestion of an historical treatment of the work on heat and energy; nor any history mentioned in connection with radioactivity, atomic structure, or the nature of light. The draft however gave only an outline of the topics without explanatory notes. This draft marks the end of McGill's work on the project. His sudden death in March 1963 resulted in the appointment as project organiser of Eric Rogers.

6.3.1 Physics for the Inquiring Mind

The majority of the history in Nuffield physics was taken directly from Eric Rogers' widely acclaimed book Physics for the Inquiring Mind. Unfortunately planetary astronomy is given in an abbreviated form which does little justice to the original. Although Professor Rogers relied in his book on some authors who tended to adopt a positivistic tone, a full reproduction of the relevant chapters would have provided a more balanced picture. Yet it must be questioned whether even this is the most suitable and adequate source. Physics for the Inquiring Mind is essentially a one-year undergraduate course in physics for non-physicists, with historical material only intended to make the "first moves towards

25. See E.J. Wenham, "The Nuffield Foundation Science Teaching Project III: Physics 11-16", School Science Review, 48 (1966-7), 337-346.

studies in the history and philosophy of science". As it is argued in the book that the works of philosophers and historians presuppose a full knowledge of scientific material and a first-hand understanding of the nature of scientific work, it seems strange to present to qualified science teachers material specifically written for non-scientists beginning a physics course.

It would have been more appropriate to make a clearer distinction between what was intended to be at the teachers' own level and what was to be imparted directly to the pupils. The teachers could have been directed towards more rigorous material written by contemporary historians of science. An example of a suitable source of material for the pupils is the American PSSC book; this was published in 1960, contains a history of astronomy programme quite similar in outline to Nuffield, yet avoids many of the pitfalls. Significantly, an historian of science, Professor Bernard Cohen, is acknowledged as having read successive drafts and supplied historical material.

6.4 The sensitivity of the historical material

Since the nineteenth century it has been fundamental to historical study to judge a period on its own terms, attempting to see theories and experiments through the eyes of men of the time and through ideas current at the time.

The authors of Nuffield physics emphasise the importance of evaluating a period from within and imply that it is not an obvious thing for pupils to do. They spell out very clearly how to deal with the pupils' comment "But sir, we know this isn't true". The pupils need to be told to "imagine that you have taken a jump back in time to the days of the early astronomers. You see what they saw; but imagine that you have not been told explanations made up by other people since then ... the teacher needs to emphasise repeatedly the cleverness of imagining good schemes and not the

stupidity of going back".²⁶ But the Teachers' Guides present a curious mixture of adhering to and ignoring this principle. It is hardly evaluating a period from within to say that the Copernican system was turned down "because the critics did not understand the mechanics of motion".²⁷ We are told that "we try now - as scientists have tried for the last 300 years - to avoid unnecessary imaginative frills".²⁸ We are warned in case the picture of science we give to pupils "might even turn into the nonsense of the medieval Aristotelians".²⁹ Our pupils "may laugh at the silly ideas of medieval philosophers ... If pupils laugh we should laugh with them at the medieval philosophers who had tangled reality with their dogmatic arguments".³⁰

Did philosophers prior to the Scientific Revolution consider their work to be nonsense and to contain unnecessary frills? How will our understanding of motion seem to scientists 500 years hence? Which of our frills will be considered imaginative and unnecessary? What laughs will we provide? It really does a disservice both to the understanding of the nature of science and to the wider education of our pupils not to show a consistent sensitivity and understanding of what has gone before.

6.5 Historical questions in Nuffield GCE O level physics examinations

The responsibility for the Nuffield O level physics examinations was undertaken by the Oxford and Cambridge Schools Examination Board on behalf of the GCE examination boards. The first examination in 1965 was available only to those pilot schools involved in constructing and trying out the course. The programme became available to all schools from September 1967; thus the examination was open to all candidates from about 1970. Since 1965 there has been a steady increase in the number

26. TG5, p.106.

27. TG5, p.141.

28. TG5, p.82.

29. TG1, p.102.

30. TG5, p.82.

of candidates. By 1978 nearly 20% of the total GCE 'O level physics summer entries were for the Nuffield examination.³¹ Each year the examination has consisted of two papers. Paper 1 has been either a 1½-hour or a 2-hour examination with all questions to be attempted; the early papers contained ten or eleven short questions, but this later became fifty multiple choice questions. Paper 2 has always been a 2-hour paper; candidates have variously been required to answer two out of four, three out of five, and four out of six questions.

6.5.1 Frequency of questions with an historical content

Since the intention of the examiners is to provide the candidates with the maximum opportunity to communicate with them, history can legitimately be brought into several answers to questions that strictly are non-historical, as with the following.

5. This question deals with experiments on the scattering of alpha particles performed by Geiger and Marsden in Rutherford's laboratory.

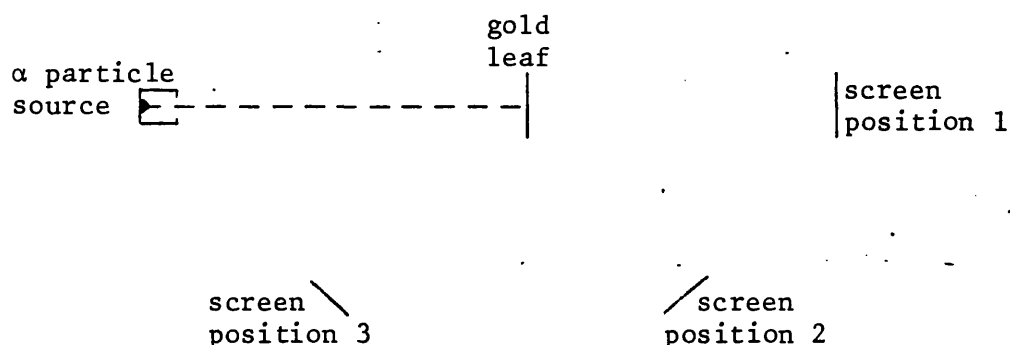


Fig. 4

- Copy the diagram, Fig. 4, and add to it lines indicating possible alpha-particle paths.
- Why was the apparatus enclosed in an evacuated container?
- What differences were noticed in the observations at screen positions 1, 2 and 3?

31. Number of candidates at the summer examination

Year	Nuffield Physics	Total GCE O level Physics
1965	87	98,089
1970	5,343	106,420
1975	21,615	130,189

Figures provided by the Oxford and Cambridge Schools Examination Board.

- (d) Describe the atomic model used by Rutherford, and say how it explains the observations in (c).
- (e) Why was gold leaf used as a target?

(1969 Paper 2, Question 5)

The present concern, however, is only with those questions which demand from the pupils some historical knowledge. These questions relate mainly to the three topics planetary astronomy, atomic structure, and the nature of light. A survey of the past papers reveals that between 1965 and 1979, taking papers 1 and 2 together, only approximately 2% of all the questions set have been historical. Clearly teachers will feel that the examination exerts no pressure on them to include history of science in their teaching.

6.5.2 Demands made by the historical questions

The type of demands made on the pupils by the examination is best illustrated by considering a sample of the questions. What emerges is that pupils do need some sense of chronology and a few historical facts, but that in essence the knowledge of history of science required is very slight. Some people may argue that this is no bad thing for a physics course. But it does lead to the danger of oversimplification and trivialisation of the historical material.

4. Select four of the following and explain their importance in the development of scientific thought. Include in your answer a description of what was done. [25]

- (a) Millikan's observation of oil drops.
- (b) Rutherford's interpretation of the scattering of alpha-particles.
- (c) Young's observation of the effect of passing light through two small openings.
- (d) Copernicus' description of a new model of the solar system.
- (e) Newton's observation of the motion of the Moon.

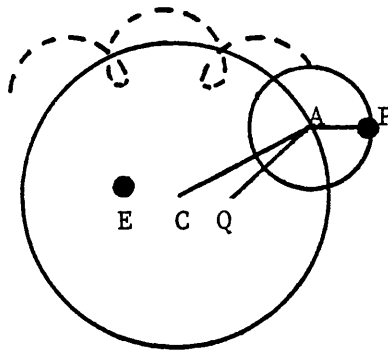
(1976, Paper 2, Question 4).

With an allowance of $7\frac{1}{2}$ minutes for each part, a description of what was done would leave little time to explain the importance in the development of scientific thought. The history demanded could be summed up very

briefly as follows.

"Before the beginning of the twentieth century people believed that atoms were solid particles. The experiments of Rutherford, Geiger, and Marsden changed this; the atom became pictured like a miniature solar system, a small central positively charged nucleus surrounded by orbiting electrons. Millikan showed that the electrical charge existed in discrete amounts as multiples of a basic unit of charge. Immediately after Newton people thought that light consisted of tiny particles. Nineteenth century experiments on interference and diffraction led to a belief that light was made up of waves. Nowadays because of phenomena like the photoelectric effect we believe that light exhibits both wave and corpuscular properties".

Such a demand could hardly stimulate an interest in the history of science.



- Fig. 1

Fig. 1 shows a system invented by Ptolemy to imitate the motion of a planet (as he saw it) in its path round the Earth - the planet Jupiter for example. The features of his system were 'fixed Earth, constant radii, rotations with constant speed'.

- (a) Explain Ptolemy's system in so far as it is illustrated by Fig. 1, and use the diagram to explain the three 'features' mentioned above.
- (b) What is meant by 'retrograde motion' of a planet? Say how it is shown in Fig. 1.
- (c) Draw a diagram to show how Newton would have explained the motion of a planet such as Jupiter (include the Sun as well as the Earth in your diagram). How would Newton have explained retrograde motion?
- (d) Why is Newton's planetary scheme regarded as a 'theory', while Ptolemy's is only a 'model'?

(1966, Paper 2, Question 3).

Part (a) requires some knowledge of the problems facing Greek astronomers, that they were committed to explain planetary loops in terms of uniform circular motion, and of the solution proposed by Ptolemy. An understanding of why they were so committed to this type of motion and an

awareness of the lack of conformity between such motion and the equant would show a greater depth of knowledge and should certainly have been included in any teaching of this section (nothing is said about this conformity in the course material).

Part (b) needs no historical knowledge, while part (c) requires pupils to know that the present-day explanation is as in Newton's time.

Part (d) seems to be a prime example of Whiggish interpretation of history.³² Few historians of science would regard Newton's scheme as a "theory" and Ptolemy's a "model".

The course material contains various scattered references to models and theories but nowhere give a full, clear, and explicit discussion on the interpretation placed on these words, and on the distinction between theories and models.

Theory is presented as a "growing structure of understanding which combines experimental knowledge with imaginative thinking and intelligent reasoning"; it is not to be thought of as absolute knowledge or abstruse unreal mathematics.³³ The test of a good theory is seen not in terms of success against failure, but as simplicity and economy against increasing complexity and clumsiness; the best theory is supposedly the most fruitful, economical, comprehensive, and intellectually satisfying. It is suggested that early on in the course theory is presented as a hunch gathered from clues and used.³⁴ In the discussion on teaching the use of a theory it emerges that theories may be some sort of picture which can answer questions and help to make sense of phenomena in a way that would not be possible

32. "The whig historian stands on the summit of the 20th century, and organises his scheme of history from the point of view of his own day ... He can say that events take on their due proportions when observed through the lapse of time. He can say that events must be judged by their ultimate issues ..." (Herbert Butterfield, The Whig Interpretation of History, London, 1931 (1968 Reprint), p.13. Whiggishness is the tendency to evaluate the past not on its own terms, but from the point of view of the present.

33. TG1, p.66.

34. TG3, p.212.

without them; experimentation, it is stated, can be used as a basis for building theories.³⁵

Models are seen as "forming essential links between experiment and theory".³⁶ They help us to express our views of nature, are helpful in constructive, imaginative thinking, but are not always meant to show what reality is like.³⁷ It is suggested that in later years models should be described as imaginary schemes, ideals, metaphors and analogues with great uses in constructing a fabric of scientific knowledge.³⁸

The above does tell something of our present use of the words "theories" and "models". But the use of these terms in connection with the history of astronomy and the phrasing of the examination questions ignores the viewpoint of the historian of science and repeats the mistake, made frequently in the course material, of not evaluating the period from within. Historians of science neither regard Newton's planetary scheme as a theory while Ptolemy's is seen "only as a model", nor do they contrast the two systems with the meanings at present attributed to the terms theories and models. They do not do this because both Ptolemy and Newton would have regarded their work as combining knowledge, intelligent reasoning, perhaps imaginative thinking, and giving an understanding of nature. The distinction we make at present between theories and models exist in neither Ptolemy's nor Newton's period.

Additional criticism can be made of the lack of internal consistency in the use of these terms. In the early examination papers Greek schemes are described as models, in Teachers' Guide 5 they are described as theories with the remarkable statement "a model of the heavens (i.e. a theory)".³⁹ Copernicus' system is described as a model in the 1976 examination (Paper 2, Question 4) as is our present picture of the world in the 1977 examination, (Paper 2, Question 3), although Newton's scheme is always given as a theory.

35. TG3, pp.335-42.

36. TG1, p.228.

37. TG2, p.123.

38. TG1, p.231.

39. TG5, pp.105 ff.

6.6 Some Lessons from Nuffield O level Physics

With the exception of the universal conservation of energy and planetary astronomy, the history of science in the rest of the course is slight and relatively incidental. Any lessons to be drawn must come from the two major historical sections. Heat and energy conservation may be difficult concepts for the pupils, but they are taught through specific and fairly familiar experimental situations; the pupils will have seen and used apparatus similar to some nineteenth-century equipment; at some stage they will have taken measurements and made calculations similar to those of the nineteenth-century scientists; the findings of these experiments are still accepted; the changing philosophies underlying the science of the period do not intrude into the work. To the author, this work seems unlikely to stimulate and inspire pupils; nor does it seem the most appropriate way of teaching about the conservation of energy. However, it should not present any undue difficulty or demands on either teachers or pupils.

On the other hand historical astronomy is quite different. It is wider in its intention and is more concerned with abstract ideas; it throws up unfamiliar and difficult conceptual models; it covers a period of some 2000 years, during which there were quite distinct changes in man's attitude not only to the findings of science but also to the nature and methods of science itself; the changing philosophies of the period are very much bound up with the work; and it includes an examination of theories no longer accepted. Clearly, as one of the four end-points of the course and with a suggested time-allowance of nearly one-quarter of the total year, it is not a section to be taken lightly. Yet the impression is that most teachers either omit planetary astronomy completely, or pass over it very quickly. Some may do this because they believe history of science should only be peripheral to a science course. But teachers do respond to the external pressure of examinations. Especially in the type of schools where Nuffield physics is taught, the reputation, status, and

possibly future prospects of the teacher is affected by the type of examination results his pupils obtain. (All too often the phrase is "the type of results he, the teacher, obtains"). Teachers of Nuffield O level physics can rest well assured that the examination prospects of their pupils will not be jeopardised by ignoring the historical material.

If the historical sections are considered important (if they are not why has so much attention been paid to them in the course?) this should be reflected in the frequency and demands made in the examination questions. But this in turn throws more responsibility on the authors of the scheme. When historical material is used it is essential that it is accurate, written with insight, care and sensitivity, reflects current thought in history of science, and is in no way misleading. A chronology of discoveries without any analysis of how and why things happened is of relatively little value and gives no real insight into why the present is as it is. To present historical material dogmatically and as a certain and static body of knowledge is quite contrary to the spirit of enquiry built into the course. If the suggested transfer of training⁴⁰ has any validity, making the pupils a "scientist for a day" would be complemented by making them an "historian of science" for a day. Historical evidence could be examined, both in documentary form and by reconstructing historical experiments and situations; evaluations, explanations and interpretations could be offered.

It may be argued that to give more detailed attention to history would be inappropriate to a science course, and make it more a course about science than in science. But if historical material is used the standard applied to that material must be as high as the standards applied to the written English, the arithmetic, or to anything else. And to draw a distinction between courses in and courses about science is to

40. TGl, pp.68-71.

pretend too much for the usual O level school experimental work.⁴¹

41. Revision of planetary astronomy is at present in hand. It is of interest to note that Professor A.J. Meadows, of Leicester University, (the independent expert asked by the Nuffield Foundation to comment on revision proposals) is one of the many people to ask whether the existing material is conceptually too difficult for O level pupils. Professor Meadows also suggests that more up-to-date material - development of the expanding universe, the idea of "horizon astronomy" as illustrated by recent studies of megalithic monuments - would be more relevant and interesting to pupils. (I am grateful to Professor Meadows for his comments).

Chapter 7

ATTITUDES TO HISTORY OF SCIENCE:

A PILOT STUDY

7.1 Objective

Attitude: 'a state of readiness, a tendency to act or react in a certain manner when confronted with certain stimuli'.¹

Among curriculum developers and educationalists in Britain and the USA during the 1960s and early 1970s there was a recognition that it is insufficient to consider only the development of the cognitive abilities of pupils; the aims of science education should also include an awareness of the attitudes of the pupils. This is evidenced by the writings of some of the reformers, and by the many surveys made during those years into pupils' attitudes to science.² However, despite the multitude of investigations no detailed examination of pupils' attitudes towards history of science and its place in the school curriculum, together with the factors affecting those attitudes, is known to the author; nor is any measuring instrument to carry out such a survey known to exist. If curriculum reformers and others consider that attitude surveys are important this does seem to be a neglected area. As this thesis has considered some of the curriculum changes involving history of science it does seem of value to draw attention to this neglect and go some way towards rectifying it. Accordingly, the objective of the present small scale survey was to carry out a pilot study as a necessary first stage in devising a measuring instrument to determine pupils' attitudes towards history of science and its relationship to the school curriculum.

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1. A.N. Oppenheim, Questionnaire Design and Attitude Measurement, London, 1966, p.105.
 2. See M.B. Ormerod and D. Duckworth, Pupils' Attitudes to science. A review of research, Windsor, 1975. Also P.L. Gardner, "Attitudes to Science: A Review" in Studies in Science Education, 2 (1975), 1-41.

7.2 Administration of the survey

The method used for attitude scaling was the Likert procedure where pupils were asked to indicate on a 5-point scale the extent of their agreement with a range of statements;³ summation of the scores indicates whether a favourable or unfavourable attitude exists within individuals or groups.

Initially eighty statements were drawn up. To give these some degree of face validity they were generated from assertions made over the past 50 years by writers discussing history of science in school curricula, and from statements of opinion expressed by practising science teachers. Following further discussions with science teachers on the relevance of the statements and their phrasing, a questionnaire with fifty items was devised. Each statement was given five possible responses ranging from a positive to a negative opinion towards history of science; the statements were re-phrased to avoid responses sets, and were scrambled into random order. This questionnaire was given to twelve science teachers to test for ambiguity in phrasing, difficulty in matching responses to statements, and general suitability for sixth-form pupils. After discussion a final questionnaire of forty-two items was drawn up. This is given as Appendix 11.

The pupils chosen for the survey were sixth-form pupils in three different schools. All the pupils had passed GCE O level examinations in at least one science subject, and were studying A level science subjects. The interest was in getting together a group of pupils who could act as a sample for a pilot study rather than making school comparisons. Thus the selection of the schools was determined by convenience rather than by design considerations. The questionnaire was administered twice with an interval of about four weeks in between.

3. A discussion on the relative merits of the Likert and other procedures and the construction of questionnaires is found in A.N. Oppenheim, Questionnaire Design and Attitude Measurement, London, 1966.

Each response earned a score of 5, 4, 3, 2, or 1. The response that indicated a most favourable opinion towards history of science scored 5, with the score progressively decreasing as the opinion became progressively less favourable. Unanswered or spoilt items were omitted from the analysis. The direction of the scoring is shown on the questionnaire in Appendix 11. The actual scores are given as Appendix 12.

7.2.1 Pupils' interpretation of statements

Although experienced science teachers helped to draw up the questionnaire, the first time the statements were tested on school pupils was at the actual survey. After the tests discussion with the pupils brought out the following observations. "Item 10 tells more about science examinations than about pupils' interest in history of science". "Item 9 may imply that scientists do not care for social problems; item 25 may imply that scientists are not cultured". Both items 9 and 25 provoked some hostility. "In item 18 a pupil could both agree, because he realises that history of science questions do not usually appear on science examination papers, and disagree, because history of science helps in understanding science thus indirectly helping in science examinations". "Item 36. Science courses already contain human interest because they interest human beings". "Several questions are repetitive" (few in fact ask precisely the same thing). "The responses 'a little' and 'some' are the same" (see 7.2.3 below).

A thorough discussion with pupils on the wording of statements is essential when devising questionnaires.

7.2.2 Scoring difficulties (items 5,15,16,39,34,10,18)

In deciding the direction of scoring it soon became apparent that certain items were neutral, indicating neither a favourable nor an unfavourable opinion towards history of science; these are items 39, 5, 15, 16 and 34. Independently minded sixth-form pupils are quite likely to claim an opinion unaffected by their teachers (item 39) and have views on

the appeal of history of science for boys and girls (items 5, 15) quite unrelated to the way their own opinions are inclined. To an historian of science history of science means a good deal more than is implied in items 16 and 34, yet this is the kind of history of science school pupils are likely to have encountered. In addition to these items pupils may favour history of science yet agree with statements 10 and 18. For each of these seven items the chosen direction of scoring was quite arbitrary. These items were included with all the other items for computer analysis, but would need to be omitted from any totals aimed at indicating an overall favourable or unfavourable opinion.

7.2.3 Choice of response offered to pupils

The questionnaire used four different sets of responses:

strongly agree		strongly disagree
definitely yes		definitely no
very much		not at all
all of the time		never

Four different sets were used to introduce variety and lessen the chances of boredom; the responses are the ones used by Skurnik and Jeffs in Science Attitude Questionnaire.⁴

On the Likert scale the middle response should indicate an uncertain or neutral opinion; on the marking, adopted favourable opinions should always score above 3 and unfavourable below this number. The pupils were not told this, but merely asked to give the most natural reply. After discussions with the pupils it became apparent that two of these sets of responses had no obviously middle, neutral response. In one of these a favourable opinion may be indicated by the four responses a "little/some/much/very much"; and an unfavourable opinion only by "not at all"; thus a favourable opinion may only score 2. In the second of these three

4. Larry S. Skurnik and Patricia M. Jeffs, Science Attitude Questionnaire, National Foundation for Educational Research, Slough, Bucks, 1971.

responses "occasionally/most of the time/all the time" may indicate a favourable opinion, and "seldom/never" an unfavourable one: again a favourable opinion could score too low. The items with these two sets of responses are items 3,8,14,21, 22,24,26,39. These two sets of responses are unsatisfactory and need to be changed.

7.3 The questionnaire as a measuring instrument

7.3.1 Determination of scales by factor analysis

Factor analysis is a statistical method for describing a large number of correlated measures in terms of a smaller number of basic dimensions which can be assumed to underlie them. The factor analysis was carried out separately on both the pre- and post-tests; as these two test administrations gave similar results the data was combined to obtain a common solution.⁵ The results showed that of the forty-two items, twenty-eight appeared to group together into three distinct factors.

Factor 1

1. It is easier to learn science if you know some history of science
2. Learning some history of science is a good way of learning about the methods of science
10. There is already enough to learn in science without introducing history of science
13. History of science is not important enough to introduce into school science courses
26. History of science interests me
27. All science pupils should learn some history of science to get an overall view of science
29. All pupils should learn some history of science at school
32. Science courses should not contain history of science
37. All sixth-form pupils should learn some history of science

5. For the factor analysis the principal component solution followed by a rotation to simple structure performed using the SPSS statistical package. See H.N. Nie et al., SPSS Statistical Package for the Social Sciences, New York, 1975. No loadings of the factors are given.

6. No knowledge of history of science is necessary for understanding present-day science
7. History of science is a good way of learning how scientific theories are formed

Factor 2

3. I enjoy learning about the quarrels of famous scientists of the past
9. If scientists knew more history of science they would show more concern for social problems
12. History of science helps in understanding the present-day relationship between science and society.
16. History of science means tracing the origins of present-day science
19. A study of history of science would be useful for showing whether science challenges religion
22. I like reading books about famous scientists of the past
23. School history courses should include some history of science
24. History of science can help you understand difficult topics in science
25. All scientists should know some history of science to make them more cultured
36. History of science gives science courses human interest
33. It would be interesting to make models of old fashioned scientific instruments

Factor 3

4. History of science is too difficult to introduce into science courses
8. Learning about the overthrow of old scientific theories helps in understanding present-day science
11. Scientists are more clever now than they were in the past
38. Scientists of the past were more likely to make mistakes than present-day scientists
30. It is a waste of time studying old scientific theories we know are wrong
20. Modern scientific methods have little in common with scientific methods of the past

The results of the factor analysis were perhaps disappointing. About 33% of the questionnaire items did not fall into factors. It was difficult to place on each of the factors an interpretation that would cover all items within the factor. Once an interpretation was made of the factor certain items outside that factor appeared to qualify for inclusion. However, factor analysis of a questionnaire of the type used is not likely to give clear-cut indications. The technique was designed to look for relationships between tests, not items. Each item has only a limited amount of variation because scores can only vary from one to five. Thus it is prone to have items grouping together because of certain statistical artifacts rather than because they have a common meaning.

7.3.1.1 Interpretation of the scales

Factor 1 The value of history of science in existing science courses

The type of science courses experienced by these pupils have been to a very large extent highly academic courses concerned with the internal findings and theories of science itself. All Factor 1 items relate to whether history of science has a place in such courses. Items 32, 13, 10 indicate directly whether science courses should contain history of science, thus making history of science part of the school curriculum (items 29, 37). Items 1,6,2,7,27 indicate the perceived usefulness of history of science in learning science. A pupil's interest in history of science (item 26) could be determined by how he sees its value in learning science.

Factor 2 The value of history of science in indicating the cultural and humanistic aspects of science

Items 3,9,12,16,19,22,25,33,36 are concerned with seeing scientists as people, their work, and the impact of science on human culture. Item 23 indicates that these topics are associated in the pupils' minds more with history courses than with science courses. Item 24 seems to have no place in this factor but would appear to qualify for Factor 1. Item 16 seems more appropriate to Factor 3.

Factor 3 Pupils' understanding of history of science as a continuous and progressive enterprise

Items 20, 11 ask whether the methods and personnel of present-day science have common features with the methods and personnel of the past; items 38, 4 whether science has become more rigorous and difficult; items 30, 8 whether a knowledge of the past helps in understanding the present.

7.3.1.2 Validity of the interpretations

To test the suggested interpretations for validity three "experts" were chosen to offer their own interpretation and act as judges. "Experts" A and B were science graduates with a higher degree in history of science and many years' experience of teaching secondary school science; "expert" C had taken part in the survey as a pupil and at the time of offering an interpretation was a university science undergraduate. The experts were not told of the author's interpretation, but were sent only the information given as Appendix 13; their responses are also given as Appendix 13.

The responses from the experts coincide to a large extent with the author's interpretation.

7.3.2 Reliability of items and scales

The reliability of the items and scales may be analysed in terms of the internal consistency of the questionnaire and its discriminatory power, and its use on subsequent occasions on the same subject.

7.3.2.1 Internal consistency

An attitude questionnaire has good internal consistency if each of the items is determining an opinion closely related to the central issue. The internal consistency of a scale is influenced by the number of items in the scale as well as by the degree to which the items reflect a clearly defined, unitary construct. The extent of the internal consistency is measured by correlating each of the items' scores against the total scores. The particular correlation used is the Cronbach-alpha coefficient corrected

for missing values.⁶ A "good" alpha-value depends to some extent upon whether the scale is used to provide measurements of individuals or groups, as well as the number of items. For measurements of attitudes of groups the following values are considered by statisticians as acceptable:

For 42 items values above about 0.80

11	"	"	"	"	0.60
6	"	"	"	"	0.50

The values determined are given in Table 1.⁷

TABLE 1 Internal Consistency

	Scale	alpha	Standardised item alpha	Number of items per scale
pre-test	HIST	0.89	0.89	42
	FAC 1	0.87	0.87	11
	FAC 2	0.65	0.64	11
	FAC 3	0.38	0.33	6
post-test	HIST	0.92	0.92	42
	FAC 1	0.91	0.91	11
	FAC 2	0.84	0.83	11
	FAC 3	0.66	0.65	6

Scale HIST values refer to the test as a whole

The alpha value comes from the results obtained; this value was adjusted for normal distribution to give the standardised alpha value. The standardised value can thus be compared with values obtained in other surveys.

The values obtained indicate good internal consistency for the test as a whole and for the three factors within the test. Only Factor 3 on the pre-test falls below the criterion adopted. This was most likely due

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6. In the pre-test there were nine missing values because of pupils omitting to answer or answering ambiguously; in the post-test there were three missing values. The correction was made by omitting these from the calculation.
 7. In this chapter figures are reported to two places of decimals, except in Section 7.4 where values are given to the nearest whole number; 0.5 and 0.5% are rounded up. Because of the missing values and rounding up the percentages do not always total 100.

to the small number of items which made up the scale.

7.3.2.2 Discriminatory power

Attitude scales have been described as "relatively crude measuring instruments ... [whose] chief function is to divide people into a number of broad groups, with regard to a particular attitude".⁸ Thus attitude questionnaires and scales must have the ability to discriminate between individuals and groups of differing attitudes. The discriminatory power was measured by correlating the score of each item against the total score of all the items using the Pearson moment correlation, to give a corrected item total correlation. A negative value of this correlation indicated that pupils who generally scored high (or low) on the whole test scored low (or high) on the particular item. Thus negative items are suspect. The correlations are given in Table 2, p.199.

For the test as a whole, items 8,16,39 are strongly negative at both the pre- and post-test stages; items 5,15,34 are slightly negative in the post-test. Each of the items 16,39,5,15,34 are neutral (see 7.2.2); had they been scored the other way around they would not have appeared negative. In item 8 a pupil favourably disposed towards history of science is likely to incline towards learning about the overthrow of old scientific theories. The pre/post-test responses are quite consistent with each other.

	all the time	most of the time	occasionally	seldom	never
Pre	2%	33%	51%	11%	2%
Post	2%	31%	53%	13%	0%

This is one of the items where the middle response "occasionally" is not viewed by the pupils as a middle, neutral response (see 7.2.3); thus a favourable opinion scores only 3 and is distorted.

For the factors within the questionnaire items 8 and 16 are again the only negative items and the above comments apply.

8. A.N. Oppenheim, as in note 3 above, p.121.

TABLE 2 Discriminatory power

Item	Corrected item - total correlation							
	Total test		Factor 1		Factor 2		Factor 3	
	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test
1	0.50	0.47	0.51	0.59				
2	0.28	0.54	0.45	0.55				
3	0.48	0.67			0.42	0.71		
4	0.39	0.33					0.28	0.55
5	0.14	-0.04						
6	0.44	0.57	0.44	0.62				
7	0.28	0.55	0.24	0.58				
8	-0.30	-0.48					-0.21	0.03
9	0.27	0.50			0.33	0.68		
10	0.64	0.74	0.68	0.73				
11	0.32	-0.01					0.35	0.52
12	0.45	0.53			0.48	0.71		
13	0.60	0.74	0.66	0.75				
14	0.70	0.83						
15	0.22	-0.02						
16	-0.16	-0.25			-0.16	-0.43		
17	0.64	0.68						
18	0.54	0.76						
19	0.10	0.39			0.19	0.46		
20	0.20	0.15					0.24	0.40
21	0.36	0.66						
22	0.41	0.61			0.45	0.70		
23	0.23	0.57			0.33	0.58		
24	0.48	0.57			0.21	0.59		
25	0.33	0.40			0.26	0.43		
26	0.78	0.80	0.70	0.64				
27	0.63	0.68	0.70	0.74				
28	0.32	0.55						
29	0.41	0.45	0.62	0.51				
30	0.62	0.61					0.19	0.39
31	0.38	0.52						
32	0.67	0.78	0.77	0.83				
33	0.24	0.46			0.33	0.58		
34	0.02	-0.07						
35	0.71	0.76						
36	0.63	0.69			0.47	0.66		
37	0.49	0.55	0.60	0.61				
38	0.21	0.30					0.19	0.48
39	-0.25	-0.25						
40	0.52	0.63						
41	0.42	0.29						
42	0.67	0.70						

Thus the discriminatory power of the questionnaire will be improved by:

- (i) reversing the direction of scoring of items 16,39,5,15,34
- (ii) changing the response of item 8 to read

strongly agree strongly disagree

7.3.2.3 Pre-test/post-test reliability

A pre-test/post-test reliability to measure the extent to which the questionnaire as a whole and the factors within the questionnaire give consistent results when applied on different occasions was determined using the Pearson correlation coefficient. The values obtained are given in Table 3.

TABLE 3 Pre-test/post-test reliabilities

	Number of items/scale	Pearson correlation coefficient
Total test	42	0.74
Factor 1	11	0.66
Factor 2	11	0.49
Factor 3	6	0.43

The differences between the pre- and post-test scores on the items was examined by means of chi-squared test and by analysis of variance. The 5% significance level is a standard used for estimating chance differences by statisticians. The results show that the questionnaire as a whole and the factors within the questionnaire have satisfactory reliability.

7.4 Pupils' opinions towards history of science and science education

Table 4 p.201 gives the absolute frequencies of response.

Table 5 p.202 gives the percentage response for each item in the pre- and post-test. In the first instance the middle response of each statement was considered neutral (see 7.2.3). The responses "agree" and "strongly agree" and their equivalents were added together for both pre- and post-

TABLE 4 Absolute Frequencies of Response

Item	Score 1		Score 2		Score 3		Score 4		Score 5	
	Pre/Post		Pre/Post		Pre/Post		Pre/Post		Pre/Post	
1	1		15	9	8	10	21	26		
2			12	7	8	9	24	29	1	
3	17	9	12	18	9	10	4	5	3	2
4	3		5	5	9	12	25	24	3	4
5			6	3	25	21	11	17	3	3
6	7	1	10	15	8	11	19	15	1	3
7			2	4	10	12	23	26	10	3
8	1		5	6	23	24	15	14	1	1
9	11	1	15	16	14	17	5	10		1
10	9	6	12	13	17	17	7	7		2
11	4	3	4	4	14	12	17	20	6	6
12	1		20	14	15	19	8	7	1	5
13	1	3	14	11	13	14	15	12	1	5
14	11	6	16	16	12	17	3	2	2	4
15	7	4	13	19	22	20	2	1		1
16	4	5	37	31	1	8	3	1		
17	1	1	3	7	4	6	31	26	5	5
18	4	3	15	19	12	11	14	11		1
19	4	2	8	11	14	17	12	14	6	1
20	1	1	8	8	8	7	23	25	4	4
21			4	10	11	13	22	19	8	3
22	10	8	14	16	21	7		3		1
23	1	2	11	11	8	14	21	15	4	3
24	4		14	9	24	29	3	7		
25	4	2	17	14	12	9	8	16	3	4
26	5	6	21	16	15	16	3	4	1	3
27	1	1	13	8	4	10	22	24	5	2
28	2	2	10	11	10	12	18	15	5	5
29	2	1	10	9	10	10	23	24		1
30	6	3	4	5	6	12	28	20	1	5
31			9	9	21	21	12	13	2	2
32	2	2	8	10	12	11	21	20	2	2
33	5	3	10	11	15	13	12	13	3	4
34	3		32	34	3	9	7	1		1
35	1	2	12	7	11	12	19	23	2	1
36	1		7	8	19	17	16	19	2	1
37	1	1	19	19	11	12	13	10	1	3
38	2	1	13	11	9	13	14	17	6	3
39	1	4	4	2	5	14	13	12	21	13
40	1		5	4	9	9	26	29	2	3
41	1		6	7	9	8	23	26	4	4
42	2	1	4	5	7	10	31	27		2

TABLE 5 Relative Frequency of Response (Percentage)

Item	Score 1		Score 2		Score 3		Score 4		Score 5	
	Pre/Post		Pre/Post		Pre/Post		Pre/Post		Pre/Post	
	%	%	%	%	%	%	%	%	%	%
1	2		33	20	18	22	47	58		
2			27	16	18	20	53	64	2	
3	38	20	27	40	20	22	9	11	7	4
4	7		11	11	20	27	56	53	7	9
5			13	7	56	47	24	38	7	7
6	16	2	22	33	18	24	42	33	2	7
7			4	9	22	27	51	58	22	7
8	2		11	13	51	53	33	31	2	2
9	24	2	33	36	31	38	11	22		2
10	20	13	27	29	38	38	16	16		4
11	9	7	9	9	31	27	38	44	13	13
12	2		44	31	33	42	18	16	2	11
13	2	7	31	24	29	31	33	27	2	11
14	24	13	36	36	27	38	7	4	4	9
15	16	9	29	42	49	44	4	2		2
16	9	11	82	69	2	18	7	2		
17	2	2	7	16	9	13	69	58	11	11
18	9	7	33	42	27	24	31	24		2
19	9	4	18	24	31	38	27	31	13	2
20	2	2	18	18	18	16	51	56	9	9
21			9	22	24	29	49	42	18	7
22	22	18	31	36	47	38		7		2
23	2	4	24	24	18	31	47	33	9	7
24	9		31	20	53	64	7	16		
25	9	4	38	31	27	20	18	36	7	9
26	11	13	47	36	33	36	7	9	2	7
27	2	2	29	18	9	22	49	53	11	4
28	4	4	22	24	22	27	40	33	11	11
29	4	2	22	20	22	22	51	53		2
30	13	7	9	11	13	27	62	44	2	11
31			20	20	47	47	27	29	4	4
32	4	4	18	22	27	24	47	44	4	4
33	11	7	22	24	33	29	27	29	7	9
34	7		71	76	7	20	16	2		2
35	2	4	27	16	24	27	42	51	4	2
36	2		16	18	42	38	36	42	4	2
37	2	2	42	42	24	27	29	22	2	7
38	4	2	29	24	20	29	31	38	13	7
39	2	9	9	4	11	31	29	27	47	29
40	2		11	9	20	20	58	64	4	7
41	2		13	16	20	18	51	58	9	9
42	4	2	9	11	16	22	69	60	2	4

tests, as were the opposite responses; the percentages thus obtained were averaged out for the two tests.⁹ The results are given in Table 6.

Discussion is based firstly on a grouping by the author of the questionnaire statements and then on the grouping given by the factor analysis. Considering Table 6:

- (i) where the scores 1+2/3/4+5 are roughly equal this is taken to indicate an even division of opinion;
- (ii) if the difference between the scores for 1+2 and 3+4 is greater than about 15% and the score for 3 less than about 50%, this is taken to indicate a majority opinion;
- (iii) if the score for 3 is greater than about 50% this is taken to indicate uncertainty.

9. Although items 3,9,21,39 show changes between pre- and post-tests, these changes do not affect the overall views expressed. It is therefore valid to average them out.

TABLE 6 Averaged Frequency of Response (Percentage)

Items	Scores 1+2	Score 3	Scores 4+5
	%	%	%
1	28	20	53
2	22	19	60
3	63	21	16
4	15	24	63
5	10	52	38
6	37	21	42
7	7	25	69
8	13	52	34
9	48	35	18
10	45	38	18
11	17	29	54
12	39	38	24
13	32	30	37
14	55	33	12
15	48	47	4
16	86	10	5
17	14	11	75
18	46	26	29
19	28	35	37
20	20	17	63
21	16	27	58
22	54	43	5
23	27	25	48
24	30	59	12
25	41	24	35
26	54	35	13
27	26	16	59
28	27	25	48
29	24	22	53
30	20	20	60
31	20	47	32
32	24	26	50
33	32	31	36
34	77	14	10
35	25	26	50
36	18	40	42
37	44	26	30
38	30	25	45
39	12	21	66
40	11	20	67
41	16	19	64
42	13	19	68

7.4.1 Opinions based on grouping
by the author

In the following section the figures given in brackets are the percentages for and against the statement.

7.4.1.1 How interested are pupils in history of science
(items 26,14,22,3,33,17)?

The majority of pupils have little interest in history of science (54% to 13%), would not find science courses more interesting if history of science were included (55/12), do not like reading books about famous scientists of the past (54/5), and do not enjoy learning about the quarrels of past scientists (63/16). (The fact that all of these statements are at variance with what follows is discussed below in 7.4.1.7a). Pupils are evenly divided about the interest to be obtained from making models of old-fashioned scientific instruments (36/32). They are however strongly in favour of hearing about experiments carried out by famous scientists of the past (75/14).

7.4.1.2 Should school science courses contain history
of science (items 32,35,13,10,29,23)?

Pupils believed that science courses should contain history of science (50/24) and that they would like such courses (50/25). There was an even division on how important history of science was to such courses (32/37), and not surprisingly a feeling that there was already enough to learn without introducing more (45/18). They believed that all pupils should learn some history of science (53/24) and history courses should include history of science (48/27).

7.4.1.3 What is the role of history of science courses
(items 40,1,42,30,8,6,18,7,2,27,36,31,24)?

Things of scientific interest can be learned from studying the work of early scientists (67/11), a knowledge of history of science making science easier to learn (53/28) because it helps in understanding science (68/13). In particular it is not a waste of time studying scientific theories now

considered wrong (60/20). There was uncertainty whether learning about the overthrow of old theories helps in understanding present-day science (13/52/34) (see 7.4.1.7a). There was a fairly even division of opinion on whether history of science was necessary for an understanding of present-day science (37/21/42) and a feeling that it did not help in passing science examinations (46/29). History of science had specific value for learning about the formation of scientific theories (69/7) and the methods of science (60/22), for giving an overall view of science (59/26), and for giving science courses human interest (42/18). There was uncertainty whether history of science was a good way of linking together physics, chemistry and biology (20/47/32). Seemingly, there was uncertainty whether history of science helped with learning difficult topics (30/59/12). (See 7.4.1.7a).

7.4.1.4 What other roles can history of science fulfil
(items 28,25,9,19,12,21)?

There was some measure of agreement that scientists needed to know some history of science for their work (48/27) but an even division on whether it made them more cultured (41/24/35). It was not accepted that scientists would show more concern for social problems if they knew history of science (48/18) (note the change of opinion pre/post test). There was an even division on whether history of science would help show whether science challenges religion (28/35/37) and doubt that it helps in understanding the present-day relationship between science and society (39/24). History of science does show how important science has been in the progress of civilisation (58/16).

7.4.1.5 Pupils' view of history of science
(items 16,34,4,41,20,11,38)

Pupils strongly believe that history of science means tracing the origins of present-day science (85/5) and learning about the lives and works of scientists of the past (77/10); it is not too difficult to introduce into science courses (63/15). They do recognise a continuity in

science believing that present-day science has much in common with the past (64/16) and that modern methods do have a good deal in common with those of the past (63/20). The change from the strong feeling that scientists were just as clever in the past (54/17) to the less strong feeling about the likelihood of mistakes in the past (45/30) could indicate a belief in the progress of science as a more precise and exact study.

7.4.1.6 Miscellaneous points
(items 5,15,37,39)

There was uncertainty about whether history of science appealed more to boys or girls (10/52/38 and 48/47/4), but there was a feeling that not all sixth-form pupils should learn history of science (44/30). Because of the shift of response between pre- and post-test (and the choice of responses given) no comment is made on the formation of pupils' opinions (item 39).

7.4.1.7 Comments on opinions expressed

(a) Consistency of pupils' responses

The pupils' responses to items 26,14,22,3,8,24 are clearly inconsistent with all the other responses. An examination of the choice of response available in each of these cases reveals that the middle response is not obviously neutral and that there apparently is no neutral item (see 7.2.3). It would seem more appropriate to take together "a little/some/much/very much" as indicating the opposite to "not at all". This would then give that most pupils had some interest in history of science (88/12), would find science courses more interesting if history of science were included (71/19), and enjoy hearing about the quarrels of famous scientists of the past (61/29). Taking "occasionally/most of the time/all of the time" as opposite of "seldom/never" gives an even division about reading books on famous scientists of the past (46/54), but a strong belief that history of science helps in understanding difficult topics in science (70/30), and an even stronger belief that learning about the overthrow of old scientific

theories helps in understanding present-day science (77/13).

(b) Extraction of the pupils' viewpoints

An analysis of the statements given and of the responses made by the pupils emphasises the necessity for extreme care in phrasing the statements and for providing sufficient statements to elicit clearly the pupils' viewpoints. This is illustrated by considering how wide a view pupils have of the study of history of science. Most historians of science would see their study as a good deal wider than merely tracing the origin of modern science and studying the lives and works of past scientists. The pupils' agreement with both of these statements could indicate a rather restricted viewpoint on their part; alternatively it could indicate that they were not provided in the questionnaire with sufficient alternatives to show a wider appreciation of history of science. Likewise, one item on sixth-form pupils (item 37) is insufficient to determine at what stage history of science should be included, according to the pupils.

A problem that may arise from attempts to cover all possibilities is pupil hostility. They may feel that the questions are repetitive and an attempt to trick them; this could lead to inconsistency of results.

7.4.2 Opinions based on the factor analysis

For the purpose of this analysis the responses will be totalled in the way suggested in 7.4.1.7a; the figures for each of the assertions are not repeated.

7.4.2.1 History of science in school science courses (items 26,29,37,10,13,32,6,1,2,7,27)

Most pupils are interested in history of science, believe that some history should be learned by all pupils, but not necessarily in the sixth form. Although there was a strong feeling that there was enough to learn in science courses already, and an even division on the importance of history of science, it was believed that science courses should contain history of science. Despite the even division on the necessity of history

of science for understanding present-day science it was agreed that it is easier to learn science if some history of science is known. History of science is a good way of learning about the methods of science, of learning about the formation of scientific theories, and of giving an overall view of science.

7.4.2.2 The humanistic and cultural aspects of science
(items 24,36,12,19,25,9,3,22,33,16,23)

Most pupils believe that history of science can help to give an understanding of difficult topics in science and give human interest to science courses; they do not believe it helps to show a present-day science-society relationship, are evenly divided on whether it shows if science challenges religion, and if it helps to make scientists more cultured. The view that scientists would not show more concern for social problems with more knowledge of history of science could indicate a hostile reaction to an implication that scientists do not show concern for social problems. Although most pupils got some enjoyment from the quarrels of past scientists, they are evenly divided on whether they like reading books on past scientists and would like making models of old-fashioned instruments. Pupils overwhelmingly believe that history of science means tracing the origins of present-day science, and to a lesser extent that history courses should contain some history of science.

7.4.2.3 The progress of science
(items 20,11,38,30,8,4)

Most pupils agree that the methods of present-day science have common features with those of the past, and that present-day scientists are neither more clever nor less likely to make mistakes than scientists of the past. There is a belief that a knowledge of the past helps in understanding the present and that history of science is not too difficult to introduce into science courses.

7.5 Some conclusions

In this study the term "opinion" has been used to indicate a view based on grounds short of proof but held as probable, the term "attitude" to represent settled behaviour based on one or more opinions. A large number of opinions regarding a central issue are considered to give rise to a somewhat higher order concept than the concept of opinion, namely the concept of attitude.¹⁰ By combining the answers to a set of opinion questions into some sort of score a respondent's attitude can be measured.¹¹ Of the various ways of combining answers into some sort of score the Likert method was adopted. This, as the basis of a good deal of modern survey work, has been widely used in educational and other social surveys, and enjoys a reputation as a highly respectable scale. It has an advantage of being less time-consuming than the Thurstone or Guttman scales to construct, and is relatively easy to administer. Factor analysis is widely used with the Likert scale as an exploratory device, and as such can play an important role at the pilot stage. In attitude surveys it is usual to specify in advance each of the theoretical constructs underlying the scale before carrying out the factor analysis. However, this need not be the case at the pilot-stage. At this stage factor analysis can be used to "help to sort responses into identifiable patterns";¹² a large number of items relating to a wide range of aspects "can be included on the pilot questionnaire, and factor analysis can then be used to explore the underlying structure".¹³ In this pilot study theoretical constructs were not specified in advance. The factor analysis was used to sort the responses into patterns. An analysis of pupils' opinions based on factor analysis and based on a grouping by the author is given

10. H.J. Eysenck, Sense and Nonsense in Psychology, Penguin Books, Harmondsworth, Middlesex, 1957, pp.285-6.

11. C.A. Moser and G. Kalton, Survey Methods in Social Investigation, London, Second Edition, 1971, p.318.

12. Gerald Hoinville, Roger Jowell and Associates, Survey Research Practice, London, 1978, p.35.

13. C.A. Moser and G. Kalton, as in n.11 above, p.366.

to indicate possible areas of investigation for theoretical constructs.

This work is presented as no more than an initial stage in devising an attitude questionnaire. An attempt has been made to highlight some of the problems to be overcome; the wording of questionnaire items, the choice of responses offered, theoretical constructs underlying the scales, the reliability of the items and the scales. As the next stage, a questionnaire modified in the light of the above and further analysis needs to be produced and tested. Only when there is a satisfactory measuring instrument can the factors underlying attitudes to history of science - factors such as the sex of the pupils, the schools they attend, their previous studies in science - be investigated.

Chapter 8

THE FUTURE OF HISTORY OF SCIENCE

IN THE SCHOOLS

8.1 Alternatives for Science Education

"All I am sure of is that the more it is possible, legitimately, to move away from a monolithic, mechanistic, dehumanized image of science; to establish a view of it as a humane study, deeply concerned both with man and society; providing scope for imagination and compassion ... the easier it will be to overcome the sense of alienation which turns many young people away from it".¹

The opinion expressed by Lord Bullock in 1976 was the same one which had helped to arouse an interest in history of science in education in the first decades of the century, and had played a part in the limited introduction of that subject into the school curriculum shortly after World War II. It is a view which now has been incorporated into the most recent consultative document of the ASE,² a document which could result in history of science finally gaining a firm and widely established place in the English secondary school.

The period around 1860 saw a battle to establish science as a valid part of the English secondary school curriculum. By that time many science histories had been written for both specialist and lay audiences. The pedagogical value of history of science - helping to understand and remember the facts of science, to illustrate its nature and methods - had long been argued. Many of the people most prominent in promoting science education were clearly sympathetic towards historical matters. The opportunities to exploit history of science did exist. Yet it played no part in the battle against the established tradition of classical education. This is not surprising. The arguments used to promote the claims of science - the mental training it gave, its utility, its effect on everyday life - needed

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1. A. Bullock, "Science - a tarnished image?", School Science Review, 57 (1975-6), 625.
 2. ASE, Alternatives for Science Education, Letchworth, 1979.

to emphasise science as a contemporary, ongoing activity. The initial battle was as much concerned with establishing that science should be taught as it was with the content and method of teaching. Science and scientists were at that time becoming increasingly highly specialised, with less time for matters not obviously relevant to advancing the existing state of scientific knowledge. History of science, with its overtones of classical and literary studies, may well have seemed too akin to the type of education science was trying, if not to replace, at least to supplement.

By the beginning of the Second World War, however, there had been a good deal of strong and articulate support for including some history of science in the school curriculum; distinct roles had been laid down for suggested historical material; History of Science had moved some way towards gaining a recognition as an established university discipline. Despite this, it seems that little use was made of it, perhaps because of the lack of attention given to it in British universities. The majority of science and history teachers received no training in the history of science either as part of their degrees or as part of their professional training. Only after the Second World War did history of science start to find its way into the curriculum of the English secondary school on a restricted but significant scale.

Of the many roles seen in the twentieth century for history of science in education, three have been argued most frequently and cogently: historical ideas and material can demonstrate the humanistic and cultural aspects of science, can counter over-specialisation, and can teach about the nature and methods of science. It was chiefly on these bases that the initial calls were made for science history to be included in the curriculum of the English secondary school. It was to counter excessive specialisation and to present the humanistic and cultural aspects of science that the calls came to fruition, with the introduction of GCE "History of Science" as an examination subject, and with its inclusion in General Studies courses. It was to demonstrate the nature of scientific theory that Nuffield physics

used the history of astronomy. The same three roles reappear in the ASE consultative document.

Alternatives for Science Education does not set out to produce outline syllabuses or teaching materials. It is a document which considers the aims of science education, suggests as possible lines for debate and development a range of curriculum alternatives, and pays a good deal more attention to the place of history of science in science education than any previous document of its kind. Among the views expressed by the working party is the belief

"that the important cultural aspects of science, its history, philosophy and contribution to the way twentieth-century man conceptualizes his environment, have not been adequately considered in the construction of examination syllabuses and courses at all levels of schooling".³

The document believes that science as a cultural activity should be one component of a sound science education programme. It argues that

"science studies that include the history, philosophy and social studies of science provide opportunities for ... explaining, and therefore understanding, the nature of advanced technological societies, the complex interaction between science and society, and the contribution science makes to our cultural heritage".⁴

It recommends

"that substantial resources be allocated to a major programme of research and development ... that develops and effectively evaluates curricula proposals in the areas of ... and the history and philosophy of science; and which develops a series of small scale and intensive studies of the nature of young people's conceptualizations of science and scientific processes".⁵

Each of the possible curriculum alternatives given in the document ensures that some historical material must be included in the teaching of all secondary school pupils.

Curriculum alternatives for the secondary school⁶ are given as Models 1, 2, and 3 representing short-, middle- and long-term goals respectively.

3. ASE, as in note 2 above, p.52. 4. ASE, as in note 2 above, p.38.

5. ASE, as in note 2 above, p.53.

6. The curriculum proposals are organised within three distinct phases; Phase 1 (5-11 years), Phase 2 (11-16 years) and Phase 3 (16-18 years). Only Phases 2 and 3 are considered in this discussion.

Model 1 consists very largely of optional studies, Model 2 has more common core with correspondingly fewer opportunities for options, Model 3 has no system of optional studies, although it is not a common curriculum defined in content terms. The quantity of history of science that would be introduced into science teaching via these models is considerable. In Model 1 a full "History and Philosophy of Science" course is suggested as one of four options. Moreover, in the other options the courses would all "utilize appropriate concepts, skills and techniques derived from subjects such as ... history ... etc."⁷ In Model 2 the core science, compulsory to all pupils, would embody the basic scientific disciplines "related throughout to a study of practical and technological applications and, to a more limited extent, historical and social implications".⁸ A "History and Philosophy of Science" course, designed to explore the history of science and technology and the changing nature of scientific ideas and methodology, remains available as a possible option at both Phase 2 and Phase 3. The suggested Phase 3 arrangements in this model, however, bring the history and philosophy of science much more to the fore, and would most probably result in far more sixth-form science pupils studying the subject than at present. In Model 3 most Phase 2 history would come in the stage "Science and Society" where "the knowledge, concepts, processes and applications raised in the earlier parts of the course would be placed in a historical, social and personal context".⁹ The Phase 3 studies would be integrated across the basic elements of Phase 2, thus historical aspects would of necessity be considered.

It is outside the scope of the present investigation to consider the document as a whole. Furthermore, the lack of details of the proposed historical aspects makes judgements on these parts difficult. It does, however, seem open to question whether an option "History and Philosophy of Science", as appears in Models 1 and 2, would be the most useful and

7. ASE, as in note 2 above, p.61 note 62.

8. ASE, as in note 2 above, p.49.

9. ASE, as in note 2 above, p.49.

appropriate of options to offer at either Phase 1 or Phase 2. Its title, which is unlikely to have much appeal for pre-sixth-form pupils, seems to suggest a watered-down version of the GCE "History of Science" courses (see 4.2). It could run into the problems of finding suitably qualified teachers and appropriate resource material. These problems would be exacerbated as Models 1 and 2 are short and medium term solutions. While the author is strongly in favour of science courses which contain and make use of historical material, there does seem to be other material which is perhaps more essential and would probably have more direct appeal, relevance, and educational value to the pupils. An option with some such title as "Scientists in the World" could contain sufficient historical material to allow an appreciation of our cultural heritage, to give an understanding of the science/society relationship, and to provide a basis for some understanding of the philosophy of science. It could also allow other material, just as essential, to be included. What seems to be the necessary and vital first stage is the detailing of "essential aspects". It would be helpful to have full and specific details of what the working party considers "essential aspects of a general science education".¹⁰ This would allow a debate on the details, their order of priority, the possible contributions of history, and the down to earth problem of how the essentials could be achieved in the classroom. The author, for example, believes that some knowledge and understanding of the distinction between science and technology, and the meaning of scientific theory are two essential aspects, which are best taught through history of science, and which every person leaving school should have had presented to them. Details along the following lines would provide a basis for a "down to earth" debate.

10. ASE, as in note 2 above, p.48.

Science and technology: meaning of scientific theory

The following allows a better appreciation of the science/technology/society relationship; it provides a foundation for more sophisticated views at sixth-form level and later.

Science

1. This is a human activity concerned with understanding natural phenomena.
2. Over the ages people have devised and modified certain methods and instruments to carry out this activity; the activity has resulted in the acquisition of a body of knowledge.
3. This body of knowledge contains "facts" and "theories"; as more and different knowledge is gained these facts and theories will change.
4. A scientific theory is the best explanation we can give at present to what we know about nature.

Technology

1. Technology is a human activity concerned with controlling and exploiting nature.
2. Until very recently most technological activity was carried out independently of scientific activity.
3. Nowadays "technologists" try to use the knowledge, methods, and instruments of the "scientist".
4. Although the words science and technology are often considered synonymous today, most scientists are still trying to understand nature and most technologists are still trying to control nature.

Clearly history of science has the roles of providing an analysis to help understand modern society, and to allow an appreciation of our cultural heritage. On the basis that it is better to build on what exists, especially for the short-term, the present Nuffield O level courses already contain material which with suitable modification could achieve these purposes. A theme on the science/technology/society interactions could readily be built around the history of dyeing (Nuffield Chemistry options)

and/or disease and public health (Nuffield Biology). A theme on our cultural heritage could be based around the Copernican revolution and/or Darwinian evolution, especially if these were set into a framework of contemporary ideas as in the Open University course Science and Belief: from Copernicus to Darwin. It is here that there could be some practical pay-off from Steele's The History of Scientific Ideas and the Nuffield Ideas Unit. What seems of particular importance is that the historical material is not presented as dogma, as in Nuffield O level physics, but as an on-going inquiry. The Chemistry Options provide an example with reconstruction of original experiments, the use of original papers, the posing of problems; all this helps in the spirit of inquiry.

Two aspects of the ASE proposals are sufficiently different from previously held views about history of science in school education as to be worthy of comment. First the document considers historical aspects of science to be quite suitable for pupils of all abilities. Second, separate history of science courses are not seen as belonging predominantly to the sixth form. As has been pointed out, the investigation carried out by the author refers only to the pupils of the top ability band. This restriction was made because past discussions on this matter were most frequently made with these pupils in mind.¹¹ Perhaps this is partly because most discussions on science education during the first half of the century centred around the more able pupil. The SMA during this time was very largely made up of grammar and public school teachers; not unnaturally School Science Review concentrated its writings on their immediate interest. But when pupils of all abilities were considered the view expressed by G. Fowles, then Senior

11. There are examples of linking history of science with the secondary modern school. In 1949 Gordon Nunn wrote "There is much to be said for introducing some history of science ... it demonstrates the struggle between true science and speculative science", G. Nunn, "Science in the secondary-modern school", School Science Review, 30 (1948-9), 151 ff. In this and other writings Nunn showed himself familiar with discussions on the role of history of science in education. There were also BBC history of science broadcasts for the secondary-modern school (see 4.1). But such examples are not very common.

Science Master at Latymer Upper School, usually prevailed.

"... the lower ranks ... offer a mental resistance to all knowledge which does not practically interest them, or, in their opinion, help towards their career ... a formal account of the historical development of scientific subjects leaves them unresponsive".¹²

It may seem surprising that history of science should have been considered more appropriate for pupils of the highest ability. It had, after all, been criticised as a "soft option" and should therefore have seemed suitable for the average and below average pupil. It had been used since at least the nineteenth century as a way of popularising science for the laymen. It requires only a small (but illogical) mental jump to extend this usage from "layman" to "less able". But, at least until recent years, the type of courses followed by pupils outside the top ability bracket were less amenable to a historical treatment. Little was included about the nature of science; the two-way interaction between science and society was not analysed; the cultural heritage of science was a rather esoteric topic. If however science courses change along the lines suggested in Alternatives for Science Education there seems no reason why historical material should not be used successfully with pupils of all abilities, particularly if it is shown to have a relevance in understanding present-day science, technology, and society.

The second difference comes from the proposal for history and philosophy of science courses for thirteen-year old pupils. From the time history of science in school education was first discussed there has been no complete uniformity of opinion about the most appropriate stage of education for its inclusion. However, it did become fairly widely accepted that biographical details and simple discussions about discoveries and the development of scientific ideas should be present throughout all stages of education. On the other hand most people accepted that any formal rigorous treatment, or any study of history of science as an independent course, was only

12. G. Fowles, "The place of the history of science in education", School Science Review, 31 (1949-50), 3.

appropriate at the Advanced (sixth-form) Stage of education. A serious study of history of science was thought to require a thorough knowledge of science itself, together with some knowledge of history to set the science in a wider context. To allow sufficient time for the "amassing of a multitude of facts" most people accepted that any formal and rigorous treatment, or any study of history of science as an independent course, was most appropriate at the Advanced (sixth-form) Stage of education.

8.2 A more secure future

Despite the many confident assertions it is not easy to assess the interest of school science teachers towards the use of historical material in science courses. Using the response in teachers' journals to articles discussing the pedagogical aspects of history of science as a yardstick, it would seem that interest was slight. Yet it must be remembered that many science teachers do not feel they are qualified to comment in detail on such matters. They have received little formal training in the subject at university or college and have experienced no pressures from external examinations to use such material. There does exist, however, a substantial body of opinion which believes that history of science should have a definite place within science courses. The problem is how to achieve it.

At the present time an attempt is being made via Physics Education to encourage more use of historical material. This followed from an informal meeting held at the Headquarters of the Institute of Physics in December 1976. The outcome of this and subsequent discussions was the promise from several volunteers to produce "Historical Case Studies", the first of which appeared in November 1979.¹³ However, past lessons seem to indicate that the production of resource material is by itself insufficient. In the opinion of the author the key lies in the two factors of the training given

13. J. Harris, "The hairpin in the bottle", Physics Education, November 1979, pp.436-40.

to teachers, and the influence of external examinations.

There is no short term solution to the problem, but the following do seem to be needed.

1. Short vacation courses of the type organised by the Department of Education and Science and the local authorities.

For teachers to be attracted to such courses they would have to be seen to have a relevance and usefulness to the school situation. This could be achieved by courses of the type "Historical material in Nuffield O level science courses" and "History of Science for understanding modern society". But one essential feature is that any participating teachers should feel they take away from the course something they can try and will be of practical value in the classroom.

2. The pressure of examinations

In 1962 two of the Nuffield O level Organizers summed up what had long been apparent. "Examinations - whatever else they do - control the success of any teaching plans. However acceptable a project may be on educational grounds, it will not be viable in the school environment unless the questions used in public Examinations are in keeping with the spirit".¹⁴ If it is thought desirable that teachers should use historical material in science courses then it is essential that more historical questions be included in science examinations. Not only that, the format of the examination must be such that these questions cannot be avoided.

3. A knowledge of contemporary thinking in the discipline History of Science.

It can be argued that one reason for the many unsatisfactory features of Nuffield O level physics was the reliance placed on out-of-date source material. Yet few teachers have the time, the access, and perhaps even the background to use regularly the many specialised learned journals on the history of science. It seems essential that the history is taught not

14. M. Waring, Social Pressures and Curriculum Innovation, London, 1979, p.11.

as dogma but as an ongoing inquiry; teachers should know the latest thinking in what they are teaching. It would seem appropriate therefore that at regular intervals (say every five years) summaries of ideas, work and debates within the academic world, relevant to material used in schools, should be made available to teachers. These should be written for teachers and perhaps in a form (with teaching notes) that could be used in the classroom. For a variety of reasons the School Science Review seems the most appropriate medium for carrying such articles. There does seem a strong case here for liaison between the British Society for the History of Science and the ASE.

These suggestions would probably increase the quantity (and quality) of the historical material used in school science courses. In the last analysis, however, the answer to the problem lies within the universities. Thomson's assertion that teachers "tend to go on teaching as they were taught themselves" is as true today as it was in 1918. Until a significant amount of history of science is included as an essential component of either a science degree, or the professional qualification of a teacher (or preferably both) it is most unlikely that any satisfactory place will be found for it within the school curriculum.

8.3 Further areas of investigation

In the research for this thesis English secondary school and university education over the past two hundred years was surveyed. A search was made for examples of history of science being used in, or advocated as part of curricula from about the mid-eighteenth century up to the present time. The mid-eighteenth century was chosen as the starting point because of the growing interest in writing about the histories of the sciences apparent from that time onwards. If some people were sufficiently interested to write about such matters then they or others might have been equally

interested in advocating or using history of science in education.

However, the choice of such a widespread time-scale presents many practical difficulties, not least of which is the monumental quantity of primary source material available and the severe demands it makes on time and resources. A wide-ranging survey can unfortunately result in some areas of potential interest being treated at best at a relatively superficial level or at worst being ignored.

In this thesis three episodes - the introduction of "History of Science" as a GCE examination subject, the work of the Nuffield History of Ideas Unit, and the history of science in Nuffield O level physics - have been considered in some detail. These episodes, seen by the author as major attempts to introduce history of science in some form into the school curriculum, have been interpreted as resulting largely from initiatives taken by certain individuals. The three Whitgift masters and Arthur McKenzie were the prime movers for GCE "History of Science". Professor Stephen Toulmin not only initiated the move towards the Nuffield History of Ideas Unit, but together with his wife, June Goodfield, almost exclusively determined the work of the Unit. Although the history of science in Nuffield physics was not originated by Professor Eric Rogers, the historical writing that appeared in the publications, in particular the history of astronomy, was almost totally his creation. But, as noted, each of these attempts had serious limitations, perhaps because they were initiatives taken, and in two of the cases largely controlled, by individuals. The more general questions of the consideration given by professional associations - in particular the Association for Science Education, its precursors the Science Masters' Association and the Association of Women Science Teachers, and the British Society for the History of Science - to the role of history of science in education and their attempts to encourage its introduction into the school curriculum have not been analysed in any detail. Yet, as has been seen, these

organisations have by no means ignored this issue.¹⁵ The extent to which professional organisations have acted as pressure groups to affect this particular curriculum change may well be an area worth further investigation. Another area of potential interest concerns women science teachers. The aversion of women teachers to excessive specialisation and the possible links between this aversion and the interest in the history of science has already been indicated, as has the commitment in the 1940s of the AWST to history of science in the curriculum.¹⁶ On the evidence of the pre-war AWST reports it does seem that their annual meetings were rather different in tone from those of the SMA; it appears, for example, that the women showed more interest than men in such matters as scientific literature and heroic biographies. Something of interest may well emerge from a study of the possible contrast between women and men science teachers, and their professional associations, in their advocacy and use of historical material in school science courses.

The wide-ranging survey made in this present work is the first of its kind. It is hoped that it may provide both a framework and a series of potential starting points for further investigations.

15. See, for example, 3.4.4 and 4.1.

16. See 3.3.3 and 4.1.

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APPENDIX 1

Comments relating to Joseph Priestley, William Whewell, and Eric Holmyard. Benchara Branford's diagram of the development of mathematical experience in the race and in the individual.

Joseph Priestley (1733-1804)

Although Priestley is now remembered mainly for his discovery of oxygen it was his highly successful History of Electricity (1766) which earned him election as Fellow of the Royal Society prior to publication. This treatise was produced while he was tutor of language and literature at Warrington Academy and before he had done any significant experimental work in science. It was intended as one of a series on the histories of all branches of experimental philosophy. In 1772 Priestley produced his less successful History of Vision, Light and Colours in which he mentions his recent experiments on air; its failure and his new interest in pneumatic chemistry ended his project on the histories of the experimental sciences. Although Priestley believed that a knowledge of the history of science was absolutely necessary for the advancement of science, he urged that people do science not by reading about it, but by using apparatus and doing experiments. In his writings on education he did not explicitly advocate teaching science through its history.

Priestley's ideas on history were influenced by Benjamin Franklin, who wanted a "universal history" to be taught in schools and colleges; Franklin advocated an historical method of teaching for "almost all kinds of useful Knowledge". He explicitly included some history of technology ("Invention of Arts, Rise of Manufactures ... History of the prodigious Force and Effect of Engines and Machines used in War ...") and implied topics that would now be considered history of science. (See J.H. Best (ed.), Benjamin Franklin on Education, New York, 1962).

Priestley himself was influential on later writers of science history including Francis Baily, whose historical treatises of the 1830s showed an

exceptionally high degree of scholarship. Baily became acquainted with Priestley at the age of seventeen and continued as a warm admirer throughout his life. His An Epitomy of Universal History published in 1813 was an extension and improvement of Priestley's work. See J. Herschel "Memoir of Francis Baily", Phil. Mag., 26 (1845), 38-75

William Whewell (1794-1866)

Whewell was a man of immense and wide-ranging talents. Although his interest in the history of science dated from at least 1819, it was only one of his many interests. Whewell made a twofold division of studies. There were the "permanent studies", with a fixed body of knowledge; the classics, geometry, mechanics, and astronomy fell into this category. Then there were the "progressive studies" with changing knowledge and new discoveries to make; these included the physical sciences, botany, chemistry, metaphysics, and history. Although Whewell believed that both types of studies were needed for the undergraduate, he saw the permanent studies as more appropriate and coming before the progressive. He would have categorised history of science as a progressive study. In Of a Liberal Education he wrote, "The Philosophy of Science cannot be learnt without the History of Science. The History of Science cannot be understood without a knowledge of science itself. The wider Sciences cannot be followed without a knowledge of mathematics. Therefore I would teach, first, Mathematics; then, the Inductive Sciences; then, the History of Science; and then I should hope to be able really to impress upon my pupils those philosophical monitions which Mr. Lyell desires him to receive" (p.125 ff). Clearly history of science was a stepping stone to philosophy.

Whewell's History of the Inductive Sciences was the first major English history of science treatise which attempted to cover the whole

range of science rather than a single branch. The material, mainly borrowed from other writers, ranged from Greek physical science and astronomy through to electricity, magnetism, chemistry, mineralogy, crystallography, botany, zoology, physiology and anatomy. It came to be regarded as a Victorian classic. Although it was translated into German in 1840/41, George Sarton later commented that he seldom saw reference to it in continental books.

Eric Holmyard (1891-1959)

Eric Holmyard showed interest in both the natural sciences and history while a student at Cambridge: he read chemistry, physics, botany, and zoology from 1908 to 1910, history 1910-11, and chemistry 1911-13. His early teaching career was at Bristol Grammar School and Marlborough College. While at Clifton College from 1920 to 1940 he spent a good deal of his time writing, both on the history of science and school chemistry text-books. His Elementary Chemistry sold over half a million copies between 1925 and 1960 (Technical Education and Industrial Training, 2 (no. 12, 1960), p.13). Although in the preface to his Higher School Certificate Inorganic Chemistry he stated "the allotment of space to individual topics is roughly in proportion to the frequency with which these topics appear in the examination papers", he recognised that the cultural aspect of science was seldom reflected in examinations but that it should appear in school text-books. He did a good deal to encourage others to write text-books which included some history (see Physics Education, 3 (1968), 117); and he vigorously urged the introduction of historical material into school science courses.

DIAGRAM OF THE DEVELOPMENT OF MATHEMATICAL EXPERIENCE IN THE RACE AND IN THE INDIVIDUAL

Time Axis runs from top to bottom through centre of Chart.
Scale from 600 B.C., onwards, is roughly one inch = 2,000 years.

INTERPRETATION (see also chapter XVI).

The two elements of mental activity in the development of knowledge (excluding the will and the feelings) are:—

(1) Thought-activity, centrally excited (physiologically), forming the conceptual element of knowledge: this is symbolized in the diagram by shaded space.

(2) Sense-activity, peripherally excited (physiologically), forming the perceptual element of knowledge; this is symbolized in the diagram by unshaded or white space.

The conceptual (shaded) element of experience, postulating its existence, becomes ultimately unrecognizable in the chart, on the rough scale of ratio adopted.

The diagram is to be considered both vertically and horizontally, with a view to the suggested parallelism between racial and individual developments, and in respect of (i) the kind, quality, and quantity of the experience or knowledge, and (ii) the external factors stimulating the development.

Only the external factors have been summarized in the diagram. There remains the internal factor, the aesthetic-scientific interest impelling the mind to a study and perfection of its own creations—the pursuit of science for its own beauty.

ADDITIONAL EXPLANATIONS.

We may roughly group the main Primary and Derivative Occupations thus:—

I. Primary Occupations.

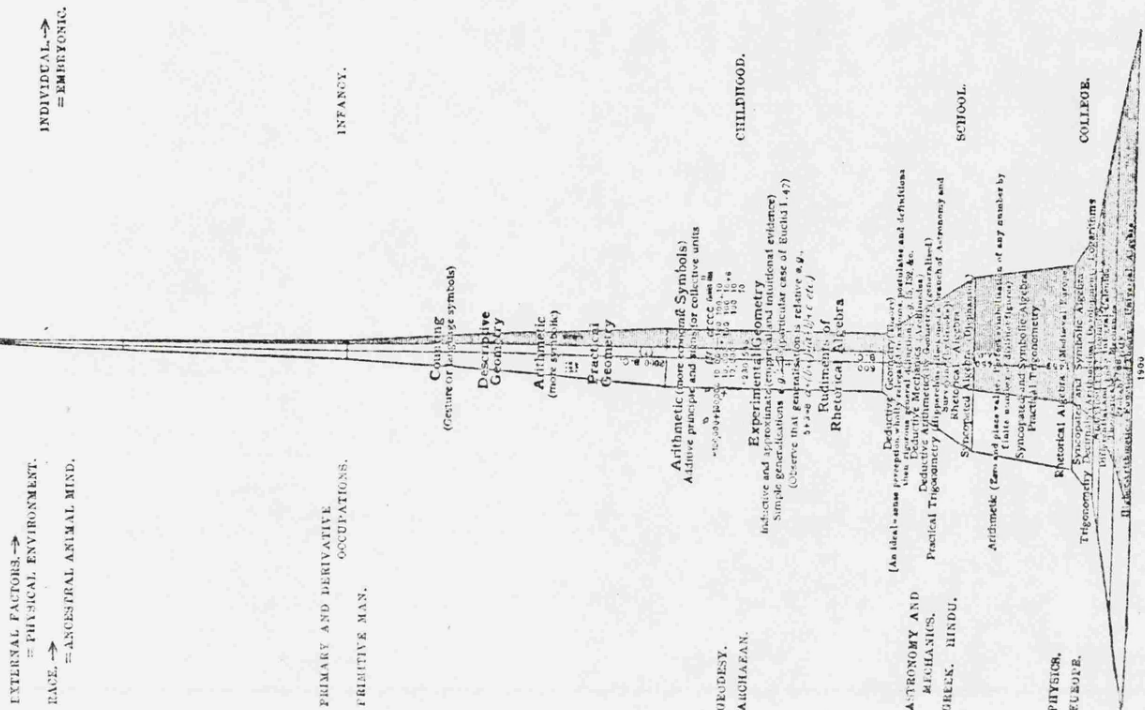
Miner.
Woodman.
Hunter.
Shepherd.
Gardener.
Peasant.
Fisher.

II. Derivative Occupations.

Trades.
Arts and Crafts (male and female).
Smiths and Wrights (Wheel- and Ship-wrights, &c.)
Builder.
Engineer.
Farmer.
Trader and Merchant.
Professions.
Scribe (Lawyer, Teacher, &c.).
Musician and Poet.
Warrior.
Architect and Engineer (e.g. Pyramid Builders).
Priest (Doctor, Teacher, Astrologer and Mathematician, &c.).
Rulers and Administrators.

Under Geodesy would fall the Surveyor (of the Nile Districts) and Cartographer.

Under Archæan would fall Egyptian, Babylonian, Phœnician, &c. (Pythagoras was a Phœnician; possibly Thales too). Along with Hinda would come Arabian and mediæval European mathematics.



APPENDIX 2

Advanced Courses Tables

Advanced Courses recognised by the Board of Education, by Subject, 1917-35

Year	Course A Science and Mathematics	Course B Classics	Course C Modern Studies	All Courses
1917-18	76	19	25	120
1918-19	140	26	76	242
1919-20	171	28	115	314
1920-1	193	34	144	371
1921-2	206	36	169	411
1922-3	205	36	169	410
1923-4	207	36	178	425
1924-5	212	36	177	434
1925-6	210	37	179	440
1926-7	211	36	182	445
1927-8	233	39	190	488
1928-9	229	38	185	483
1929-30	227	38	181	483
1930-1	230	37	182	494
1931-2	229	37	179	492
1932-3	232	37	175	495
1933-4	228	37	166	485
1934-5	227	36	166	481

Notes

(i) In later years, the numbers in the right-hand column exceed the sum of the courses listed in the three central columns. This is because 'all courses' included Advanced, Recognised courses in Categories D, E and F. The numbers of courses in these Categories were relatively small.

(ii) After 1926, the Regulations of the Board did not specify groups of subjects but allowed schools to submit for recognition such subjects as were thought fit. The Board anticipated that the submissions would normally fall into one or other of the groups used up until 1926, so the letters A to F, associated with the groups, were retained after that date.

Advanced Courses Recognised by the Board of Education,
by Type of School and Subject, 1924-5

Group*	No. of Recognised Courses		
	Boys' Schools	Girl's Schools	Mixed Schools
A Science and Mathematics	141	37	34
B Classics	34	2	-
C Modern Studies	50	103	24
D Classical with Modern Studies	4	1	-
E Geography	4	0	-
F Other combinations of Subjects	0	0	0
TOTAL:	233	143	58

* See Note (ii) to Table above.

Taken from E.W. Jenkins, From Armstrong to Nuffield, London, 1979, p.184.

APPENDIX 3

Advanced Courses Suggested in the Thomson Report

The choice of the subjects must lie with the teacher. There is great wealth of material and a wide scope for teachers of varied gifts who know how to use their opportunities. We cannot do more than make a few tentative suggestions as follows:-

A. - (i) A course on the outlines of cosmical physics and astronomical principles of great interest, such as the measurement of time, the calendar, the size and mass of the earth and sun; the applications of spectroscopy to elucidate the composition of the stars, nebulae, &c.; (ii) A course on the general principles of geology, without too much technical detail, illustrated by local examples and the use of geological maps; (iii) A course on physiology and hygiene, which would include a discussion of the part played by bacteria and other lower organisms in fermentation and in the spread of disease; (iv) A course of physical meteorology; the composition and general circulation of the atmosphere, relation of wind to pressure, storm, clouds, rain, snow, thunderstorm, the aurora, weather mapping.

B. Courses on the history of Science, e.g., (i) The history of astronomy from the Greeks to Newton including some account of the geocentric and heliocentric systems. (ii) The history of mechanics on the lines of the earlier portions of Mach's "Principles of Mechanics."

C. Courses on the development of scientific ideas, e.g., the constitution of matter, the conservation of energy, the doctrine of evolution, heredity, immunity.

D. The lives and work of scientific men e.g., Leonardo da Vinci, Galileo, Newton, Lavoisier, Cavendish, Faraday, Clerk Maxwell, Kelvin, Pasteur, Darwin, Helmholtz.

E. The bearing of scientific inventions on industrial progress, e.g., in connection with the history of farming, or with other local industries; methods of transport by land, water and air; means of communication such as signalling, telegraphy, telephones; methods of lighting.

F. Courses of a more practical kind than those mentioned above on the particular application of Science, e.g. on the internal combustion engine or the dynamo; such courses would appeal to boys of a mechanical turn of mind.

G. A course on the method and philosophy of Science, historically treated, with special reference to the work of Aristotle and his predecessors, Archimedes, Galileo, and Bacon, and the later experimental philosophers.

It will be seen that many of these courses - and the list does not pretend to be exhaustive - give special opportunities to a teacher who combines some knowledge of history with his knowledge of Science, and should appeal to boys with historical tastes.

APPENDIX 4

Draft Syllabus and Specimen Examination Paper From Whitgift School

AIMS

To formulate a syllabus which is suitable for pupils aged 16-18 following a Course of Study for Advanced Standard of the General Certificate of Education, but the paper is to be of ordinary standard (i.e. HSC Subsidiary). Syllabus to be covered intensively in three periods a week for one year, or less intensively in two periods a week for two years. The Syllabus should be suitable for boys taking any Advanced Standard subjects (Classics, Modern Languages, History, Mathematics, Sciences, etc.), and for a class drawn from different Advanced Courses. The Syllabus should endeavour to provide a link between the various Advanced Courses, and be wide enough to enable boys to give more detailed attention to those sections with which they are already familiar. (See last paragraph).

The Course as a whole should endeavour to provide the pupil with a historical perspective, and with the conception that "Science" is a process, and to familiarise him with some of the chief phases of the evolution of modern scientific methods and techniques. Causes and Consequences should be regarded as more significant and important than a catalogue of facts.

The study of such a course should serve as a basis for other courses in international co-operation and understanding.

METHOD

To achieve these aims, the paper (2½ hours) should be divided into six sections, each section containing five questions. Candidates should answer five questions, not more than two from any one section. The questions should be of an elementary nature. This would necessitate the study of at least three sections, though it is to be hoped that the Syllabus would be covered as a whole, but difficulties of Staffing and Textbooks may render this treatment too difficult in the first few years of the examination. Until suitable textbooks are available, Sherwood Taylor's "Science Past and Present" might be used; this has already been tried by VIth Forms in schools. Other books may be used for the individual sections e.g. Farrington: Greek Science I & II (Pelican) Butterfield: Origins of Modern Science (Bell) and, doubtless, a suitable reading list could be prepared.

SYLLABUS

The subject as a whole should survey the historical evolution of Scientific Thought from the earliest times (beginning with Greeks) to the present day but little emphasis need be placed on the twentieth century. The subject as a whole will be seen to be a logical evolution and social application of the already well-established method and practices.

Skeleton Outline of Syllabus in sections (Suitable Topics for Questions)

- Six Sections: A Greek and Roman Science and Philosophy
B Mediaeval Period (700 - 1500)
C Renaissance (1500 - 1650)
D Eighteenth Century (1650 - 1800)
E Nineteenth Century
F General Questions

Section A: Greek and Roman Science and Philosophy

Topics Early technological developments. Greeks as the first "Scientists"; Greek Physical Theories; Greek Mathematics; Greek Medicine; Relations of Greek Philosophy and Science: Greek Applied Science; Interrelation of Greek Social Organisation and Scientific developments; Life and Work of Plato, Aristotle.

Section B: Mediaeval Period (700 - 1500)

Topics: Contribution of the Arabs; Mediaeval Views of the Universe; Feudalism and Social Structure and Techniques; Catholicism and Aristotle; Alchemy and Astrology; Growth of the Universities; Life and Work of Thomas Aquinas, Roger Bacon.

Section C: Renaissance Period (1500 - 1650)

Topics: The Emergence of Scientific Method; Science and the Arts (Vesalius etc.); Copernicus and the New Astronomy to Kepler; Works of Galileo; Works of Gilbert; Works of Harvey; Significance of Francis Bacon and Descartes.

Section D: 1650 - 1800

Topics: Foundation and Early History of Royal Society; Work of Newton; Organisation of Scientific Academies; Advances in Astronomy and Biology; Industrial Revolution; Phlogiston and Lavoisier; Encyclopaedists and the Idea of Progress.

Section E: Nineteenth Century

Topics: Growth of separate Sciences; Applications of Science to Industry; Advances in Medicine (Lister, Simpson) and Public Health; Evolution (Lyell, Darwin, Mendel); Life and Work of Davy, Faraday, Pasteur, etc; Curie and J.J. Thomson as an introduction to modern developments.

Section F: General Questions

e.g. Scientific Method; Interrelation of Theory and Experiment; Interrelation of Religion and Science; Science and Ethics; Influence of Social Organisation on Scientific Progress and vice versa etc. etc.; Tactics and Strategy of Science; Vitalism and Materialism; the limitations and control of Science.

A predominantly Classical Form could concentrate on Sections A,B,C.
A predominantly Historical " " " " Sections B,C,D
A " Mathematical " " " " Sections B,C,D or C,D,E
A " Modern Language Form " " " Sections C,D,E
A " Scientific " " " " Sections C,D,E

Specimen Examination Paper

- A
1. Write an account of early Ionian theories of the Universe. Suggest reasons for the development of these ideas.
 2. What do you consider to be (i) the great successes and (ii) the limitations of Greek Science?
 3. Consider the statement "Aristotle was the first biologist".
 4. Summarise some of the chief achievements of Greek Mathematics.
 5. Write a short account of the contribution of Hippocrates to the study of medicine.
- B
1. To what causes do you attribute the lack of scientific progress in the Mediaeval period?
 2. Discuss the contributions of Mediaeval alchemy to chemistry.
 3. Trace the development of Universities in the fourteenth and fifteenth centuries.
 4. Give some account of agricultural techniques in the Feudal Period.
 5. Write an account of the life and work of Roger Bacon.
- C
1. Briefly summarise the achievements of Harvey. Give some account of the influence of his discoveries in biological and medical study.
 2. Outline the Copernican theory of the Universe. State why this replaced the older Ptolemaic theory.
 3. Assess the historical significance of Francis Bacon or Descartes in the development of scientific method.
 4. Write an account of the life and work of Galileo.
 5. Give some account of the interrelation of the development of overseas trade and scientific advance in the XVIth Century.
- D
1. How far do you consider R. Boyle to merit the title "The father of English Chemistry"?
 2. Write an account of the early history of the Royal Society, drawing attention to conditions which led to its foundation.
 3. "Newton, the lawgiver". What do you understand by this phrase?
 4. Discuss the influence of scientific developments on the Industrial Revolution during the XVIII Century.
 5. Trace the development of the theories of Combustion up to and including Lavoisier.
- E
1. Trace in broad outline the development of the theory of Evolution from the Greeks to Darwin.
 2. Give some account of the contribution of Pasteur to the development of Medical Science.
 3. Show how scientific discoveries of the nineteenth century changed the mode of life of the average citizen.
 4. Write an account of the life and work of Faraday.
 5. Discuss the conflict between religion and science in the XIXth Century.
- F
1. "What do you understand by the term scientific method? Illustrate your answer by reference to examples chosen from more than one branch of science.
 2. "Science progresses on the stepping stones of its own mistakes". (sic)
 3. Discuss the value to the progress of science of hypotheses which were subsequently discarded.
 4. "The progress of science has been conditioned by the social organisation of the day". Discuss this.
 5. Write a short essay (i) The limitations of Science.
(ii) Vitalism v. Materialism.
(iii) Science and Ethics.

APPENDIX 5

Cambridge Syndicate History and Philosophy of Science

Syllabus 1952

Candidates will be required to answer five questions in 2½ hours, including one question from Section F and one from each of three other sections. Four questions will be set on each Section.

Skeleton Outline of Syllabus in Sections (Suitable Topics for Questions)

Six Sections: A Early Science and Philosophy
B Mediaeval Period (700 - 1500)
C Renaissance (1500 - 1650)
D Eighteenth Century (1650 - 1800)
E Nineteenth Century
F General

Section A: Early Science and Philosophy

Topics: Early technological development. Primitive views of natural phenomena. Greeks as the first "Scientists"; Greek Physical Theories; Greek Mathematics; Greek Medicine; Relations of Greek Philosophy and Science; Greek Applied Science; Interrelation of Greek Social Organisation and Scientific developments; Life and Work of Plato, Aristotle.

Section B: Mediaeval Period (700 - 1500)

Topics: Contribution of the Arabs; Mediaeval Views of the Universe; Feudalism and Social Structure and Techniques; Catholicism and Aristotle; Alchemy and Astrology; Growth of the Universities; Life and Work of Thomas Aquinas, Roger Bacon.

Section C: Renaissance Period (1500 - 1650)

Topics: The Emergence of Scientific Method; Science and the Arts (Vesalius etc.); Copernicus and the New Astronomy to Kepler; Works of Galileo; Works of Gilbert; Works of Harvey; Significance of Francis Bacon and Descartes.

Section D: 1650 - 1800

Topics: Foundation and Early History of Royal Society; Work of Newton; Organisation of Scientific Academies; Advances in Astronomy and Biology; Industrial Revolution; Phlogiston and Lavoisier; Encyclopaedists and the Idea of Progress.

Section E: Nineteenth Century

Topics: Growth of separate Sciences; Applications of Science to Industry; Advances in Medicine (Lister, Simpson) and Public Health; Evolution (Lyell, Darwin, Mendel); Life and Work of Davy, Faraday, Pasteur, etc; Curie and J.J. Thomson as an introduction to modern developments.

Section F: General

The questions in this section will be based on general topics, such as the following, which should have been studied in relation to sections A-E above:

Scientific Method; Interrelation of Theory and Experiment;
Interrelation of Religion and Science; Science and Ethics;
Influence of Social Organisation on Scientific Progress and
vice versa etc. etc.; Tactics and Strategy of Science;
Vitalism and Materialism; the limitations and control of
Science.

APPENDIX 6

Draft Syllabuses of Dr. Van Praagh, Mr. Ayres and Mr. McKenzie

DR. VAN PRAAGH, CHRIST'S HOSPITAL

Suggested 'Case Histories' - Chemistry

1. Combustion. To illustrate the method of chemical discovery

Early reactions to 'fire' - awe, fear.

Early hypotheses put forward to explain the phenomena.

17th Century experiments on fire and air.

Further attempted explanation - the Phlogiston Theory.

Experimental work of Lavoisier, leading to the elucidation of the nature of burning - oxygen.

Effect of this understanding on the development of Chemistry.

Extension of the understanding of oxidation to:

- (a) fuels, their history and method of use,
- (b) rapid combustion, development of explosives,
- (c) slow combustion - (i) food as fuel,
(ii) corrosion of metals.

2. The Nature of Matter

Greek ideas. The Four Elements.

The Arab chemists.

Boyle and the modern 'elements'.

Ideas on mixtures and compounds in the 18th Century.

Dalton and the Chemical Atomic Theory.

Davy and Faraday's researches in electro-chemistry, leading to the isolation of new elements, the hypothesis of ions, and ultimately to the recognition of the atomic nature of electricity.

(? extension to cathode rays, X-rays, radioactivity and theories of atomic structure, leading to the artificial disintegration of the atom and its applications).

3. The Metals To illustrate the influence of science on 'civilisation'.

Metals known to early civilisations.

Mode of occurrence of the metals in the earth's crust.

Historical development of the methods of extraction, showing how the understanding of chemistry enabled new metals to be obtained and used.

Production of alloys with desired properties.

Correlation between physical properties of alloys and their internal structure.

Applications in Engineering.

4. History of Organic Chemistry

Early ideas on substances occurring in living material.

Wöhler. The breakdown of the barrier between organic and inorganic chemistry.

Characterisation of new compounds - identification, analysis and synthesis.

More detailed study of one group of substances, e.g. oils, fats, carbohydrates, dyes, drugs, plastics.

Biology

1. The evolution of the methods of combating bacterial diseases

The early concepts of spontaneous generation in the processes of fermentation and the like.
Empirical work of Jenner and the development of the technique of vaccination.
Pasteur's work disproving the theories of spontaneous generation.
Koch's work on anthrax and the life-history of the bacillus.
Pasteur - the development of work on anthrax; work on hydrophobia.
Friedrich Loeffler and the investigation of foot-and-mouth disease; filter-passing viruses.

The development of antiseptics by Lister, as a side-issue.

Modern ideas of asepsis.

The recent discovery of "anti-biotics". Fleming and Penicillin.

2. Inheritance

Early thought - Hippocrates and Aristotle; leading almost by direct descent to the "pangenesis" of Darwin.

Francis Galton and Karl Pearson; the introduction of statistics and the methods of biometrics.

Weismann's theory of the germ-plasm.

Late Darwinism and the study of discontinuous variation - Bateson.

De Vries and the doctrine of mutations.

The re-discovery of the work of Mendel. The implications of Mendelian inheritance.

Boveri, Sutton etc. and the adaptation of the hypotheses arising out of Mendelism to terms expressible in the behaviour of Chromosomes.

Castle's introduction of *Drosophila* as material for work on inheritance.

T.H. Morgan, Bridges, Muller etc. The theory of the gene.

Recent work on the structural details of nuclei and on the statistics of inheritance.

3. Man's control of animal vectors in maintaining Public Health

The history of the menace of malaria. The work of Ross.

The part played by the anophelene mosquito, and the life-history of the parasite. Construction of the Panama Canal.

Methods of control applied to:- (a) adult insects, (b) larvae, (c) human communities through hygiene, prophylactics.

The tsetse-fly problem in Africa. Diseases of human and cattle communities. The native population a reservoir for the parasite, with the cattle showing immunity when indigenous.

The problem of tackling the disease through:- (a) the insect, (b) the immunised mammalian host; and (c) the actual or potential patient.

The control of the housefly through measures of hygiene. Public Health.

Life-history of the fly, the various levels of vulnerability of its several stages. Habits of the imago and its part in spreading disease.

MR. AYRES

Chemistry Section

1. Prehistoric Period.

Native metals and smelting
Glass and early Chinese art
Influence of Astrology in chemical symbols
The age of Alchemy

2. Awakening of Chemistry

Robert Boyle and Robert Hooke (1635-1703)
The Phlogiston Theory

3. The Chemical Revolution

- (a) The great English chemists. Black, Cavendish and Priestley
- (b) Scheele and Lavoisier
- (c) Discovery and Weighing elements
Dalton, Avogadro and Gay Lussac

4. Classification.

Work of Meyer and Mendeleef. Moseley and Bohr.

5. Organic Chemistry as an example of classification - hydrocarbons - use of models.

6. Synthetic and Substitute materials and their effect on the economy of the country. Synthetic Fertilizers and explosives. Fuels, Dyes, Plastics.

Types of Questions

1. What reasons can you give for the rapid advance of chemical knowledge in Europe in the 19th Century compared with its slow development in the East?
2. How far would the replacement of Aluminium for Iron affect our national life? What limitations are there in the substitution of light metals for heavy ones?
3. How would this nation be affected by a complete blockade of her ports? What chemical industries would survive and what substitutes could be used in everyday life?
4. Write a brief account of the scientific work of Lavoisier and its effect on the growth of chemistry in the 18th Century.

MR. MCKENZIE

1. Astronomy from Copernicus to Newton

Ptolemaic and Copernican systems. Kepler's laws based on observations of Tycho Brahé. Galileo's astronomical discoveries and advocacy of Copernican theory. Newton's law of gravitation and the Principia.

2. The foundation of mechanics

The rise of the concept of a mechanical universe in contrast to the teleology of Aristotle. Galileo's experiments with the inclined plane and concept of inertia. Newton's laws of motion. Scientific method. Influence of Descartes and Bacon. Induction and Deduction.

3. The mechanical view of heat

Caloric theory. Experiments of Rumford, Mayer and Joule leading to establishment of Kinetic theory of heat. Principles of conservation and degradation of energy. Statistical nature of second law of thermodynamics.

4. The nature of light

Newton's experiments on dispersion as an early and perfect example of scientific method. Simple qualitative account of interference, diffraction and polarisation leading to the establishment of the wave theory by Young and Fresnel. The aether and significance of Michelson-Morley experiment. Photo-electric effect and quantum theory. General idea of wave mechanics.

5. Magnetism and Electricity

- (a) Experiments of Gilbert and elementary phenomena of magnetism. Molecular theory of magnetism. The compass and navigation.
- (b) Galvani and Volta. The simple cell.
- (c) Principle of the electric motor.
- (d) Faraday's discovery of electromagnetic induction. Principle of the dynamo. Significance of electricity in the development of industry and communications.

6. Atomic Electricity

Elementary account of the discovery of the electron, radioactivity and X-rays. Modern views of the atom. Artificial disintegration. The atomic pile and the atomic bomb.

7. The rise and overthrow of the Phlogiston theory

Seventeenth Century experiments on fire and air. The Phlogiston theory of Becher and Stahl. Priestley's discovery of dephlogisticated air. Cavendish's synthesis of water. Lavoisier's experiments.

8. Dalton's atomic theory

Greek ideas. The Four Elements. Boyle and the modern 'element'. Laws of fixed, multiple and reciprocal proportions. Dalton's atomic theory. Gay Lussac's gas law and Avogadro's hypothesis.

9. Foundation of Geology

Rise of palaeontology and stratigraphy. Werner and James Hutton: catastrophism versus uniformitarianism. William Smith, Cuvier and Lyell.

10. Harvey and the circulation of the blood

Ideas of Galen. Harvey. Malpighi.

11. Evolution

Lamarck, Darwin and the Origin of Species.

12. Mechanism of Heredity

Galton, Weismann and the germ plasm. Mendel. De Vries and the doctrine of Mutations. Morgan.

13. Bacteriology and disease

(see syllabus of Dr. Van Praagh, Biology para. 1).

APPENDIX 7

Draft Syllabus Submitted to the Oxford and Cambridge Examination Board

General Science at alternative O level

A meeting was held on Thursday 7th July in London to draw up the new science syllabus, proposed by the Board at its meeting on 24th February 1949, on the lines agreed at an earlier meeting of the full committee on the 14th May 1949.

Present. Headmaster of King Edward VII School, Sheffield (in the chair), Headmaster of Nottingham High School, Mr. R.H. Dyball (City of London School), Dr. G. Van Praagh (Christ's Hospital), the Secretaries.

It was decided to submit the following syllabus and specimen paper to the Board for approval.

Introduction

The syllabus is intended to illustrate the methods, influence and social consequences of science and to cover the historical development of some of the most important scientific generalisations. A generous choice of questions will be given so that candidates need study only a selection of the topics in the syllabus. A minimum of quantitative work and only the simplest mathematics will be required. The items in italics will not be examined specifically; they represent more recent advances which follow naturally from the earlier historical development.

SYLLABUS

1. Measurement of time and space

The development of the calendar. Early maps; the measurement of latitude and longitude. Historical development of the measurement of time leading to the pendulum clock and chronometer. The measurement of earth, lunar, solar and stellar distances. The wave length of light as a standard of length and the quartz crystal as a standard of time.

2. Motion and gravitation

Aristotle's views on motion. Ptolemaic and Copernician systems. Galileo. Newton's laws of motion. Kepler's laws; the inverse square law of gravitation and its explanation of Kepler's laws; Newton's deduction of the period of the Moon round the Earth from g . The discovery of Neptune and Pluto. Limitations of Newton's laws of motion and gravitation; relativity and wave mechanics.

3. Conservation of energy

The principle of work arising from the study of machines; the abandonment of the search for a perpetual motion machine. The caloric theory and its breakdown; the growth of the idea of heat as a form of energy; the development of the principle of work into the conservation of energy including heat, light and electrical energy. Degradation of energy. Equivalence of mass and energy.

4. The nature of light

The laws of straight line propagation, reflection and refraction; their qualitative application to the telescope and microscope. Newton's experiments on colours. The corpuscular theory of light. Simple qualitative account of interference, diffraction and polarisation leading to the establishment of the wave theory of Young and Fresnel. The aether and significance of the Michelson-Morley experiment. Photo-electric effect and quantum theory. General idea of wave mechanics.

5. Magnetism and Electricity

- (a) Experiments of Gilbert and elementary phenomena of magnetism. Molecular theory of magnetism. The compass and navigation.
- (b) Galvani and Volta. The simple cell.
- (c) Principle of the electric motor.
- (d) Faraday's discovery of electromagnetic induction. Principle of the dynamo. The Grid system. Significance of electricity in the development of industry and communications.

6. Technology

Stone, Bronze, Iron and Steel Ages. Modern substitutes, e.g. aluminium and light alloys, plastics. Corresponding power "ages", slave, wind and water, coal, oil. Electric power distribution. Atomic power. Influence of distribution of natural resources on population and politics.

7. Combustion

17th Century experiments on fire and air.

The Phlogiston Theory. Experimental work of Priestley and Lavoisier, leading to the elucidation of the nature of burning. Conservation of mass.

Extension of the understanding of oxidation to:

- (a) fuels, their history and method of use;
- (b) rapid combustion, development of explosives.
- (c) slow combustion - (i) food as fuel,
(ii) corrosion of metals.

8. History of Organic Chemistry

Early ideas on substances occurring in living material.

Wöhler. The breakdown of the barrier between organic and inorganic chemistry.

Characterisation of new compounds - identification, analysis and synthesis.

More detailed study of one group of substances, e.g. oils, fertilisers, fats, carbohydrates, dyes, drugs, plastics. Synthetic materials as substitutes for natural materials.

9. The Nature of Matter

Greek ideas. The Four Elements.

Boyle and the modern 'elements'.

Ideas on mixtures and compounds in the 18th Century.

Dalton and the chemical atomic theory. Qualitative treatment of the kinetic theory of matter.

Davy and Faraday's researches in electro-chemistry, leading to the isolation of new elements, the hypothesis of ions, and ultimately to the recognition of the atomic nature of electricity. The grouping of atoms in molecules, crystals and giant molecules.

10. The Structure of the Atom

The discharge of electricity through gases; cathode rays and their nature; the electron. X rays, their discovery, production, properties and applications in industry, surgery and medicine. The nuclear theory of the atom; the explanation of valency forces and isotopes. The relation between mass and energy. Natural and artificial disintegration of matter. The atomic bomb, the atomic pile.

11. The Nature and Continuance of Life

Early ideas of Aristotle and Galen. Cells and their contents. The diversity of life and its classification. The investigations of Lamarck and Cuvier leading to the theory of evolution by Darwin. The impact of Darwin's theory on thought and the work of Mendel and Weismann on Heredity and applied genetics. The gene theory. Recent work on the structural details of nuclei and on the statistics of inheritance.

12. The Human body

Respiration, digestion, circulation, reproduction, hormones and ductless glands, nerves and muscles in reactions. The work of Harvey, Hales, Hill, Sherrington and Adrian.

13. Food

Green leaves and photosynthesis; domestic animals and plants; crop rotation, soil fertility and conservation; agricultural research; irrigation; forestry. Diet, kinds and sources of food; calories and vitamins; preservation of food; increase in population and supply of food, (Malthus).

14. Disease and its Control

Early medicine and its history, Aperiants. Anaesthesia. Vaccination and innoculation. Spontaneous generation. Antisepsis and Asepsis. Sanitation and Water supply. Influence of the development of the microscope. Animal vectors of diseases as in malaria, plague and sleeping sickness. Chemotherapy. Insulin. Penicillin. Virus diseases of plants and animals.

SPECIMEN PAPER

Time - 2 hours

Candidates should attempt four questions only

1. Explain, with examples, the nature and limitations of a scientific law.
2. Why did modern science and the scientific method become established in the seventeenth century rather than at an earlier date?
3. Write an account of the work associated with one of the following:
Harvey, Lavoisier, Joule.
4. Describe how the law of gravitation was discovered and verified.
5. Discuss Newton's experiments on colour as an example of scientific method.
6. Write an account of the generation and distribution of electrical power
and of its significance in industry.
7. What scientific researches have arisen from the need for accurate navigation?
8. Write an account of one or more of the products derived from coal.
9. Discuss the development of the chemical atomic theory.
10. Indicate the connection between the progress of metallurgy and the course of history.
11. Describe the production and uses of X rays.
12. Give a general account of the development of a mammalian animal from the fertilised egg to the newly born animal. Discuss the care the young animal receives from its parents after birth.
13. Describe the advances made in food production throughout the centuries.
14. Write an account of the way in which human beings or animals have been protected against a particular disease.

APPENDIX 8

Oxford and Cambridge Board 1952 Syllabus

History of Science

A single paper of 2 hours will be set.

The syllabus is intended to illustrate the methods, influence, and social consequences of science and to cover the historical development of some of the most important scientific generalizations. It is not expected that candidates will have studied all the topics; a generous choice of questions will be given and answers to not more than four questions will be asked for. A minimum of quantitative work and only the simplest mathematics will be required. It is assumed that candidates will have a foundation of General Science, studied in the middle school.

1. Measurement of time and space

The development of the calendar. Early maps, the measurement of latitude and longitude. Historical development of the measurement of time leading to the pendulum clock and chronometer. The measurement of earth, lunar, solar, and stellar distances.

2. Motion and gravitation

Aristotle's views on motion. Ptolemaic and Copernican systems. Galileo. Newton's laws of motion. Kepler's laws; the inverse square law of gravitation and its explanation of Kepler's laws; Newton's deduction of the period of the Moon round the Earth from g . The discovery of Neptune and Pluto.

3. Conservation of energy

The principle of work arising from the study of machines; the recognition of the impossibility of a perpetual motion machine. The caloric theory and its breakdown; the growth of the idea of heat as a form of energy; the development of the principle of work into the conservation of energy including heat, light, and electrical energy.

4. The nature of light

The laws of straight line propagation, reflection, and refraction; Newton's experiments on colour; their qualitative application to the telescope and microscope. The corpuscular theory of light. Simple qualitative account of interference, diffraction and polarization leading to the establishment of the wave theory by Young and Fresnel. Photo-electric effect and quantum theory.

5. Magnetism and Electricity

Experiments of Gilbert and elementary phenomena of magnetism. Molecular theory of magnetism. The compass and navigation. Galvani and Volta. The simple cell. Principle of the electric motor. Faraday's discovery of electromagnetic induction. Principle of the dynamo. The Grid system. Significance of electricity in the development of industry and communications.

6. Technology

Stone, Bronze, Iron, and Steel Ages. Modern structural materials, e.g. aluminium and light alloys, plastics. Sources of power: slave, wind and water, coal, oil. Electric power distribution. Atomic power. Influence of distribution of natural resources on population, industry, and politics.

7. Combustion

Seventeenth-century experiments on fire and air.
The Phlogiston Theory. Experimental work of Priestley and Lavoisier,
leading to the elucidation of the nature of burning. Conservation of
mass.

Extension of the understanding of oxidation to:

- (a) fuels, their history and method of use,
- (b) rapid combustion, development of explosives,
- (c) slow combustion - (i) food as fuel,
 (ii) corrosion of metals.

8. History of Organic Chemistry

Early ideas on substances occurring in living material.
Wohler. The breakdown of the barrier between organic and inorganic chemistry.
Characterization of new compounds - identification, analysis, and synthesis.
More detailed study of one group of substances, e.g. oils, fats, carbohydrates, dyes, plastics.
Synthetic materials as substitutes for natural materials.

9. The Nature of Matter

Greek ideas. The Four Elements.
Boyle and the modern 'elements'.
Ideas on mixtures and compounds in the eighteenth century.
Dalton and the chemical atomic theory. Berthollet's views. Qualitative treatment of the kinetic theory of matter.
Davy and Faraday's researches in electro-chemistry; the hypothesis of ions and the recognition of the atomic nature of electricity. Radio-activity. Valency forces, the grouping of atoms and ions in simple molecules, ionic lattices, and giant molecules.

10. The Structure of the Atom

The discharge of electricity through gases; cathode rays and their nature; the electron. X-rays, their discovery, production, properties, and applications in industry, surgery, and medicine. The nuclear theory of the atom; the explanation of valency forces and isotopes. The relation between mass and energy. Natural and artificial disintegration of matter. The atomic bomb, the atomic pile. Artificial radio-active elements.

1. The Nature and Continuance of Life

Early ideas of Aristotle and Galen. Cells and their contents. The diversity of life and its classification. The investigations of Lamarck and Cuvier leading to the theory of evolution by Darwin. The impact of Darwin's theory on thought and the work of Mendel and Weismann on Heredity and applied genetics. The gene theory.

12. The Human Body

Respiration, digestion, circulation, reproduction, hormones and ductless glands, nerves and muscles in reactions. The work of Harvey, Hales, Hill, Sherrington, and Adrian.

13. Food

Green leaves and photosynthesis; domestic animals and plants; crop rotation, soil fertility and conservation; irrigation; forestry. Diet, kinds and sources of food; calories and vitamins; preservation of food; increase in population and supply of food.

14. Disease and its Control

Early medicine and its history. Aperients. Anaesthesia. Vaccination and inoculation. Spontaneous generation. Antisepsis and Asepsis. Sanitation and Water supply. Influence of the development of the microscope. Animal vectors of diseases as in malaria, plague, and sleeping sickness.

Chemotherapy. Insulin. Penicillin. Virus diseases of plants and animals.

APPENDIX 9

Notes Used at Whitgift School

WESTERN EUROPE

AD

- 787 Charlemagne (748-814) founds School of the Palace under direction of ALCUIN (732-804), who also founded Abbey School at Tours,
- 800- 900 3 Monastic Schools founded in Paris for study of Trivium (Grammar, Rhetoric, Logic) and Quadrivium (Arithmetic, Geometry, Music, Astronomy) as preparation for Theology. Monastic monopoly of learning established in many Cathedral schools. But Medical School at Salerno was entirely secular. Feudal system established.
- 900-1100 Norman Invasions - Sicily occupied 1092. Windmills and water-mills; breast harness for horses and horseshoes. Animal and natural sources of energy begin to replace Slave Labour of Ancient World.
- 1100-1200 Intensive translation from Arabic into Latin, ADELARD of Bath introduces Arab learning in his *Questiones Naturales* (1116). LEONARDO of Pisa in his *Liber Abaci* popularises use of Arabic-Hindu numerals (1202).
- 1200-1300 Foundation of Monastic Orders - Franciscans 1209; Dominicans 1215. Organisation of Universities and Colleges of Residence, e.g. Paris 1101 - charter 1200; Bologna (Law) 1113; Oxford 1167 - charter 1214; Montpellier (Medicine) 1200; Padua 1222 and Naples 1224 by Frederick II, Cambridge 1231, University College Oxford 1232, Sorbonne 1258, Balliol 1263 Merton 1264, Peterhouse 1286 etc.
- The Complete works of Aristotle available in Latin by 1250
Capital Encyclopaedias of Knowledge compiled by Alexander of Neckham
D & F (1157-1217). Vincent of Beauvais D (1190-1264), Albertus
means Magnus D (1206-80), ROGER BACON F (1214-94).
- Dominican Scholasticism systemised by Thomas Aquinas D (1227-74)
or Experimental approach to Physical problems, especially Optics,
Franciscan by Robert Grosseteste F (1175-1253) - 1st Chancellor of Oxford
1214; John of Peckham F (1220-92), Roger Bacon F (1214-94, and
Witelo (fl:1270), who all based their work on Al-Hazen.
Sine experientia nihil sufficienter se iri potest (Roger Bacon)
During 13th Century development of Ship's Compass, and replacement of Steering Oar by fixed underwater Rudder (? first used in Hansa ships) made Ships more suitable for Ocean voyages.
- 1300-1400 Intensive development of the study of Greek, and collection of Greek MSS. Rise of Humanism - Petrarch (1307-74) and Boccaccio (1313-75)
Authoritarian teaching of Scholasticism discouraged Research and Experiment, but Astrology and Alchemy widely practised.
University life disrupted by Black Death (1347-52)
Papal residence at Avignon (1349-1418) stimulated growth of German Universities - Prague 1348, Cracow 1364, Vienna 1365, Heidelberg 1385, Cologne 1388 etc.
Conservation of Trade Guilds discouraged Technical advances.

1400-1500 Large-scale expansion of Trade between N. Italy, S. Germany, Low Countries and Hanseatic Ports following upon mechanised spinning (Bologna 1272), wire drawing machinery (Nuremberg 1350), big development in Mining (Harz and Tyrol) and in metal-working - water-powered Blast Furnaces, Rolling Mills and Cast Iron - Emergence of new class of wealthy merchants and bankers, e.g. Fuggers, Welsors, Medicis, as persons of Learning and the Arts.
Platonic Academy founded at Florence by Cosimo de Medici 1440
Printing with movable type (Haarlem, Mainz 1435-55) makes books accessible to all classes and weakens monastic monopoly of MSS.
Capture of Constantinople by Turks 1453 augments supply of MSS. and of teachers of Greek. Greek Cardinal Bessarion (1403-72) founds St. Mark's Library, Venice.
NICHOLAS of Cusa (Rhineland) (1401-64) revives experimental method - De Staticis Experimentis. His observation of growing plant gives first formal proof that air has weight.

Critical study of Ptolemy's Almagest by George Purbach (1623-61) at Vienna and of the Greek text by his pupil Johannes Muller (1436-76) of Königsberg (REGIOMONTANUS) - First Treatise on Trigonometry. This work completed by Nicholas COPERNICUS (1473-1543) in De Revolutionibus Orbium Coelestium (printed Nuremberg 1543): Heliocentric Theory, 80 circles of Ptolemy reduced to 34, but circular orbits retained.

Turkish control of Eastern Trade Routes stimulated search for alternative routes: Columbus, following Ptolemy's Geography (Latin translation 1475) reaches West Indies 1492; Diaz reaches Cape of Good Hope 1492, Vasco da Gama reaches India 1497-8.

Numerous technical devices proposed by LEONARDO da Vinci (1452-1519) who also projected a Treatise on Anatomy. VESALIUS (1514-69) published De Corporis Humani Fabrici based on dissection 1543.

Mediaeval Medicine limited to Greek and Arabic sources: PARACELSUS (1493-1541) after working at Fugger mines in Tyrol introduced mineral drugs, and founded iatro-chemistry. By 1544 Greek texts of all major scientific works had been printed, e.g. Ptolemy 1515, Galen 1515, Hippocrates 1527, Euclid 1533, Archimedes 1544.

NOTE ON CHINESE SCIENCE

"Three inventions - printing (and paper), gunpowder, and the magnet, which were unknown to the Ancients, and of which the origin, though recent, is obscure, have changed the whole face and state of things throughout the world, the first in literature, the second in warfare, the third in navigation". (Francis Bacon - Novum Organum 1620) All these inventions were known in China several centuries before they were developed in the West and were probably transmitted to the West through commercial contacts in the 11th and 12th Centuries.

PAPER: First made in China by Ts'ai Lun 105 AD. Manufactured in Baghdad by Mongul captives 793; known in Egypt 900, Morocco 1100, Spain 1156, France 1189, Italy 1250, Germany 1300.

PRINTING: First used in China with wooden blocks about 500 AD. Movable wooden characters 1000 AD. Movable metal type 1390 AD. Block printing at Ravenna 1289, Limoges 1381; movable metal type Antwerp 1417, Haarlem 1435, Avignon 1444, Mainz (Gutenberg) 1436-50.

GUNPOWDER: First used for fireworks in China about 500 AD. Formula 1040 AD. Propellant for war weapons 1045 - bullets and bamboo barrels 1259. Roger Bacon quotes a formula 1242; first reported use in warfare 1324. Small firearms 1381.

MAGNET: Directive properties of magnet first mentioned in Chinese dictionary 121 AD. Use by Chinese mariners reported 900 AD and by Arab mariners 1242 (?transmission via India). Mentioned in Neckham's Encyclopaedia 1200; Peter Peregrinus teacher of Roger Bacon, wrote a treatise De Magnete 1269. Compass card probably developed in S. Italy (?Amalfi) during 13th Century.

In 1300 Chinese Sciences, Arts and Techniques, augmented by Arabian-Persian and Hindu learning, following upon Mongol conquests of 1250, were 200-300 years in advance of contemporary West, but owing to lack of contact subsequent developments in the West were quite independent.

TRANSITION from the MEDITERRANEAN to the ATLANTIC

The rise of commercial centres on the Atlantic coasts following upon the maritime voyages of discovery was accompanied by the growth of scientific studies and technical advances in Holland and England. Development of quantitative experimental methods, notably at University of Padua, and in writings of SIMON STEVIN (1548-1620), Dutch military engineer, on "Statics and Hydrostatics" (1586), of Robert Norman (1571) and William Gilbert on "The Magnet" (1600).

Notable advances in metallurgy and mining. BIRINGUCCIO-Pirotechnia first printed treatise on metallurgy (1540), Georg Bauer (AGRICOLA) De Re Metallica (1556).

Precise astronomical observations in Denmark and Prague by TYCHO BRAHE (1546-1601). Development of scientific instruments - Thermometer (Galileo 1592), Microscope and Telescope (Holland 1608).

MODERN SCIENCE I (1550-1700)

EMERGENCE OF NORTH ATLANTIC STATES - Holland, France, England.

Influx of gold and silver from America caused steep price inflation in Western Europe. Cost of foodstuffs rose 300% between 1500 and 1560. Collapse of German silver mining industry and rapid decline of all Central European mining, and finance houses - completed by Thirty Years War (1618-48). Development of Nationalism and Mercantilism in N.W. European states.

Expansion of Protestantism (Calvinists, Huguenots, Puritans). Counter-Reformation closes all Catholic Universities (except Padua) to Non-Catholics. Removal of religious ban on Usury stimulates Banking and Commercial enterprise, and increases supply of credit in Protestant countries.

HOLLAND

- Dutch, excluded by Spain from Lisbon and Antwerp, seek N-W and N-E Passages to Far East. Spain attempts to conquer United Provinces.
- 1567 Sir Thomas Gresham leaves Antwerp for London. Decline of Antwerp as Financial and Trading Centre.
- 1572 Massacre of St. Bartholomew. "Sea Beggars" begin resistance to Spain.
- 1575 University of Leyden (non-sectarian) founded by William the Silent.

- 1588 Blockade of Antwerp - Spanish Armada - Rise of Amsterdam as a commercial centre.
- 1592 Cornelius Houtman founds Company for Eastern Trade. First voyage 1595.
- 1598 Spain and Holland offer Prize for finding position of ship and of sight of land.
- 1602 East India Co. founded, followed by Levant Co. and West India Co. (1621) Portuguese Eastern Empire absorbed by Dutch.
1621 Batavia founded.
- 1603 Jews permitted to settle and trade in Holland (NB Spinoza 1630-77)
- 1609 Bank of Amsterdam founded
- 1611 Bourse of Amsterdam founded
- 1636 Tulipmania
- 1642 Van Diemen, Governor of Batavia, sends Tasman to find great South land.
- 1650 Peak of Dutch maritime and commercial power: 16,000 Dutch ships out of 20,000 in all Europe.
- 1652-4 and 1664-7 Wars with England
- 1672 French invade Holland
- 1685 Revocation of Edict of Nantes
- 1688 William III King of England
- 1713 Treaty of Utrecht marks end of Holland as a great Power

FRANCE

- 1560-98 Wars of Religion ended by Edict of Nantes
- 1602 Canada Co. founded. Quebec founded 1608
- 1615 Mercantilist doctrines formulated by Antoine de Montchrétien
State control of major industries - silk, carpet, glass
Colonial Empire developed in North America
- 1659 Ban on foreign shipping in French ports
- 1661 COLBERT chief Minister to Louis XIV until 1683. Intensive commercial development, and expansion of ship building and all forms of industry.
- 1664 Conseil de Commerce. Compagnies des Indes Orientales, des Indes Occidentales, du Nord, du Levant, de Chine, d'Afrique.
Le véritable moteur de l'industrie est le marchand (Savary - Parfait Négociant)
- 1665 Journal des Savants first scientific journal
- 1666 Académie des Sciences - Naturae Investigandae et Perficiendis Artibus. Huygens invited to Paris (remained until 1681)
- 1667 Tariff - war against Dutch and English goods.
- 1669 Paris Observatory established. Cassini (Bologna) first Director
- 1672 French invade Holland
French fail to support Colbert's ideas. Merchant Bourgeoisie buy land to enter Nobility, and refuse to risk money abroad.
Provinces resent centralisation in Paris
- 1683 Death of Colbert
- 1685 Revocation of Edict of Nantes. Huguenots flee to England
- 1700 Religious Wars renewed.

ENGLAND

- 1444 Merchant Adventurers Charter
- 1494 Exclusion from New World by Papal Treaty forces English to seek N-E and N-W passages to Far East
- 1514 Trinity House Charter
- 1550 Muscovy Co. opens trade with Russia
- 1571 Royal Exchange built by Gresham after withdrawal from Antwerp
- 1580 Rapid development of maritime commerce following upon Dutch War of Independence. Defeat of Spanish Armada (1688)
English shipping increases 400% between 1580 and 1640

- 1584 Venetians excluded from English Ports
- 1585 Virginia Co.
- 1598 Hause (Steelyard) eliminated. Gresham College opened
- 1600 East India Co. trades with Sumatra, Java, Moluccas
- 1612 East India Co. opens Factory at Surat
- 1645 Invisible College meets at Gresham College
- 1650 Navigation Act to exclude foreign shipping
- 1652-4 and 1664-7 Dutch Wars
- 1655 Jews encouraged to settle and trade
- 1663 Royal Society chartered
- 1669 Thomas Mun - England's Treasure by Foreign Trade, or the Balance of our Foreign Trade is the Rule of our Treasure - challenges Mercantilist theory of accumulating gold and silver, Foreshadows Adam Smith's "Wealth of Nations" (1774)
- 1675 Royal Observatory at Greenwich - "in order to the finding out the longitude of places, for perfecting navigation and astronomy"
- 1685 Influx of Huguenots following revocation of Edict of Nantes
- 1688 Union of Holland and England under William III
- 1694 Bank of England - National Debt
- 1696 John Bellers, Quaker, formulates idea of Socialism - Colleges of Industry - "He that will not work, shall not eat"
- 1698 Defoe - Essay on Projects. Savary's Patent for Steam Engine
- 1713 Treaty of Utrecht assures to England Trade of the entire World

SCIENTIFIC ACADEMIES

- 1560 Accademia Secretorum Naturae - Naples - Della Porta
- 1603-20 Accademia del Lincei (Lynx-Eyed) - Rome - Duke Federigo Cosi
- 1619 Scientific Academy founded at Rostock by Joachim Jung (1587-1657)
- 1645 Invisible College meets at Gresham College and later at Wadham College, Oxford
Informal scientific meetings in Paris at Mersenne's Coll.
- 1652 Collogium Naturae Curiosorum - Halle
- 1657-67 Accademia del Cimento - Florence - Duke Ferdinand di Medici
- 1663 Royal Society chartered - London. Nullius in verba - not under bond to abide by any master's authority (Horace)
"we value no knowledge but as it has a tendency to use (Boyle)"
- 1666 Académie des Sciences - Paris - Naturae Investigandae et Perficiendis Artibus
- 1700 Berlin Academy (Leibnitz)

SCIENTIFIC JOURNALS

- 1665 January: Journal des Scavans (Savants) - Paris
- 1665 March: Philosophical Transactions - London
- 1682 Acta Eruditorum (Leibnitz - Hanover)

THE SCIENTIFIC REVOLUTION (1550-1700)

Descriptive quantitative methods replace mediaeval essentialist qualitative aims. Aim to explain HOW rather than WHY or WHAT, e.g. "I do not intend to investigate the CAUSE of the acceleration of natural motion, but to investigate and demonstrate some of the properties of accelerated motion, whatever the cause of this acceleration may be." GALILEO - Two New Sciences (1639)

New scientific approach (Induction based on Experiment) formulated by FRANCIS BACON - Novum Organum (1620), who also emphasised the practical application of scientific knowledge - "The true and lawful goal of Science is that human life be endowed with new powers and inventions".

METHOD: Problem first simplified by omitting all but selected factors which can be related mathematically; simplified form of problem confirmed by controlled experiments; complicating factors then reintroduced and incorporated into the theory one by one. 1. Description, 2. Abstraction, 3. Functional Expression = Natural Law. "I seek to avoid all questions about the nature or quality of Gravity which we would not be understood to determine by any hypothesis. Hypotheses non fingo" - NEWTON (1687). Explanation made by means of functional relationships: factors to be explained (dependent variables) as functions of conditions (independent variables). Functional relationships expressed mathematically - Mathematics the language of Science "Physical world can be reduced to system of Universal Mathematics" - DESCARTES (1637) Emphasis on systematic measurements of ever-increasing accuracy, permitted by steadily improving scientific instruments.

SCIENTIFIC INSTRUMENTS

Thermometer - Galileo (1592-1603): first clinical use by Sanctorio 1611
Telescope - Lippershay and Metius (Middelburg) 1608
Microscope - Janssen (Middelburg) 1609
Slide Rule - William Oughtred (London) 1622
Mercury Barometer - Torricelli (Florence) 1643
Vacuum Air Pump - Guericke (Magdeburg) 1650
Pendulum Clock - Huygens (Paris) 1657

ADVANCES IN MATHEMATICS

Logarithms: John Napier (1550-1617); Henry Briggs (1561-1630)
Decimal Notation: Vieta (1540-1603) and Briggs (1561-1630)
Analytical Geometry: (Algebraic Equation corresponding to any Geometrical Shape) Vieta (1540-1603), Fermat (1601-65) Descartes (1596-1650)
Differential and Integral Calculus: Kepler (1571-1630) in 1604, Cavalieri (1598-1647) in 1629; John Wallis (1616-1703) in 1656, Isaac Newton (1642-1727) in 1665-6 but not published until 1704; Leibnitz (1646-1716) published 1684
Petty (1623-87) "Political Arithmetic" (1691). Beginnings of Statistics and Actuarial Mathematics.

MECHANICS

STEVINUS (1548-1620) Parallelogram of Forces: Hydrostatics (1586)
GALILEO (1564-1642) Dynamics - Pendulums, etc.
NEWTON (1642-1727) Principia (1687) - Laws of Motion - Gravitation

OPTICS

KEPLER (1571-1630): SNELL - Sine Law of Refraction (Leyden) 1621 also formulated by Descartes (1639); Optical Experiments by HOOKE (1635-1703); NEWTON (1642-1727) Rainbow; Prism; Theories of Colour; Corpuscular Theory of Light; HUYGENS (1629-95) Polarisation of Light; Undulatory Theory of Light.

ASTRONOMY

TYCHO BRAHE (1546-1601) Denmark and Prague: Increased Accuracy of Observations, Nova of 1572.
KEPLER (1571-1630) Prague: Three Laws of Planetary Motion (1609-19); Elliptical Orbits
GALILEO (1564-1642) Telescopic Observations: Sunspots, Satellites of Jupiter, etc. (1610)
CASSINI (1625-1712) Paris: Measured distance of Mars and Sun; Sun 87 million miles
ROMER (Denmark) estimated speed of light at 138,000 miles per second (1676)

MAGNETISM

ROBERT NORMAN: The Newe Attractive (1581) Magnetic Dip
WILLIAM GILBERT: De Magneto (1600)

STRUCTURE OF MATTER AND CHEMISTRY

VAN HELMONT (1577-1644) Louvain: Concept of Gas (Chaos)
GASSENDI: (1592-1655) Paris 3 States of Matter, Solid, Liquid, Gaseous
Revives Atomic Theory (1649) also adopted by JUNG in Botany
BOYLE (1627-91) London Sceptical Chymist (1661) - Atomic Hypothesis
(from Jung) Experiments with Pumps - Boyle's Law (1662)
MAYOW (1643-79) Oxford Spiritus Nitro-aereus (Oxygen) essential element
in combustion (rediscovered by Priestley 1774)

MEDICINE AND BIOLOGY

Leyden now leading Medical Schools of Europe. Advances in Anatomy based
on Dissection.

HARVEY (1578-1657) Padua and London - Circulation of the Blood
De Generatione Animalium (1651) Embryology

Microscopists:

MALPIGHI (1624-94) Bologna: Capillaries, Lymph Nodes, etc.
LEEUEWENHOEK (1632-1723) Delft: Muscle Fibres, Bacteria, Protozoa
SWAMMERDAM (1637-80) Amsterdam "Bible of Nature" Structure of Insects
HOOKE (1635-1703) London Micrographia (1665) Biological Observations
GREW (1641-1712) London Anatomy of Plants (1682)

Physiology:

DESCARTES (1596-1650) De Homine - First Textbook of Physiology: Man as
a Machine
BORELLI (1608-79) Pisa: De Motu Animalium

Nutrition

SANCTORIUS (1561-1636) Padua: Weighing Balance for study of Metabolism,
First clinical use of Thermometer
VAN HELMONT (1577-1644) Louvain: Chemical Study of Nutrition
SYLVIVS (1614-1672) Leyden: Chemical Approach to Disease: Hospital
Training for Medical Students
SYDENHAM (1624-89) Oxford and London "English Hippocrates".

BOTANY

Botanical Gardens established at Medical Schools: Padua (1545)
Bologna (1567), Leyden (1577), London (Gerarde) 1587, Paris (1620),
Oxford (1632), Chelsea (1673), Edinburgh (1680).
New Plants imported from New World. Attempts at classification:
Cesalpine (Padua) 1583, Bauhin (Basel) 1623, Jung (Rostock) 1587-1687;(1657)
John Ray (1628-1705) - The Wisdom of God, manifested in the Works of
Creation (1691)

EXPERIMENTAL STEAM ENGINES

Della Porta (1560): (Pneumatics of Hero of Alexandria translated 1575)
De Caus (1615), Branca (1629), Kircher (1652), Marquis of Worcester (1663),
Huygens (1680), Denys Papin (1690), Savery's Patent (1698).

APPENDIX 10

Number of Candidates for GCE "History of Science" Examinations

Year	Cambridge Syndicate Examination	Oxford and Cambridge Board Examination	Total
1952	8	59	67
1953	23	51	74
1954	13	72	85
1955	24	100	124
1956	49	132	181
1957	38	148	186
1958	80	149	229
1959	105	163	268
1960	106	181	287
1961	84	216	300
1962	58	192	250
1963	61	169	230
1964	70	224	294
1965	99	333	432
1966	89	206	295
1967	115	148	263
1968	105	111	216
1969	74	80	154
1970	99	89	188
1971	72	82	154
1972	48	104	152
1973	76	95	171
1974	60	85	145
1975	60	50	110
1976	37	54	91
1977	32	106	138
1978	35	122	157
1979	37	61	98

(Figures supplied by the two examining bodies)

APPENDIX 11

Attitude Questionnaire

The purpose of this questionnaire is to find out about what you think of HISTORY OF SCIENCE in school SCIENCE COURSES. The questionnaire contains a large number of statements; I want to know what you feel and think about these ideas and whether you agree with them or not. This is NOT A TEST and THERE ARE NO RIGHT OR WRONG ANSWERS. I would like your own opinion of each of the statements.

PLEASE FILL IN THE FOLLOWING

For
official
use

Write your name here

Boy or girl

Name of School

Today's date

PRACTICE QUESTION

1. Holidays are fun

strongly agree agree uncertain disagree strongly disagree

Each statement has 5 possible answers. Read the statement carefully and each possible answer. Then decide which ONE answer best fits your feelings and underline that answer.

1. Holidays are fun

strongly agree agree uncertain disagree strongly disagree

The answer 'strongly agree' has been chosen here by underlining the words 'strongly agree'. If your opinion was 'disagree' you would have underlined the word 'disagree'.

Please choose only ONE answer for each statement.

Please try to answer all the questions.

Do not think too long about any one statement; give the first 'natural' answer as it comes to you.

You may change an answer if you wish.

1. It is easier to learn science if you know some history of science 5-1
strongly agree agree uncertain disagree strongly disagree
2. Learning some history of science is a good way of learning about the methods of science 1-5
strongly disagree disagree uncertain agree strongly agree
3. I enjoy learning about the quarrels of famous scientists of the past 5-1
very much much some a little not at all
4. History of science is too difficult to introduce into science courses 1-5
strongly agree agree uncertain disagree strongly disagree
5. History of science appeals equally to boys and girls 5-1
strongly agree agree uncertain disagree strongly disagree
6. No knowledge of history of science is necessary for understanding present-day science 5-1
strongly disagree disagree uncertain agree strongly agree
7. History of science is a good way of learning how scientific theories are formed 1-5
definitely not no maybe yes definitely yes
8. Learning about the overthrow of old scientific theories helps in understanding present-day science 5-1
all of the time most of the time occasionally seldom never
9. If scientists knew more history of science they would show more concern for social problems 5-1
strongly agree agree uncertain disagree strongly disagree
10. There is already enough to learn in science without introducing history of science 1-5
definitely yes yes maybe no definitely not
11. Scientists are more clever now than they were in the past 5-1
definitely not no maybe yes definitely yes
12. History of science helps in understanding the present-day relationship between science and society 1-5
definitely not no maybe yes definitely yes

13. History of science is not important enough to introduce into school science courses 1-5
strongly agree agree uncertain disagree strongly disagree
14. I would find science courses more interesting if they contained some history of science 1-5
not at all a little some much very much
15. History of science has more appeal for boys than girls 5-1
strongly agree agree uncertain disagree strongly disagree
16. History of science means tracing the origins of present-day science 1-5
strongly agree agree uncertain disagree strongly disagree
17. It is not interesting to hear about experiments carried out by famous scientists of the past 1-5
strongly agree agree uncertain disagree strongly disagree
18. Knowing about history of science does not help in passing science examinations 1-5
strongly agree agree uncertain disagree strongly disagree
19. A study of some history of science would be useful for showing whether science challenges religion 5-1
definitely yes yes maybe no definitely not
20. Modern scientific methods have little in common with scientific methods of the past 1-5
strongly agree agree uncertain disagree strongly disagree
21. History of science shows how important science has been in the progress of civilisation 1-5
not at all a little some much very much
22. I like reading books about famous scientists of the past 5-1
all of the time most of the time occasionally seldom never
23. School history courses should include some history of science 1-5
definitely not no maybe yes definitely yes
24. History of science can help you understand difficult topics in science 1-5
never seldom occasionally most of the time all of the time

25. All scientists should know some history of science to make them more cultured 5-1
strongly agree agree uncertain disagree strongly disagree
26. History of science interests me 1-5
not at all a little some much very much
27. All science pupils should learn some history of science to get an overall view of science 1-5
strongly disagree disagree uncertain agree strongly agree
28. A scientists does not need to know any history of science for his work 1-5
strongly agree agree uncertain disagree strongly disagree
29. All pupils should learn some history of science at school 5-1
strongly agree agree uncertain disagree strongly disagree
30. It is a waste of time studying old scientific theories we know are wrong 5-1
strongly disagree disagree uncertain agree strongly agree
31. History of science is a good way of linking together physics, chemistry and biology 1-5
definitely not no maybe yes definitely yes
32. Science courses should not contain history of science 1-5
strongly agree agree uncertain disagree strongly disagree
33. It would be interesting to make models of old fashioned scientific instruments 5-1
definitely yes yes maybe no definitely not
34. History of science means learning about the lives and works of scientists of the past 1-5
strongly agree agree uncertain disagree strongly disagree
35. I would not like science courses which contained history of science 1-5
strongly agree agree uncertain disagree strongly disagree
36. History of science gives science courses human interest 5-1
definitely yes yes maybe no definitely not
37. All sixth form pupils should learn some history of science 1-5
definitely not no maybe yes definitely yes

38. Scientists of the past were more likely to make mistakes than present-day scientists 1-5
strongly agree agree uncertain disagree strongly disagree
39. My attitude to history of science has been mainly influenced by my teachers 5-1
not at all a little some much very much
40. Little of scientific interest can be learned from studying the works of the early scientists 1-5
strongly agree agree uncertain disagree strongly disagree
41. Present-day science has little in common with science of the past 5-1
strongly disagree disagree uncertain agree strongly agree
42. History of science does not help you to understand science 1-5
strongly agree agree uncertain disagree strongly disagree

APPENDIX 12

Raw scores from attitude survey

- Column 1: identifies the 45 pupils
- Columns 2-43: each successive column gives the scores obtained
on each successive question from 1 to 42: the score 9
indicates an unanswered or spoilt item.
- Column 44: identifies the pre-test (1) and post-test (2).

Initial Test

[illegible]

APPENDIX 13

Information given to "experts" and their responses

A questionnaire was given to sixth form science pupils to determine some of their opinions and attitudes towards history of science and its place in the school curriculum.

Statistical analysis of the responses indicate that some of the items of the questionnaire fell into three separate and distinct groups. It is assumed that each of these groups (called "Factors") is concerned with some particular and different aspect of history of science and its place in the school curriculum.

Can you give any interpretation to each of these three Factors and say what aspect is investigated in each case?

FACTOR 1

- 1 It is easier to learn science if you know some history of science
- 2 Learning some history of science is a good way of learning about the methods of science
- 10 There is already enough to learn in science without introducing history of science
- 13 History of science is not important enough to introduce into school science courses
- 26 History of science interests me
- 27 All science pupils should learn some history of science to get an overall view of science
- 29 All pupils should learn some history of science at school
- 32 Science courses should not contain history of science
- 37 All sixth form pupils should learn some history of science
- 6 No knowledge of history of science is necessary for understanding present-day science
- 7 History of science is a good way of learning how scientific theories are formed

FACTOR 2

- 3 I enjoy learning about the quarrels of famous scientists of the past
- 9 If scientists knew more history of science they would show more concern for social problems
- 12 History of science helps in understanding the present-day relationship between science and society
- 16 History of science means tracing the origins of present-day science
- 19 A study of history of science would be useful for showing whether science challenges religion
- 22 I like reading books about famous scientists of the past
- 23 School history courses should include some history of science
- 24 History of science can help you understand difficult topics in science
- 25 All scientists should know some history of science to make them more cultured
- 36 History of science gives science courses human interest
- 33 It would be interesting to make models of old fashioned scientific instruments

FACTOR 3

- 4 History of science is too difficult to introduce into science courses
- 8 Learning about the overthrow of old scientific theories helps in understanding present-day science
- 11 Scientists are more clever now than they were in the past
- 38 Scientists of the past were more likely to make mistakes than present-day scientists
- 30 It is a waste of time studying old scientific theories we know are wrong
- 20 Modern scientific methods have little in common with scientific methods of the past

Experts' Interpretations

EXPERT A

- Factor 1 Seems concerned with the relationship of History of Science to school science courses, and more specifically to the question of whether a knowledge of history of science helps the learning/ understanding of present-day science. Science here is to be understood as a body of knowledge rather than in any of its other aspects (see III)
- Factor 2 This seems clearly to be concerned with the cultural rôle of the study of history of science. That is it is connected with the Human and Sociological relations of history of science.
- Factor 3 This Factor is not unrelated to Factor 1 in that it is concerned with the relationship between the understanding of history of science and the understanding of modern science - but here it is the aspect of science as a human activity rather than as a mere set of school subjects.

Having said this much, there seem to be a few items which are 'misplaced'. Items 2 and 7 would seem to have more to do with Factor 3 than Factor 1 - suggesting that the division between these two Factors might not be so clear cut. Likewise item 4 would seem to fit Factor 1 better than Factor 3. Item 24 in Factor 2 would also have gone well with Factor 1.

Some items that might have been expected to enter into one or other of the Factors do not do so,

e.g. Item 18 ... might be in Factor 1

Item 21 ... might be in Factor 2

EXPERT B

- Factor 1 These questions would, on the whole, give some idea of the extent to which pupils regard history of science as relevant for understanding science and about science. I assume that the frequent use of "should" would help to indicate the strength of their feelings about the relevance.
- Factor 2 The social/humanistic/"extra" scientific aspects and usefulness of a study of history of science as seen from pupils' viewpoints. Could help to decide on the degree of emphasis of sociological dimension of science in history - on it as affects us now - in any proposed course.
- Factor 3 Attitudes to assumed relationship between the previous activities of science, and earlier science itself, and present-day content and method. An evolutionary evaluation.

EXPERT C

- Factor 1 This seems to investigate attitudes towards the general worthiness of history of science as a subject of study at school. Questions 1,2,10,13,32,6 and 7 probably lead to similar conclusions, either for or against history of science in school. These presumably tie in with the answers to questions 27,29 and 37.
- Factor 2 This is a tough one. I find it hard to spot a trend in these questions. The answers to them would be far more personalized than those in section 1, which were fairly dogmatic statements producing highly polarized responses. I would expect most science students would agree that the study of history of science is in general a good thing. With this decided, most of the answers in Section 1 are determined. However those in Section 2 are less clear. For example, one's attitude towards history of science has little bearing on whether one would enjoy modelling scientific instruments.
- Factor 3 Some of these questions are like those in Factor 1, i.e. 4,8 and 30. The others, 11,38 and 20 are similar to each other and test opinions about history of science itself rather than history of science as a subject of study.

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The distinction between primary and secondary source material is not absolute as the category of a source may change with the context of discussion. In this investigation many sources have been used as both primary and secondary source material. For this reason no division is made within the bibliography.

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ABSTRACT

HISTORY OF SCIENCE IN EDUCATION

by

W.J.M. Sherratt

Of the many roles seen in the twentieth century for history of science in education three have been argued most frequently and cogently: historical ideas and material can demonstrate the humanistic and cultural aspects of science, can counter over-specialisation, and can teach about the nature and methods of science. Calls for history of science to be included in the curriculum of the English secondary school have been made chiefly on these bases. They have come usually from science specialists, and the material has been advocated as appropriate mainly for pupils within the top ability range.

After providing a background to school events by tracing the establishment of History of Science as an academic discipline in British universities, the factors underlying these calls and some of the responses made during the first half of the twentieth century is examined. The post-World War II fruition of these calls - the introduction of History of Science as a GCE examination subject, the use of history of science in General Studies courses, and the inclusion of historical ideas and material in the Nuffield science reforms - is considered, together with the American influences of the period. Particular attention is given to GCE History of Science and to the historical contents of Nuffield O level physics. The former is interpreted as curriculum development resulting from initiatives taken by certain individuals; the latter is seen as a major attempt to include historical material in a school science course. A small scale pilot-study, carried out as the first stage of devising an attitude questionnaire, is described.