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AN HISTORICAL STUDY OF THE POPULARISATION OF SCIENCE IN GENERAL SCIENCE PERIODICALS IN BRITAIN, c. 1890 - c. 1939

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ABSTRACT

The popularisation of science has recently been engaging the attention of historians and sociologists of science. This thesis investigates the nature and functions of scientific popularisation and discusses its significance for the organisation and practice of science. The analysis is confined to the medium of the general science periodical, which constitutes a natural unit of analysis.

The introductory chapter sets out the major questions to be addressed, and the methods employed in the study. Essentially a scene-setting exercise, chapter 2 discusses the nature of general science periodicals, from the point of view of their production and their reception, and locates them in historical context. Comparisons and contrasts between the popularisation of specific scientific fields in these periodicals are made in the third and fourth chapters, and emerging differences interpreted in terms of the interactions between social groups. Chapter 4 also considers the popularisation of science as a whole, as well as in terms of specific fields. Themes emerging in these chapters are developed and brought together in chapter 5, which examines the significance of changing historical context for the nature and functions of popularisation. A comparative analysis with some American general science periodicals provides the substance of chapter 6. Chapter 7 restates the main conclusions of the study, which concern not only the nature and functions of popularisation, but also the public image of science and the evolution of scientific authority. The critical bibliography lists the periodicals used in the thesis. It contains bibliographical information and a short description of each journal.

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NOTES AND REFERENCES

Where no author is given for a book or article, then the work is either

(a) anonymous, or

(b) an editorial, in which case this will have been made clear in the main text.

CHAPTER 1

INTRODUCTION: METHODS AND PROBLEMS

Historical studies are undertaken with the purpose of solving problems. The intention in this instance was no different: the objective has been to explain and understand particular social, cultural and intellectual phenomena relating to science. Specifically, three major problems were tackled. These are related, multi-level issues: the nature of scientific popularisation; the nature and development of the public image of science; and the nature of science itself. It has subsequently also proved possible to draw some provisional conclusions regarding the evolution of scientific authority and legitimacy.

1. The popularisation of science

Two separate but overlapping issues must be clarified. They are, firstly, the problem of demarcation between "popular science" and something else and secondly, the questions relating to the nature and functions of the popularisation process. The literature on popularisation is sparse. It has really only been attracting the attention of historians, philosophers and sociologists in the last decade or so (i.e. since the mid 1970s) as a subject for discussion and research.

Peter Farago's Science and the media (1976)[1] and June Goodfield's Reflections on science and the media (1981)[2] are concerned with the presently existing relationships between science and the media of mass communication, particularly the daily press. In this respect they are not untypical[3]. There are, however, a number of works which are more relevant to this thesis, although they tend to disagree on fundamentals.

In his 1986 work, The science critic[4], Maurice Goldsmith dispenses with the term popularisation, and replaces it with 'the popular presentation of science'[5]. This move reflects the prevailing confusion over the concept of popularisation. Goldsmith is seeking to exclude particular types of scientific communication which analysts have recently begun to incorporate into the category of popularisation. He is in effect reverting to a less sophisticated conception of popularisation in which information is presented to a "public" by scientific experts. George Basalla also talks in terms of presentation[6]. This implies the communication is one way. Popularisation is, rather, a two-way process. Historically, however, this is difficult to analyse because most source materials represent only one side.

In this thesis, popularisation is conceived as a process of communication about science. This includes the extremes of communication between specialists in different fields as well as, for example, informal conversation between non-scientists. Contemporary analysts such as Richard Whitley[7], Michel Cloître and Terry Shinn[8] also adopt this broad viewpoint. Whilst the general conceptualisation is expanded, the object of study is clarified and narrowed. Once it is appreciated that there are many forms of popularisation, which involve interactions between groups, individuals, ideas and culture, it becomes possible to focus study on one of these forms, and to analyse its nature and functions. The alternative is to study the ill-defined notion preferred by Goldsmith and to founder within an unsuitable Mertonian framework.

Popularisation of science, once seen as a process of communication, can be analysed without struggling to clarify what the entity "popular science" may or may not be. This is the most fruitful of approaches and, accordingly, is the one adopted in the present thesis[9]. Yet the term, together with related labels (e.g. "semi-popular") is liberally bandied about in the literature, often with no attempt at definition and laden with assumptions. A brief consideration of its use, and of the difficulties which accompany endeavour to stipulate its meaning, is therefore appropriate.

A number of limited attempts to define "popular science" have been made by scholars. There is little agreement between them, however, as they make distinctions to serve the purposes of their own arguments. Basalla, for instance, regards 'popular science' and 'pop.science' as distinguishable entities. The former, he asserts 'is science presented not to the masses but to a highly educated, and thereby limited, segment of the population' in which he includes 'one group of scientists writing for another group of scientists and technicians'. The latter, contrastingly, is 'the portrayal of science in popular culture'[10]. Conversely, for R.G.A. Dolby, the chief characteristic of 'popular science' is that it 'gains its support without the mediation of the scientific expert', and, together with 'the popularisation of orthodox science', constitutes what he describes as 'the science of popular culture'[11]. Whilst this categorisation is undoubtedly valuable in some instances, in the context of the general science periodical at the turn of the century, it makes assumptions regarding certain developmental questions prior to their investigation.

The essential problem is that a notion such as "popular science" presupposes a counterpart, a "non-popular science" as it were. The most obvious candidate would be "academic science" or something similar, and signifying the type of esoteric knowledge and activities shared by relatively isolated groups of specialists. Historically, this is a most unsatisfactory distinction. The demarcation between scientists and non-scientists has not always been as clear as it is now, a state of affairs which obtained at the end of the nineteenth century. Moreover, identities were constantly shifting during the period of this study (something which is explored in subsequent chapters, especially chapter 3). The overlap between such categories significantly reduces their value as analytical frameworks. Popularisation is a process of such intricacy and complexity that the imposition of such superficial frames of reference, which amounts to describing processes in terms of things, is manifestly undesirable.

One historian, Susan Sheets-Pyenson, is aware of some of these difficulties. She distinguishes between 'high' and 'low' science in the first half of the nineteenth century. Whilst offering extremely valuable insights into the popularisation process, Sheets-Pyenson herself falls into the trap of stating that 'popular science' attempts to make 'high' scientific discourse intelligible to the non-scientist', and fails to define this 'popular science' any further[12].

The most thorough and valuable analysis of scientific popularisation to date has been given by Richard Whitley in his memorable article 'Knowledge producers and knowledge acquirers. Popularisation as a relation between scientific fields and their publics'[13]. This article introduces a collection of studies which demonstrate the variety of forms and functions which the popularisation process has assumed in different scientific fields at different historical periods. As its title suggests, Whitley is arguing that popularisation is best viewed as a relationship between scientific practitioners in particular scientific disciplines and their audiences. Given the importance of this article, it will be useful to consider Whitley's conclusions, and the route by which he arrives at them, in some detail.

Whitley begins by outlining what he calls 'the traditional view'[14] of popularisation, according to which popularisation is seen as 'the transmission of scientific knowledge from scientists to the lay pulbic for purposes of edification, legitimation and training'. It is, furthermore, entirely separate and distinct from research activity, and unrelated to the process by which knowledge is produced and validated. Whitley goes on to analyse this view in terms of audiences, producers of knowledge, the knowledge itself and the impact of popularisation on the production of that knowledge.

Traditionally, he states, audiences for popularisation have been seen as 'large, diffuse, undifferentiated and passive' and whose 'sole distinguishing characteristic is their exclusion from the process of kncwledge production and validation'[15]. Conversely, the perception of knowledge producers is rather that of an organised, highly trained and specialised élite who are engaged, in isolation, in the pursuit of "truth". As regards the knowledge itself, as it is produced in isolation from the lay public, it must be translated into ordinary language if it is to reach that public. This process, (i.e. popular-isation) transforms the way the knowledge is expressed but retains its truth status. Finally, since, according to the traditional view, the knowledge producers and their audience are distinct, the popularisa-tion process can have no effect on the production of new knowledge.

Whitley attacks this characterisation on all four fronts. He points out, firstly, that there is not one audience for scientific popularisation, but many. Among these he lists students, military and business groups, and professionals. Furthermore, he challenges the ideal of scientists as members of autonomous communities producing truth, basing his challenge largely on work in the sociology of science, which argues that truth is 'a sociologically contingent construction'[16] and not an absolute[17]. Whitley also undermines this ideal of autonomy by invoking the specialised and differentiated nature of science and the differences of organisation, control and procedure which exist between scientific disciplines. Knowledge, moreover, must alter its nature in the process of translation, for 'the transformation of knowledge produced by one community into the language and concepts of another is very difficult, if not impossible, without seriously changing the nature of that knowledge'[18]. That is, the meaning of the knowledge is largely inseparable from the context of its production[19]. Finally, in response to the notion that popularisation has no effect on knowledge production, Whitley cites several examples, including, most notably, the allocation of research resources, where popularisation has demonstrably affected the prosecution of research.

Whilst admitting his 'traditional view' to be something of an artificial construct, Whitely claims that its elements can be seen to run through current discussions of popularisation. One significant example of this is to be found in Walter Bodmer's unsophisticated 1986 Bernal lecture to the Royal Society[20]. The construction nevertheless achieves what the author intends it to, namely, it allows him to demonstrate that perceptions of the nature and functions of popularisation are underpinned or, rather, determined, by perceptions of the nature of science. Furthermore, he argues that his critique shows that audiences for popularisation, as well as its forms and functions are historically specific.

Whitely then proceeds to posit an alternative conception of popularisation, rooted in a different idea of scienceitself. He analyses the popularisation process, offers a means of categorising its different forms, gives examples of some circumstances in which these forms occur, and describes some consequences which the process has for the pursuit of scientific research. This conception is based on the following considerations. Firstly, that scientific fields vary enormously in terms of, for example, organisation, research procedures, autonomy and regulation of standards and in the extent to which the language of theirfield is formalised. This variation occurs between historical periods and contemporary fields. Thus the scientific community is far from being the highly organised, autonomous entity which was part of the 'traditional view', but is made up of several diverse social groups organised in different ways. Moreover, the relationships these bear to each other, and to groups outside the community are many, varied and liable to change. In addition, 'what constitutes scientific knowledge has changed and depends upon particular social relationships and collective judgements'[21]. Viewing knowledge production as a process of social negotiation means that 'expository practises are not epistemologically neutral'[22]. In other words, popularisation is important to the production of new scientific knowledge.

Three major conclusions are drawn by following through the logical implications of these points. The forms and functions of popularisation depend on, firstly, 'general connections between scientists and non-scientists and between the particular scientific field and other sciences'[23], and secondly, on the manner in which research is organised in scientific fields and the audiences at which the popularisations are aimed. Thirdly, the concept of popularisation must be extended beyond its 'traditional' usage to include intra-scientific communication, i.e. communication, about science, between scientific practitioners in different fields. The 'contingent and varied nature'[24] of popularisation is underlined by this extension of the concept.

The remainder of Whitely's paper is devoted to classifying forms of popularisation, advancing reasons for their occurrence, and considering their consequences. His classification is based on (a) the differing degree of 'formalisation and technical precision'[25] and (b) the differing extent to which the presentation is in terms of true, universal knowledge and inversely, the role which arguments and detail assume between fields.

In explaining why popularisation takes the forms and functions it does, Whitely examines the effect of the system of knowledge production. He concludes that two factors are significant. These are the 'degree of standardisation and formalisation of work procedures and symbol systems'[26] and 'the social and scientific prestige of a scientific field'[27]. The greater is this prestige, the more scientific knowledge is presented as certain, and the less attention is given to details and the exposition of arguments. Putting these considerations in the context of the relationship between scientific fields and their audiences, Whitely claims the cognitive distance separating them affects the form of popularisation. So too, he argues can the extent to which audiences control resources, and hence scientific practitioners depend on the interests and attitudes of those audiences. Popularisation is modified according to these interests and attitudes, adapted to suit prevailing trends and fashions, as too are intellectual objectives.

Early in the article, it is stated that 'Popularisation often has a direct impact upon what research is done, how it is done and how it is interpreted'[28]. He ends by clarifying this claim. Popularisation affects the pursuit of science in three ways, he asserts. Firstly, it influences the general social status of individual fields. Secondly, it also influences the status of these fields in a more specific, intellectual context. Finally, and focussing even more narrowly, popularisation can have implications for the importance of particular problems and methods within the individual fields.

It would not be profitable to try to assess the validity of Whitley's conclusions regarding the forms and functions of popularisation at this point. As the present study is concerned with some of the issues he addresses, and analyses the form and functions of the process of scientific popularisation in one particular medium, it will, however, be appropriate to compare the conclusions reached with those of Whitely at the end of the study.

2. Studying popularisation

a) General historiographical considerations

An increasing awareness among historians of science in the past twenty-five years or so that their discipline was not simply a servant of science but a part of history in its own right, has led to an improved quality of scholarship and the development of new historical approaches. Along with this has grown an understanding that science is a cultural product like any other and must be treated as such, and, further, that it cannot be separated from other cultural products/ activities. None of which should be taken to imply the kind of crude determinism which marred, for example, attempts at Marxist history of science during the 1930s.

The work of historians and sociologists of science (for example Steven Shapin, Paul Forman and Barry Barnes among many) has led to a realisation that science is more than an objective body of knowledge and that the scope of its study extends beyond major discoveries and heroic figures. It is becoming widely accepted that science is more than this, and more than its institutions. To understand science, many historians now believe that aspects other than these must be taken into account, which include all persons involved in scientific activity and scientific communication. Since science is a part of culture, its study must be located in a cultural context and its interactions with that context, its role in that culture investigated. More recently, ideas and attitudes about science have come to be regarded as an important element of the scientific enterprise and a crucial factor in its organisation and development.

Accordingly, the present analysis of the popularisation of science demands contextual location if it is to be at all valuable. Such location leads to context bound relativism. Yet, in attempting to avoid a Whiggish approach, care must be taken not to fall into the naïve assumption that we too are not context bound. Complete objectivity therefore becomes impossible: the presuppositions historians of science bring to their work in this respect are as deep as problem formulation and methods. Also, context bound relativism often fails to tackle important developmental questions. It is therefore necessary to examine changing context. Here, by following this approach it has been possible to offer explanations and interpretations of the changing nature of popularisation, the changing public image of science and some changing relationships within the scientific enterprise. Available source materials also affect the choice of methods and problems.

b) <u>The image of science in popular culture</u>

Analysing the image of science in popular culture is a necessary element in the understanding of science, its nature and its cultural role. The present section discusses the views of some scholars who have written on popular culture, examines some fundamental problems of the field and posits a possible solution appropriate to this study.

Firstly, however, the notion of "popular culture" itself requires consideration. Lamentably, the concept is ill-defined in the literature. Even the contributors to a periodical specifically devoted to the subject, the Journal of popular culture, fail to address the issue. They prefer simply to get on with the job of doing history and/or sociology, resembling in this respect scholars of "popular science" or of science itself.

In order to define the concept of "popular culture" along Saussurean lines[29], one must take into account both the like and the unlike. That is, the idea must be compared and contrasted with others. Historically, "popular culture", together with "mass culture", has been used in opposition to "high culture" (which includes, for example, opera, classical music, romantic poetry etc.). The terms "mass" and "popular", when applied to culture, have traditionally signified a culture shared by a part or a majority of any society, other than the social élite. As Kando has pointed out, however, the two have assumed different meanings derived from an essentially judgemental basis[30]. "Mass" culture has overtones of the "bad" and "popular" of the good. That is, popular culture has come to include more "worthy" human activities, traditions and beliefs such as jazz music, punk rock and folk heritage. "Mass" culture, in contrast, is more commonly applied to, for instance, American hamburger restaurants and tabloid newspapers. Further, the concept of popular culture is pluralist. It can be said to include elements shared by more limited proportions of a population, whereas the term "mass" itself denotes something which is more or less universal.

For the purposes of this thesis "popular culture" is taken to refer to the systems of action and belief shared by particular groups within the population as a whole, but who do not themselves constitute a social élite. With specific reference to the image of science in popular culture, what is meant are ideas about science (and their physical embodiment) held by a group or groups of the population, excluding the scientific élite itself. That is, the image of science in popular culture can be said, in the context of the present thesis, to refer to the conflagration of perceptions of and attitudes towards science held by the majority of the population, with the exception of those engaged in the professional practice of science.

It has been argued that the traditional historical method, when applied to the study of popular culture, has one major shortcoming.[31] Incorporating new insights into an analysis of the sources, growth, reception and significance of a phenomenon would be incomplete without consideration of immediate experience. The historical method requires that experiences be mediated, usually through surviving 'facts' or 'artifacts'[32]. Immediate experiences, however, leave no 'facts' or 'artifacts' behind to study, yet they are a crucial element in popular phenomena, without which any assessment of the nature and significance of such phenomena would suffer. Precisely what this means for the present study is that the experiences of the audience are not mediated and thus fall beyond the scope of the historical method. There is little surviving evidence (other than, for example, correspondence) from which the audiences' reactions may be deduced.

In attempting to find a solution to this problem, Joseph Arpad redefined mediate experience to include that which leaves behind it a 'mentifact' (an idea or image), a 'psychofact' (an attitude or feeling) or a 'sociofact' (a behavioural pattern)[33]. This move improved the situation only as far as contemporary studies of popular culture are concerned, as it required direct access to human experience.

Neither of the alternatives Arpad suggested for historical popular culture studies are totally satisfactory. Deducing the experiences and reactions of audiences from pre-existing problems, purposes and circumstances and/or from what surviving facts or artifacts remain is the only possible approach. Given that much of the audience response would have been social and cultural, as opposed to personal and psychological, such deductions can be valuable and revealing.

A number of different approaches to the problems of this thesis are therefore possible, depending on the available sources. In his article 'Popular culture and social history', the historian William H. Cohn stated that

> 'the object, then [of historical studies of popular culture], is to portray an historical idea in transformation, to connect ideas with the concrete experiences of history'[34].

According to Cohn's view, the most appropriate subject for a thesis such as this would be the changing image of science in popular culture. Yet as has been indicated, such an analysis would be rendered extremely difficult by the fundamental lack of evidence relating to what Cohn terms the 'consumers' (as opposed to the 'producers') of popular culture. Another historian, Gregory Singleton, has argued that what is perceived and what is presented are distinct, and the former is of far greater significance[35]. The materials with which the historian of the 'popularisation' of science has to work are, however, limited. It is not even possible in many cases to say precisely who these 'consumers' were, let alone what were their reactions to particular forms of scientific popularisation.

Despite the indubitable cogency of Singleton's argument, a study which concentrates on the 'producers' of certain aspects of popular culture can indeed be a useful, interesting and informative enterprise. In particular, where evidence relating to audiences is as rare and difficult to come by as it is in the presentation of science, there is little alternative. Singleton accuses those engaged in popular culture studies of assuming that the media in question either 'accurately reflect popular atttitudes'[36] or, alternatively, 'reformulate the public mind'[37]. No such extreme claims are made in the present thesis. It is, nevertheless, shown that in one medium, the attitudes and beliefs of audiences influenced and informed both the form and the content of the presentation (see chapters 3 and 5). Furthermore, it is demonstrated that although audiences did not passively accept everything they were given (and did contribute directly and indirectly to the presentation of science), the 'producers' were attempting to make them do so. They were, in fact, aiming to reconstruct the image of science in popular culture. In addition, it seems difficult to believe that the public image of science could possibly be as different from its presentations as Singleton has argued.

It has been suggested (by Singleton and other social historians) that the study of representative groups from within the audience could be a means of surmounting these difficulties. This method would be unsatisfactory for at least two reasons. Firstly, the choice of such groups from a largely unidentifiable audience would be problematic, and, secondly, it is highly unlikely that any such choice could be representative. Furthermore, in this context, the concept of a wider audience is of crucial significance (see chapters 4 and 5). Given the available sources, by studying the media themselves and by taking into account general contextual factors and any interactions between them, it is possible to conduct a stimulating and fruitful analysis of the image of science and its construction, as well as the nature and purpose of the popularisation of science.

The limited evidence relating to the readership necessarily affects the kinds of questions which can be asked and the types of problem which it is possible to tackle. This thesis must concentrate on the popularisers, the producers of the artifacts (i.e. texts) with which the historian has to work. These producers were a part of the scientific community. It has been possible to ask questions about the aims and objectives of these producers, the infra-structure of the scientific community and the relationships between the individuals and groups which constituted that infra-structure (e.g. the relationships between producers, and producers' relationships with readers, at least as perceived and reacted to by the producers). Examination of changing contexts and relationships was revealing in terms of the changing nature of the popularisation process and the changing public image of science.

Texts in periodicals are the main source materials used in this study, that is primary, popularising texts. Contexts are needed to interpret these texts. One school, led by Gilbert and Mulkay, holds that analysis must be confined to variation in 'accounting repertoires' in different social contexts (that is, which different linguistic modes are adopted in which set of circumstances), as textual analysis cannot be used to explain the actions and beliefs of scientists, since accounts vary according to social contexts and their interpretation is so flexible[38]. The method advocated by Gilbert and Mulkay is not valueless, but unnecessarily limiting. Although the hermeneutic approach does presuppose access to the intentional capacity of the agent, interpretations can be made, which is, of course, what history is all about. Further, the more restrictive approach involves just as much interpretation in, for example, the definitions of 'accounting repertoires' and their variation with social contexts[39].

One possible solution to the problem of the absence of a link between the producers of popularisation and the image of science in popular culture is to be found in the concept of hegemony. Hegemony 'the key to élite control'[40], is normally an element of analyses based on class conflict, and is 'a kind of cultural supremacy which sanctions the social authority of the ruling class'[41]. It is, however, possible to transfer the concept to the domain of science and utilise it in the context of social élites. To interpret the popularisation of science (in a particular medium and during a specific period) in terms of an attempt to challenge the prevailing hegemony and replace it with an alternative, offers a dynamic and revealing resolution of a fundamental dilemma. The power, authority and legitimacy of élites within society have a crucial cultural and psychological aspect. These depend, according to Berman, on the ability of the élite 'to convince the classes below it that its interests are those of society at large'[42]. In other words, they depend on the establishment of an identity of interests. This thesis is concerned with the process of attempted foundation of a new hegemonic class, a new social élite within British society at the end of the nineteenth century and the beginning of the twentieth.

3. General science periodicals, c. 1890-1939

Historical investigations into the nature of scientific popularisation benefit from a natural unit of analysis. The general science periodical provides precisely such a unit. The difficulties attendant on an attempt to define 'popular' science extend to the demarcation between 'popular' and 'academic' periodicals. For reasons outlined in section 1 above, the 'popular' science periodical is an arbitrarily constructed category unsuitable for this type of historical analysis. In contrast, general science periodicals constituted a readily recognisable group of publications which can be clearly defined for practical consideration. By the 1890s, they possessed both an historical and a contemporary identity.

Both the range and sheer volume of the Victorian periodical press were great[43]. Of these journals, those described by modern writers[44] as 'popular science' included mechanics magazines, natural history journals and general science periodicals. By the late 1800s mechanics magazines were in decline and it was only those prepared to abandon the traditional formula in the quest for a newly emerging readership (such as the English mechanic[45]) which survived into the twentieth century. Journals for the amateur naturalist continued in the new century but failed to flourish as they had in the old. General science periodicals fared much better: a significant decrease in activity occurred only around the time of the First World War (see chapter 2, figures 1 and 2). Most other journals which might be classified as 'popular' were of a more specialist kind. Even those devoted to natural history tended to concentrate on zoology and, to a lesser extent, botany[46]. Other examples included journals on aquatics, wireless and birds.

The periodicals used in the present study were commercial publications, that is, they were not produced by scientific societies. Whalen and Tobin distinguish general science periodicals from what they term 'periodicals of scientific study' (in which the Scientific american is included).[46a] The difference between the two, according to these authors, lies essentially in their conception of science as, respectively, 'an integrated body of unifiable knowledge and general categorical descriptions'[46b] and a study. Further, whereas the general science periodicals were committed to the advancement of science, the periodicals of scientific study were rather concerned with self-improvement.

Susan Sheets-Pyenson defines mechanics magazines and general science periodicals in terms of readership and content.[46c] Mechanics magazines were produced for the working man, the artisan inventor. Their content reflected this: technological material dominated, tools, machines and practical operations were described and the emphasis on practical utility led to an absence of theoretical speculation. These magazines provided 'urban workers with advice on how to advance their social position through scientific pursuits'.[46d] In contrast, general science periodicals had a much smaller, middle class readership. Early in the nineteenth century these journals also attempted to reach artisans but by the 1860s were exclusively directed towards the middle classes.

Although in some respects these distinctions blur towards the end of the nineteenth century, they nevertheless serve to illustrate that there were two distinct kinds of publication and provide the basis for the exclusion of mechanics magazines from this study.

The essential point about the general science periodical was that it incorporated material from a variety of scientific disciplines. Its readership ranged between the specialist and the general: from groups of scientists working in disparate fields, to schoolteachers, to much larger and heterogeneous groups represented by, for example, the working man with wireless as a hobby. Typically, the periodical comprised a collection of articles, book reviews, news of recent scientific developments, correspondence and so on. These were truly 'scientific' journals: their subject was science and not, for example, physics or biochemistry alone.

Several reasons may be advanced in justification of the choice of the general science periodical for the analytical unit of this thesis. One can point to:

(a) the many forms of communication encompassed within the process of popularisation and the consequent necessity of selective and specialised study to obtain a thorough assessment of at least one part of it;

(b) the relative staying power of the general science periodical compared with that of its nineteenth century companions the natural history journal and the mechanics magazine;

(c) the existence of a wide variety within the readership which allows for an understanding of the changing relationships between a journal's readers and its producers;

(d) the appreciation of the relationships between the popularisation of different sciences made possible by the variety exhibited in the contents;

(e) the authority they could more readily assume in representing, as it were, the whole of science and not just one small part;

(f) the availability of material;

(g) their approximation to a natural historical unit.

These factors provide the background to the adoption of the general science periodical as the basic framework of this thesis. In the following chapter, these points are elaborated upon, and the nature of the general science periodical is explored more thoroughly.

The choice of period was determined by a number of considerations. The most important of these is to be found in an analysis of general science periodical activity. In these terms, the final decade of the nineteenth century and the first decade of the twentieth century constituted a high point. The First World War marked a dramatic turning point - the numbers of periodicals being founded and ceasing publication were subsequently reduced dramatically. These features are illustrated by figures 1 and 2 (chapter 2) and discussed at length in chapters 2 and 5.

As W.H. Brock has argued, the peak which occurred in the 1890s was a direct consequence of preceding developments in professionalisation and specialisation of science[47]. Although professionalisation and the associated processes of specialisation and differentiation had been underway well before 1890, the early part of the twentieth century was crucial in the course of their evolution. Changes in the relationship between science, government and industry were critical during this period. The rate at which professionalisation proceeded and its mode of development differed between disciplines. Explorations of the significance of these factors for general science periodicals are made in chapters 3 and 4.

For a study such as this, the period was also dynamic due to the increasing proportions ofliterate and voting populations. The education reforms of the later nineteenth and early twentieth centuries (beginning with the 1870 Forster Act) resulted in an increase in adult literacy and the quality of education, issues which are addressed in chapter 2. Legislation from 1867 onwards gradually extended the size of the voting public until 1928, when universal adult suffrage was finally achieved by a lowering of the age at which women could vote from thirty to twenty-one. How this affected the periodicals is shown in chapter 5.

Innovations in science combine with the above reasons to make the years 1890-1939 especially interesting. For instance, radioactivity and relativity theory contributed to the changing face of physics and in addition both in their different ways provoked considerable popular fascination. In the biological sciences too, there was the rediscovery of Mendelian genetics, the growth of experimental biology and the emergence of biochemistry as a discipline. And at a fundamental level, there grew a strong tendency in biology towards reductionism, with explanation in physico-chemical terms.

The length of the period allows the greatest possible use to be made of the major primary source (i.e. the general science periodicals) by studying the changes which occurred in content, presentation and policy over time. A substantial period is required in order that benefits from the unique feature of periodicals i.e. their persistence and regularity may be maximised. Moreover, the years 1890-1939 constituted the transitional and rapidly changing period between Victorian amateurism and the state-funded, highly professional, so-called 'big science' characteristic of Western culture after 1945[48].

Studies of the British Association for the Advancement of Science have remarked on the very much greater role assumed by the popularising activities of that organisation in the 1920s, but more especially in the 1930s, as a response to a suspicion of science which was then gaining increasing currency among the general public[49]. The Association itself in 1946 characterised the historical development of popularisation into 3 phases, with which Brock is essentially in agreement[50]. These were the Victorian period, typified by the activities of Huxley and Tyndall; a period from the 1880s to the First World War when science was 'less easily disseminated'[51]; and a third phase, from 1918 onwards, when scientific popularisation embarked on a period of renewed activity (although the Association divided this third phase into two - the first part, from 1919 to the early 1930s, during which instrumentalism and mysticism typified popularisation, and the second, from 1936,'when the presentation of the social, political and cultural implications of science and technology became the principal aims of popularisation'[52]). Contemporary commentaries[53] concentrate on the Victorian (Huxley) era, the 1930s, or both, and about the intervening period there exists, by and large, a conspicuous silence. These factors contrive to make the period chosen for this study ripe for investigation, especially the years 1890-1918.

In the present thesis, the popularisation of science in general science periodicals is examined during this relatively unexplored period (see in particular chapters 3 and 5), as is the changing mode of presentation between this period and the next. A periodisation of popularisation attempted in chapter 5 does not disagree with that of Brock and the British Association, although analysis of the years 1890-1918 demands an alternative rationalisation. Finally, it is demonstrated in chapter 5 how closely the British Association's popularising role was connected with that of the general science periodical in the person of Richard Arman Gregory.

The full range of general science periodicals used in this study was established by a systematic search of the <u>British union catalogue</u>

of periodicals[54]. Because this catalogue frequently lists only journal titles, possible candidates were then checked in the British Museum catalogue of printed books[55] and, if not eliminated thereby, were subsequently examined themselves. In addition, the latter catalogue was thoroughly combed under the heading of Periodical publications for London, Manchester, Oxford, Cambridge, Edinburgh and Glasgow. This procedure ensured that the overwhelming majority of general science periodicals presently held by British libraries were located. Although it may, of course, be the case that some periodicals of this type published during the period in question have not been preserved, no evidence of this was found. The Catalogue of the Newspaper Library[56] was found to be a helpful resource. It is of considerable interest to note (as a glance at the critical bibliography will show) that between 1890 and 1939 all but one of the general science periodicals published in Britain were in fact published in London. Manchester produced only one and Edinburgh and Glasgow none, although Natural science, originally a London-based periodical, came to be published in both London and Edinburgh towards the end of its life. Discovery moved to Cambridge in 1938 to be published by the University Press.

It is therefore evident that these journals were very much centred on the English capital. Their centralisation in the metropolis provides the chief justification for the English emphasis of the study. It is, however, necessary to take the Scottish situation into account, and it is appropriate to summarise that situation at this point.

Scotland must be considered as a separate nation. Although it was incorporated into Britain by the 1707 Act of Union, it maintained its independent educational, religious and judicial systems. It is the first of these which carries the greatest implications for the present thesis.

Historians have emphasised a number of differences between the English and Scottish systems of education. Most conspicuous of these has been the 'democratic' nature of the latter, a widely held view being that a far greater degree of educational opportunity existed for the children of all classes in Scotland. This view has been expressly challenged by T.C. Smout, who has shown the system to have been 'meritocratic' rather than 'democratic'[57]. The Scottish system, like the English, was largely geared to meet the needs of the middle classes. This was particularly the case after 1870, when its 'democratic' nature visibly deteriorated.

Nineteenth-century Scottish universities were characterised by a general approach to education, which contrasted markedly with the specialisation favoured by their counterparts south of the border. The closing decades of the century, however, saw a wider acceptance and institutional embodiment of English values in this respect[58]. Despite the essentially 'meritocratic' nature of Scottish education in general, opportunities for lower class advancement did, nevertheless, exceed those available in England, even at the level of entrance to university.

The principal significance of these factors for general science periodicals between 1890 and 1939 lay in relation to readership. For instance, it is unlikely that the kind of new readership which emerged in England at the turn of the century was matched in Scotland, thereby removing an important stimulant to journal foundation. A different type of reader (i.e. the middle class male reader with a general university education) was probably a feature of the Scottish scene. The later arrival of specialisation, to which general science periodicals were at least in part a response, may be one reason for the absence of this type of publication in Scotland.

One final respect in which the Scottish situation departed from that which obtained in England concerns the significance of the Baconian tradition. Such a tradition was strong in England, in both the academic and wider cultures[59]. It was, however, largely absent from Scottish universities which can be said, in fact, to have adopted what has been described by Davie as an anti-Baconian position[60]. This meant that one of the main imperatives behind the production of the English general science periodical, as argued in chapter 4, was missing.

4. The professionalisation of science

Part of the problematic nature of the "popular science" concept related to the difficulties of demarcation between scientist/non-scientist, expert/layman, etc.[61]. These were particularly acute during a period when precisely such roles were being defined and redefined. Attempts at such demarcation would result in arbitrary and meaningless categories. Moreover, the attempts would themselves be the target for accusations of Whiggism. Understanding the reactions and interactions of the period in terms of these changing roles has, however, proved to be crucial to the analysis of popularisation in general science periodicals with respect to both form and function. In short, the professionalisation of science is a vital explanatory element in this thesis.

In her Science and culture, Susan Cannon levels a charge of Whiggism at most studies of nineteenth century professionalisation, which she describes thus: 'Science once was not professionalised; it now is; the process whereby it became so is a path to the present; and that is good' [62]. Now this may be an accurate characterisation of much of the scholarship Cannon is attacking. The second half, however, is not logically linked to the first. That is, because historical change does occur, it is not necessarily 'good' nor is it necessarily a path to the present, a point which has been abundantly emphasised above in section 3.

This thesis does not assume that professionals are any 'better' than amateurs and the implications which Cannon claims to reveal most adamantly have no place here. In fact, professionalisation was invoked as the most satisfactory framework only after the actions and interactions taking place within general science periodicals had been identified. The actors were seen to be fighting for control, certain groups were attempting to exclude others, to secure recognition and rewards and to persuade others to certain actions. General science periodicals were being used to achieve particular objectives which the participants themselves identified as the desire for professionalisation. A study of the popularisation of science in this medium and at this time would be radically incomplete without the consideration of the role of professionalisation.

Brock has also pointed to the unhistorical characterisations of professional scientists which stem from definitions based in twentieth century conceptions[63]. For his own purposes, Nathan Reingold's threefold categorisation of the scientific community into 'researchers', 'practitioners' and 'cultivators' is deemed appropriate[64]. This flexible framework is indeed a useful tool in the present analysis, with the professionalisation process being marked by a decline in 'cultivators', and a rise in 'practitioners'. Yet Reingold's typology is derived from a consideration of the scientific community of mid-nineteenth-century America, and begins to break down if applied to late nineteenth and early twentieth century Britain[65] at which time a dynamic process of redefining relationships was underway.

There is a significant body of literature in the sociology of science which concerns itself with the existence of barriers within and around science. The importance of scientific professionalisation has become clear, as, for example, in Richard Whitley's 1977 article on 'Changes in the social and intellectual organisation of the sciences'[66]. Of particular relevance to the arguments of this thesis, however, is R.G.A. Dolby's essay 'On the autonomy of pure science' in which he addresses the problem of 'The construction and maintenance of barriers between scientific establishments and popular culture'[67].

Dolby argues that what were originally cognitive barriers, erected in order to improve the knowledge production process, were only subsequently transformed into social barriers. This study shows how difficult it is to distinguish absolutely between the cognitive and social aspects. According to Dolby, the analysis of the construction of boundaries leads to interpretations centred on 'the rational institutionalisation of objective features of science' or 'the ideological workings of professional self-interest'[68]. Whilst he correctly points to the ambiguity of the issues and the consequent difficulty of their resolution in terms of definite explanation, his analysis favours the intellectual interpretation. He presents the erection of barriers as moves towards the efficient production of knowledge. Since the very questions with which Dolby is most specifically concerned bear upon the relationship between knowledge generation and barriers within and around science, this view is only to be expected.

The materials and concerns of the present study relate far more to the social and professional element. The most interesting aspects of general science periodicals bear directly on the social organisation of science. That is, the most fruitful and revealing factor in the study of these periodicals, and to a considerable extent determined by the periodicals themselves, is the changing nature of the relationships between their producers and their consumers. Insights into the knowledge production process may be derived from this analysis, consequences of its primary and proper orientation in focussing on the social organisation of science.

Despite agreement on essentials, there are several further points on which this analysis departs from Dolby's. For instance, he concentrates, as is the wont of sociologists of science, on conflicts and controversies. Whilst there is no doubt that these can be and frequently are extremely useful and revealing case studies, and in fact play a significant part in the arguments of this thesis, such a focus on unrepresentative areas can nevertheless carry with it the danger of presenting a fragmentary picture. Accordingly, periods of resolution and gradual develoment are also taken into account.

Crucial to the professionalisation of science and the process of barrier construction are the concepts of authority, control, expertise and autonomy. In this and in later chapters (particularly chapters 3 and 4), the relationships between these concepts and processes are explored. In investigating the mechanics of barrier construction it was hoped to discover something of the underlying motives, at least in the context of the popularisation of science in general science periodicals, and thereby making a contribution to the understanding of the social/intellectual dichotomy. For example, whereas Dolby invokes the notion of expertise as a tool in the construction of barriers, the present analysis demonstrates that its role can be somewhat different. It is shown, for instance, that the construction of barriers contributed to the recognition of the scientific expert and his authority. The two analyses are, however, complementary rather than contradictory.

In explaining the means by which these barriers were constructed (in two cases), Dolby emphasis the creation of what he terms 'intellectual distance'. This is the process whereby the participants on one side of a debate point to the differences between the activity they pursue and that of their opponents, thereby conferring some advantage on their own position. In chapters 3 and 4 several other means (both social and cognitive) to the same end of excluding a certain group or groups from participation are illustrated. One interesting corollary of this creation of distance is the inverse relationship, pointed out by a number of commentators, the most recent of which is Harry Collins[69], between distance and certainty. It is argued, by Collins and others[70], that the further one is removed from the process of knowledge production, the more likely one is to see that knowledge in terms of certainty. This consequence has important implications for the authority and legitimacy of science in the public arena, in view of the distancing mechanisms which were at work in general science periodicals and which are described in chapters 3 and 4.

Notes and references

1. Peter Farago, Science and the media (Oxford, 1976).
2. June Goodfield, Reflections on science and the media (Washington, 1981).
3. E.g. Amitai Etzoni and Clyde Nunn, 'The public appreciation of science in contemporary America', in Gerald Holton and William A. Blanpied (eds.), Science and its public: the changing relationship, Boston studies in the philosophy of science, 33 (Boston and Dordrecht, 1976), 229-43; David Perlman, 'Science and the mass media', Ibid., 245-60; Bernard Dixon, 'Telling the people: science in the public press since the Second World War', in A.J. Meadows (ed.), Development of science publishing in Europe (Oxford and Amsterdam, 1980), 215-35.
4. Maurice Goldsmith, The science critic (London, 1986).
5. Ibid., p. 2.
6. George Basalla, 'Pop.science: the depiction of science in popular culture', in Holton and Blanpied (eds.), op. cit. (note 3), 261-78.
7. Richard Whitley, 'Knowledge producers and knowledge acquirers. Popularisation as a relation between scientific fields and their publics', in Terry Shinn and Richard Whitley, Expository science: forms and functions of popularisation, Sociology of the sciences yearbook, 9 (Dordrecht, 1985), 3-28.
8. Michel Cloître and Terry Shinn, 'Expository practise: social, cognitive and epistemological linkage', in Shinn and Whitley (eds.), op. cit. (note 7), 31-60.
9. This approach was also adopted in an unpublished Ph.D. thesis: G. Kitteringham, Studies in the popularisation of science, 1800-1830 (University of Kent Ph.D. thesis, 1981).

10. Basalla, op. cit. (note 6), p. 261.

11. R.G.A. Dolby, 'On the autonomy of pure science: the construction and maintenance of barriers between scientific establishments and popular culture', in Norbert Elias, Herminio Martins and Richard Whitley (eds.), Scientific establishments and hierarchies, Sociology of the sciences yearbook, 6 (Dordrecht, 1982), 267-92.

12. Susan Sheets-Pyenson, 'Popular science periodicals in Paris and London: the emergence of a low scientific culture,1820-1875', Annals of science, 42(1985), 549-72, p. 551.

13. Whitley, op. cit. (note 7).

14. Ibid., p. 3.

15. Ibid., p. 4.

16. Ibid., p. 6.

17. For example, Bruno Latour and Steve Woolgar, Laboratory life (London and Beverly Hills, 1979); Karin D. Knorr-Cetina, The manufacture of knowledge (Oxford, 1981). The difficulties of attempting to define the concept of truth in absolute terms are well known to philosophers.

18. Whitley, op. cit. (note 7), p. 7.

19. This problem is probably most familiar to historians and philosophers of science in the form of the Kuhnian notion of incommensurability. Here, the meanings of concepts are determined by their relations with other terms and concepts in a theory, and by their position within the paradigm as a whole. In translation to another paradigm, meanings inevitably alter, as the context, the paradigm, which gives them their meanings, has changed. Kuhn relied very much on the work of linguistic philosophers Wharf and Sapir, for whom translation between cultural contexts is impossible without the existence of a meaningful linguistic link between those contexts. See Thomas S. Kuhn,

The structure of scientific revolutions, 2nd ed. (Chicago, 1970), especially 'Postscript', pp. 174-210.

20. Walter Bodmer, *The public understanding of science. The Bernal lecture* (London, 1986).
21. Whitley, *op. cit.* (note 7), p. 11.
22. *Ibid.*, p. 11.
23. *Ibid.*, p. 12.
24. *Ibid.*, p. 14.
25. *Ibid.*, p. 14.
26. *Ibid.*, p. 18.
27. *Ibid.*, p. 18.
28. *Ibid.*, p. 9.
29. Ferdinand de Saussure, *Course in general linguistics*, 2nd ed. (London, 1974).
30. Thomas M. Kando, *Leisure and popular culture in transition*, 2nd ed. (London, 1980), particularly chapter 3, 'What is popular culture, and is it good culture?', pp. 38-64. Kando defines popular culture as 'the typical cultural and recreational activities of typical segments of a society' p. 41.
31. Joseph J. Arpad, 'Immediate experience and the historical method', *Journal of popular culture*, *11*(1977-8), 140-154.
32. The terms are Arpad's and presumably mean documents and objects.
33. *Ibid.*, pp. 142-3.
34. William H. Cohn, 'Popular culture and social history', *Journal of popular culture*, *11*(1977-8), 167-79, p. 170.
35. Gregory H. Singleton, 'Popular culture or the culture of the populace?', *Journal of popular culture*, *11*(1977-8), 254-66.
36. *Ibid.*, p. 255.
37. *Ibid.*, p. 255.
38. G.N. Gilbert and M. Mulkay, *Opening Pandora's box* (Cambridge, 1984); G.N. Gilbert and M. Mulkay, 'Joking apart: some

recommendations concerning the analysis of scientific discourse', Social studies of science, 12(1982), 585-613; G.N. Gilbert and M. Mulkay, 'What is the ultimate question? Some remarks in the defence of the analysis of scientific discourse', Social studies of science, 12(1982), 309-19.

39. For critique of Gilbert and Mulkay, see Steven Shapin, 'Talking history: reflections on discourse analysis', Isis, 75(1984), 125-30.

40. Morris Berman, '"Hegemony" and the amateur tradition in British science', Journal of social history, 8(1974-5), 30-50, p. 32.

41. Ibid., p. 33.

42. Ibid., p. 32.

43. See, for example, Joanne Shattock and Michael Wolff (eds.), The Victorian periodical press: samplings and soundings (Leicester, 1982).

44. E.g. Susan Sheets-Pyenson, Low scientific culture in London and Paris, 1820-75 (University of Pennsylvania Ph.D. thesis, 1976).

45. Ibid. See also W.H. Brock, 'The development of commercial science journals in Victorian Britain', in Meadows (ed.), op. cit. (note 3), 95-122, pp. 111-5.

46. See chapter 3, section 4 for a discussion of 'natural history'.
For footnotes 46a-d, see p 91.

47. Brock, op. cit. (note 45), p. 105.

48. Derek J. de Solla Price, Little science, big science (Columbia, 1963).

49. E.g. W.H. Brock, 'Advancing science: the British Association and the professional practice of science', in P. Collins and R.M. MacLeod , The parliament of science (Northwood, 1981) 89-117; P. Collins, 'The British Association as public apologist for science, 1919-46', Ibid., 211-36.

50. Brock, op. cit. (note 49), p. 109.

51. B.A. discussion paper, quoted in Brock _op. cit._ (note 49), p. 109.

52. _Ibid._

53. Bodmer, _op. cit._ (note 20).

54. _British union catalogue of periodicals_, 4 vols. (London, 1955-8), and supplements.

55. _The British Museum. General catalogue of printed books_, 263 vols. (London, 1959-66), and supplements.

56. _The British Library. Catalogue of the Newspaper Library Colindale_, 8 vols. (London, 1975).

57. T.C. Smout, _A century of the Scottish people 1830-1950_ (London, 1986).

58. George Davie, _The democratic intellect_ , 2nd ed. (Edinburgh, 1964).

59. See chapter 3.

60. See Davie, _op. cit._ (note 58), pp. 169-200, especially pp. 184-5.

61. These issues are part of the problem of demarcation between "science" and "non-science" which has been one of the major concerns of philosophers of science such as Karl Popper, Imre Lakatos and Paul Feyerabend and which has remained largely unresolved, although much better understood, through their efforts. See, for example, Karl R. Popper, 'Science: conjectures and refutations', in _Conjectures and refutations_, 4th ed. (London, 1972), 33-65; A.F. Chalmers, _What is this thing called science?_ 2nd ed. (Milton Keynes, 1982).

62. Susan Cannon, _Science in culture_ (Folkestone, 1978), p. 141.

63. Brock, _op. cit._ (note 49), pp. 91-2.

64. Nathan Reingold , 'Definitions and speculations: the professionalisation of science in America in the nineteenth century', in Alexandra Oleson and Sanborn C. Brown (eds.) _The pursuit_

of knowledge in the early American republic (London and Baltimore, 1976) 33-69.

65. See chapter 3, section 3.

66. Richard Whitley, 'Changes in the social and intellectual organisation of the sciences: professionalisation and the arithmetic ideal', in E. Mendelsohn, P. Weingart and R. Whitley (eds.), The social production of scientific knowledge, Sociology of the sciences yearbook 1 (Dordrecht, 1977), 143-69.

67. Dolby, op. cit. (note 11).

68. Dolby, op. cit. (note 11), p. 269.

69. H. Collins, 'Certainty and the public understanding of science: science on television', Social studies of science, 17 (1987), 689-713.

70. E.g. Whitley, op. cit. (note 7).

CHAPTER 2

THE RISE AND FALL OF THE GENERAL SCIENCE PERIODICAL

1. Introduction

The aim of this chapter is to reach a broad understanding of the world of the general science periodical between 1890 and 1939. As a means to this end, the nature of these periodicals is considered, and the social, political and economic context in which they each arose and (in most cases) eventually died is described. Also discussed are the readership of the periodicals, the nature of their production, and the relationships these aspects bore to the said context.

In this initial, and of necessity somewhat general examination of these periodicals, one of the most significant points to emerge concerns the adequacy of purely economic interpretations. It is concluded that although indubitably important, economic factors alone are insufficient to explain general science periodical activity during this period, not least in terms of their production.

2. The nature of the periodical [1]

A number of characteristic features serve to define the members of a particular class of publication as periodicals. The most obvious of these is periodicity, that is, the successive numbers of a periodical appeared at least in principle at regular intervals. This important characteristic is, however, a necessary but not a sufficient condition for a periodical. During the nineteenth century books were frequently issued in parts at intervals, including, most notably, the novels of Dickens and some encyclopaedias. What distinguished these works from the periodical proper was the latter's duration: the publisher's intention was from the outset to continue the publication indefinitely. A further point of distinction was the variety exhibited in the constitution of a periodical. Not only were the contents heterogeneous and diverse, but they were normally contributed by a number of individual writers. As a periodical appeared in separate issues and at intervals, a unifying identity was created by maintaining relative stability in terms of editorial policy and format. Continuity expressed in the title of each organ, and in the placing of each issue in a series by consecutive numbering, lent additional support to this identity. A further important factor in this respect was the thematic unity possessed by many periodicals.

The periodical can be seen as almost a hybrid between the book and the newspaper. It undoubtedly shared characteristics with both forms. The criteria described above, whilst establishing a means of demarcation between the periodical and the book, were nevertheless common to both the periodical and the newspaper. The readership of the periodical was, however, less general than that of the newspaper and could often be identified in terms of common interest rather than geographical location, as was frequently the case with newspapers. Additionally, the newspaper was more severely restricted by time - as well as normally concentrating on daily (or weekly) events, it was also forced to meet more rapid deadlines. Simply put, newspapers were more focussed on news.

As regards terminology, in this thesis 'periodical' and 'journal' are used interchangeably. 'Journal' is a term with a slightly narrower meaning and is defined by the Oxford English dictionary as 'any periodical publication containing news or dealing with matters of current interest in any particular sphere'. Despite its non-academic implications, the term 'magazine' serves well to express the essentially miscellaneous content of the publications in this thesis, and was in any case employed by several of these publications themselves. These were Discovery (1904), Knowledge and Conquest. The majority, however, used 'journal', but Nature preferred 'periodical'. The periodicals' own choice of label carried implications, especially for their potential readership and functions, which become apparent below. Therefore the terms 'journal' and 'periodical' are those mainly employed in this thesis, with 'magazine' resorted to only occasionally and where appropriate[2].

General science periodicals were among such publications. Their content was mostly scientific. The word 'general' is descriptive of two aspects of these periodicals. Firstly, the material included was drawn from a range of different disciplines, which provided an overview, a general picture of science. Secondly, this variety in subject matter facilitated specific comment on issues affecting science as a whole, for instance the relationship between science and industry or even the nature of science itself. The precise nature of the general science periodical is explored more fully in the remainder of this chapter.

3. Features of general science periodicals

The medium of communication upon which this thesis is based is the general science periodical. Here attention is focussed on how being a periodical was important to the nature and functions of this particular mode of communication. The emphasis is not on the significance of the scientific or the general but on the literary form. A comprehensive discussion requires that the perspectives of publishers, editors, contributors, readers and even historical researchers be considered. Furthermore, a number of characteristic features of these journals, which serve to identify them more distinctively and completely, constitute an essential element in this discussion and are similarly examined from multiple perspectives.

It is therefore of crucial significance that the periodicals involved in this study appeared in single issues at stated regular time intervals[3] (weekly, monthly or quarterly), and that those responsible (publishers, editors, etc.) intended this state of affairs to continue indefinitely. For the historian, chronological identification of significant social, political, economic and intellectual factors is rendered much easier than would be the case with, for example, books: changes in content, presentation, editorial policy and readership, in relation to the growth of science and external circumstances, may be revealed by comparisons of one journal through different historical periods. The extent to which individual editors and publishers affected the kind of publication produced can be similarly investigated. Further, the vicissitudes undergone by a journal within its lifetime, the extent of this lifetime and the context of its expiry provide important evidence for the nature and problems of popularisation, in addition to proving illuminating with regard to the commercial considerations vital to this type of publication.

A study of the state of popularisation at any one time is, however, likely to be less comprehensive than (a) a similar study using a wide range of books as primary sources or (b) a study of changes over time. A diachronic approach has therefore been adopted. General science periodicals offer an opportunity for analysis of sustained and systematic attempts at scientific popularisation. Moreover, they bring the ability to examine change over both small and extended periods of time. Concentration on a definite historical entity (i.e. the general science periodical), which has been treated as such by historians[4], also has its advantages. It focusses the study, which might otherwise have tended to degenerate into a task of almost impossible breadth with a consequent lack of precision; or alternatively, an arbitrarily selective viewpoint dictated by practical concerns such as the availability of material or the most fruitful research avenue pursued. The broad cross-section of the population represented within the world of the general science periodical means that interactions between groups and developing relationships can be studied[5].

To theeditors, continual publication meant the opportunity to tailor their product to meet the demands of readers as expressed in several ways including sales and correspondence (both spontaneous and invited). For example, Armchair science was initially priced at 7d per issue in 1929. The price had increased to 1s (one shilling) by 1930 but was lowered to 6d, with a subsequent reduction in both size and quality, by 1933. Periodicals had to be continually modified, thereby producing a publication characteristic of and appropriate to the time, whereas books could rapidly become palpably outdated and forgotten as only a demand for further editions would keep a book 'alive'. For editors and publishers there was also the challenging requirement of sustaining sales (single and subscription), sometimes over many years and in a way unnecessary with books. Brock has pointed out that periodicals such as these, conducted on a 'commercial' basis, did not have the 'captive audience of members and specialised libraries'[6] which learned societies did have for their journals. In turn, a degree of continuing commitment was demanded of the readership which was unparalleled in the book-buying and book-reading public. On offer was something eminently collectable which served as a regular source of, variously, information, education, news and entertainment. Paradoxically, periodicals were also characterised by their disposability but could yet exert a constant presence by renewal.

The correspondence column was a normal ingredient of the general science periodical[7]. Such columns exhibited great diversity in content, length and function. In theory, the historical researcher could obtain some idea of the readership of a journal from information about the correspondents, such as name, address and occupation. In practice, however, anything of much academic value is gleaned only with difficulty.

The column was important from the point of view of readers in providing a tangible link with the periodical. A sense of community and involvement could be created. Professional scientists, committed amateurs and interested non-scientific readers communicated with themselves and with each other by means of this unique forum. Initially where professional scientists interacted with those beyond the boundaries of their profession, as time progressed, correspondence columns tended to develop a formalised 'question and answer' complexion in which the norm was for questions set by readers to be answered by 'experts'.

Working scientists could avail themselves of the opportunity to discuss matters which were not permitted (in virtue of style or content) in the more formal arena of the specialised academic journal. There was, for example, a debate in the correspondence column of Knowledge in 1903 on the issue of 'Man's place in the universe'[8]. This concerned the possibilities of the evolution of life in general, and human life in particular, on planets other than Earth. Professional astronomers such as E.W. Maunder————————→and Marcel Moye (Professor at the University of Montpellier) joined with amateurs, for example Agnes Clerke and J.E. Gore, in the discussions. That one of the key figures was the naturalist A.R. Wallace illustrates the role of the correspondence column in facilitating communication between those working in different disciplines when questions extended beyond the confines of one conventionally defined area. The use of the correspondence columns of Nature to announce discoveries and establish priority claims is of course well known. This function was, however, gradually assumed and for many years contributions of a quite different nature, received from interested amateurs and dabblers in science, were included.

From the editorial viewpoint, feedback from readers could aid policy decisions designed to meet readership demands. Conquest, for example, referred to 'the benefit which results from a free interchange of views and ideas between editor and readers'. The context was that in which a suggestion of 'an Edinburgh reader' led to an alteration in the cover design. Indeed, it was claimed that

> 'We could mention ... the kindly criticisms which, again and again, have been applied with advantage to the improvement of the magazine'[9].

In those journals which served primarily a means of communication between scientific professionals, it was not unusual for controversies to be conducted in the space set aside for correspondence. In the case of Nature, this tactic went some way to preserving editorial neutrality. Bedrock and Science progress differed in that they were riddled throughout with disputes which often reached a personal level. An additional bonus to editors and publishers was, of course, that letters and queries filled space and did not require payment to contributors.

The typical general science journal comprised a disparate collection of articles (originals, reprints, abstracts, etc.) reviews, correspondence and the inevitable collections of miscellany (e.g. 'Notes' in Nature and Knowledge, of which the most obvious function was the provision of news information). The articles varied in length from less than one hundred words to those which exceeded ten thousand words. Of course the average length varied between journals but the essential point is that they were manifestly very much shorter than books. The variety of material which this enabled the editor to include could have attracted a larger and more heterogeneous readership. This brevity and variety encouraged 'dipping' by the reader which demanded less sustained effort, concentration, time and commitment than did the reading of a book. Yet at the same time the periodical potentially could provide a much wider and up-to-date coverage.

The serialisation of articles (in, for example, Knowledge, Discovery, Nature, Armchair science and Conquest) varied between two extremes: from those with a distinct narrative line such as Gamow's 'Mr. Tompkins in wonderland' series in Discovery[10] and Harry F. Witherby's expeditional accounts in Knowledge[11], to those grouping together a loosely connected collection of articles like R.I. Pocock's 'Animals of interest' in Conquest[12]. By such means the editor was able to treat a subject in greater depth, simultaneously maintaining variety in each number. Further, serialisation was an important method of ensuring sequential reading, a device not unprecedented in both scientific and non-scientific literature. Brock has described how the editors of nineteenth-century periodicals such as William Crookes indulged in the practice 'deliberately to ensure that the interested reader would purchase the next issue'[13]. Serialisation of articles also benefited editors in its attempted use as a means of expanding the existing readership. Thus C.P. Snow ran a series in Discovery for 'younger readers' entitled 'Invitations to knowledge'[14] and the series written by Maunder 'Astronomy without a telescope' published during 1901 in Knowledge[15] was clearly aimed at a less committed readership than that habitually addressed. One intention was therefore the cultivation of new readers, keeping them for the duration of the series and hopefully beyond. General science periodicals began 'new series' (i.e. beginning at volume 1 again) from time to time, often with an eye to potential new readers, as a high volume number could be discouraging. This practice also served to distinguish between controlling regimes as it often coincided with a transfer of editorial responsibility (see figure 1).

The selection of books for review in any one journal can be revealing of editorial policy on a range of issues[16]. It can also provide important evidence as regards the constitution of the readership. For example, if a significant number of books reviewed were, say, elementary text books, the inference that elements of the readership were involved in education, probably as schoolteachers, would be justified. Reviews appealed to readers as a way of keeping up with all the publications in any one field. They further provided information and authoritative opinion about individual books.

Reprints and translations of lectures and papers could similarly help readers to keep abreast of developments in particular scientific fields. Editors and publishers benefited from not having to pay an original contributor or to wait for an article. Further, the contributor need not be persuaded to put pen to paper which was a considerable problem to editors (see below). Publishing the text of a lecture or address provided a useful service for those who could not attend, for example those living outside the metropolis. More significantly, it probably meant that the address (or paper) reached a greater audience - for instance scientists working in other disciplines or other sections of the readership. Such reprinted addresses and papers were invariably considered to be significant and worthy of wider attention. In the case of Nature, many such addresses and papers (e.g. those given at the annual meetings of the British Association or delivered to the Royal Society) were published far more rapidly than they would have been using official channels.

Although each of the features discussed above have been extremely useful as a research resource in the way outlined, none have been more so than the editorial. One way in which the periodicals' essential continuity manifested itself was in the explicit articulation of editorial policy and, frequently, a rationalisation of it. Such statements cannot, however, be taken at face value. Editorials revealed variation in attitudes in response to changes in both the socio-cultural environment and the nature and organisation of science. One fundamental example is that of the differing conceptions and presentations of the journals' own functions occasioned by the necessity of adapting to new contexts.

This is described at length below in Chapters 4 and 5.

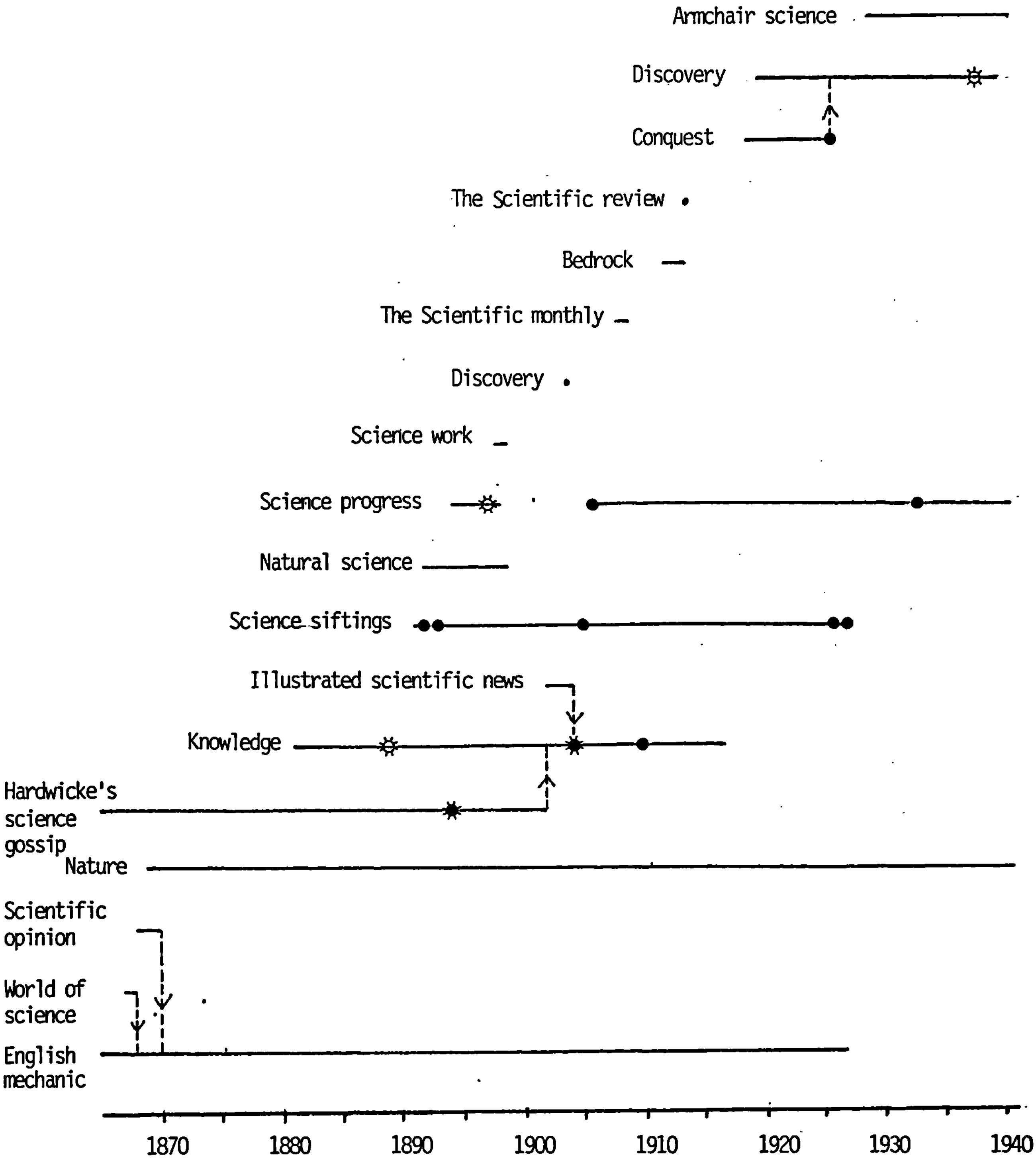
The editorial forum was also used to mount campaigns - a pertinent example being that launched by Nature during the First World War to mobilise administrators, legislators and scientists into action over the lack of chemical expertise in industry. Additionally, the editorial space could offer an authoritative viewpoint on controversial issues such as vivisection. Announcements of editorial alterations, mergers or future plans were normally located there. The column was one means by which a sense of community could be generated among a periodical's readership. Editorials were not always written by editors themselves, although theirs was the ultimate responsibility. A range of people contributed to such articles, although in cases where information is available, these were largely professional scientists. Nature's column in particular displayed great variety in authorship. The journal's chief leader writer during the 1930s was Rainald Brightman, then employed as Chief Librarian for I.C.I.'s Dyestuffs Group.

4. The readership

a) General considerations

A visual representation of the periodicals concerned, their periods of publication, interrelationships, name changes and dates of new series is provided in figure 1. Information from this chart as given in figure 2 displays some interesting features of periodical behaviour. Although the periods in this table are not of equal length and therefore cannot be compared as they stand, they do impart some historical sense to the figures. Taking periods of five years' length shows that the peak activity, as measured by the total numbers of general science periodicals published over the whole period, occurred between 1895 and 1899. The numbers of periodicals involved

Figure 1: Chart showing general science periodicals 1865-1940: period of publication and interrelationships



KEY The horizontal lines represent the period for which the periodicals were published.

The broken vertical lines joining the horizontals indicate a merger or takeover.

● indicates a name change. ☼ indicates a new series.

Although the English mechanic was not a general science periodical it is included here because it is referred to in the text and it incorporated two such periodicals.

are, however, so small that it is difficult to draw conclusions of much significance from their analysis. What is, nevertheless, clear is the existence of a marked contrast between the period of lively activity up to 1914 and the slow moving situation which obtained during the First World War and continued until 1939. In attempting to furnish explanations for these fluctuating trends in periodical activity, the problem is considered from two points of view. Firstly the nature of the readership is explored. This is then followed by an examination of what was involved in the production of a general science periodical.

Figure 2. Table showing journal activity at different times

PERIOD	NUMBER OF PERIODICALS FOUNDED	NUMBER OF PERIODICALS CEASING PUBLICATION	NUMBER OF PERIODICALS BEING PUBLISHED
1890-1900	4	3	8
1901-14	6	6	10
1915-18	0	1	5
1919-39	3	3	7

The nature of potential or actual readership was fundamental to the types of periodical produced and the rates at which this took place. Besides constituting markets for particular kinds of periodicals, there were other, sometimes more significant reasons why the available pool of readers was important to those responsible for the periodicals to the extent of being a determining factor in the sort of periodicals in existence at any one time. It would not be possible to describe the typical reader - the essential point lies in the great diversity which characterised the readership of general science periodicals during the relevant decades. This encompassed, at one extreme, élite members of the high science community (e.g. Nature) and, at the other, the working man with a limited general education and a fascination for the curious (e.g. Science siftings).

b) The social distribution of the readership

Few members of the most privileged stratum of society were to be found among the readership of these periodicals[18]. By the end of the nineteenth century science had long ceased to be an upper class pursuit. Its practitioners were taken mostly from the ranks of the middle classes. The wealthy patron of science had largely disappeared. Public schools did little to encourage the study of science: apart from their general anti-intellectualism, science had something of a reputation as being suitable only for those who failed at the schools' cherished classics[19]. The situation did, however, begin to show some improvement during the Great War. For example, in 1917 a General Science paper became compulsory for the Civil Service examinations. Nevertheless,science as a whole and these general periodicals in particular remained largely beyond the experience of the social élite throughout the period of study.

At the opposite end of the social spectrum, a substantial working class component of the readership was manifestly unlikely prior to the First World War, for several reasons. Illiteracy and semi-literacy were widespread because of poor elementary and little secondary education. Around the turn of the century 40% of the English working classes lived in poverty[20]. Although the masses were acquiring the reading habit, they preferred cheap fiction and publications such as George Newnes' Tit-bits. Launched in 1880, Tit-bits had a circulation of 671,000 in 1897[21]. It was a weekly sixteen-page paper which cost a penny and which initiated a new type of cheap, popular journalism. Comprising a multifarious collection of extracts from other publications, readers' contributions, jokes, riddles and the like, it was read for entertainment and made few demands on its readers who required an extremely limited span of attention and virtually no ability to concentrate. Tit-bits' success ensured it was rapidly followed by a number of imitators which soon enjoyed a similar degree of success.

1891 saw the establishment of a new general science periodical blatantly modelled on Tit-bits. Science siftings transferred Newnes' successful formula into the scientific arena. It was a weekly sixteen-page 'scientific paper' costing one penny and actually subtitled 'The "tit-bits" of popular science'. A diverse collection of miscellaneous scientific 'facts', readers' questions and other similar, equally brief items, Science siftings too expected little of readers in the way of education, time or effort. Its readership was most likely composed of a mixture of lower middle and upper working class men and women, and it was in this respect unique. The remaining general science periodicals of the pre-war years were too difficult for those with such a poor education, of an unappealing format and, crucially, sold at a prohibitive cost; hence their readership was derived mostly from the middle classes.

Post war conditions in many respects encouraged working class readers. Improved education and greater provision of libraries contributed (see below). So too did the reduction in the 'economic and demographic distance between classes and between strata within classes'[22] which accompanied the First World War. Better standards of living included a rise in real wages and more leisure time, particularly for the lower orders of society. These circumstances favoured more serious working class reading habits. Indeed, Conquest and Discovery deviated from the traditional readership in this respect, and attracted some working class readers. Yet general science periodicals faced competition from the cinema, wireless and other types of publication (especially newspapers) which became important alternatives to occupy leisure hours (see below). Finally, and most significantly, concessions were made to working class readers in terms of content and presentation during the 1920's (see Chapter 6).

The majority of the readership of general science periodicals between 1890 and 1939 therefore belonged to the 'middle classes'. The term acts as something of an umbrella, encompassing a diverse variety of social groups. Writers disagree on what parameters are appropriate for defining the limits of the 'middle class'. Suggestions include occupation, education, income, values and, at least before 1914, employment of servants. All these aspects have relevance for the discussion below in which the readership is analysed and broken down into more specific groups and reasons are advanced for their involvement.

The 'middle classes' included businessmen (some of the wealthiest of which could earn in excess of £2,000 a year), the professions (a G.P. earned on average c. £400 in 1913)[23], the clergy, employers, proprietors, supervisors, schoolteachers and various clerical workers (whose income would have been as low as £76 per annum). In 1900, approximately half the lower middle class earned more than £160 per annum. Such an income translated into a comfortable standard of living, plenty of food[24] and possibly a house in one of the rapidly growing suburbs of the industrial cities. Some of the lower middle class earned considerably less than this, however, and found themselves only as well off as the upper working class because of their insistence on adhering to a middle class lifestyle. Estimates as to the percentage of the population the middle class made up are as high as 30% at the turn of the century[25]. What <u>is</u> certain is that their numbers and percentage of the population increased throughout the twentieth century and beyond, as part of a general social transformation. The numbers of salaried clerks and administrators (the 'white-collar revolution') grew at the expense of manual labour and may be attributed to the changing nature of industry.

c) Education

A widespread concern with education coincided with the period of most rapid proliferation and collapse of general science periodicals. This concern was attributable to the lower middle class males (small businessmen, clerks etc.) to whom the Franchise Reform Acts of 1867 and 1884 had conceded significant political influence. This crucial section of the enfranchised population were 'interested in their children getting on'[26]. Their demand for secondary education as the most satisfactory method of achieving this was met as their political support was vital to both political parties.

Drawing conclusions about any possible relationship between the proliferation of periodicals and increasing literacy rates is fraught with difficulties. Although the 1870 Education Act led, some ten years later, to universal compulsory attendance at elementary schools, the standards of tuition and learning were poor. Hence, despite literacy as defined by the ability to sign a marriage register approaching 100% by 1900[27], in terms of a practical capability to read and understand, it was considerably less than this figure[28].

Considerable advances were made in education (of which the main beneficiaries were the middle classes) following the Education Act of 1902 which made certain provisions for increasing secondary education. Financial support was to be provided by the newly established Local

Authorities (which replaced the older School Boards). But fees were still levied, restricting the intake of pupils to those from more affluent families or those with scholarships. Nevertheless, more children were getting a better education. From the scientific point of view it was unfortunate that these secondary schools were at first usually existing grammar schools modelled very much on the traditional public school. This was, however, mitigated to some extent by the grants in aid to science teaching made available as early as 1872[29]. The number of scholarships (from elementary to secondary schools) and of secondary schools rose rapidly between 1895 and 1913. It was possible for these children to advance further and take a degree at one of the university type establishments which were also growing swiftly.

Therefore basic requirements for a readership of general science periodicals were made available to more people from 1902 with increasing educational provision in general and of scientific education in particular. In 1904 the Board of Education set out Regulations for grant-aided secondary schools. These required that a four year science course be part of the curriculum up to the age of sixteen, which included a minimum of three hours per week and covered both practical and theoretical science. In this type of school, then, science rapidly became an established part of the curriculum and enjoyed a status on a par with that of other subjects. Drawbacks remaining were rather related to lack of resources and staff. Some of the periodicals specifically aimed some material at schoolchildren. Discovery (1904) for instance, introduced articles 'for our younger friends'[30]. The correspondence indicates that schoolteachers numbered among the readership of general science periodicals and in some cases encouraged their pupils to join them. One correspondent wrote to Discovery that 'I think that you have solved the problem of producing a magazine that is read in schools as well as by the general public'[31].

To summarise: the contemporary attention paid to education created an environment conducive to the attempted launch of new periodicals. The resultant educational reforms furnished a much larger potential readership than had existed previously. It is significant, moreover, that this concern with education abated in the years following the Great War. The Franchise Reform Act of 1919 extended the vote to all but 5% of the male population. The new majority in the electorate were preoccupied with issues other than education. These circumstances coincided with a considerable diminution in periodical activity.

d) Reader motivation

Traditionally, periodicals were read because they offered entertainment, could perform an informative or educative function, and provided news. This was no less true of general science periodicals than of any other kind. Yet numerous more specific reasons may be advanced in order to explain precisely why the journals in this study were read by certain sorts of people. These reasons span the work-leisure spectrum.

Beyond the general interest probably aroused by education, professionals' reading of these journals may have had occupation-related motivations. The medical profession would make use of them to learn of advances in fields related to their own (for instance x-rays). Science was also employed by one section of the medical community as a tool (both rhetorical and practical) for higher professional esteem[32]. Several institutions associated with medicine took some of these journals[33]. In turn, members of the legal profession were supplied with an opportunity to discover how the use of science was becoming more and more common to assist in the solution of crimes and to provide evidence in court cases. Such material was present in a range of journals from Nature to Conquest.

Despite the twentieth century propensity for regarding science and religion as fundamentally incompatible[34], the long-standing interest of the clergy in creation and other areas of science connected with Christian belief marked them out as potential readers. Controversies raged in general science periodicals from time to time which bore on theological issues and therefore proved attractive to the clergy. These included the debate on the origin of life conducted in Nature at the turn of the century[35] which was subsequently continued in the rekindled mechanist/vitalist controversy of 1911-13 in Nature and Science progress[36]. The general formula of these journals also permitted discussion of matters such as the relation between science and religion. Discovery ran a series entitled 'Science and religion' in the mid-1930s[37] and an article of the same title, written by a cleric, Father Desmond Morse-Boycott was to be found in the very first issue of Armchair science[38].

Businessmen or industrialists might have wished to keep abreast of new developments which might have applications for their own enterprises. The Scientific review, when explaining the purpose and value of arranging each issue in sections devoted to discrete sciences, suggested that its readers might be 'interested in one particular subject from a business point of view'[39]. The establishment of the Department of Scientific and Industrial Research (D.S.I.R.) in 1916 presumably provoked interest in this direction. Government grants, matched by industrial monies, combined to initiate new industrial Research Associations. Possible commercial advantage and financial commitment undoubtedly imparted a degree of curiosity to the business and industrial communities.

Beyond those motives for reading general science periodicals which related to occupation directly, are those which bore on leisure and other activities extending from the home (e.g. Conquest's 'Home hints'). A journal may have been read for its value in the pursuit of a hobby: not only in terms of information and news, but as a means of providing a sense of belonging to a club of like-minded individuals. Knowledge functioned in such a manner for amateur naturalists and astronomers with a high degree of commitment[40]. Of special interest in this context was Conquest, a must for the amateur wireless buff, particularly an absolute beginner, during the 1920s. As has been described above, Science siftings took to an extreme the inherent potentialities of the periodical form for entertainment which, although less developed, was nevertheless present in the majority of these general science periodicals.

e) Subscriptions

Up to this stage in the analysis, reference has been made to readers only. An important distinction must be made, however, between the reader and the subscriber. One highly significant class of subscriber was the institution. Included therein were public libraries[41], universities, local and national scientific societies[42], other scientific and technical establishments (e.g. the Royal Botanic Gardens at Kew or the Wigan Mining and Technical College) and industrial research laboratories. In developments not unconnected with the prevailing interest in education, public libraries had witnessed rapid growth between 1890 and 1914. In fact by the latter date, two-thirds of all existing libraries had been opened only since 1890[43]. Libraries issuing books ('service points') increased from 480 in 1896 to 920 in 1911[44]. These were situated mainly in urban centres. Numbers continued to rise with the Public Libraries Act of 1919, although slowly at first. This Act gave library powers to counties which allowed for the building up of a rural service. That several public libraries still have holdings of these general science periodicals would have strongly suggested that they were available to readers at the time, although it seems that in 1907, 41% of periodicals in libraries were donated[45]. Institutional subscribers were important, not only because of the valuable information which is accessible to the historical researcher, but because of the relatively greater number of readers per issue. That subscribers were always outnumbered by readers was not, however, solely attributable to this institutional element.

The individual reader had the choice of reading one or more issues of a periodical at, for instance, a public library or borrowing a friend's copy, buying one or more issues from a bookstall or subscribing for (usually) a year. Each required different motivations. The subscriber had to make a commitment to taking future interest and quality on trust for six months or a whole year in advance[46]. Subscribing, however, bought several advantages. For readers living in the countryside each issue was delivered to the door by post when the nearest town might very have been inadequately supplied with suitable books. Regular receipt of a journal of this nature kept one up to date and imparted a sense of contact and community. Further, subscribing guaranteed a copy: a set could be collected and even bound (properly or contained in binding cases) and consulted as a source of reference.

Subscriptions were also given as gifts in which case no commitment was made on behalf of the individual in receipt of the journal. Although undoubtedly in a minority, the gift subscription deserves mention in view of the fact that several of the periodicals made precisely that suggestion in advertisements. One virtue of giving a subscription was its very duration, ensuring the giver would be remembered.

Finally, the cost of subscribing, often compared favourably with book prices. For example, in 1901 a year's subscription to Knowledge was 7s 6d (seven shillings and sixpence). During that same year, those books reviewed in periodical and which therefore can be assumed to be of interest to its readers, ranged in price between, on average, 1s 6d and 17s. For example, D. E. Strasburger's Handbook of practical botany, cost 10s 6d.[47] It was therefore possible to read about many publications which together would have had a total cost amounting to many times the subscription price. For those involved in scientific activity, this was a relatively inexpensive means of keeping up with the literature.

f) The scientifically trained reader

It would be impossible to explain fluctuations in general science periodical activity (as well as their nature and functions) without reference to the professionalisation of science[48]. One journal, The Scientific review, claimed to address 'the scientist, the engineer, the professional man'[49]. The 5,000 registered 'scientists' in the 1911 census placed in the professional category (which grew to a figure of 49,000 in 1951) must mainly have held academic posts. Of the 1,500 estimated chemists in industry, most were not scientifically trained and were 'paid a labourer's wages'[50]. The standards of living of the majority of science graduates in fact placed them firmly in the lower middle class. During the Edwardian years there was a trend towards employing graduate chemists in industry (small numbers had, of course, been employed in this way in the late nineteenth century), particularly as a result of the educational changes already described. The establishment of the Department of Scientific and Industrial Research (D.S.I.R.) in 1916 helped to redefine the relationship between science and the state. The interwar years saw further advances in professionalisation, particularly in terms of employment possibilities. (This is discussed in depth in the following chapters).

One major problem for the scientific community and which was particularly acute before World War One was the lack of employment available for science graduates. They were being produced in progressively greater numbers[51] by the increasing number of universities and university colleges. These institutions took advantage of the educational advances at the secondary and elementary levels, the consequent demand for teachers and the inadequate resources available to train them. The government was persuaded to help finance a substantial number of graduates who would then become teachers for at least seven years in state aided schools. According to MacLeod, 'In 1900, there were about 2,000 men of science of graduate standing in Britain, about half of whom were secondary and primary schoolteachers'[52]. Cardwell estimates[53] that of all full-time science degree students between 1911 and 1914, well over 40% were to become elementary teachers, which included a significant portion not financed by the state and therefore not bound to embark on a teaching career. There were few alternatives open to science graduates.

Two scientifically trained audiences can therefore be identified. Working scientists located mostly in academic institutions but, after 1916, increasingly in an industrial environment made up the first. As Science progress commented in 1906:

> 'Specialisation and the multiplication of scientific and technical journals render it increasingly difficult, even for those actually engaged in scientific work, to keep abreast of the advance of knowledge'[54].

Scientific societies, university libraries and industrial research institutions still hold runs of, for example, Knowledge[55], Natural science[56], Science progress[57] and Discovery[58]. Correspondence also reveals practising scientists to be among the readership.

The second and more numerous group were those science graduates who became schoolteachers[59]. They were of great significance - in fact a special periodical, Science and technology (1906-08), was established 'for teachers and students'[60] as a response to the educational changes described above. The journal was, however, mainly concerned with the practical educational matters, in particular the promotion of the teaching profession. Some journals addressed both types of 'scientist', for example, Natural science and Science progress (the latter specifically referred to 'teachers and students' in its introductory editorial[61]). Discovery was indubitably read by teachers; amongst the groups responsible for starting the journal and pledged to support it were several representing teachers[62]. In fact, the N.U.T. guaranteed 625 subscriptions before the journal got off the ground[63].

The rapid increase in the number of periodical publications in the 1860's following the abolition of the so-called 'taxes on knowledge' has been well documented[64]. It has also been claimed that the 1880s and 1890s saw subsequent high points in the numbers of scientific journals (of all types) published[65]. This has been explained by the continuation and exacerbation of the trend towards specialisation and differentiation, as well as,

> '.. the corresponding, ultimately futile, attempts to found general, semi-popular journals e.g. Macmillan's Natural science (1892-99), which might keep growing numbers of teachers and scientifically literate students abreast of specialised developments.'[66]

The evidence (figures 1 and 2) supports the view that during the last decade of the nineteenth century and the first of the twentieth, a substantial number of what are described as review type journals were published. A type of general science periodical, the review journal attempted to keep its readers up to date with current developments and trends in science. This took its most extreme form with summaries of and references to specialised scientific papers (e.g. Science work, Science progress). The final example of this kind appears to have been established in 1914 (The Scientific review). That most of these ventures were 'ultimately futile' is retrospectively beyond doubt; their survival rate was extremely poor. That they arose as a specific response to the increase in specialised scholarly academic journals is less certain. Two points do, however, support such a thesis. Firstly, there existed a time lag between increases in the two types of periodical (i.e. the specialised academic journals enjoyed their peak in the 1890s the general journals in the 1900s. Secondly, editorials sometimes actually stated, as did Science progress in 1906, that 'specialisation and multiplication of scientific and technical journals'[67] was an important reason for starting up a new review journal. The editors of Natural science referred to 'the enormous increase in periodical literature'[68] which they linked with specialisation and professionalisation and in addition claimed that:

> 'for some time now no adequate systematic attempt has been made in Britain to interpret simply, and without excessive technicalities, the main results of work on Natural Science to those who try to follow the general progress of modern thought'.[69]

It is therefore clearly the case that a market emerged during the 1890s for general science periodicals, and that it consisted of a number of elements. Specialisation and differentiation meant working scientists found maintaining an awareness of developments in fields other than their own increasingly difficult. Brock is quite correct in identifying science teachers as a potential readership and, despite the ambiguities inherent in his phrase 'scientifically literate students', he nevertheless manages to convey the idea that improvements in education, both in general terms and with particular reference to the growing opportunities for the study of science to degree level, meant that there arose a new group of potential readers.

5. Periodical production

a) Introductory remarks

In order that a more balanced picture of the situation can be obtained, the activities and motives of publishers, editors and contributors must be considered. The present section is devoted to a discussion of some interesting aspects of periodical production and after a general review is centred on the case of *Discovery*.

Although this example may not necessarily be representative, it does offer valuable insights into what exactly was involved in the establishment and running of a general science periodical. This approach has been adopted due to the comparative paucity of available archival material.

It must be emphasised from the outset that financial gain was not the main motive behind the establishment of the majority of these journals. Previous writers have classified periodicals according to four types[70]. Within this somewhat unsatisfactory arrangement, general science periodicals would have been either those whose origins lay with learned or professional bodies or those produced with the aim of financial profitability. More appropriate, however, is Brock's classification[71], in which three types of commercial science journals (as distinct from those sponsored by scientific societies) are specified: firstly, those established as 'purely financial speculations'; secondly, '... those launched altruistically by their owners for the good of science' and 'heavily subsidised'; and finally, those set up because of a positive commitment to the advancement of science, combined with the hope of reaping some kind of financial reward.

Examples of all three types were to be found among general science periodicals. Science siftings was exceptional in that the evidence points to potential financial return as the primary motivation for its launch. Not only did it mimic the commercially proven Tit-bits formula, but rapidly adapted the nature of its contents when conditions became less favourable for this type of journal in the 1920s. Of course the relationship that commercial reasons bore to others in the foundation of the journals and their subsequent conduct was not the same for each organ. In his study of commercial science periodicals in Victorian Britain, Brock has emphasised the notion of economic viability:

> 'Commercial journals were, and are, at the mercy of financial solvency, as well as the personal whims, of proprietors and publishing houses, the changing tastes of their readers and advertisers as well as the general economic climate'.[72]

Whilst this was undoubtedly the case, one essential point of this thesis as a whole, and of this chapter in particular, is that factors other than the commercial were usually the driving force behind these general science periodicals: the majority belonged to the second and third types described above.

For instance, Nature failed to make a profit for the first thirty years of its existence. Further, MacLeod refers to the journal's 'nagging deficit'[73] which extended over a similar period. Yet after twenty years of this, Norman Lockyer (Nature's founder-editor) wrote '... we may claim that it has not disappointed the hopes of its founders, not failed in the task it undertook'.[74] Natural science, also published by Macmillan, was a consistent financial drain on its proprietors (who were also its editors). It never made any profit but in fact lost money throughout its life and its contributors were never paid. Sir Peter Chalmers Mitchell wrote in his autobiography that after he was persuaded to join the journal as 'part-owner, writer and joint editor', 'We never had sufficient capital, never were able to pay either ourselves or our contributors, but we managed to keep it going for several years, and to achieve at least a good reputation and the pride of being proprietors'.[75]

It was really only publishing firms who could afford to subsidise loss-making journals for any considerable length of time. Losses could be offset against the proceeds accrued from more lucrative endeavours. Macmillan was not the only publisher to behave in this way. Brock cites Taylor and Francis: 'its several private journals are the best examples of altruistic publishing during the nineteenth century.'[76] The present study adds John Murray to the list.

b) General review

Accompanying the widespread concern with education which coincided with the years of greatest journal activity was a general increase in all types of publication characteristic of the period[77]. This was most particularly the case during the Edwardian era. In order that some kind of sense may be made of the nature of the general science periodicals and their activity at this time, they must be located within the context of the periodical.

To begin with, the numbers of periodicals were constantly growing[78]. It was not unusual, however, for a fledgling general science journal to justify its appearance on the grounds that it filled a demand, and was unique in doing so. Natural science was one such, and claimed in its first editorial:

> '... for some time no adequate systematic attempt has been made in Britain to interpret simply, and without excessive technicalities, the main results of contemporary work in Natural Science to those who try to follow the general progress of modern thought.'[79]

Although a rhetoric of justification is only to be expected, it is nevertheless interesting that so many of these periodicals professed to be filling precisely the same gap in the existing literature, and performing much the same functions. Moreover, W.T. Stead, editor of the Review of reviews[80] and self-appointed periodicals expert, was apparently in agreement. In his introduction to the 1891 Annual index to periodicals he wrote of the American journal, the Popular science monthly, that it had no British counterpart. Aware of the impending appearance of Natural science, he commented: 'Possibly Natural science may supply this need.'[81] The following year, having already noted that the periodical published its first number in March, Stead bemoaned the fact that there was:

> '... no popular review of the progress of science, which is passing more and more into the hands of a Brahmin caste of specialist experts, whose very language is an unknown tongue.'[82]

Obviously Natural science had not supplied the need. Worse still, Stead described it as a 'specialist' journal.

Together with Science progress, Natural science hoped to reach not only working scientists, the new class of scientific teachers and those with science degrees, but also a more general type of reader. Both failed to sell enough copies to their proposed readership to survive. Both were relatively expensive. One shilling for a monthly in the 1890s was well above average for the time, and Natural science had few illustrations. Originally a monthly, Science progress cost 2s 6d and illustrations were rare. The journal had a more restricted appeal than its contemporaries. It was rather difficult for any but a narrow audience to appreciate, yet possibly not quite what the scientist would want. Its long articles required time and concentration to read. Scientists desired brief summaries and easily accessible reports; the general reader had an appetite for more entertainment value. Despite changing to a quarterly (a form becoming increasingly less popular by the end of the century) and raising the price to 3s in 1897 in an attempt to combat these difficulties, the journal was forced to cease publication the following year. It reappeared in 1906 and appealed mainly to practising scientists, providing them with the news and summaries they needed. The price rose to 5s in order to compensate for the loss of an element of the previous readership. Further, by this time, those with a sufficiently high standard of scientific education had increased enough to maintain a journal such as the new Science progress in the twentieth century, albeit at a price which had almost doubled.

The example of Science siftings has already demonstrated how the general science periodicals could imitate other types of journal and even follow trends. For instance, as Stead remarked at the end of the 1890s, the then current vogue for publishing threepenny illustrated monthly magazines 'does not seem to have been attended with great success.'[83] It would appear that several of these magazines had been forced to put their prices up. A similar lack of success would seem to have befallen those general science journals similarly priced at threepence (Science work, Discovery (1904) and The scientific review).

During the 1890s a number of extremely successful sixpenny monthlies were established. Chief among these was George Newnes' Strand magazine which, in the year following its foundation, achieved a regular monthly circulation in excess of 300,000.[84] Although less elementary than publications in the Tit-bits mould, of the Strand and its emulators, Stead nonetheless remarked that it was 'light reading' which did not provoke its readers to too great exercise of thinking.'[85] By 1892 Stead was deliberating on the 'phenomenal success' of the publication. He attributed this to '... plenty of variety, plenty of stories, and plenty of pictures.'[86] New technology enabled proprietors to produce journals which were profusely illustrated, at an economic price. The Strand had 'a picture on almost every page.'[87] In 1902, the Illustrated scientific news demonstrated that the lesson of the more general periodicals had been learned. It was undoubtedly a factor in the demise of many of the periodicals which attempted to reach an audience beyond practising scientists and those with a high standard of scientific education: most were poorly illustrated or not illustrated at all.

In 1904, the Illustrated scientific news merged with Knowledge, already priced at 6d and illustrated. Knowledge included some engravings, sketches and diagrams, poor quality photographs and a few of better quality. Being considerably older and more established than the Illustrated scientific news, it had the advantage of a relatively constant and stable readership. Crucially to the merger, however, this readership was changing[88]. The two periodicals pooled their resources. The resulting publication had greater variety than either of its constituents and improved illustrations both in terms of quality and quantity. The price remained at 6d. A scientific journal could not hope for circulation figures comparable to those of the Strand: it was addressing a considerably smaller public. Knowledge at this time paved the way for the establishment of general science periodicals after the First World War which reached a larger readership and were well illustrated (Conquest, Discovery, Armchair science).[89]

It is therefore clear that in the majority of instances, the policy of low price/high circulation was ineffective. The periodicals failed to cater for a wide enough audience. That this was possible had been amply demonstrated by Science siftings, but its lead was not followed, at least not before 1914. This shows that although a market for a wider circulation general science periodical existed and moreover, had been shown to exist, all but one failed to exploit it. The world of general science periodicals was motivated by concerns beyond the purely commercial, and was preoccupied with other issues up to 1914. These concerns are described in subsequent chapters.

An additional factor in the demise of so many general science periodicals in the first half of the period under study was undoubtedly the stiff competition they faced from 'the tens of thousands of newspapers and magazines' [90] which made up the press. The proliferation of periodical publications during the Victorian era is notorious. Prices ranged from one penny to one guinea per issue and the enormous variety in content ranged from the general and trivial to the esoteric and specialised. Competition from newspapers was also fierce. The most expensive was The Times at 3d; the cheapest included among their number Harmsworth's hugely successful Daily mail at ½d[91]. The prices of single issues of general science periodicals compared extremely unfavourably with these[92]. Crucially important also was the competition between themselves.

Although two periodicals, The scientific review and Bedrock ceased publication in 1914, neither failure can be attributed to the war - they collapsed in March and April respectively and war broke out only in August. They were followed into obscurity by Knowledge in 1917, the demise of which was hastened by the altered circumstances brought about by the war. Apart from a decline in sales, publishing in general was little affected during the first year of the war. This was not to remain so for very long: by the end of 1915 imports of paper making materials had been reduced, and the impact of the tightening of the German blockade on shipping worsened the situation as the war progressed and prices rose correspondingly.[93] Shortages of other vital materials also caused difficulties, most notably the copper and lead necessary for type and plates [94]. Additional problems had to be faced as military recruitment denied publishers more and more of their staff[95]. Not only staff but readers too would have been extensively recruited or otherwise engaged in war work.

The inter-war period witnessed the founding of only three general science periodicals. Two of these, Conquest and Discovery, began in the post-war period of reconstruction and the economic boom which collapsed in the winter of 1920-21. Despite some degree of recovery, the economic climate throughout the inter-war period was generally unsuitable for embarking on a new commercial venture such as a journal. Publishers faced high prices (paper, printing costs etc.[96]) as well as problems with strikes[97]. Most prohibitive of all was the high cost of labour.

Further deterrents to journal establishment acted between the two World Wars. Competition was encountered from radio, cinema and other recreative activities. Crossword puzzles were especially prominent and could sell newspapers or journals. One correspondent wrote to The Bookseller in 1925 that 'I have heard it from many sources that the sale of general literature - magazines and periodicals particularly - has been seriously affected.'[98] Armchair science responded to the craze as late as 1932 when a 'Science for all cross-word' was introduced as a regular feature. By 1926, Science siftings (then called Popular science and in its death throes) included fifteen weekly prize competitions, one of which was usually a crossword puzzle. This serves to indicate the extremes to which some of these periodicals were prepared to stretch in their attempts to maintain the circulation necessary to break even.

Finally, it must be pointed out that the peak of general science periodical activity (i.e. 1890-1914) coincided with what has been called 'an heroic age of radiations.'[99] Radium in particular was immensely popular during the first years of the twentieth century. What followed after the war, although greatly popular nevertheless did not arouse the same kind of interest as had radioactivity. Despite the unprecedented attention which relativity, for instance, received, it nevertheless had a sinister aspect[100]. In this respect it symbolised public attitudes towards science in the inter-war years. Public enthusiasm was tempered by a negative element epitomised by the reaction to the use of poison gas during the conflict[101]. Radium had been a wondrous, almost miraculous phenomenon which, moreover, glowed in the dark, produced photographs of living skeletons and healed the sick. The unfavourable economic conditions, the example of the pre-war years and the widespread ambivalent attitude towards science did little to promote the establishment of general science periodicals. Those which did emerge did so in the face of poor commercial odds in these respects; their impetus must have found its origin elsewhere.

c) The founding of journals: the case of *Discovery*

Sir J.J. Thomson, when addressing the Royal Society as its President on 30 November 1917, referred to a proposed new journal. The Executive Committee of the Conjoint Board of Scientific Societies had recently been made aware of the possibility by a group of scientists and other intellectuals. On 19 December, Richard Gregory (soon to take over from Lockyer as editor of *Nature*) wrote to George Macmillan, the publisher, enclosing a letter on the subject which he had received in his capacity as a member of the Education Committee of the Conjoint Board[102]. The matter did not, however, progress any further until 1919 when the war was over.

On 13 May 1919, Professor Robert Seymour Conway, a classical scholar at that time Professor of Latin at Manchester, wrote to Macmillan requesting permission to call the new journal Discovery[103]. This granted, he again approached the firm to propose that they publish it[104]. Macmillan must have refused, for three days later, on 28 July 1919, Conway sent a circular letter to a number of publishers of which John Murray was one. This letter drew attention to the project which had 'been in preparation for the last two years.'[105] Conway stated:

> 'the need for a popular journal of the Progress of Knowledge has long been felt but it has never before been possible to secure the union of so large a number of Bodies interested in all sides of knowledge.'[106]

The bodies referred to included the Royal Society, the British Academy, the Joint Board of Scientific Societies, the Council for Humanistic Studies [107], the Literary Association, the Workers Educational Association, the Association of Assistant Masters and Assistant Mistresses, the Association of Public School Science Masters, the National Union of Teachers, the Association of Headmistresses and the Headmasters' Conference.

Murray must have liked the proposal as an agreement was eventually drawn up [108] between Murray and the Trustees on the basis of the draft scheme Conway had enclosed in his original letter (and which, incidentally, had also been received by Macmillan). 'Discovery: a monthly popular journal of knowledge'[109] was to be organised in the following manner. The four trustees (Sir J.J. Thomson, O.M., P.R.S., Sir Frederic George Kenyon, K.C.B., P.B.A., Professor Albert Charles Seward, Sc.D., F.R.S., and Professor Robert Seymour Conway, Litt.D., F.B.A.) who owned the copyright of the journal, appointed a committee of management which was composed of representatives of some of the bodies noted above[110]. If Conway's draft scheme was adopted (and there is nothing to suggest that, in its essentials, it was not) then only one third of the committee belonged to scientific organisations. The editor, appointed jointly by the committee and Murray, was initially A.S. Russell, Reader in Chemistry at Christ Church, Oxford. The societies and associations represented on the committee undertook to provide the editor with a list each year of those willing to write articles on subjects chosen by the committee[111]. Murray was to bear all production expenses, receive all profit, and pay the editor, contributors and committee[112].

Despite the composition of the committee, the majority of articles were always scientific. In fact, the percentage of scientific articles increased from approximately 65% in 1921 to around 90% by 1925 and then remained relatively constant.[113] It seems likely that this was a deliberate policy instituted by those who originally planned the journal and subsequently controlled it. J.J. Thomson's position as senior trustee bears this out. The original non-scientific content and rhetoric in all probability served a number of functions: firstly, to work as an element in persuading a publisher to join the project at such an apparently unfavourable time (see above); secondly, to attract readers with a limited interest in science; and finally, to play an important role in an attempt to cultivate a particular image of science.[114]. Editorial control can be discounted in view of the fact that Russell was replaced by a succession of non-scientific editors and Murray was replaced by Benn as publisher, yet the scientific bias was continued.

These then are the facts which describe the initial setting up of the journal. It was not unusual for a single scientific society to publish its own periodical (e.g. Proceedings of... .), and in more recent years there has been a tendency for commercial publishers to publish on behalf of societies, a committee of the society assuming editorial responsibilities. Discovery, however, was unique among all other general science periodicals between 1890 and 1939. Conway was quite correct in pointing to the cooperation of all the bodies concerned as exceptional. In fact it was most unusual for an academic body to be involved. The impetus behind the founding of a journal was normally due to proprietors, editors or publishers, and in some instances these overlapped (e.g. the proprietors of Natural science were also its editors; Discovery, after being taken over by Benn Brothers Ltd. in 1924 was edited by John A. Benn between 1927 and 1932). In several cases the proprietors went so far as to establish their own publishing companies (e.g. The Knowledge Publishing Company and The Scientific Review Publishing Company).

d) Contributors

Traditionally, editors had struggled to persuade scientists, particularly those of some reknown, to write for non-academic, non-specialist scientific periodicals. One factor which expedited Nature's success was Lockyer's personal acquaintance with most of those scientists who had contributed to early and less successful periodicals such as the Natural history review[115]. He also had access to many of the scientists published by Macmillan. Yet even Nature met with problems. Before the journal began, a circular sent to several contemporary eminent scientists yielded disappointing results. Most 'implied that they would be too busy to contribute regularly to the journal'.[116]

With regard to the extent of his personal contacts, Lockyer was undoubtedly exceptional. In 1912, the editors of Knowledge (Wilfred Mark Webb and E.S. Grew) complained of 'some difficulty in obtaining just the sort of articles which are suitable for Knowledge[117]. They wanted less specialised material: apparently scientists looking for an organ to publish their work were only submitting articles to Knowledge because getting original results published in academic journals was sometimes proving difficult[118]. By way of a solution, Webb and Grew came up with the following:

> 'There must be much among their researches that would appeal to the amateur and we invite chemists and physicists to make suggestions on those matters to us for the mutual advantage of ourselves and our readers'[119].

Their approach was, in fact, determined by their editorial policy of attempted reconcilation of amateur and professional groups of scientific workers[120].

E.J.M. Hudson, the editor of The Scientific review, was in 1914 'particularly anxious to get in touch with a few young scientists and engineers who can write really original, up to date articles'[121]. He was especially interested in young and relatively unknown scientific practitioners who would no doubt have been prepared to accept lower fees than their more established colleagues.

Despite such problems, there occurred a clear increase in the proportion of contributions from professional scientists to these general science periodicals over the period under consideration. In fact many of the longer lived journals shared a number of prolific contributors drawn from the professional scientific community. These writers can be said to have constituted a group whose presence imparted a sense of unity to the journals. As a consequence, the scientific writer who had made his/her living from writing articles and books on scientific subjects and who had been an established figure in British general science periodicals for several decades, tended to disappear from these periodicals[122].

One of the most important reasons scientists have for publishing is the return they receive in terms of recognition, respect and status from colleagues[123]. No such rewards are forthcoming with poularisations which are, in the words of one sociologist, 'if not despised, certainly held in much lower esteem than articles containing original research results'[124]. At the turn of the century much the same conditions obtained and therefore alternative rewards had to be offered. Popularisations played an invaluable part in the acquisition of a broadly based acknowledgement of and popular support for science and its status as a profession. They helped to establish its authority in a wider forum and attract funding for research. In their attempts to achieve this and thereby obtain status, recognition and rewards, professional scientists endeavoured to grasp control of this means of presenting science to various publics within society by ousting scientific writers and amateurs, and replacing them with professional scientists and their acolytes.

These were the main motives which caused scientists to write for general science periodicals and applied particularly to that central dominating group. Frequently such motives masqueraded behind a rhetoric of advancement of science. Of course others contributed for different reasons. The extract from Knowledge quoted above shows that some were interested only as a means of publishing original results. Further, it is interesting that of those journals about which information is available, only one, Natural science, obtained the services of its contributors entirely gratis.

Thus two methods of finding contributors were by means of (a) informal contacts and (b) public appeal. Where the latter was employed it usually supplemented the former (as in the case of Knowledge). Articles were generally commissioned. Although marginal and by the turn of the century fast disappearing, spontaneous submissions still supplied some articles for journals such as Knowledge. This practice had virtually vanished by the end of the First World War, with the conspicuous exception of Nature[125].

The problem of rooting out contributors would have been considerably eased in the case of Discovery, as the societies and associations represented on the committee were obliged to submit a list of authors and subjects to the editor each year. Nevertheless, at a meeting on 15 November 1919, Russell reported to the committee that he had encountered setbacks in this matter, claiming that many 'scientific people' were busy until the end of the year[126].

e) Education

The groups involved in the establishment of Discovery included several concerned with education. These were the National Union of Teachers, the Association of Headmistresses (with three members between them on the committee), the Workers' Educational Association, The Association of Assistant Masters and Mistresses, the Association of Public School Science Masters, the Headmasters Conference and the related Library Association. The potential readership these could hope to reach was large - ranging through elementary, secondary and adult education as well as the public schools. The role of the Library Association would have been significant in persuading libraries to subscribe since, as the draft scheme expressed it, these groups were 'to undertake to promote its circulation'[127]. If this undertaking was fulfilled, both institutions and individuals could have taken out subscriptions as a result[128]. Involved academics undoubtedly provided higher educational interest.

During the period when Murray published the journal, in dealings with the firm and the Trustees, the former was represented by R.B. Lattimer, the firm's educational editor, and the latter by Conway. The close relationship which existed between the periodical and the educational world was exceptional. Nature was the only other general science periodical which came close: Richard Gregory jointly founded School world in 1899 and continued as joint-editor when this journal was incorporated into the Journal of education in 1918, a position he held until 1939. Gregory was also active in the Education Section of the British Association, which he was instrumental in establishing in 1901 and of which he was both secretary and president. Conquest claimed to have received a letter from the Minister of Education, who, the reader was informed, 'considers Conquest to be of "high educational interest"[129]. The educational aspect would have guaranteed Discovery a certain number of readers.

f) Readership, advertising and sales

It is possible to draw conclusions regarding the relative import-

Figure 3: Graph showing sales of Discovery, January 1920 - March 1924

ance of subscribers and (less committed) readers to each of the general science periodicals, although without available records, a quantitative assessment cannot be made. The sales of Science progress were fairly regular[130]. Combined with its high price and narrow technical content, this implies quite a high percentage of subscribers. The probability that many of these were institutions is great. Nature similarly had low counter sales[131]. On the contrary, the gaudy, coloured covers of Conquest and Armchair science point to a more important role for counter sales in these journals. The Discovery records at John Murray publishers list only total sales figures, i.e. both subscriptions and counter sales. If figure 3 is consulted, however, it can be seen that the variation in sales between months was on occasion considerable. At least for the first year (particularly the dramatic drop which took place between January and April), non-renewal of subscriptions cannot be responsible. Fluctuating counter sales must almost inevitably account for this degree of variation as the only other possibility, cancellation of subscriptions, required much greater effort and extent of dissatisfaction. Further, the committee was most keen that Discovery should be sold on bookstalls[132].

Overseas readers would almost certainly have been subscribers. Conquest, in only its sixth issue, stated:

> 'subscribers are also to be found in Cairo, Alexandria, Khartoum, Athens and many large cities in the Mediterranean, while our Indian subscription list is growing fast'.[133]

These are cited in addition to South Africa 'where subscribers are to be found even in the most inaccessible regions'.[134] The extent to which Nature penetrated beyond these shores has been well documented[135]. Knowledge began to publish Crommelin's astronomical column 'The face of the sky' two months in advance from the beginning of 1912 'so that it will reach subscribers all over the world in time'.[136]

Readership, advertising and the survival of a general science periodical were ultimately tied together. Advertisements sometimes meant the difference between life and death for journals. Increased readership meant increased income from advertisers, some of which could be channelled back into the journal, improve it (e.g. by increasing the number of illustrations or pages it contained) and thereby attract more readers. The declining sales figures for Discovery were accompanied by a drop in advertising revenue.[137] This revenue was a less significant feature of the journal's budget than might be expected from a commercially operated publication, particularly in view of the importance attributed to it by Ernest Benn[138], the successful publisher, who was to take over from Murray in 1924 and publish Discovery for more than a decade. For example, income from advertising for October 1920 is given in Murray's ledgers as £45 4s but the cost of advertising the journal itself came to more than half this sum at £26 13s 6d for the same month. In other words, this relatively low income may have been one reason why Discovery failed to make a profit or break even. Moreover, there existed the possibility of conflict between the publisher and the committee. John Murray paid all the production expenses. One clause in Conway's draft scheme accorded the committee the right to veto any type of advertisement it deemed 'undesirable'[139]. Such a situation, with the commercial and the scientific interest separate, most likely led to disputes. The journal was clearly not being conducted on the basis of commercial viability - considerations of this nature had to bow to more important priorities. Disagreements could doubtedless be avoided if interests coincided: for example, Brabazon (proprietor, director), Bradley (editor) and Low (technical adviser) of Armchair science were a small group with similar aims and interests. The financial burden was not separated from decision making about content.

The link between advertising and sales was epitomised by Conquest. In June 1921, the journal carried an advertisement for its own advertising space. The charge was directly connected with the sales i.e. one pound per page per thousand readers. It was claimed that the average net sales for the period November 1920 to April 1921 amounted to 15,569.

Figure 3 provides a graphic demonstration of the continuous decline in sales suffered by Discovery between January 1920 and March 1924. One period of relative stability is apparent: that of July 1920 to January 1921. After this a rapid decrease set in. A variety of causes may be cited to explain the general trend, for example the problems created by conflicting ideals referred to above or bad editorial policy. Murray and the committee possibly blamed the latter as Russell was removed from the editorial chair in June 1921. His replacement was Edward Liveing, described by Who was who as an 'author and commercial historian'[140]. Russell's new position was variously described as 'scientific adviser', and 'sub-editor' in the journal and in John Murray's ledgers. Doubtlessly connected with the failing fortunes of Discovery was the breaking of the postwar boom 'abruptly in the winter of 1920-21'[141]. Financial crisis meant people had less money to spend on non-essentials such as general science periodicals. But, most dramatically, the date of the drop in sales figures coincided with Discovery's first anniversary: the immediate cause of the striking fall of January 1921 was the failure to renew subscriptions. A vital factor in this regard was the doubling of the price with the first issue of that year. No doubt affected by the slump, the journal was losing money for Murray. Lattimer reported:

> 'there is an actual discrepancy, apart from sold advertisements, of about £20 per number. As adverts average about £50 a number, the balance of £30 would not meet expenses'[142].

He and Murray persuaded the committee to accept an increase of 6d per issue. Further, it was 'proposed to include more and better illustrations'[143] to make the price rise more palatable to readers. More specifically, this meant the use of better quality paper in order that the half-tone process could be employed. Photographs could thereby be introduced (on pages with text and not as separate plates) and hopefully attract more readers. The rise was calculated to create a profit for Murray[144] ('£20 plus reserve from sold advertisements')[145], but was based on a circulation of 12,500 per month and advertising revenue of £50. Both these figures were far too optimistic. As noted above, they declined from January 1921 and Murray continued to lose. This illustrates the impossibility of stating a minimum level of sales for periodical viability. So many other factors were involved, as the example of advertising revenue amply illustrates. Science progress compensated for its low circulation (never more than 1,187) with a high price (5s which eventually rose to 7s 6d.).[146]

The Murray file lapses into silence until October 1923 when an extended correspondence began between Conway, Lattimer and Murray himself. Negotiations took place as to the future of the journal, each side rejecting each others offers. Lattimer wrote to Conway that 'Mr. Murray has taken an interest in the magazine, and will be sorry to see it go under if it can be saved'[147]. Despite this, in John Murray's own words:

> 'We have financed it from the first and have lost a good many thousands of pounds thereby and we cannot afford to continue this'[148]

Conway went on to find a future for the journal elsewhere. Several attempts failed, including a proposed takeover by Conquest much speculated on during November and December. According to Conway, these negotiations were 'concluded by the veto of our senior trustee [Sir J.J. Thomson], on grounds which I cannot question, but which were quite new to me'[149]. This illustrates the authoritative position Thomson held in relation to the journal. Eventually a private benefactor, Mr. Victor Branford, stepped in and supported Discovery until it was taken over by Benn Brothers Ltd. in April 1924. Branford's interference with the running of the journal was the kind of thing the contributors and editors of Knowledge and Natural science sought to avoid by establishing their own companies[150].

Towards the end of 1937, John A. Benn who had himself edited Discovery, opened a correspondence with Macmillan in the hope that they could be persuaded to take the journal over. Personal interest in the journal prompted this action: Benn claimed he 'would not like to see it die'[151], and the onus of finding a new publisher lay with the committee. Benn dealt with Daniel Macmillan and Richard Gregory and revealed some interesting details. Firstly, the revenue from advertising had doubled from the time of Murray[152]. Yet the circulation was down to 2,000 per month. Despite this, Benn's losses were less than Murray's. Benn wrote that 'the present loss is due to editorial salaries. If one of your sub-editors took it over, there would be a balance at once'[153]. He even suggested that 'these charges [i.e. overheads] could be shared by, say Nature'[154]. Macmillan declined the offer, which was subsequently taken up by the Cambridge University Press.

6. Summary

The aims of this chapter can be understood at two levels. In general terms, the objective was to acquire an appreciation of how, why and by whom general science periodicals were produced and read. A more specific objective, however, lay in the desire to explain the fluctuations in activity which these periodicals underwent. Although the elements here considered were crucial to the development of general science periodicals, they alone are insufficient to explain it. Whilst, for example, the emergence of a market for this type of publication was a necessary condition for their foundation, it was not sufficient. Economic factors by themselves do not provide a satisfactory account of why each journal took the precise form it did, why some journals failed and some survived, why each addressed a particular readership and why the general science periodical as a medium of communication functioned as it did.

Answering such questions may well be too demanding and ambitious a task for a thesis such as this. Yet they are fundamental and interesting problems which at the very least must be tackled. The following three chapters are devoted to the attempt to provide answers by exploring factors other than the economic which were at work in shaping the development of general science periodicals between 1890 and 1939. A clue is offered by one historian who has remarked that 'By the nineteenth century, growing numbers of British and European scientific and medical journals had come to embrace powerful professional functions and wield significant social influence'[155]. It is shown below that this was not less true of the general science periodical than it was of the more specialised organs of the professional disciplinary élites.

Notes and references

1. This discussion relies on David A. Kronick, A history of scientific and technical periodicals (Metuchen, 1976), pp. 15-18. Whilst Kronick's work relates mainly to the eighteenth century, it is nevertheless the most comprehensive analysis of the issue located, and required little adaptation to render it appropriate to the period of this study. The Victorian periodicals review was a useful source although no analysis of this fundamental issue could be found. A search of the Social science citation index (Philadelphia, 1976-86) failed to reveal a more thorough or accurate consideration of the question than Kronick's.
2. 'Serial' is not used as its normal meaning includes irregular publications.
3. Yet it was well understood that a delay might not kill the journal.
4. e.g. Susan Sheets-Pyenson, 'Popular science periodicals in Paris and London: the emergence of a low scientific culture 1820-1875', Annals of science, 42(1985), 549-72; Matthew D. Whalen and Mary F. Tobin, 'Periodicals and the popularisation of science in America, 1860-1910', Journal of American culture, 3(1980), 195-203; W.H. Brock, 'The development of commercial science journals in Victorian Britain', in A.J. Meadows (ed.), Development of science publishing in Europe (Amsterdam and Oxford, 1980), 95-122.
5. See Chapters 3 and 4.
6. Brock, op. cit. (note 4), p. 96.
7. The Scientific review, a short-lived publication of 1914, was exceptional in that this typical feature was omitted from its pages.

8. E.W. Maunder, 'Man's place in the universe', Knowledge, 26, (1903), 81-3, 220-1, 268; A.R. Wallace, 'Man's place in the universe', Ibid., 107; A.M. Clerke, 'Man's place in the universe', Ibid., 108; J.E. Gore, 'Man's place in the universe', Ibid., 108; W.H.S. Monck, 'Man's place in the universe', Ibid., 109; Camille Flammarion, 'Man's place in the universe', Ibid., 121; Marcel Moye, 'Man's place in the universe', Ibid., 131; W. Woods Smith, 'Man's place in the universe', Ibid., 257.
9. 'Notes of the month', Conquest, 6(1924-5), 1.
10. G. Gamow, 'Mr. Tompkins in wonderland': Dream I: the toy universe', Discovery, n.s.1(1938), 431-9; 'Dream II: the quantum room', Discovery, n.s. 2(1939), 24-8; 'Dream III: City speed limit', Ibid., 63-8; 'Dream IV: More uncertainty', Ibid., 134-41; 'Dream V: Mr. Tompkins takes a holiday', Ibid., 175-80; 'Dream VI: Last adventure', Ibid., 230-5.
11. E.g. Harry F. Witherby, 'The White Nile - from Khartoum to Kawa': 'I: The desert railway, Khartoum and Omdurman', Knowledge, 24(1901), 75-9; 'II: The river - essential alike to man, beast and bird', Ibid., 137-40; 'III: The country and the people', Ibid., 174-7; 'IV: Camping and collecting', Ibid., 220-3; 'V: Birds', Ibid., 243-5; 'VI: A dance, a sandstorm and a rare bird', Ibid., 266-8.
12. R.I. Pocock, 'Animals of interest', Conquest, 1(1919-20), 15-17; 75-6, 83; 135-7; 224-6; 277-80; 335-7; 385-8; 426-8; 527-9; 573-7.
13. Brock, op. cit. (note 4), p. 97.
14. First article, Michael Lorant, 'The size of the universe', Discovery, n.s. 2(1939), 200-06.
15. E. Walter Maunder, 'Astronomy without a telescope': 'I: Introductory', Knowledge, 23(1900), 9-11; 'II: The zodiacal

light', Ibid., 61-3; 'III: The northern stars', Ibid., 81-3; 'IV: A total solar eclipse', Ibid., 104-6; 'V: Observations of the sun', Ibid., 132-4; 'IV: The Milky Way', Ibid., 158-9; 'VII: Meteors - the Perseids', Ibid., 174-5; 'VIII: Four variable stars', Ibid., 199-200; 'IX: Aurorae', Ibid., 223-5; 'X: The Meteors of November', Ibid., 251-2.

16. See, for example, chapter 3, section 4.

17. 'When we speak of Edwardian England we usually mean a period ending not when the King died on 6 May 1910, but when England declared war on Germany on 4 August 1914' Simon Nowell-Smith (ed.), Edwardian England (London, 1964), p.vi.

18. Some exceptions undoubtedly existed. For example, when Discovery was on the verge of collapse in 1923, Lord Stuart of Wortley wrote to John Murray the publisher to offer condolences. He claimed to possess a complete, personal set of the journal collected from the first issue (John Murray archive).

19. Eric Hobsbawm, Industry and empire (London, 1967), p. 141 describes the public schools as 'actively anti-intellectual, anti-scientific'.

20. Ibid., p. 134.

21. Richard D. Altick, The English common reader (Chicago, 1957), p. 396.

22. J.M. Winter, The Great War and the British people, (London, 1985), p. 281.

23. John Burnett, A history of the cost of living (Harmondsworth, 1969), p. 298.

24. Retrospectively, it can be said that nutritional knowledge was poor, for example vitamins were only 'discovered' in 1912. The middle classes were in substantially better health than the working classes, in spite of their ignorance, simply because

they could afford more food, in greater variety and fresher.

25. Hobsbawm, op. cit. (note 19), p. 139.

26. Nigel Middleton and Sophia Weitzmann, A place for everyone (London, 1976), p. 117.

27. Altick, op. cit. (note 21), p. 171, pp. 365-6. See also Lawrence Stone, 'Literacy and education in England, 1640-1900', Past and present, no. 42 (1969), 69-139. Problems exist in defining the term. Not only is the standard definition in terms of signing the marriage register too limited to be of any real use, it is inaccurate.

28. Altick, op. cit. (note 21), p. 365.

29. The situation was somewhat different in girls' schools. The Science and Art Department's regulations had not affected girls' education in the same way as they had that of boys; neither was there the restrictive obsession with the classics. In some girls' schools no science whatsoever was taught. See David Layton, Interpreters of science, (London, 1984), p. 34.

30. 'The juvenile philosopher', Discovery, 1(1904), 18. Also Lorant, op. cit. (note 14).

31. C.A. Mitchell, 'April hundredth issue', Discovery, 9,(1928), 149.

32. Christopher Lawrence, 'Incommunicable knowledge: science, technology and the clinical art in Britain 1850-1914', Journal of contemporary history, 20,(1985), 503-20.

33. For example, Natural science is held by St. Mary's Hospital Medical School and the Pharmaceutical Society and Science progress by the Royal College of Physicians, Edinburgh, the British Medical Association, the Royal Society of Medicine, the Royal College of Surgeons, St. Mary's Hospital Medical School and the University College Medical School.

34. See Ian G. Barbour, Issues in science and religion (London, 1966), p. 115.

35. E.g. 'The end of the world', Nature, 66(1902), 601-2; Oliver Lodge and Theo.D.A. Cockerell 'Germs in space', Nature, 67(1902-03), 103; Samuel Wilks, 'Coleridge's theory of life', Nature, 68(1903), 102.

36. E.g. L. Doncaster, 'Vitalism', Science progress, 6,(1911-12), 386-92; Carl Snyder, 'Life without oxygen', Ibid, 107-34; F. Carrell, 'The interpretation of life', Ibid., 372-85; Hugh S. Elliot, 'The spectre of vitalism', Science progress, 7(1912-13), 437-59.

37. Rt. Rev. H. Hensley, 'What are the scientist's moral obligations?', Discovery, 14(1933), 336; Rt. Rev. H. Hensley, 'Moral aspects of the search for truth', Ibid., 368; Hillaire Belloc, 'What is the issue?', Discovery, 15(1934), 3; J.B.S. Haldane, 'A reply to the Bishop of Durham', Ibid., 31-4; F.S. Marvin, 'Is human progress an exploded myth?', Ibid., 78; Very Rev. W.R. Inge, 'What is the future of the universe?', Ibid., 132; Julian Huxley, 'Religion as an objective problem', Ibid., 164-6, 187-9; Alfred Noyes, 'Science and religion', Ibid., 337.

38. Father Desmond Morse-Boycott, 'Science and religion', Armchair science, 1(1929), 25.

39. E.J.M. Hudson, 'The wheels of time', The Scientific review, 1(1914), 1-3, p.1.

40. See chapter 3.

41. E.g. the British union catalogue of periodicals (London, 1955) lists the following public libraries as holding Knowledge: Birmingham, Bradford, Bath, Birkenhead, Bristol, Cardiff, Leeds, Liverpool, Manchester, Nottingham, Newcastle-upon-Tyne, Preston (Harris Public Library), Sheffield, Southwark, West Ham and Westminster.

42. E.g. the British union catalogue of periodicals (London, 1955) lists the Zoological society and the Pharmaceutical society as holding Knowledge. This journal was taken by the Ealing Microscopical and Natural History Society before 1900 (at least), and was presented by one of their members.

43. Thomas Kelly, History of public libraries in Great Britain, 1845-1975 (London, 1977), p. 188.

44. Figures taken from Derek Hudson, 'Reading' in Nowell-Smith, op. cit. (note 17), 303-26, p. 309. Although Kelly op. cit. (note 43) points out that before the First World War, despite advances already made, two-fifths of Britain was without a library service and this lack was not confined to rural areas.

45. Kelly, op. cit. (note 43), p. 188.

46. This contrasts with both the type of commitment required of a book, particularly in reading it, but also in buying it, as well as the lack of commitment involved in reading many periodical articles.

Footnotes omitted from Chapter 1, p. 32.

46a. Whalen and Tobin, op.cit. (note 4).

46b. Ibid., p.196.

46c. Susan Sheets-Pyenson, Low scientific culture in London and Paris, 1820-1875 (University of Pennsylvania Ph.D. thesis, 1976).

46d. Ibid., p.107.

47. 'Notices of books', _Knowledge_, _24_(1901), 110-12, p. 111.

48. See, in particular, chapter 3.

49. Hudson, _op. cit._ (note 39), p. 1.

50. D.S.L. Cardwell, _The organization of science in England_ (London, 1972), p. 207.

51. _Ibid_., p. 220; Russell Moseley, 'Tadpoles and frogs: some aspects of the professionalisation of British physics, 1870-1939', _Social studies of science_, _7_(1977), 423-46.

52. R.M. MacLeod, 'Resources of science in Victorian England: The endowment of science movement, 1868-1900', in P. Mathias (ed.) _Science and society_ 1600-1900 (Cambridge, 1972), 111-66, p.163.

53. Cardwell, _op. cit._ (note 50), pp. 214-5.

54. 'Editorial', _Science progress in the twentieth century_, _1_(1906), 1-2, p.1.

55. E.g. Zoological Society, Royal Society of Edinburgh, Leeds University Library. Information from the *British union catalogue of periodicals* (London, 1955) and supplements.
56. E.g. Pharmaceutical Society, Zoological Society.
57. E.g. Road Research Laboratory (D.S.I.R.), British Scientific Instrument Research Association, Associated Electrical Industries, Zoological Society, British Psychological Society.
58. E.g. Boots Pure Drug. Co., Nottingham, British Cast Iron Research Association, Kodak Ltd., Rothamstead Experimental Station, Harpenden, Royal Geographical Society, Royal Botanic Gardens, Edinburgh.
59. The *British union catalogue of periodicals* (London, 1955) lists the London County Council Education Library as holding *Science progress* and *Discovery* and the National Training Committee for training of teachers, Edinburgh, as holding *Knowledge*.
60. *Science and technology*, subtitled 'A journal for teachers and students'.
61. *Op. cit.* (note 54), p. 2.
62. See below, section 5.
63. In addition, the negotiations with Murray were carried out by the firm's educational editor (John Murray archive).
64. See, for example, Altick, *op. cit.* (note 21), chapter 15, pp. 348-64. Also Brock, *op. cit.* (note 4).
65. Brock, *op. cit.* (note 4), p. 105.
66. Brock, *op. cit.* (note 4), p. 105.
67. *Op. cit.* (note 54), p. 1.
68. 'Introduction', *Natural science*, *1*(1892) 1-2, p.1.
69. *Ibid.*, p. 1.
70. E.g. D.E. Davinson, *Periodicals* (London, 1964), pp. 18-19.

The four types are: those emanating from professional or learned bodies; those issued for financial gain; House Journals of commercial and industrial organisations; and newspapers.

71. Brock, op. cit. (note 4), p. 95.
72. Brock, op. cit. (note 4), p. 96.
73. R.M. MacLeod, 'Securing the foundations', Nature, 224(1969), 441-4, p. 443.
74. Lockyer quoted in MacLeod, op. cit. (note 73), p. 444.
75. Sir P.C. Mitchell, My fill of days (London, 1937), p. 194.
76. Brock, op. cit. (note 4), p. 105.
77. Hudson, op. cit. (note 44), p. 309.
78. W.T. Stead, 'Preface', Annual index to periodicals 1891, 2(1892), 5-6, p. 5.
79. Op. cit. (note 68), p. 1.
80. This journal had a circulation of 300,000 in 1890, which indicates the enormous popularity of periodical literature. Altick, op. cit. (note 21), p. 396.
81. Stead, op. cit. (note 78), p. 5.
82. W.T. Stead, 'Introduction', Annual index to periodicals 1892, 3(1893), 1-2, p.2.
83. W.T. Stead, 'Introduction', Annual index to periodicals 1899, 10,(1900), v-vii, p.v.
84. Figures from Altick, op. cit. (note 21), p. 396.
85. Stead, op. cit. (note 81), p. 5.
86. Stead, op. cit. (note 82), p. 1.
87. Ibid.,p. 1.
88. See chapter 3.
89. See chapter 5, section 6.
90. Joanne Shattock and Michael Wolff (eds.), The Victorian periodical press: samplings and soundings (Leicester, 1982), p. xiii.

91. Hudson, _op. cit._ (note 44), p. 320.

92. See critical biography. Of course, over a period of, for example, a month, the situation could look different. It is, however, easy to see why the journals might nevertheless have seemed to offer less value for money. Taking the _Daily mail_ for six days a week for a month would have cost only 1s.

93. R.J.L. Kingsford, _The Publishers' Association, 1896-1946_ (Cambridge, 1970), chapter 4, pp. 51-72. Ordinary book paper was priced at 2½d per pound in 1915, 5d per pound in 1916 and 9½ - 11d per pound in 1918.

94. _Ibid._, p. 57.

95. _Ibid._, p. 58. In 1918, in 62 publishing firms surveyed, there were 1,559 men of military age and over, and 1,522 women and boys under age working. Of these 1,559 men, 429 were over 51 years of age, 90 had been discharged from the Army and many had been registered as unfit or in low medical grades.

96. When _Discovery_ doubled its price at the end of 1920, Lattimer reported to Murray that the printers and binders 'are now asking for a further increase'. Lattimer to Murray, 1 October 1920 (John Murray archive).

97. Kingsford, _op. cit._ (note 93), pp. 88-9.

98. Quoted in Kingsford, _op. cit._ (note 93), pp. 89-90.

99. Lawrence Badash, 'Radium, radioactivity and the popularity of scientific discovery', _Proceedings of the American Philosophical Society_, _122_,(1978), 145-54.

100. Marshall Missner, 'Why Einstein became famous in America', _Social studies of science_, _15_(1985), 267-91.

101. See chapter 5, section 5.

102. Richard Gregory to George Macmillan, 19 December 1917. Macmillan firm letters.

103. R.S. Conway, 13 May 1919. Macmillan firm letters. Richard Gregory had published a widely read book of the same title in 1916, and hence Macmillan's permission to use the name '<u>Discovery</u>' was required. See chapter 6, section 5.

104. R.S. Conway, 25 July 1919. Macmillan firm letters.

105. Conway to Murray, 28 July 1919. (John Murray archive).

106. <u>Ibid</u>.

107. This included the Classical Association, the Historical Association, the English Association, the Modern Language Association, the Geographical Association, the British Psychological Society and the Royal Society of Economics.

108. Agreement signed on 22 March 1920 but dating from 25 October 1919, between John Murray and R.S. Conway on behalf of the Trustees. (John Murray archive).

109. <u>Ibid.</u>

110. According to Conway's draft scheme, the committee of management included five members (nominated by and) from the Educational Committee of the Joint Board of Scientific Societies (of whom Richard Gregory was a member), one member each from those bodies listed in note 106 above, two members from the National Union of Teachers and one from the Association of Headmistresses.

111. The space left in the draft agreement for these subjects was filled in by Russell. They were: astronomy; physics; chemistry; geology; botany; heredity and evolution; natural history; classics and early civilisation; English studies; modern languages; comparative philology; history; geography; psychology; economics.

112. Editor: initially agreed 1/8d per copy for each copy sold over 5,000. This was raised to 1/4d when the price of the journal was raised to 1s in January 1921. In 1921 (June) the new editor (Liveing) split the royalty with Russell (then sub-editor), both receiving 1/8d. Plus £100 per annum. Committee:£50 per

annum plus 2½% on the published price of all copies sold above 10,000 per month in any year. If average sales for the first 10 months were less than 10,000, payment for the second year was only £40. If average sales less than 5,000, payment for the second year only £30. Contributors: 'not more than one pound per 1,000 words'. Possibly the low editorial salary (low sales, see below) influenced the rapid turnover of editors (see critical bibliography). The salary compared unfavourably with Richard Gregory's secure annual payment of £500 for editing Nature in 1921. Publishers were often the best, and sometimes the only, source of finance for the establishment of a journal, which could be very expensive. A.M. Low, for instance, who managed to obtain private finance for Armchair science in 1929, needed a figure of '£50,000, for the mere beginning'. Low, quoted in Ursula Bloom, He lit the lamp (London, 1958), p. 98.

113. Figures based on a quantitative survey of all major (i.e. those included in the list of contributors and therefore excluding editorials and correspondence) articles for the years 1920-1939.

114. See chapter 5, sections 5, 6 and 7.

115. R.M. MacLeod, 'Private army of contributors', Nature, 224(1969), 445-9.

116. 'Selections from the letters of Sir Norman Lockyer', Nature, 224(1969), 473-6, p. 473. G.B. Airy and Lyon Playfair were among those who refused. William Crookes, on the contrary, appeared keen to be involved. (Norman Lockyer papers).

117. 'Editorial', Knowledge, n.s. 9(1912), 1.

118. Whilst academic/specialist journals were under pressure from increasing submissions, it is also the case that by submitting

to a general science periodical, the refereeing system could be bypassed.

119. Op. cit. (note 17).

120. See chapter 3.

121. Hudson, op. cit. (note 39), p.1.

122. See chapter 5, section 3.

123. W.O. Hagstrom, 'Gift giving as an organising principle in science', in Barry Barnes (ed.), Sociology of science (Harmondsworth, 1972), 105-20.

124. Ibid., p. 105.

125. In Nature's case, these submissions were original contributions to knowledge, often in the form of correspondence. The publication of this type of material was an important role assumed by the journal, particularly after 1919.

126. Report of meeting, Lattimer to Murray, 17 November 1919 (John Murray archive).

127. 'Draft scheme for Discovery' (John Murray archive).

128. The National Union of Teachers guaranteed 625 subscriptions prior to the journal's launch. Information from John Murray archive, although it is nowhere made clear whether these subscriptions came from schools or individuals.

129. '"Conquest" in distant climes', Conquest, 1(1919-20), 293.

130. Information on sales from John Murray archive (ledgers).

131. MacLeod, op. cit. (note 73), p. 443.

132. Lattimer reported to Murray, op. cit. (note 126) that at the meeting of 15 November 1919, the committee expressed the view that the sale of the journal on bookstalls was 'highly desirable'.

133. Op. cit. (note 129).

134. Ibid.

135. MacLeod, _op. cit._ (note 73), p. 443.

136. _Op. cit._ (note 117). The correspondence of several general science periodicals also indicates overseas readers.

137. Setting aside initial interest from advertisers which may be discounted because the journal was new and would undoubtedly have had some curiosity value, the situation had reached a kind of equilibrium of £50 per month during the second half of 1920. After March 1921 this had stabilised at around half the previous value. This drop coincided with the sharper drop in sales shown graphically in figure 3.

138. E.J.P. Benn, _Confessions of a capitalist_, 10th ed., (London, 1927).

139. Draft scheme (John Murray archive).

140. _Who was who_ 1961-70 (London, 1972), p. 682.

141. A.J.P. Taylor, _English history_ (Oxford, 1965), p. 144.

142. Lattimer's report to Murray (1 October 1920) of the meeting with the committee at which various suggestions for rectifying the situation were discussed. Lattimer persuaded them to accept Murray's solution (John Murray archive).

143. _Ibid._

144. Although Murray was prepared to accept a loss over the first year, he wrote to Conway on 29 August 1919: 'I estimate that the cost of running it for a year including payment of £100 to the editor, will be about £1,450 and the yield at 6d per copy will be under £800' - the actual loss must have been greater than he had anticipated (John Murray archive).

145. _Op. cit._(note 142).

146. See critical bibliography. Circulation figures from John Murray archive (ledgers).

147. Lattimer to Conway, 10 October 1923 (John Murray archive).

148. Murray to Lord Stuart of Wortley, 30 November 1923 (John Murray archive).

149. Conway to Murray, 28 December 1923 (John Murray archive).

150. The _Natural Science_ Periodical Company Ltd. and the _Knowledge_ Publishing Company.

151. John A. Benn to Daniel Macmillan, 16 November 1937 (Macmillan firm letters).

152. The annual income from advertising for the year June 1936 to June 1937 was £643. Under Murray, with an average monthly advertising revenue of £25, the annual total was £300.

153. John A. Benn to Richard Gregory, 25 October 1937 (Macmillan firm letters).

154. Benn, _op. cit._ (note 151).

155. R.M. MacLeod, 'Printing under the golden lamp: Taylor and Francis Ltd., and work in progress on scientific periodical publishing', _Victorian periodicals newsletter_, No. 5(1969) 11-12, p.12.

CHAPTER 3

RELATIONSHIPS REDEFINED: AMATEURS AND PROFESSIONALS IN GENERAL SCIENCE PERIODICALS

1. Introduction

This chapter analyses the relationships between professional scientists and amateur participants in science from c.1890 to c.1930. Specifically considered is the question of precisely how general science periodicals attempted to influence changing perceptions of these relationships, and the implications these changes had for the subsequent organisation and conduct of the scientific enterprise itself. The analysis contributes to an understanding of the nature of the general science periodical in terms of both content and function. Situating one distinct section of the readership - the serious amateur - in the context of four different sciences reveals the diversity in subject matter, presentation and purpose which made up what was typically an extremely heterogeneous organ. Examination of this aspect of general science periodicals provides support for the broader thesis regarding the close connection between the periodicals and the process of the professionalisation of science.

2. The professionalisation of science

For much of the nineteenth century, science operated according to the tradition of the gentleman amateur. Men of science generally conformed to the ideal of wealthy amateurs pursuing a hobby and science was itself regarded as but one aspect of general culture. Although the last decades of the century saw increasing moves towards professionalisation, 'the amateur was still "regarded as the true representative of scientific research"'[1], as late as the 1890s.

Despite the successes achieved by the 'endowment of research' movement, namely the setting up of 'university, government and private research establishments and fellowship schemes'[2] between 1885 and 1900, by this latter date employment prospects for science graduates were bleak indeed. According to Cardwell, most had little alternative but to become school teachers. He reckons that there were no more than 225 graduate chemists employed in industry in 1902.[3] The situation was not much improved by 1914,[4] by which time the number of graduates in science had increased fourfold.[5] Career opportunities in chemistry, although woefully inadequate, were better than those offered by any other discipline. For example in physics, it has been estimated that there existed only seventy five university teaching posts in 1900 and virtually no openings in industry.[6] Other disciplines had even less to offer than physics. The state provided only 250 jobs for scientists in 1900 and as late as 1914 the Institute of Chemistry (a professional body founded in 1877) complained that chemists in the employ of the state 'are treated as if they belong to a non-professional class'.[7] In fact the dynamic process which transformed science from an amateur pursuit, often of the leisured classes, into a professional exercise, had its origins in the mid-nineteenth century and extended well into the twentieth.

An extensive sociological literature offers virtually innumerable criteria for defining a profession. Examples include the existence of a professional body (which has the maintenance of professional standards as one of its main functions), special training in a particular kind of knowledge, appropriate qualifications (usually a degree), a monopoly on certain types of activity, opportunities for full time employment practising the skills acquired in training, etc.[8] The profusion of definitions is largely due to their basis in analysis of different existing professions, traditionally law, medicine and the clergy, but also newer professions such as science and engineering. Furthermore, it is inappropriate to transfer conclusions based for the most part on twentieth century professions to a nineteenth-century situation which was, moreover, undergoing rapid and fundamental change. Historians of science mostly adopt definitions which, although less detailed than those of the sociologists, are more appropriate to their chosen historical period and more useful in its study.

Accordingly, for the purpose of this thesis, for a scientific discipline to be described as a profession, it must have satisfied the following conditions. Its members were engaged in full-time employment practising their discipline and from which they derived their major source of income. To be admitted to the professional élite an aspirant must have measured up to certain shared standards of expertise (i.e. special skills and knowledge exclusive to members of the profession). This expertise was normally acquired in training, an initiation process which was itself under professional control. Control is an extremely important concept. One aspect of the process of professionalisation was the gaining of control over a particular area of knowledge. Further, for an occupation to become a fully-fledged profession it must have been recognised as such outside itself and therefore the process necessarily involved transition towards this recognition.[9] Such control was achieved and maintained in several ways, one of which was the general science periodical.

The tradition of the gentleman amateur was antithetical to the ideal of the professional. It interfered with the control which was vital to the emerging professionals. Therefore a change, in fact a redefinition of relationships was essential to the process of professionalisation. The general science periodical presented a forum which was highly suitable for the working out of these new relationships. In the 1890s (and beyond), both professionals and amateurs contributed to and were involved in the production of the periodicals which therefore afforded opportunities for interaction between the two groups. The general periodical allowed the professionals greater freedom in choice of issues introduced and modes of presentation employed than did the increasingly formalised specialist professional publications. Closely tied to this redefinition of relationships was the presentation of an image of science designed to influence public attitudes as a way to encourage recognition of professional status. (This is discussed in Chapter 4).

Apart from the context of professionalisation, the nature of general science periodical activity from 1890 would make little or no sense. In the analysis which follows, four subject areas have been selected: astronomy , 'natural history', physics, and chemistry. These four were chosen essentially because of the varying degrees of professionalisation they exhibited. Chemistry was the first scientific discipline to become fully professionalised, whereas even in the 1980s a few amateur astronomers and naturalists continue to thrive. It is a useful indicator of amateur scientific activity that in the decades between 1890 and 1929, there were founded thirty-nine scientific societies which were to become corresponding societies of the British Association. Of these, at least two-thirds were devoted to natural history subjects. Furthermore, the membership of the corresponding societies more than doubled between 1904 and 1914.[10]

Language is vitally important to any culture or society.[11] It encapsulates the beliefs, norms, traditions and values of a community: in fact it defines that community. The idea of linguistic relativism (which underlies the Kuhnian notion of incommensurability)[12] is valuable in understanding how language can be used in defining relationships. For instance, limited knowledge of the language of a community means communication with and access to that community is severely restricted. That an individual outside the scientific community possesses only such limited knowledge can be emphasised by using the language without explanation, that is, without the provision of a translative link between linguistic contexts. The comparable limitations, from the reader's point of view, of belonging to or communicating with the scientific community and participating in their activities, can in this way be highlighted. This was one significant factor in the construction of barriers between professional and amateur practitioners of science.

3. Astronomy

a) Background

Towards the end of the nineteenth century, amateur astronomers enjoyed considerable status within the British astronomical community. Their valuable and original contributions to new knowledge placed them in a strong position in relation to the existing professionals (mainly those employed at observatories such as Greenwich or South Kensington). The century had witnessed developments in astronomical research, most notably the emergence of a new kind of astronomy. The centuries old astronomy of position and calculation was challenged by a new application of physics to the heavens. Astrophysics was born out of the use of spectroscopy, and its concerns were with the physical nature of celestial phenomena as opposed to the analysis of movements of planets, stars, etc. The extent to which the new astronomy depended on a full understanding of certain aspects of physical science excluded those without formal training.

In the face of their growing exclusion from this type of work, amateurs turned to new areas and brought innovations into the field. Their greatest success concerned the introduction of photographical techniques. They were able to follow up novel and even daring ideas because, unlike their professional counterparts, they were unhindered by the conservatism which inevitably accompanied concern with career prospects and recognition. In addition, they were less restricted by disciplinary barriers which were becoming increasingly significant for professional scientists.

Aspiring professionals, therefore, had to deal not only with the philosophical ideal of the amateur scientist, but its embodiment in a powerful and effective group of researchers. Control over their discipline was essential in order to acquire full professional status. They also wanted specialisation, technical knowledge by means of advanced education, expensive, large scale equipment and state support. The amateur, both real and ideal, offered practical and philosophical resistance to this programme. The new successes of the amateurs were swiftly taken from their hands. For example, in photography the expert knowledge and costly equipment brought by the professionals soon left them behind.

In his paper on 'The controversy over telescope size in late Victorian Britain,'[13] John Lankford claimed that 'The triumph of professionalism was a contingent historical and political process.'[14] The present study provides further evidence and justification for his claim. The context to which changes in the respective status of amateur and professional astronomers were a response and the means by which they came about are explored.

Lankford also attempted to show that models which have been constructed as frameworks for the explanation of the dynamics of professionalisation are not generally applicable. Among others, he cites those of A.M. Carr-Saunders and P.A. Wilson,[15] and Nathan Reingold,[16] as unsatisfactory examples, specifically in terms of the development of astronomy. Lankford's main point is that in astronomy 'the professional never achieved a complete monopoly; instead the role of amateurs became institutionalised within the discipline'.[17]

Controversies were often particularly important to participants in terms of working out relationships and articulating philosophies, and hence their study can be, historically, an extremely revealing exercise. Nevertheless, Lankford's analysis of one single such controversy and its limited number of participants has produced a necessarily narrow perspective of the process by which amateur status changed. A broader perspective of these processes has been obtained by analysing general science periodicals with particular reference to the mechanics of the changes in question. In has, for instance, demonstrated the importance of sustained discourse and the concept of control.

In the general science periodicals, the two groups were initially separated by a variety of means. Conflicts, such as Lankford's debates over telescope size, entered their pages. An alternative identity was then provided for the amateur astronomers. Their role and status were redefined and a new and different set of problems were prescribed for them. The role of the amateur as 'data-collector' was an obvious if not inevitable step given impetus by the changes the subject had undergone. Attempts to justify the restriction of amateur work in this way relied on an essentially Baconian rhetoric. Utilisation of the Baconian myth in this manner served several purposes.[18]

Agnes M. Clerke, who is described in Who was who as a 'scientific writer'[19] and who was a contributor to Knowledge, was already in 1887 spelling out the new role for amateurs and their relationship with professionals. She saw the astronomical community as united

> 'into a body animated by the single aim of collecting "particulars" in their special branch for what Bacon termed a History of Nature, eventually to be interpreted according to the sagacious insight of some one among them gifted above his fellows'.[20]

Before proceeding to examine these processes at work in the general science periodicals, one important event must be mentioned. As part of the attempt to establish a clear distinction between the two kinds of astronomical workers, and subsequent placing of disciplinary control in professional hands, amateurs were institutionalised. In 1890 the British Astronomical Association was founded. The avowed purposes of the new organisation were:

> 'To meet the wishes and requirements of those who find the subscription of the Royal Astronomical Society too high, or its papers too advanced or, who are, as in the case of ladies, practically excluded from becoming Fellows.'[21]

Further, to

> 'afford a means of direction and organisation in the work of observation to amateur astronomers.'[22]

H.H. Turner, at that time Chief Assistant at the Royal Observatory, Greenwich, but soon to be appointed Savilian Professor of Astronomy at Oxford, privately commented:

> 'As a professional astronomer I shall have nothing to do with the new one [i.e. society] which I think is really meant for the education of amateurs.'[23]

b) The periodicals

(i) Nature

Astronomy had featured significantly in Nature from its inception in 1869, mainly because of Norman Lockyer's own involvement in the subject. The part played by this influential periodical in the interactions which led to the establishment of a new role for the amateur as little more than a lower status worker for the the professional was investigated.[24] It was found that Nature subscribed to this new view of the relationship within the astronomical community and that its presentation increasingly promoted separation between the two kinds of astronomer. Nothing less would be expected from a publication which acted as the public voice of the new scientific professional.

For several decades, W.F. Denning was a regular contributor to Nature. He was the last amateur astronomer to receive the gold medal of the Royal Astronomical Society.[25] In his frequent articles (usually on meteors, his particular sphere of interest), his letters and his contributions to the weekly 'Our astronomical column', he acted as something of a coordinator of amateur astronomical activity. He often recommended what amateurs should do, for example:

> 'What we essentially require are observations of the earlier stages of the shower [of meteorites] during the last half of July, and as the present year offers a good prospect for obtaining them, I trust observers will make a special effort in this direction.'[26]

Further, he invited amateurs to send details of their observations to him directly. Thus 'Our Astronomical Column' reported, speaking of the white spots on Jupiter, that

> 'Mr. Denning will be pleased to receive records of new or old observations of these objects.'[27]

It is therefore unsurprising that Denning has been described by Lankford as 'committed to a primitive Baconian approach to science'.[28] His dislike of the technical aspects of astronomy was also evident. His contributions were usually written in a chatty, informal style. As he perceived the practice of science,

> 'Observation need not be filtered through the analytical medium of physics or mathematics'.[29]

This attitude emerged in his 1909 review of Sir Robert Ball's Treatise on spherical astronomy, which he complained was too mathematical: 'The book will be found very useful by students whose mathematical attainments are sufficient to obtain a first class in the mathematical tripos at Cambridge'.[30]

Denning was not the only amateur to reach the pages of Nature. The work of others, including Frank McClean, A.S. Williams and Rev. T.E.R. Phillips was reported. When Isaac Roberts, a prominent astronomical photographer and personal friend of Lockyer died, the following comment appeared in his Nature obituary:

> 'It is possible that he may be nearly the last of a distinguished series, for it is not unlikely that, as science tends to specialise in particular directions, such instances will become less and less frequent. The wealthy amateur, it may be, will continue to provide the means for others, but the requirements for the production of valuable work tend to become more and more severe, and the actual prosecution will soon be reserved for those who have been able to give up their whole life to special study.'[31]

Obituaries were one of those features of Nature intended to appeal to a broad readership. Therefore the implication that in the near future 'valuable work' would only be done by a professional élite was not only aimed at the serious amateur. It was rather part of a process which encouraged a perception among its whole readership of amateurs as distinct from and inferior to professionals. This process by which the rift between the two sections of the astronomical community grew wider, was aided by the deaths of several important amateurs. Not least of these were A.A. Cômmon (1903), Roberts (1904) and McClean (1904).

During the 1890s and 1900s, Nature clearly provided for a significant readership of amateur astronomers. Denning and others not only had their work reported, they also made direct contributions. 'Our astronomical column' typically contained a large amount of descriptive materials (i.e. observation reports), tables of where celestial phenomena could be located on each night of the following week and the astronomical occurrences for the coming month. All these aided amateur observation. Occasional reports on local scientific societies also appeared. For example, the Leeds Astronomical Society was described as being 'in a thriving condition'.[32] Although the amateurs for which the journal catered were, by and large, extremely committed and produced a high standard of work, the far less experienced also had letters published in the correspondence describing their observations.

Despite this encouragement of amateur activity, there was already in 1890 evidence of a distinction between professional and amateur astronomers. For example, that year saw a regular feature in 'Our astronomical column' by Alfred Fowler (one of Lockyer's assistants at his South Kensington Solar Physics Observatory) entitled 'Objects for the spectroscope'. Lockyer himself began a series in August on a 'Comparison of the spectra of nebulae and stars of groups I and II with those of comets and aurorae'[33] in which he presented arguments and evidence in favour of his own meteoritic hypothesis.[34] Two articles adopted a not uncommon historical approach which came to be widely used in other general science periodicals. R.A. Gregory, then also working as Lockyer's assistant at South Kensington, and A.A. Common each charted the "progressive" development of, respectively, lunar photography[35] and telescopes.[36] They constructed frameworks within which the new professional astronomers, with their expensive equipment and institutions, became the successors or natural heirs of earlier workers.

After 1900 there was a noticeable exacerbation in this separation of amateurs and professionals. By 1910, the regular weekly reports were becoming more technical and increasingly concerned with astrophysics. Greater emphasis was placed on the status of professionals. Reports of activity in large, mostly foreign observatories began to figure more prominently, as did longer articles, such as 'The new Hamburg observatory'.[37] That is to say, a move occurred away from presenting the astronomical community as comprising British astronomers (both amateur and professional) towards a more international conception of a community of professionals. Shifting attitudes were exemplified by an anonymous reviewer of 1910, who described the work under review as 'Somewhat scrappy and not always trustworthy, it gives the impression of being the work of an amateur'.[38] His identification of the amateur with work that was somehow inferior, as in his further remark that 'the information given is often amateurish and sometimes in error'[39] reflected the diminution in status which was by that time affecting the amateur astronomer.

Figure 4: Graph showing the decline in 'amateur' correspondence in *Nature*, 1890-1939[40]

A particularly relevant indicator of this trend (i.e. of differentiation between professional and amateur astronomers) was to be found in the correspondence pages. The category here entitled 'amateur' correspondence is made up of several types of letter. Firstly, there were letters from amateurs themselves describing their own observations. These were frequently anecdotal in character. In addition are included communications which gave advance notice of astronomical events and those which appealed for observations and were written by either professionals or amateurs.[41] A few 'miscellaneous' inevitably featured, for example the brief controversy of 1890 between Denning and W.H.S. Monck concerning the radiant point of the Perseid meteors.[42]

The graph illustrates the general decrease in this type of correspondence which is itself indicative of the severely declining amateur profile in Nature. The apparently anomalous figure for 1910 is attributable to the appearance of Halley's comet that year: of the seventeen letters pertinent to amateurs, eight concerned the comet.

Whilst the quantitative measure is a useful indicator of changes in Nature's approach to amateur astronomy, qualitative considerations offer further insights. In 1900, for example, there appeared a professionals' synthesis of collected observations of meteors. A.S. Herschel (son of Sir John Herschel and friend and admirer of Lockyer) gave an analytical unity to a multiplicity of observations of the Co-Leonid and Co-Bielid meteor showers.[43] Also during that same year the correspondence column featured a joint contribution from G. Johnstone Stoney and Arthur Downing (one of the founders of the B.A.A. and its second president, at that time employed as superintendent of the Nautical Almanac Office) of a type which was to become increasingly familiar to readers of Nature. This letter was a precursor to a longer paper. In it the pair computed the effect of perturbations on the Leonid meteors and predicted and explained the behaviour of these meteors.[44]

Such qualitative analysis reveals how amateurs were gradually being squeezed out of the correspondence column. Their often anecdotal contributions were being replaced by professional communications which concentrated on astrophysics and theoretical issues. The lack of cometary observations was bemoaned by Denning in 1922.[45] The nature of appeals too was changing. Professionals were more and more requesting their fellow professionals for help.[46] It is significant that for the 1921 eclipse of the sun, an appeal was made for professionals to 'suggest observations which might be made with small telescopes and the equipment generally possessed by an amateur'.[47] The author was compiling a list of observations and instructions as to how they should be made for the event. The importance of this particular modification in the relationships between professional and amateur astronomers is discussed below.

Despite their gradual exclusion from the correspondence (as part of Gregory's wider policy of making Nature a journal for communication between professional scientists[48]) amateurs nevertheless continued to be involved with the journal, although their profile dwindled. Reports of their observations were increasingly confined to 'Our astronomical column' where they were coordinated by Denning until his death, which coincided with the end of the column in 1931.[49] He mediated between the two groups, and was something of a hybrid himself.[50] Amateurs thereby came to be cut off from direct communication with professional astronomers. Ultimately they constituted a separate group whose participation in the scientific enterprise slowly but consistently diminished.

(ii) Knowledge

Although Nature was involved in the changes taking place in astronomy, it is Knowledge which reveals itself to have been more constitutive in these developments. The journal had always had extensive astronomical coverage. Its founder-editor, Richard A. Proctor, and his successor, Arthur C.Ranyard, were both amateur astronomers. Upon the latter's death in 1894, Witherby, a naturalist, took up the reins and appointed Edward Walter Maunder, Chief Assistant at the Royal Observatory, Greenwich, as astronomical editor. Maunder was, crucially, the main force behind the establishment of the British Astronomical Association. The strong astronomical and amateur traditions of the periodical made it an ideal medium for the advocacy and conscious infusion into the astronomical community of alternative conceptions of the relationships between, and functions of, its members.

At the turn of the century, the monthly astronomical column was written by Alfred Fowler, F.R.A.S. Fowler was a professional who worked at the Solar Physics Observatory at South Kensington as Lockyer's assistant until 1901 when, upon the latter's retirement, he became assistant Professor in the Royal College of Science. (While still working under Lockyer he sometimes wrote the astronomical column in Nature.) The monthly feature 'The face of the sky' dealt with the sun, the moon, the planets and stars in order, giving positions and other features. Some of this was quite technical: the inclusion of terms such as 'horizontal parallax' indicates that the column was not intended for beginners. Conversely, the absence of spectroscopic material or information about nebulae, for example, shows what limited appeal this feature would have had for the professional.

Several professional astronomers besides Maunder himself contributed to Knowledge, both as article writers and correspondents. These included

A.C.D.Crommelin (also assistant at Greenwich), Eugène Antoniadi and E.C. Pickering (Director of the Harvard College Observatory for forty-two years from 1877-1919). Furthermore, several were involved in the organisation and direction of amateurs in the B.A.A.

Numerous amateurs also found their way into the pages of the journal, the most prominent being W.F. Denning, who had his own column, 'Notes on Comets and Meteors'. Other amateur contributors counted among their number Agnes M. Clerke, Isaac Roberts, W.E. Wilson (a wealthy amateur in the old tradition), Sir Samuel Wilks (physician), J.E. Gore (engineer) and A. Stanley Williams, who was, like Denning, involved in controversies with professionals over telescope size.[51] The clergy were represented by T.E.R. Phillips and Arnold D. Taylor. Significantly, some of these amateurs were important figures in the B.A.A.[52]

Knowledge offered rare opportunities for direct communication between amateurs and professionals. Only the B.A.A. could provide anything comparable. The range of appeal of the periodical was wide. For instance in 1899 E.W. Maunder's series 'Constellation studies'[53] was designed as a sequel to his earlier 'Astronomy without a telescope'[54] as a means of interesting and enabling beginners to embark on astronomical observation without expense, previous training or experience. The recruitment of new observers was part of the professional programme. Not only were they needed to replace the old amateurs who were expiring at a rapid rate (most of those contributing to Knowledge, with the conspicuous exception of Denning, did not live beyond 1915), but their induction into the world of astronomy took place in the context of the newly defined relationships between the two groups. They accepted the new situation and problems, and ultimately came to replace the old style amateurs from whom the new professionals inevitably encountered resistance.[55] Eventually the conflict between amateurs and professionals, which had initially served well in the process of redefinition in reinforcing divisions, died out.

Little had altered by 1903. What changes there were marked the beginning of a trend which continued for the remainder of the journal's life. Fowler had ceased to write 'The face of the sky' (he was replaced by W. Shackleton, yet another of Lockyer's South Kensington assistants) and began a regular series, 'The chemistry of the stars'.[56] The astrophysical subject matter necessarily excluded the untrained, ill-equipped amateur from active participation. The series could hope to do no more than relate the doings and describe the instrumentation of professionals. Such articles were to become increasingly frequent as the decade wore on.

The astronomical content of Knowledge declined following editorial changes at the end of 1903. In May 1910 further administrative reorganisation led to the appointment of an amateur astronomical editor in G.F. Chambers, J.P., F.R.A.S. He was to be helped by Mr. F.A. Bellamy, M.A., F.R.A.S., first assistant at the University Observatory, Oxford. 'The face of the sky', still in Shackleton's hands, continued to guide and direct amateur workers with a consistency which could only have been achieved by a periodical publication. Although the column showed a slight increase in technicality, it covered what by this time had been earmarked and widely recognised as areas of study suitable for amateurs. Professionals in large observatories turned their increasingly large telescopes on more remote objects or concentrated their efforts on astrophysics. The solar system, meteors and variable stars could be observed with small telescopes, field glasses or even the naked eye and were therefore largely given over to amateur observers. It was even thought necessary to introduce a special sub-heading, 'telescopic objects', to distinguish from those which could be viewed with the naked eye.

Despite their considerable diminuition, contributions from amateurs were still in evidence. Frank C. Dennett's monthly 'Sunspot disturbances' functioned somewhat after the manner of Denning's 'Notes on comets and meteors' in that Dennett organised amateurs and collected their observations. 'On the study of stars by amateur observers'[57] by Chambers was but the first article in a series designed to give practical help and instruction for those with little astronomical knowledge to embark on a course of observation.

The 'Astronomical notes' were a new feature which dealt largely with the activities of professionals, especially American astronomers at the exceptionally well equipped observatories of, for example, Mount Wilson and Flagstaff. As with Nature, a move towards an international, and therefore more professional, conception of astronomy occurred. For instance articles on foreign institutions such as the German Astronomical Society appeared.[58] One article, 'Numbering the stars', [59] comprised an historical introduction and an account of the by then virtually completed Astronomische gesellschaft star catalogue. This international project was completely removed from the experience and potential of the majority of even the most committed and skilled amateurs. The divide between amateurs and professionals was enforced by these and other measures, such as biographical sketches.[60]

In the last issues of Knowledge (1916-17) the culmination of these trends may be seen. The amateur presence in the journal became gradually less conspicuous until Denning was one of the few remaining amateur contributors and he himself had, by this time, been largely assimilated into the professional community. He spelled out, on more than one occasion, the importance of mass observation by amateurs and the subsequent ordering and interpretation of their data by professionals. For example, he remarked:

'More abundant observations of greater accuracy are needed...

Fortunately, an observer may, from naked-eye records, obtain a degree of accuracy scarcely considered possible'.

He went on:

'Multiple observations of identical meteors are extremely valuable when accurate, as they indicate beyond question the correct place of a radiant. In cases where radiants are assumed from records of meteors by one person there must always be doubts attached to them, except in those instances which are unusually well corroborated by ample data. To apply radiants to singly observed meteors is a most delicate and difficult proceeding, requiring sound judgement, based upon long experience and a consideration of all the features involved'.[61]

That is, a lone observer could not do anything with her/his data; many observers had to be coordinated and their combined results given over to a person with the appropriate skill and experience to be properly dealt with. The editorial policy of professional astronomers directing amateur labours was most blatantly manifested and consistently executed in the professional control of the regular monthly column. 'The face of the sky' was conducted successively by Fowler, Shackleton and Crommelin. The last of these was, significantly, later to write regular astronomical columns for both Conquest and Discovery.

The new relationships within astronomy were firmly established by the end of the First World War. Two journals survived long enough in the inter-war period to be able to influence amateur activity in regular astronomical columns. These were Discovery and Conquest. Both journals presented astronomical participants as basically divided into two separate groups of workers. Amateurs did routine work for professionals. The situation in the 1920s represented the culmination of trends begun in the closing decades of the nineteenth century.

(iii) Discovery

The regular feature, 'Among the stars: a monthly commentary', was written by J.A. Lloyd[62] until 1927, when he was replaced by A.C.D. Crommelin. Both authors addressed amateur observers as a distinct and identifiable group, but the work these produced would not have been of the same standard as that of the amateurs who read and used Knowledge. Revealingly, Lloyd stated at one stage that 'some interesting problems in relation to the earth's rotation have lately been engaging the attention of astronomers',[63] implying that 'astronomers' were a special breed apart from the readership of Discovery. Technicalities were avoided. For instance, expressions such as '...a little to the left of...' were preferred to precise measurements in disciplinary terminology. In this way amateurs were excluded from a constitutive element of the science: its language.

The divisions present in the regular monthly column were reinforced by articles, two of which were particularly significant. These described the policy advocated not only by the periodical itself but by the larger professional community whose members constituted the great majority of contributors. 'The amateur's work in astronomy', [64] a normative piece by Leon Campbell of the Harvard College Observatory explicitly stated the kinds of observing suitable for amateurs and the relationship this bore to the work of the professional:

> '...professional astronomers rely almost entirely on the results of these amateur observers for the fundamental data necessary to a better knowledge of the causes underlying the variations'.[65]

Campbell described and commended already existing schemes for coordinating amateurs, the main purpose of which was 'to secure those observations that will be of the greatest value to the professional astronomer'.[66] In attempting to recruit newcomers to astronomical observation he insisted in

Baconian tones that 'the work is not difficult. It requires considerable perseverance and patience'.[67] In an article addressed to professional astronomers, amateur observers and a more general readership (which included potential recruits to both of the participating groups), Campbell was endeavouring not only to draw new workers into the field, but to ensure that they would, together with existing amateurs, be organised and directed by his professional colleagues. He concluded:

> 'A closer relation between amateur and professional will doubtless tend towards a more widespread interest in astronomy, and both astronomer and amateur will benefit by the contact and cooperation'.[68]

In contrast, 'Astronomy widens its vision', [69] by Crommelin, part of a series in which the current state of and future prospects for a number of disciplines were discussed, had no place for the amateur. A purely descriptive article with an international theme, it concentrated on the possibilities offered by constructing increasingly larger telescopes. The emphasis on professional work was typical. Many articles were accounts of stellar and spectroscopic astronomy, areas which relied to a great degree on expensive instrumentation. More accessible articles were frequently framed in historical terms and twentieth-century professionals portrayed as genealogical successors to the earliest astronomers. Amateurs were largely ignored.

(iv) Conquest

During its first year Conquest did have regular monthly astronomical articles but these were unlike the standard column and were not designed to help observers in any practical way. Written by J.H. Elgie, an amateur and

B.A.A. member, they were sometimes topical. For example, 'The herald of winter'[70] of December 1919 referred to Orion, but most of the text was devoted to the myth which gave the constellation its name, and much romanticising about 'scenes of stellar gorgeousness'[71] and the like.

By 1922 the feature had settled down to detailing the month's events, concentrating on those 'which are well worth the attention of the humblest amateur possessed of but slender means'.[72] In most months, separate accounts of professional activity and instrumentation provided the greatest contrast presented by any of these periodicals.

From July 1925, when the column was placed in the hands of J.A. Lloyd, F.R.A.S., it was specifically devoted to amateur interests. Lloyd subscribed to the new relationships which the general science periodicals had been significantly involved with establishing. In introductory articles he wrote:

> 'It is perhaps not generally known that the branch of astronomy that is concerned with the physical features of the planets is almost entirely in the hands of amateurs. ...Moreover, the routine work of an official observatory prevents the staff from devoting more than cursory attention to this and kindred subjects'.[73]

Lloyd then spelled out exactly what was known/unknown about each planet, at least as far as was sufficient to define problems for amateurs. He offered practical hints on how to proceed, for example by suggesting the most appropriate telescope size for particular kinds of observational work. In the June issue of that year Lloyd advised 'The astronomer on holiday',[74] which in effect delimited areas of study for which a telescope was unnecessary. The amateur reader was nevertheless left in no doubt as to the great divide which by this time existed between him/her and the professional élite.

It is therefore evident that in the four decades following 1890, attempts were made in general science periodicals to influence the structure of the astronomical community in ways which paralleled developments in other areas. Amateurs were relegated to a supportive, dependent and subordinate position with respect to professionals. The latter group acquired control over the discipline. A distinct hierarchical structure replaced a cooperative relationship in which both groups enjoyed comparable status. General science periodicals contributed to this change in two main ways: firstly, by directing the work of amateurs through regular astronomical columns; and secondly, by offering particular representations of the astronomical community. Regular publication was the key to their effectiveness. It was possible to introduce variations in presentation gradually over a period of time, maintain a constant yet ever changing profile in the astronomical world and to guide amateurs, defining their problems, methods and identity with a consistency unique to the medium.

4. Natural history

a) Background

The history of astronomy is undoubtedly complex. In comparison with that of natural history, however, it appears relatively straightforward. The most conspicuous problem in the study of the latter is revealed by a consideration of the modifications of meaning over time undergone by the expression 'natural history' in terms of the subject matter it designated.

During the late eighteenth and early nineteenth centuries, the term was used in an all-encompassing manner, to include virtually anything in science which would not today be regarded as part of the 'physical sciences'. Grouped together under the label 'natural history' were those areas of study which later became known as, for example, zoology, botany, ornithology, meteorology, entomology and geology. Specialisation in the late nineteenth century progressed to the extent where David Allen can claim that differing reactions by particular groups of naturalists to Darwin's Origin of species (first edition, 1859) indicated that '...the main constituent studies were by now largely self-contained'.[75] Yet 'natural history' was still a widely-used term at the end of the nineteenth century, despite considerable ambiguities attached to its meaning. Each of the 'constituent studies' altered at its own rate and underwent individual developments. This makes the study of natural history a much more involved operation than a study of astronomy. Whereas the latter examines one more or less definable scientific discipline, the former takes for its raw material what was essentially a cluster of such disciplines, their growth from common roots and their relationships.

Vicissitudes which the relationships between amateurs and professionals in natural history underwent after 1890 can be analysed in terms of two complementary frameworks. One is provided by David E. Allen in his social history of natural history, The naturalist in Britain,[76] and the other by Garland E. Allen in his self-admittedly 'internalist' account of the development of late nineteenth- and early twentieth-century biological science, Life science in the twentieth century.[77] Both have valuable insights to offer. D.E. Allen's work is, however, more closely related to the concerns of this chapter. Specifically, he attends to the importance of the amateur in the development of several scientific disciplines. In contrast, G.E. Allen is unconcerned with this aspect. Accordingly, the following account draws more heavily on D.E. Allen's social history than G.E.Allen's internalist narrative.

Before 1859, study of nature had consisted, virtually exclusively, of collection and classification. Darwinian evolution posed a whole set of new problems to be solved. This required different skills and techniques, other than those of the traditional naturalist. The new 'biologists', typified by T.H. Huxley, had 'to probe beneath the surface of nature and explore processes and mechanisms'.[78] Field work was thereby fundamentally devalued and emphasis shifted to laboratory experimentation. Furthermore, some of these new scientists had imbibed the professional ethic whilst studying in Germany. Because of these circumstances, conflict arose between the new professionals and the existing amateurs.

The proliferation of specialist scientific journals in the second half of the nineteenth century has been described in Chapter 2.[79] Increasing numbers of scientists allowed for the creation of a literature which did not depend upon amateurs for its survival. Together with specialisation and differentiation of the sciences this led to the evolution of a scientific language (or rather languages) particularly suited to the requirements of the scientific élite. The linguistic barrier performed overlapping cognitive and social functions. Scientific knowledge production benefitted; amateur practitioners were more and more excluded from reading and comprehending scientific texts. Amateurs were understandably resentful at this turn of events: general science periodicals (sometimes founded as a response to these developments) frequently commented on this question of language. Knowledge, for example, lamented in 1910 that scientific work 'seems to have passed more and more completely into the hands of professional scientific men, whose language is unintelligible to any but their brethren'.[80] Also, in their deeper probing into nature's secrets, the professionals came to be perceived as violating nature and ignoring the aesthetic aspects of their work.

Antagonisms, however, worked both ways. The young biologists believed that their 'programme' was urgent and of the utmost importance. The opposition they encountered from older men, especially those in universities with control over resources, left them frustrated. Natural history, systematics and field work became associated with this older generation which led to the younger generation of biologists becoming 'militant anti-amateurs'.[81] The length of time the new biologists had to wait to realise their aims strengthened feelings of hostility. Led by their mentor Huxley and committed to the professional ideal, these new biologists were closely connected with Norman Lockyer, the 'Young Guard' of British science, and the foundation of Nature, to which several were regular contributors. Amateurs had little to do with the new professionalising science and continued to work much as before, although accounts of local flora and fauna proliferated. It was not until after the First World War that amateurs and professionals were to cooperate in a manner similar to that of astronomy.

From c.1890, changes occurred in the relationships between and within these groups as well as in attitudes towards what each group should have been doing. Most notable in the 1890s was a move among amateurs away from collecting specimens, to preservation and ultimately conservation. Naturalist activity gradually switched to observation rather than hunting, shooting and collecting. This fundamental change in attitude can be explained by citing a number of influential factors.[82] Photography provided an impulse, particularly during the Edwardian era. So too did the large-scale feeding of wild birds which began in the winter of 1890-91, the involvement of women, and the greater popularity of flats as opposed to houses which proved awkward for the storage of collections.

Also significant in the changing attitudes towards nature and ultimately in the reconciliation of professionals and amateurs in natural history was a cluster of ideas which D.E. Allen collects together under the label of "vitalism". He attributes a considerable degree of importance to these ideas but does admit that their influence was not, in many cases, consciously realised. Although writings in general science periodicals displayed evidence of such an influence, Allen's label of "vitalism" was rarely used, and the fundamental ideas which constituted the cluster were explicitly articulated only occasionally.

According to Allen, the new so-called "vitalist" philosophy of the late nineteenth century can be seen as part of the 'neo-romantic' cultural movement with which it coincided. This philosophy arose in part as a reaction against Darwinian evolution. Elements of pre-Darwinian orthodox belief were combined with the encouragement of a more positive, cooperative conception of evolution, and the harsh, competitive interpretation of evolutionary theory was rejected. Darwin had reduced the difference between man and animals to one of degree, rather than of kind. This was now taken further - the idea of a creative life force shared by all life-forms and directing evolution led to a reverence for and an aesthetic appreciation of all nature. To kill became wrong: man and animals were equally part of one unified nature. Professional scientists, notably J.A. Thomson, expounded this philosophy which became widespread. This was achieved most effectively in education: nature study was the educational embodiment of the philosophy and became a compulsory subject in all government schools in Britain by 1900.

These ideas affected natural history in other ways, claims Allen, for example in their influence on writings in popular media. In a positive sense, works permeated with an emotional aspect drew more and more readers into the world of, e.g. ornithology (the works of W.H. Hudson fall into this category). This emotional element, however, also had a negative impact when taken too far. Life histories frequently degenerated into anthropomorphism.

In addition, field work was encouraged as opposed to isolation from nature in the laboratory. Here the pervasive influence of Bergsonian philosophy made itself felt.[85] For Bergson, intuition was a way of acquiring knowledge, a knowledge utterly different from that derived from analysis. Through intuition, a direct appreciation of, or a kind of identification with an object could be made. It was a particularly appropriate way of learning about nature as it gave direct access to the "life-force" (Bergson's élan vital). Analysis in the laboratory precluded such knowledge at a transcendent level, this knowing experience, which could only be arrived at by means of an intuitive communion with nature. In this respect Allen's "vitalism" was to prove significant in the eventual reconciliation of amateurs and professionals.

In a parallel fashion, G.E. Allen points to the significance of a contrasting cluster of attitudes which he terms "mechanism". Essentially, this amounts to the belief that biological laws can and should be reduced to physico-chemical laws. Allen argues that 'experimentation and a mechanistic outlook became prominent in biology between 1890 and 1915'.[84] Biologists, he claims, derived their experimental and materialist philosophy from the physical sciences and physiology. These biologists were the heirs of Huxley who had managed to get their programme underway. They were reacting, not only against the pre-Darwinian idealism in biology, but to the post-Darwinian preoccupation with morphology. Such an outlook was prevalent between these dates, and its origin in the physical sciences and physiology is made all the more plausible in view of the British biologists admiration for the German model, its professional ideal, and their desire for a status equivalent to that of physics and chemistry. Further, G.E. Allen maintains that materialism in biology continued indefinitely as the dominant ideology from the 1890s, although developing from a somewhat naive mechanism into a more sophisticated holism after the First World War.

The increase in ornithological interest around the turn of the century was helped considerably by the writings of W.H. Hudson. The bicycle and, later, motorised transport opened up the countryside to many more people. Because of the increasing numbers becoming involved, and the nature of the subject, ornithology took the lead in reforming itself and moving towards a cooperative and highly coordinated enterprise which joined amateurs and professionals in a way not unlike that reached in astronomy. The paths the two took were very different. Ornithology is therefore the discipline which is the most frequently discussed below.

The nature of the subject itself also favoured the cooperative approach. Large numbers of birds required large numbers of observers all over the country. Studies on geographical distribution and migration were the most suitable. During the 1880s some pioneering work on migration was carried out, but it was only from 1907, due largely to the efforts of Harry F. Witherby and Francis C.R. Jourdain and the increase in the numbers of people engaged in ornithology, that such large-scale ventures took off. Even so, and despite the popularising efforts of Julian Huxley after 1912, it was only after the First World War that amateurs and professionals cooperated together in mass observation schemes, with the professionals organising and interpreting the data which was largely gathered by the amateurs.

b) The periodicals

(i) Nature[86]

The role of Nature in the developing relationships between amateur natural historians and professional biologists was not a conspicuous one. As an organ largely produced by and for the new professionals and edited by Lockyer, it upheld the distinction and maintained the distance between the two groups. By the time cooperation and reconciliation approached, Nature was pursuing its policy of becoming almost exclusively a journal of professional communication. Yet, as ever, Nature provided a crucial example and some important developments were reflected in its pages.

The mode of classification adopted by the journal reveals something of its policy with regard to amateur natural history. At the turn of the century, entries under 'natural history' in the index made virtually no mention of professional activity.[87] Most of what Nature considered to be 'natural history' definitely belonged to the amateur world, was almost entirely separate from the professional world, and furthermore consisted largely of book reviews.

The books reviewed were mostly of a 'popular' character and the majority of the reviews were written by Richard Lydekker. Lydekker had joined the Geological Survey of India in 1872 and worked on fossils in the Indian Museum. Upon the death of his father in 1882 he returned to England. He worked at the Natural History Museum until his death in 1915 but was not an official Museum employee: he was supported by his own private income. The type of book described above, the typical amateur work which was essentially a survey of a local district, was regularly featured. In one such, it was remarked that 'collectors will find the catalogue exceptionally valuable'.[88] The tension between the two points of view, collection and conservation was clearly manifested in the texts. For example, one review said of observation with field glasses:

> 'and it may become a most welcome substitute for the predatory habits of private egg collectors, who are perhaps the most dangerous enemies of our wild birds.'[89]

This review of three books was one of many to include a work by W.H. Hudson.

That amateurs contributed to the journal, and were still in the process of awakening to conservation, is evident from the correspondence. For instance, one G. Stallard wrote that he had killed 29 chamois and determined their temperatures.[90]

Similarly, most of the entries under 'ornithology' were reviews. Lydekker expressed his (typically professional) dislike of the type of survey work which blossomed among amateur naturalists after 1860. He remarked that recording the past distribution of existing species and the characteristics of the rapidly disappearing species were 'the chief justification for... country ornithologies'.[91] Most interesting was again the correspondence. Oswald H. Latter, Senior Science Master at Charterhouse School wrote (on 30th August) to request that readers, especially those destined to take seaside holidays, make observations of swifts and send them to him.[92] This illustrates the fact that even in 1900, the correspondence columns of Nature could be used for communication between amateurs. Despite concessions such as these made by Nature, the journal's underlying lack of commitment to amateur natural historians is highlighted by the virtual absence of reports of meetings of local scientific societies.[93]

It is therefore clear that to a limited extent Nature provided for the amateur naturalist. Nevertheless, the naturalist's role, be it the old one of collecting and classifying or the newer, emerging one of observing, was well defined and clearly demarcated from the professional identity. So much so, in fact, that Lydekker, reviewing a work by W.P. Pycraft (himself a professional)[94] felt it necessary to point out that although the work was 'popular',

> 'the volume contains many passages which are well worth the attention of the scientific ornithologist.'[95]

Material indexed under biology was concerned with the activities and researches of professionals, laboratory work, but most importantly with theory.

A decade later, although shooting and collecting were still part of the ornithologists' scene, attitudes had changed. Conservation ideas figured directly and in greater quantity. Conflict nevertheless remained. An anonymous review, 'Kentish birds', [96] noted the importance, when compiling a list of rare birds, 'of the existence on the spot of a bird-stuffer'. Yet the alternative viewpoint was presented in the same article; the emphasis was shifting. Although the amateur and professional were still perceived as distinct, the germs of change are discernable. An anonymous reviewer commented of W.P. Pycraft:

> '...but we must confess that he seems to us somewhat hard upon the "field naturalist", the results of whose labours he terms "a pitifully small gain to science". It is true that such an one often lacks the training or opportunity necessary for scientific research, but his province is more especially to supply material for the work of his fellows, and must never forget that Darwin and Wallace - not to mention later instances - were essentially field naturalists'.[97]

Large numbers of reviews of nature study books provided the staple of the natural history in 1910. Significantly (for both were linked by the vitalist philosophy), this was accompanied by a virtual obsession with conservation. Yet ambiguity remained. Hence a man who had 'killed only one hundred specimens' could still be described as 'certainly not a destructive ornithologist'.[98]

Thus the distinctions between naturalists and scientists were as sharp as ever, although the early seeds of what was to become a cooperative relationship were present. Catering for an amateur audience served several functions, not least of which being to attract committed subscribers at a time of financial uncertainty. Enunciation of the 'radical' differences between amateurs and professionals defined an independent professional élite and acted as persuasive advertising for the claims of the new profession. Furthermore, many of these amateurs belonged to the traditional, influential professions of law, medicine and the church. Together with teachers, they could effectively disseminate the idea of a viable and autonomous profession.

(ii) Knowledge

Nowhere was the contrast between astronomy and natural history more apparent than in Knowledge. They were the two subject areas which made up the bulk of the periodical's material at the beginning of the twentieth century. As a crucial step on the road to recognition and rewards, professional astronomers ensured that their own position and status as professionals should be clearly distinguishable. This was achieved by divisive measures (e.g. conflict) and control over amateur methods and problems. The mutual hostility which had existed between amateurs and professionals for some considerable time, precluded such a course of development in natural history.

Between 1894 and 1904, Harry Forbes Witherby, a publisher and amateur ornithologist, was editor of Knowledge. During this period E.W. Maunder was astronomical editor. Although these facts help in understanding the dissimilarities in the presentation of the two subjects, it would be a gross oversimplification to suggest an explanation in purely personal terms. The existing relationships between students of nature meant that a professional like Maunder could not be appointed to direct a periodical aimed at the amateur audience. Far from providing a forum where amateurs and professionals could communicate, interact, exchange ideas and define roles, Knowledge was at this time largely a vehicle for purely amateur communication. Rejected by the professionals, amateurs used its pages to work out their own roles and to define their own methods and problems. They did not have the guiding hand of the authoritative professional telling them what to do. At the same time, there was no conflict between the two groups in the sense of direct confrontation in bitter controversies, the root issues of which were generally status and authority.

In the transition amateur natural history was at this time making from collection and classification to observation, ornithology was a key area. Amateurs began to organise cooperative ventures to study geographical distribution and migration movements. Witherby himself was an outstanding figure in these developments, initially as editor of Knowledge and subsequently as founder-editor of the monthly British Birds (1907), where he used the periodical to organise mass observation exercises.

The profusion of ornithological material in Knowledge is no doubt attributable to Witherby. He conducted the monthly 'Ornithological notes' which revealed the conflict between collection and observation. Although amateurs wrote in with observations, so too did those who had shot birds. The majority of the contributors were amateurs and some were significant figures in the changes occurring in natural history at that time. Rev. F.C.R. Jourdain laid down rules of practice which guaranteed that a bird could be identified by observation alone, thereby rendering obsolete the requirement that birds must be shot to ensure certain identification. Other crucial figures included William Eagle Clarke, who took part in the early British Association funded survey on bird migration (1880s), one of the first cooperative ventures. The conflict between the two approaches in natural history was symbolised by the masthead of the 'Ornithological notes' column which showed both a gun and a pair of field glasses.

It is clear, however, which way opinion, as represented in the journal, was heading. That this was not merely an impression derived from editorial selectivity is shown by the fact that Witherby himself was still shooting birds.[99] The correspondence columns became a vehicle for the expression of impassioned views on the conservation issue. For example, one C.E. Martin wrote:

> 'In almost every issue of Knowledge we find such and such a rare bird in such and such a neighbourhood has been shot there! Whatever reason is there for the immediate despatch of every rare bird that appears within gunshot of these collecting maniacs and their agents?'.

and that:

> '...this collecting of skins... is antagonistic to the true interests of Nature observation'.[100]

Ornithological articles were mainly written from the conservation point of view. Further, they were clearly influences by that cluster of attitudes and beliefs which D.E. Allen dubbed "vitalism": man and nature were part of the same unity and man was not in the business of control over nature. Writings inspired by these ideas ultimately lead to anthropomorphism. Charles A. Witchell exemplied these trends. In one article 'The bad language of wild birds',[101] whilst criticising other writers for being too poetic, he attributed human emotions to birds: 'This must be credited to hatred and ill-will'. At the same time Witchell encouraged his readers to go out in the field and observe:

> 'The subject is so new that anyone who will carefully notice may do good work, and at no cost to bird life.'

This theme was carried on in 'The love gifts of birds'.[102] Witchell suggested that the country should learn from the city in its treatment of birds (city feeding of wild birds became hugely popular in the winter of 1890-91) and continued:

> 'In some earlier articles in Knowledge I have endeavoured to prove to the person who is developing an interest in bird life (with the usual results), that if he does but sit down under a hedge instead of searching it, and looks and listens, he may gather a richer store than ever filled a collecting box, though it be but a store in memory's cinematograph.'

In the same article, when speaking of the gifts of food made by male to female birds in courtship, Witchell claimed:

> 'This incident proves the bird to be akin to man in sense and feeling.'

'On the duty of a field naturalist' (by E.A.S.E.)[103] put forward the main tasks of the naturalist as 'truth, keen observation and sympathy'. The 'sympathy' implies this author too was influenced by vitalism.

Collectors, of course, still existed. The Rev. T.R.R. Stebbing advocated collecting box crustacea as other specimens were apt to smell and take up a lot of space.[104] Stebbing was highly unusual among amateur contributors in his interest in theory, specifically Darwinism. Darwin got very little mention in Knowledge at this time (unlike Nature), in fact theorising was extremely rare. Articles for and by professionals were few and far between. Although Richard Lydekker did contribute, his status as a museum worker was ambiguous. Museums were essentially storehouses for collections and came under attack from the new biologists.[105] He nevertheless criticised the collector approach:

> 'At the present day, owing partly to the anxiety to describe new species, and partly to the desire to obtain specimens of every animal for our museums, there appears a great tendency for intelligent explorers and travellers to degenerate from field naturalists into mere collectors.'[106]

Professional activities were not described and laboratories not mentioned.

At the start of 1904 Knowledge merged with the Illustrated scientific news. The latter was edited by E.S. Grew, who had enjoyed an education in mathematics and a career in journalism. Together with Major B. Baden-Powell (brother of the famous scout), Grew assumed Witherby's editorial responsibilities. The Illustrated scientific news had concentrated on the physical sciences. Baden-Powell's interests included aeronautics and war. The reign of the new editors saw greater changes in the policy of the journal. Natural history ceased to be as prominent as it had been under Witherby.

By 1907, the 'Ornithological notes' were just one of many, including physical, chemical, geological, zoological and botanical notes, microscopy and photography pure and applied. The 'Zoological notes' were conducted by Lydekker and 'Microscopy' by F. Shillington Scales (eminent physician, curator, honorary secretary and Vice-President of the Royal Microscopical Society). Most significantly, the 'Ornithological notes' were taken over by W.P. Pycraft, another employee of the Natural History Museum, whose low opinion of the amateur field naturalist has been noted above. Much of the material in Pycraft's column was nothing more than brief reporting of articles or recorded observations from the current issues of British birds, the Field and the Zoologist. Witherby continued in his role as coordinator of amateur observations at British birds and no doubt took some of his Knowledge readers with him.

The conflict between shooting/collecting and preserving/observing had virtually vanished from the journal by this date. Pycraft persistently and vigorously attacked the collecting mentality. For example, in describing how pairs of birds of species once common in Britain, but eradicated/chased away by humans, occasionally returned to old breeding grounds, he wrote:

> 'Owing to the evil work of that pest the "collector" of British birds' eggs, these stragglers are rarely successful.'[107]

The majority of articles proper dealing with natural history subjects were similar in that they took the form of a professional describing the lives and habits of particular animals from a zoological standpoint. Frequently these were foreign species which could not be studied in Britain. In this context amateurs were mostly excluded.

To do justice to the periodical as it stood in 1907 it must be said that a small number of articles for amateur naturalists remained. Changing the readerhip of the journal had of necessity to be a gradual transition as anything too hurried carried the risk of financial collapse. One such article, 'Test diatoms at home',[108] provided detailed instructions on how to obtain a sample of diatoms, to clean them and finally to mount them. The reader was actually assumed to have considerable knowledge of microscopical techniques. Following these instructions, the (serious) amateur microscopist could hope for a specimen slide '...approaching more closely to the professional standard'. Crucially the author, Professor G.H. Bryan, was a professional and, although his research centred on aeronautical engineering and mathematics, he was a one time president of the Cambridge Entomological Society. Along with Lydekker, he was one of Nature's most prolific leader writers of the twentieth century's opening decade.

What is most striking about the period between 1904 and 1910 is the extent to which amateur contributions had declined and were replaced by professional writers. One consequence of this was the absence of any debate over the collection/conservation issue: the professional attitude towards collection was no doubt responsible. The high professional profile and the growth of physics and chemistry at the expense of natural history and astronomy, created a journal in which it was possible for a professional physicist to make the following reductionist claim:

> 'The origin of life... comes... more with the realm of chemistry, or indeed more appropriately physics, than within that of biology or zoology.'[109]

All these radical changes show how Knowledge had shifted from being essentially an amateur publication to one controlled by professionals and with their interests at heart.

The trend initiated by Grew and Baden-Powell suffered a reversal at the hands of Wilfred Mark Webb, who supplanted Baden-Powell in 1910. Webb was active in the nature study movement[110] and embraced its underlying vitalist philosophy. He demonstrated commitment to conservation work and later in life was to become a member of the Council of the National Trust. Because of his influence, Knowledge showed signs of growing into a journal shared (although by no means equally) between amateurs and professionals. Vitalist ideas were gaining an increasingly widespread currency and were responsible for imparting the critical impulse to perceptions which ultimately led to reconciliation of the two 'communities' of nature students. One of their chief and ablest exponents was J. Arthur Thomson, to whom Webb gave the job of writing the 'Zoological notes'.

The 'Notes' assumed greater importance under Webb than they had previously done. The ornithological notes were the responsibility of Hugh Boyd Watt until the last months of 1912. Watt was an amateur who maintained the conservation theme. He bemoaned the lack of knowledge of migration[111] but failed to suggest how the situation was to be rectified. Typical of the amateur position was this recognition of problems combined with lack of ideas with regard to their resolution. When Webb took over the column (November 1912, by which time it had been renamed 'Ornithology') its increased length enabled him to write what were virtually articles instead of brief concise paragraphs. 'The Brent Valley Bird Sanctuary - an experiment in bird protection',[112] his contribution to the December issue, was a reprint of a paper he had previously delivered to the Conference of Delegates of the British Association. Here he described his efforts as Chairman of the Brent Valley Bird Sanctuary Committee to help preserve the bird life in a small wood. The descriptions were doubtlessly intended to provide a model for action by other societies.

Furthermore, Webb publicised James Buckland's address to the Selbourne Society (of which Webb was secretary) in 1910. 'The extermination of birds'[113] occupied a whole glossy page and took the form of an appeal. Buckland had claimed that the feather trade had exterminated the white heron in China. Predictably, responses from the feather dealers denied this and other accusations. Knowledge appealed for 'independent evidence' on certain questions of fact. The position of the journal had been outlined at the outset:

> 'The true naturalist, for scientific reasons, grieves to see any bird exterminated.'

Further:

> 'An obligation rests on us to ensure that our children's children shall not be bereft of the heritage of beauty which nature has evolved during countless years, beside which the age of man is a negligible quantity'.

The possibility of a mutually beneficial relationship between amateur naturalists and professional scientists was admitted under Webb. How this relationship should develop was clarified. For example, in 'The protura',[114] Richard Bagnall related anecdotally how he found insects lacking both wings and antennae. Examination under the microscope merely reinforced Bagnall's initial impression that he had discovered a 'completely new' kind of insect. He was to be disappointed, however, because on contacting Professor Filipo

Silvestri he found that the latter had described these insects as long ago as 1907. The moral of this tale was, of course, that the professional authority invariably possessed wider knowledge and greater expertise to which the amateur must of necessity be subordinated.

Despite moves away from the 1904-10 policy, such as amateur participation with Knowledge, professionalism and its concerns remained an integral part of the periodical. Margaret R. Thomson wrote 'The subtlety of life',[115] one of a number of articles promoting the idea of 'life' as an object of study. Investigation of the fundamentals of life in the laboratory had previously been the exclusive preserve of the professional biologist. Describing it here was indicative of links being established between the disparate worlds of the professional and the amateur.

Until 1904, Knowledge, in so far as natural history was concerned, was essentially a medium for communication between amateurs and was largely separated from the world of the professional. Between 1904 and 1910, the policy pursued attempted to make Knowledge into a journal for a wide range of interested non-scientists and for communication between scientists in different fields. Although a residue remained from the periodical's previous twenty years of existence, the intention in this period was clearly to purge Knowledge of the amateur participant. The journal was to be of use to aspiring professional scientists in two ways: firstly to establish and propagandise their new professional status, and secondly to keep them informed of progress in other disciplines. Following the 1910 management changes, new blood and a new philosophy eventually began to find a place for the amateur and started on the road to reconciliation between two groups. The door was opened by altering the attitudes and beliefs which constituted two mutually exclusive ideologies. The plan for the future was that of the professional as the authoritative and naturally senior partner in any relationship. Once the ground had been broken, the possibilities for cooperation were realised and remained to be explored in the 1920s and 1930s.

(iii) Discovery

During the 1920s, this periodical encouraged the combination of amateur and professional efforts. Controlled largely by professionals, the unique opportunities afforded by the general science periodical made Discovery's attempts to contribute to the reconciliation of the two groups of 'natural history' workers, both interesting and significant. It contained within its pages what amounted to a manifesto which defined the new status, methods and problems of the amateur naturalist. In these respects it invites a drawing of parallels with the functions of Knowledge performed for astronomy around 1900.

The world of the professional theoretical biologist had been closed to the amateur in earlier general science periodicals. In contrast, the Discovery subscriber could read of this work, past, present and future, in articles penned by those engaged in the work, the professionals themselves. A typical example would be Julian Huxley's 'Recent work on heredity'.[116] Such articles undoubtedly reinforced the divisions established by tradition but, as was the case with astronomy, clear definition of the professional élite as a distinct and autonomous entity was a necessary condition for cooperation.

Amateurs were actively encouraged to make their own observations. Descriptive accounts of British flora and fauna were frequently accompanied by hints on how to proceed. Occasionally articles went further. 'Private sea-water aquaria'[117] was described as an 'extremely practical article' by its authors, T.A. Stephenson of the Zoology Department at University College and W. Edgar Evans of the Royal Botanic Garden. Here detailed instructions for the establishment of a marine aquarium were given. Numerous texts included statements about the lack of current knowledge of the behaviour of certain species. Typically:

> 'The habits of spiders are so imperfectly known that new features are certain to be observed by anyone who keeps and watches them.'[118]

Ornithology was the first discipline included under the 'natural history' umbrella to become organised in respect of its professional/amateur relationship. As a precursor to the more explicit statements which were to follow, Julian Huxley made the following request in 1922 in the context of an article in which he described his own researches into the red-throated diver:

> 'In conclusion, let me ask anyone who may be in a position to fill any of the gaps in my observations to be so good as to write to me with the information. I shall be most grateful. Especially interesting would be observations on the first period, before mating up, in Great Britain.'[119]

The preceding account of Huxley's own observations provided a model for the amateur to follow.

One amateur ornithologist, E.M. Nicholson, campaigned tirelessly for changes in ornithology - specifically reconciliation between professionals and amateurs and a high degree of organisation. In 1930, he contributed a seminal article to Discovery: 'The next step in ornithology'[120] was a declaration of intent, a plan for the future.

Writing from the amateur point of view, Nicholson outlined the problems with the existing situation. He pointed out that 'the whole tradition of ornithology is strongly anti-scientific', condemned the prevalent dilettantism and referred to

> 'that essential change of attitude without which ornithology must continue to be an amateur and haphazard pursuit leading nowhere in particular'.

and argued that

> '... most of the people concerned are wasting all their time, and practically all of them are wasting a good deal of their time'.

His proposed solution was 'guidance' and organisation. These were to be provided by 'the small minority of trained, whole-time experts'. As Nicholson perceived the situation:

> 'That the ordinary observer is a creature of habit rather than enterprise is inevitable from the circumstances of his life; he has neither scientific training nor the opportunities to keep abreast of his subject, and no one is more ready to recognise how much he might benefit from expert direction within suitable limits. The strength of the demand to be given something useful to do is evidence that the tendency towards a more definite organisation of ornithological work is not confined to the scientist, who appeals for more eyes and ears to secure data which he urgently needs, but is shared by the keen yet untrained lay observer aware of the repetitive and unfruitful nature of his ordinary occupations'.

Nicholson was appealing to both groups. Amateurs and professionals needed one another. A periodical read by both was the ideal medium for attempting a reconciliation. Discovery provided precisely such a medium.

5. Physics

It has been argued that physics in Britain only attained professional status as late as the Second World War.[121] So far as this argument is based on the insufficient employment opportunities available to graduates it is justified. In addition, the conclusion is supported by the lack of recognition as a profession the discipline received outside its own boundaries. These two aspects are, of course, closely connected.

By the 1890s, a considerable number of posts for graduate physicists had been created at the new university colleges, polytechnics and technical colleges. the increase in numbers of those teaching physics naturally meant a corresponding rise in those graduating from such institutions. The teaching posts were welcomed by advocates of professionalisation, for education, as a means of both persuasion and provision of an intellectual identity, constituted an essential and integral part of the professionalisation process. Yet the constantly increasing population of teachers (at all levels) engendered a critical situation, highlighting the pressure of demand for extra-educational employment - in industry and for government, for example. Simply stated, the supply of graduate scientists far exceeded the demand for their services. It was really only at the National Physical Laboratory (founded 1900) where such posts existed. Opportunities did increase between the two World Wars (particularly in government service), at the War Office Research Department, the Patent Office and the Radio Research Board, for instance), but the situation remained unsatisfactory until the second.

Despite the obstacles which hampered the professionalisation of physics it was, by the end of the nineteenth century, far more advanced than 'natural history'. Although employment prospects were severely limited, they nevertheless greatly exceeded those available within 'natural history'. Physics also had an established intellectual identity. Of greatest importance to this discussion, however, is the fact that professional physicists had already achieved undisputed control over their discipline.

The distinctive work of nineteenth-century physicists, namely electromagnetic theory, thermodynamics and kinetic energy, had considerable mathematical input. Physics became increasingly mathematised. The relationship between theory and experiment grew to be more intimate. Much experimentation increasingly demanded expensive instrumentation in addition to the necessary imaginative and manipulative skills. These developments had the effect of excluding amateur participants. Without formal training they found it more and more difficult to understand the latest researches, let alone follow them up. Lack of adequate facilities precluded many. Whereas in natural history and astronomy there were suitable tasks for them to perform - meaning not only were many amateurs competent, but also that professionals needed and therefore permitted amateur involvement. In contrast, there was no parallel role in physics: the amateur was redundant. Neither was the amateur in physics sufficiently powerful to be able to mount a serious challenge to the professional as was later to be the case in astronomy.

Therefore the general science periodicals in this study did not address amateur physicists because such an audience was effectively extinct by the 1890s. Furthermore, the priorities of emerging professional physicists lay elsewhere. They used the periodicals more appropriately according to the more advanced stage they had reached in the professionalisation process: namely, to secure recognition and rewards <u>outside</u> their own discipline. In this context it is significantly telling that after a long and thorough search only one physics article was found which gave detailed, practical advice to non-professionals on how to experiment. This article, concerned with x-rays, appeared in the issue of Knowledge for April 1896.[122] The new method of photography was perceived as the 'discovery', and not the phenomenon itself. The accompanying illustrations reveal that the purpose of the article was to offer a new tool to students of nature (the x-ray photographs in question represented a sparrow, a mouse, a snake and a child's hand). At this date Knowledge published physics-related articles only very infrequently indeed.

6. Chemistry

Chemistry presented yet another set of circumstances. The growing complexity of chemical theory and its language of expression throughout the course of the nineteenth century similarly tended towards the exclusion of amateurs.[123] As with physics, the growing reliance on laboratory facilities contributed to the disappearance of amateur involvement in the science. Again there was no obvious role into which the amateur could step. Amateur chemists were neither a threat nor a benefit to the professional élite.

The more obvious practical potential of chemical research had ensured an important, if rudimentary provision for employment outside the world of education. Independent, self-employed chemists and academics both acted as consultants to government and industry, especially in analytical work. There were additionally a small number of full-time posts available in industry. (Approximately 225 graduate chemists were so employed in 1902).[124]

In spite of its palpable utilitarian value (which was at that time much greater than that of physics), chemistry suffered from a lack of wider recognition. The problem was exacerbated by the ambiguity attached to the word 'chemist' due particularly to its connection with apothecaries.[125] Furthermore, the Pharmacy Act of 1868 prohibited anyone but pharmacists using the designation 'chemist'. This ambiguous status gave added impetus to the campaign for professional recognition within society. Chemistry appeared little in general science periodicals. Where it did, however, the medium was used to further the immediate concerns of the professional community. During this period the amateur had largely disappeared into obscurity and therefore no provision was made for that type of subscriber.

7. Conclusion

The decisive importance which the professionalisation process had for general science periodicals is therefore evident not only in the extent to which it affected the presentation of the different sciences but, more fundamentally, in the way it dictated the uses to which the periodicals were put.

One preliminary and basic stage in the process was the establishment of professional control over the discipline. This had already been achieved in chemistry and physics before 1890, whereas astronomy and 'natural history' retained a significant amateur element. Charting the development of the relationships between professionals and amateurs reveals parallels. Both astronomy and natural history were transformed by the introduction of a new paradigm, ironically initiated in each case largely by amateurs (astrophysics and evolution respectively). There then followed successive phases of professionalisation, conflict and eventual reconciliation. This developmental model must not, of course, be too rigidly applied. Differences existed in relation to, for example, the origins, nature, severity and outcome of the conflicts, as well as the nature of the reconciliations and the means by which they were achieved. The above framework is nevertheless useful in understanding exactly how general science periodicals contributed to the transition from one situation where the amateur was dominant in science (as both an ideology and a practical reality) to another in which the amateur was more or less completely under professional control.

It has been shown above precisely how amateur scientists came to possess a status subordinate to that of their professional counterparts. Ultimately, in both astronomy and 'natural history', the amateur role was diminished until it became that of data collector on behalf of the professional. Baconian rhetoric was employed to justify this role.[126] The Baconian myth perpetuated the notion that science was open to all comers, and the remaining amateurs were visible evidence of this. Yet their differentiation from professionals and their gradual subordination belied the authenticity of this picture. The Baconian rhetoric not only served to persuade the amateurs themselves of the legitimacy of the changes then taking place, but further, contributed to the establishment and justification of the newly acquired status of the professional élite in a wider cultural context. Controlled amateurs were therefore useful as examples to the wider public: their existence reinforced the notion that science was a democratic enterprise. It was essential that such an impression be conveyed in order that recognition and support for the new élite could be secured in the wider 'democratic' society.

The data-collecting amateur was also directly useful to the professional. It is in the nature of certain sciences that they have an inherent 'observational' component. By accumulating observations, amateurs served professionals in relieving them of onerous routine work. Although observation and theory are inseperable, experimental science like physics and chemistry depends far more obviously on theoretical knowledge from the initial conception of an experiment through to the interpretation of results. It was therefore possible for professionals to set useful tasks for amateurs whilst retaining theoretical knowledge as their own preserve only in those sciences which by their very nature allowed it. Amateurs could not participate in physics and chemistry beyond a trivial level as this would have constituted a threat to professional control by encroaching upon the latter's exclusive domain: theory.

In 1910, with its editorship in amateur hands (i.e. Webb and Grew), Knowledge published an article entitled 'Science and the amateur'.[127] Significantly, the author was Henry A. Miers, a professional scientist and university administrator (he was at that time Principal of the University of London). This presentation of journal policy found Miers writing that Knowledge was to be:

> '...a journal written for ordinary, intelligent people who, without having received any special training, have yet a real knowledge of scientific principles and perhaps a considerable acquaintance with some one branch of science: a journal... designed also to bring the professional worker in touch with those who are interested in his work and are willing and competent to assist him: through it he will perhaps have the opportunity of directing their labours and so making them valuable collaborators in fields of research where such assistance is sorely needed'.[128]

Between 1890 and 1930, the redefinition of relationships between scientific practitioners in general science periodicals was a crucial ingredient in the process of professionalising science. This chapter has been concerned with the ways in which these periodicals helped professionals to gain control over amateurs. In so doing they undermined the existing amateur tradition and appropriated it to serve their own ends. This was, however, but one of several directions in which general science periodicals influenced the transition to professional status. These are explored in subsequent chapters.

Notes and references

1. R.M. Pike, quoted in Morris Berman, '"Hegemony" and the amateur tradition in British Science', Journal of social history, 8(1974-5), 30-50, p.39.
2. Roy M. MacLeod, 'Resources of science in Victorian England: the endowment of science movement, 1868-1900', in Peter Mathias (ed.), Science and society 1600-1900 (Cambridge, 1972), 111-66, p.164.
3. D.S.L. Cardwell, The organisation of science in England (London, 1972), p.207.
4. Ibid., p.215.
5. Pike, quoted in Roy and Kay MacLeod, 'The contradictions of professionalism: scientists, trade unionism and the First World War', Social studies of science, 9(1979), 1-32, p.3.
6. Russell Moseley, 'Tadpoles and frogs: some aspects of the professionalisation of British physics, 1870-1939', Social studies of Science, 7(1977), 423-46, p.429.
7. Quoted in Berman, op.cit. (note 1), p.38.
8. Geoffrey Millerson, The qualifying associations (London, 1964), p.5.
9. Ibid., p.12. Millerson discusses the necessity of 'realisation and recognition of the occupation as a profession, by those outside the occupation', to the professionalisation process.
10. R.M. MacLeod, J.R. Friday and C. Gregor, The corresponding societies of the British Association for the Advancement of Science 1883-1929 (London, 1975), pp.137-141.
11. See Chapter 1, section 1.
12. T.S. Kuhn, The structure of scientific revolutions 2nd ed., (Chicago, 1970).
13. John Lankford, 'Amateurs versus professionals: the controversy over telescope size in late Victorian Britain', Isis, 72(1981), 11-28.

14. Ibid., p.11.

15. A.M. Carr-Saunders and P.A. Wilson, The professions (London, 1964), pp.352-365.

16. Nathan Reingold, 'Definitions and speculations: the professionalisation of science in America in the nineteenth century', in Alexandra Oleson and Sanborn C. Brown (eds.), The pursuit of knowledge in the early American republic (London and Baltimore, 1976), 33-69.

17. Lankford, op.cit. (note 13), p.11.

18. See below, also Chapter 4, section 6 and Chapter 5, section 7.

19. Who was who, volume 6 (1897-1915), (London, 1920), p.142.

20. Agnes M. Clerke, A popular history of astronomy during the nineteenth century 2nd ed., (Edinburgh, 1887), p. 7.

21. The organising committee quoted in Lankford, op.cit. (note 13), p.21.

22. Ibid.

23. H.H. Turner, quoted in A.J. Meadows, Science and controversy (London, 1972), p.225.

24. At least one volume from each year up to 1930 was examined.

25. Lankford, op.cit. (note 13), p.13.

26. W.F. Denning, 'The Perseid meteor shower', Nature, 62(1900), 173-4, p.173.

27. 'Our astronomical column', Nature, 70(1904), 560.

28. Lankford, op.cit. (note 13), p.20.

29. Ibid., p.20.

30. W.F.D., 'Spherical astronomy', Nature, 88(1909), 123.

31. 'Dr. Isaac Roberts, F.R.S.', Nature, 70(1904), 302-3, p.302.

32. 'Our astronomical column', Nature, 70(1904), 256.

33. J. Norman Lockyer, 'Comparison of the spectra of nebulae and stars of groups I and II with those of comets and aurorae', Nature, 42(1890), 342-5.

34. See Meadows, op.cit. (note 23), Chapter 7, pp.175-208 for a thorough discussion of Lockyer's meteoritic hypothesis.

35. Richard A. Gregory, 'Lunar photography', Nature, 42(1890), 568-71.
36. A.A. Common, 'Astronomical telescopes', Nature, 42(1890), 183-7.
37. H.C.P., 'The new Hamburg Observatory', Nature, 85(1910-11), 309-10.
38. 'Amateur astronomy', Nature, 83(1910), 485.
39. Ibid.
40. All the correspondence for each of the years 1890, 1900, 1910, 1920, 1930 and 1939 was examined. Intermediate years were also investigated (as part of the general analysis) but not systematically quantified.
41. Difficulties sometimes arose in distinguishing whether or not a particular correspondent was an amateur or not. In most cases it was relatively straightforward - if biographical details could not be uncovered other clues might suffice. For example, an observatory address would indicate a professional position, sometimes the style of the letter and so on. A small percentage remained of uncertain authorship in these terms, but the relevance of these letters to amateurs is the main point at issue here.
42. W.H.S. Monck, 'The Perseid meteors', Nature, 42(1890), 296; W.F. Denning, 'The Perseid meteors', Ibid., p.342; W.H.S. Monck, 'The Perseid meteors', Ibid., p.390; W.F. Denning, 'The Perseid meteor shower', Ibid., p.390.
43. A.S. Herschel, 'Contemporary meteor-showers of the Leonid and Bielid meteor periods', Nature, 61(1899-1900), 222-6, 271-3.
44. G. Johnstone Stoney and A.M.W. Downing, 'The Leonids - a forecast', Nature, 63(1900-01), 6.
45. W.F. Denning, 'Observation of comets', Nature, 109(1922), 613.
46. E.g. Kr. Birkeland, 'Transit of Halley's Comet across Venus and the Earth in May', Nature, 83(1910), 217-8.
47. J. Hargreaves, 'The annular eclipse of the sun on April 8', Nature, 106(1921), 830.
48. See Chapter 5, section 6.

49. Following the simultaneous demise of Denning and 'Our astronomical column' at the end of June 1931, amateur observations ceased to be reported in Nature. The replacement feature, 'Astronomical topics' only lasted for two years. Thereafter, information as to future astronomical occurrences was given brief (but not weekly) space in the 'News and views' column (which began its life in 1926). Amateur contributions, however, can be said to have died with Denning.

50. Denning was one of the last amateur astronomers to become assimilated into the professional élite.

51. Lankford, op.cit. (note 13).

52. E.g. Phillips, Gore.

53. E.W. Maunder, 'Constellation studies', Knowledge, 24(1901), 12,33,57, 85, 105, 128, 152, 178, 228, 248, 273.

54. E.W. Maunder, 'Astronomy without a telescope', Knowledge, 23(1900), 9, 61, 81, 104, 132, 158, 174, 199, 223, 251.

55. An early example of an amateur astronomer resisting professionalisation was R.A. Proctor (d.1888). Lankford, op.cit. (note 13) gives an account of the controversy over telescope size showing how vigorously Denning and A.S. Williams opposed the new professional ascendancy.

56. A. Fowler, 'The chemistry of the stars', Knowledge, 26(1903), 30, 79, 128, 176, 227, 272.

57. G.F. Chambers, F.R.A.S., 'On the study of double stars by amateur observers', Knowledge, n.s.7(1910), 289-91.

58. F., 'The German Astronomical Society', Knowledge, n.s.7(1910), 480.

59. F.W. Henkel, B.A., F.R.A.S., 'Numbering the stars', Knowledge, n.s. 7 (1910), 23-5.

60. Biographical sketches had many functions, one of which was to mark individuals out as special.

61. W.F. Denning, 'The principal meteoric showers', Knowledge n.s. 13(1916), 38. My emphasis. A radiant is the point from which a shower of 'meteors' originates.

62. Lloyd worked at the Telpyn Observatory, Ruthin, North Wales.
63. J.A. Lloyd, F.R.A.S., 'Among the stars: a monthly commentary', Discovery, 8(1927), 133.
64. Leon Campbell, 'The amateur's work in astronomy', Discovery, 7(1926), 322-4.
65. Ibid., p.323.
66. Ibid., p.323.
67. Ibid., p.324.
68. Ibid., p.324.
69. A.C.D. Crommelin, 'Astronomy widens its vision', Discovery, 10(1929),78-80.
70. Joseph H. Elgie, 'The herald of winter', Conquest, 1(1919-20), 94-6.
71. Ibid., p.94.
72. W.G. Mitchell, 'The heavens in December', Conquest, 4(1922-3), 80-2.
73. J.A. Lloyd, 'The planets through a telescope', Conquest, 6(1924-5), 273-8, p.273.
74. J.A. Lloyd, 'The astronomer on holiday', Conquest, 6(1924-5), 307.
75. D.E. Allen, The naturalist in Britain (London, 1976), p.179.
76. Ibid.
77. Garland E. Allen, Life science in the twentieth century (Cambridge, 1978).
78. D. Allen, op.cit. (note 75), p.180.
79. See Chapter 2.
80. Henry A. Miers, 'Science and the amateur', Knowledge and illustrated scientific news, n.s. 7(1910), 162.
81. D. Allen, op.cit. (note 75), p.184.
82. D. Allen, op.cit. (note 75), pp. 229-35.
83. The point of this exercise is to clarify the terms used in the analysis below. It is not intended to be a comprehensive account of these philosophies, but related only to the issues involved in the mechanist/vitalist debate in biology at the turn of the century, specifically those elements of relevance to the relationships between amateur naturalists and professional biologists.

84. G. Allen, op.cit. (note 71), p.xix.

85. Bergsonian vitalism was very influential at the turn of the century, particularly following the publication of Creative evolution in 1907 and its translation into English in 1911.

86. At least one volume per year was examined for the years 1890-1925. After the War, Nature became more and more a journal for specialist professional communication. A qualitative narrative approach was found to be more meaningful and revealing than a quantitative measurement.

87. Exceptions to this were events, etc. at natural history museums, e.g. 'The unveiling of the Huxley memorial statue', Nature, 62(1900), 10-12.

88. 'Church Stretton', Nature, 62(1900), 571.

89. 'Three books of popular natural history', Nature, 62(1900), 417-8, p.418.

90. G. Stallard, 'The temperatures of recently killed chamois', Nature, 62 (1900), 293.

91. R.L., 'The birds of Surrey', Nature, 62(1900), 339.

92. Oswald H. Latter, 'The migration of swifts', Nature, 62(1900),413.

93. And this despite the fact that membership of local scientific societies (i.e. of the Corresponding Societies of the B.A.) rose from 23,013 in 1904 to 49,597 in 1914. Figures from R.M. MacLeod, J.R. Friday and C. Gregor, The Corresponding Societies of the British Association for the Advancement of Science (London, 1975), p.141.

94. Pycraft was assistant Linacre Professor of comparative anatomy at Oxford and later Assistant keeper in charge of Osteological collections at the British Museum (Natural History).

95. R.L., 'The study of bird life', Nature, 62(1900), 221.

96. 'Kentish birds', Nature, 84(1910), 241-2.

97. 'A history of birds', Nature, 84(1910), 367-8, p.367. My emphasis.

98. 'Naturalists' notes from the old Spanish Main', Nature, 84(1910), 525.

99. For example, Harry F. Witherby, 'Two months on the Guadalquiver II: the Marismas', Knowledge, 22(1899), 51-4. Here Witherby related how he shot a flamingo.

100. C.E. Martin, 'The shooting of birds', Knowledge, 22(1899), 28-9.

101. Charles A. Witchell, 'The bad language of wild birds', Knowledge, 22(1899), 28-9.

102. Charles A. Witchell, 'The love gifts of birds', Knowledge, 22(1899), 76-7.

103. E.A.S.E., 'On the duty of a field-naturalist', Knowledge, 22(1899), 260-1.

104. T.R.R. Stebbing, 'The karkinokosm, or world of crustacea. VII: The box crustacea', Knowledge, 22(1899), 29-31.

105. D. Allen, op.cit. (note 75), p.184. Professor F.W. Oliver attacked the British Museum and Kew at the British Association meeting of 1906.

106. R. Lydekker, 'A contrast in noses', Knowledge, 22(1899), 174-6.

107. W.P. Pycraft, 'Ornithological notes', Knowledge, n.s. 4(1907), 209.

108. G.H. Bryan, F.R.S., 'Test diatoms at home', Knowledge, n.s. 4(1907), 274-5.

109. John Butler Burke, 'Physics and biology', Knowledge, n.s. 4(1907), 61-2, p.61.

110. See E.W. Jenkins, 'Science, sentimentalism or social control? The nature study movement in England and Wales, 1899-1914', History of education, 10(1981), 33-43, pp.36-7. Webb was a member of the Executive Committee of the Nature Study Exhibition of 1902.

111. Hugh Boyd Watt, 'Ornithological notes', Knowledge, n.s. 9(1912), 115-6.

112. Wilfred Mark Webb, 'Notes: ornithology, the Brent Valley Bird Sanctuary - an experiment in bird protection', Knowledge, n.s. 9(1912), 437-8.

113. 'The extermination of birds', Knowledge, n.s. 7 (1910), 292.

114. Richard S. Bagnall, 'Some primitive British insects. I. The protura', Knowledge, n.s. 9(1912), 215.

115. Margaret R. Thomson, 'The subtlety of life', Knowledge, n.s. 9(1912), 299-300.

116. Julian Huxley, 'Recent work on heredity', Discovery, 1(1920), 199-203.

117. T.A. Stephenson and W. Edgar Evans, 'Private sea-water aquaria', Discovery, 7(1926), 51-7.

118. Theodore H. Savory, M.A., 'How wolf-spiders behave', Discovery, 11(1930), 165-6.

119. Julian Huxley, 'The courtship of the red-throated diver', Discovery, 3(1922), 44-8.

120. E.M. Nicholson, 'The next step in ornithology', Discovery, 11(1930), 330-1, 338.

121. Moseley, op.cit. (note 6).

122. J.W. Gifford, 'Electrography, or the new photography', Knowledge, 19(1896), 73-6.

123. See Chapter 4, section 4(a).

124. Cardwell, op.cit. (note 3), p.207.

125. B.W.G. Holt, 'Social aspects in the emergence of chemistry as an exact science: the British chemical profession', British journal of sociology, 21(1970), 181-99. Also see Chapter 4, section 4(a).

126. For an account of the use of Baconian rhetoric in the public arena see Richard Yeo, 'Baconianism in nineteenth-century Britain', History of Science, 23(1985), 251-98, pp.283-8.

127. Henry A. Miers, 'Science and the amateur', Knowledge, n.s. 7(1910), 162.

128. Ibid., my emphasis.

CHAPTER 4

THE ROAD TO PROFESSIONAL RECOGNITION: PERSUASION AND PARTICIPATION

1. Introduction

The professionalisation of science involved several different (although frequently overlapping) stages. One of the earliest was the achievement of control over one's own discipline. The previous chapter showed how general science periodicals were used to this effect in astronomy and natural history. It also described how physics and chemistry had more or less reached this level of control and could advance to subsequent stages. Two of the most important of these were the provision of employment and the recognition of status as a profession in the wider community.[1]

Public support was necessary for the acquisition of a professional apparatus. The support that emerging scientists desired and needed encompassed recognition of status, acceptance of authority, respect, and a reaction to the provision of rewards, grants, funding, employment and honours which was at best a positive commitment and at least mere acquiscence. Thus support was not in this context confined to the narrow concept of the financial, but was extended to include the notion of a sympathetic substratum of public opinion underpinning and sustaining the position of the professional scientist in the wider society.

In this chapter it is demonstrated how professional scientists used general science periodicals as a means of persuasion to achieve these aims. The diversity of the readership for these periodicals has been outlined in Chapter 2. In order to communicate with the different elements which possessed a greater or lesser degree of interest in science, opportunities both specific to individual disciplines and of a more general nature were utilised.

2. Background

In July 1894, there appeared in Nature an article entitled 'Popularising science', written by H.G. Wells.[2] Wells was by no means alone in his recognition of the importance of popularisation for the future of science:

> 'The fact remains that in an age when the endowment of research is rapidly passing out of the hands of private or quasi-private organisations into those of the state, the maintenance of an intelligent exterior interest in current investigation becomes of almost vital importance to continual progress. Let that adjective "intelligent" be insisted upon. Time was when enquiry could go on unaffected even by the scornful misrepresentation of such a powerful enemy as Swift, because it was mainly the occupation of men of considerable means. But now that our growing edifice of knowledge spreads more and more over a substructure of grants and votes, and the appliances needed for instruction and further research increase steadily in cost, even the affectation of contempt for popular opinion becomes unwise.'

The public image of science had by this date assumed a significance for the practice of science which was qualitatively different from its earlier influence.

The movement for the state endowment of research had achieved a degree of success by the end of the nineteenth century. Between 1882 and 1900, the government grant to the Royal Society was worth £4,000 annually.[3] The society was given greater control over its distribution of the grant. Most importantly, whereas the money had previously been used to cover the cost of equipment and publications, sums could now be awarded for personal research purposes. Institutions such as the National Physical Laboratory (1900) and the London School of Tropical Medicine (1899) were established with government support.

It was, however, government aid to the universities which began to provide the sort of permanent paid employment demanded by scientists. The first grant of £15,000 in 1889[4] grew to £26,000 in 1897 and £170,000 by 1913.[5] (In addition the universities received some municipal aid.) The number of available posts at university-type establishments in science and technology rose from a mere 60 in 1850 to more than 400 by the turn of the century.[6] In 1894 the first imperial fellowship scheme for scientific research was started, using funds from the Royal Commission for the 1851 Exhibition.[7]

Initiatives such as these were but the first tentative steps on the road to large-scale state support for science. The attitudes of individuals and groups beyond the scientific community became crucial in attracting further support, one aspect of which necessarily involved justifying existing scientific activity in the wider public arena. As Wells emphasised, the popularisation of science and its funding had become inextricably linked.

It will be recalled that a scientific discipline is here defined to be a profession if its members were engaged in the full-time practice of that discipline and from which practice their main source of income was derived. Further, they had to possess a sense of community, certain agreed standards and external recognition of their status. The increase in the levels of funding was therefore important in the process of professionalisation; both were concerned with the acquisition of recognition and rewards for science and scientists. The way science was perceived by a wider population was, as stated by Wells, vital to the provision of science funding. It went beyond this, however, to become a central factor in the professionalisation process as a determinant element in the distribution of recognition and rewards.

Richard A. Proctor was one of numerous amateur scientists opposed to the endowment of research. In his Wages and wants of scientific workers (1876), Proctor argued that the existence of widely available positions of full-time employment for scientists would lead to a decline in 'popular' scientific literature, because of the extinction of men and women who had 'ennobled themselves by being forced to live by their pens'.[8] Some of those who took up the new full-time posts continued to produce literature for a readership which extended outside the narrow confines of their own specialism. It can be claimed that they still 'lived by their pens' in the sense that their writings continued to justify and increase public support (financial and other) for science, as well as establishing and maintaining the status and authority of the scientific profession within society as a whole. Yet as early as 1894, '"popular science"' could be described as 'a phrase that conveys a certain flavour of contempt to many a scientific worker '.[9] The attitude to which H.G. Wells was referring gained currency among scientists in a way which bore some relation to advances in scientific professionalisation.

The Victorian era is remembered for its scientist-popularisers: most notably the likes of T.H. Huxley and John Tyndall, although Tyndall was himself condemned for spending too much time on popularisation during his lifetime. By the turn of the century the growth of this unsympathetic attitude to popular science may possibly be attributed to the belief among professional scientists that popular writing was simply not a task for them. Full-time employment as a practising scientist meant less time for popular writing as well as the removal of one of the primary motivations for so doing (i.e. financial necessity). Further, in their attempt to demarcate between themselves and various non-professionals, spheres of activity were more clearly defined. Wells pointed to the dangers of this attitude and emphasised the importance of an 'intelligent exterior interest'.[10] A group of professional scientists and their supporters realised the crucial nature of public perceptions to their own position and advancement and took steps to gain control of these just as they had internal disciplinary matters.[11]

In the sections which immediately follow, the selection of material by the general science periodicals and the variety of modes of presentation employed in physics and chemistry are analysed. These two fields were chosen by virtue of the extent of disciplinary control they had already achieved. This analysis constitutes the first stage in the demonstration of how, by addressing a large, heterogeneous readership, these periodicals were effective in securing recognition and rewards for science and its practitioners in the wider culture.

3. Physics

a) The situation

Throughout the nineteenth century, physics became increasingly mathematical in nature. So much so, in fact, that the language of the discipline grew to be accessible only to those who had undergone training equivalent to that of the available degree courses at university-type establishments.[12] Because of the growth of these establishments, the numbers with such an education increased, but the equipment and facilities required eventually came to exclude almost anyone, but those members of the new profession employed at universities and other institutions where research was conducted, from making original contributions to knowledge.

The greatest share of full-time employment and state funding available to scientists before 1914 was enjoyed by chemists.[13] Physicists, however, came a creditable second. Having attained a firm control over their own discipline, professional physicsts sought to extend their sphere of activity; to secure wider status and recognition. They demanded further financial support, not only from the state, but also from the industrial world. It was, as H.G. Wells was at pains to impress,[14] essential that existing provision of monies be justified to both government and wider public. General science periodicals were used for these purposes. Recognition, respect and authority within society were crucial to the process of professionalisation, and attempts were made to use these periodicals as an instrument in effecting these aims. One of their most important methods was the restructuring of relationships between professional scientists and the periodicals' readership.

For physics graduates, as Moseley has shown,[15] employment was particularly difficult to find in a field which gave them the opportunity to practise their hard-earned skills. This was becoming an especially acute problem due to their rapidly growing numbers:

> 'By 1914 there were probably well over 7,000 graduate scientists in Britain and more with advanced degrees than there had been scientists altogether in 1850'.[16]

In 1900, the number of graduate scientists from all disciplines was only 2,000. This new class of graduate constituted an immediate audience for the general science periodical. Not merely sympathetic, but enthusiastic about the changes in attitude towards science and scientists advocated by professionals, they were the most obvious group within the potential readership to offer the kind of support required by the new élite. Despite their position outside the élite, these graduates lent their support to the professionals. Through their education they had acquired a shared body of knowledge, a shared language, and had been assimilated into a tradition. By this process they came to identify themselves with the community of scientific practitioners. Further, the two groups had shared interests. This was a significant concept in the subsequent extension of support further beyond the boundaries of the emerging profession.

These graduates were, of course, particularly important in that such a significant percentage became schoolteachers. (Of the 2,000 scientific graduates existing in 1900, about half were teachers in primary and secondary schools).[17] Among this group can also be found a number of contributors to general science periodicals - many still forced to 'live by their pens',[18] others no doubt keeping their interest in physics (or other science) alive, and some possibly even hoping thereby to gain entry to the rarefied world of the scientific professional.

Norman Lockyer and a group of his associates had been campaigning for greater state involvement in science for several decades before the outbreak of war in 1914. Their efforts had intensified at the turn of the century, as exemplified by the foundation of the British Science Guild in 1905. It was only the perilous circumstances in which the nation found itself at the beginning of the war which spurred the government to act. Having relied on German scientific and technical expertise for a number of vital products, Britain found itself without essential supplies of, for example, dyestuffs, optical glass, tungsten for steel making, magnetos and numerous drugs and pharmaceutical preparations. Initiatives calculated to remedy the situation culminated in the establishment of the Department of

Scientific and Industrial Research (D.S.I.R.) in 1916. A fund of one million pounds (the so-called 'million fund') was provided which, when matched with industrial money, supported industrial Research Associations. The arguments advanced by Wells in 1894[19] thus became all the more pertinent.

The areas within physics which received most attention in the general science periodicals from 1890 were x-rays, radioactivity, atomic structure, relativity and applied physics and technology. Using examples taken mainly from these areas, it is shown in the next section how the means by which physics was presented in these periodicals contributed to the redefinition of relationships between professional scientists and a wider audience, thereby helping to secure the much desired status and authority within society as a whole. Factors other than those directly relating to the organisation and internal development of physics were also involved in the selection and presentation of material. Such influences are discussed at length in Chapter 5 below.

It is, nevertheless, necessary to point out that the periodicals' own selection of material did itself affect the image of science they conveyed. X-rays were immediately fascinating to what appears to have been the entire nation; they had 'magical' properties as well as rapidly recognised practical potential. Radioactivity too was fascinating - it was a mysterious, romantic, magical and intriguing phenomenon.[20] A few personalities were significant in both these cases but nonemore so than with relativity: Einstein was to become the most famous scientist of the twentieth century.[21] The impact of relativity was heightened by one dramatic event in 1919: the eclipse expedition undertaken to "test" the theory. Applied physics (and physics based technology) came much closer to the experience of the readership. In what follows, the importance of these characteristics for perceptions of the nature of science will become clear.

b) The periodicals

Detailed consideration of physics articles in the periodicals revealed the existence of two apparently paradoxical trends. In combination, these offered a persuasive argument for the recognition of physics as a profession. Any analysis such as this must of necessity be based on a selection of material. In order that the pitfalls associated with this be minimised and a representative picture obtained, as great an amount of material as could be was surveyed. In most cases, it was possible to examine the major part of the physics content of each journal. With Nature, however, the extent and variety of the physics element was so great that sampling was necessary. This was randomised by studying individual issues from a number of years, taken from the same time of each year, and covering the whole year. Furthermore, efforts were concentrated on those subjects which made up the bulk of the physics material in these periodicals. Examples used in the analysis below are drawn mostly from these areas (i.e. structure of matter, radioactivity, x-rays, relativity, applied physics and technology).

(i) The scientific élite: science as privileged knowledge.

By 1890, the majority of the physics material in Nature was aimed at professional scientists. Between 1898 and 1905, most of the references listed in the index were letters, or brief entries in the 'Societies and academies' sections. The letters largely provided for communications between specialists, either to announce results or to engage in dispute. Ernest Rutherford and Frederick Soddy were among the often eminent contributors. The 'Societies and academies' column was made up of extremely short references to papers delivered at, most usually, the Royal Society and the Paris Academy of Sciences. It functioned as a news summary for practising research scientists, was situated at the end of each issue and printed in very small type. Although the 'Notes' was originally intended to appeal to 'interested bystanders',[22] the mentions of radioactivity were rather news bulletins for professionals. For example, articles in other periodicals such as the Physical review were described.[23]

Of the articles proper, reprints of papers given to the Royal Society[24] were again for professional specialists. Others were a means of communicating between members of different disciplines. J.J. Thomson's 'Radium',[25] for example, was an attempt to persuade (chemists presumably) of the validity of his view that radioactive phenomena could be attributed to rearrangements within the atom. The article with the broadest appeal during this period was taken from the British medical journal.[26] The relative simplicity of the physics of this text (due, of course, to its original source) merely served to emphasise the élitist nature of the larger part of the material.

A similar situation obtained with Nature's treatment of relativity up to 1921. The journal was demonstrably a vehicle for specialist communication, most of the material being correspondence between professional physicists, frequently dealing with the finer points of theoretical controversy. One book review claimed that with Einstein's theory, 'the rationality of the universe becomes an exciting romance'.[27] Such exceptions to the norm served only to exacerbate the contrast between the physics community and the non-professional reader.

These two examples are typical of the presentation of physics in Nature after 1890. It reflected the growing sense of community among physicists and their increasing isolation from both the rest of the scientific community and the rest of society. The construction of a distinct identity for the professional élite also characterised the presentation of physics in other general science periodicals with a decidedly more heterogeneous readership.

Most physics texts contained within them the conception of professional physicists constituting an élite, a relatively small group of individuals with special skills, training and abilities. This picture was supported by the increasingly significant involvement of professional scientists and engineers in these general science periodicals, most particularly in terms of contributions.[28] One means by which this notion of an élite was conveyed was to set accounts of scientific activity within a hypothetico-deductive framework. Integrated into the text, the most crucial manifestation of this method was the creative, imaginative leap made by physicists which, according to Conquest, showed them to be 'special',[29] 'inspired'[30] individuals with, as expressed by Discovery, 'insight and experimental genius'.[31] Likening the physicist to 'the mystic and the seer',[32] as did both these periodicals, carried the implication that physicists were members of a select brethren. Creating the idea of a closed community of practitioners with privileged, secret knowledge was important in establishing a professional identity. Equally significant was the separation of non-professionals from this recognisable élite.

Barriers to the sharing of scientific knowledge were commonly erected. For Conquest, the 'astonishing conclusions' drawn by the likes of Rutherford, Bohr and Planck remained the property of professional scientists because 'only those equipped with specialised training can grasp their significance'.[33] Similarly, in Discovery it was claimed of relativity that:

> 'To understand it really and truly one needs a pretty fair training both in mathematical physics and philosophy'.[34]

The emphasis on training served to set the professional scientist apart. The personality approach also had a contributory effect to the distancing of the reader. Relativity presented the most extreme case in Einstein, to the extent where Conquest of September 1922 featured 'An interview with Dr.

Einstein', in which he was more than once described as ' a man of genius'.[35] It was not only in the more pronounced instances such as this, or the dubbing of Kelvin, Maxwell and Tait as 'the great immortals'[36] which marked out the professional élite as special. Rather it was the result of a far more deep-seated and thoroughgoing theme in the presentation. This was exemplified in Discovery's 1938 review of The Evolution of physics by Albert Einstein and Leopold Infeld,[37] which was divided into two sections labelled respectively (a) 'The specialist writes' and (b) 'The general reader writes'. Significantly the 'general reader' passively accepted all the book told him and his review dealt exclusively with its benefits. The 'specialist' in contrast, was far more critical.

The physics content of Knowledge was greater between 1904 and 1910 than at any other period of its lifetime. The presentation of physics in terms of personalities again set the professional physicist aside from the remainder of humanity. For instance Rutherford, a 'great authority', was quoted at length on 'the cause of the Earth's heat'.[38] The 'Notes' often detailed the works of named scientists in a widely intelligible way with information being taken from journals such as the Philosophical magazine, and the Astrophysical journal. The international flavour of these columns advertised the professional character of the larger physics community and, moreover, were largely written by the professionals themselves.

In certain other respects the presentation barred the sharing of knowledge. Descriptions of the products of scientific activity in terms of the mysterious, the mystical and the magical were not uncommon. References to 'mystic signs'[39] (i.e. Greek letters) and 'the mysterious electric current'[40] were typical. One text likened the highly penetrative properties of neutrons to the ability of a ghost to pass through a wall.[41] Another recounted how:

> 'The universe is... of the stuff out of which dreams are made, and the faith of the mystic and the knowledge of the scientist converge'.[42]

This kind of expression functioned, as did invocations of awe and amazement, to create a further divide between the reader and the world of science.

To those unversed in disciplinary language, knowledge of the shared concepts, values and culture of the emerging professional community was denied and further, accesss to that community was severely restricted.[43] Physics texts in general science periodicals frequently avoided the use of this language or employed it without any attempt at explanation. When Knowledge first appeared in 1881, the necessity of combining both languages, the scientific and the everyday, was strongly emphasised by both Richard Proctor, the journal's editor, and a number of correspondents. An example was given in the first editorial: '"mean equatorial horizontal solar parallax"' was reexpressed as 'sun's distance'.[44] At this early stage, however, Knowledge was a periodical written for and by amateurs. As professionals gained control[45] this policy was abandoned and many articles began to take for granted a considerable degree of familiarity with technical language and ideas. For example, in one typical article, the reader would have needed a knowledge of the nature of such concepts as capacitance, inductance, harmonic oscillation, and the relationships between them.[46]

(ii) The scientific democracy: science as shared knowledge

Participation is a key concept in this analysis, just as it was in the preceding account of professional-amateur interplay. Whereas amateur involvement in natural history and astronomy was channelled into observational work, participation even in this sense was not encouraged for the heterogenous, non-professional readership of physics articles in the majority of general science periodicals. It was rather actively discouraged where theoretical understanding was significant. Of course in most cases experiment without theory was evidently pointless. Examples were practical work with some utilitarian value or, alternatively, "experimentation" for entertainment purposes. An example with an element of both was wireless, a hobby very much in vogue in the 1920s and one of Conquest's most prominent features.[47] A number of articles on the subject were practically oriented: instructions were given on how, for example, to construct a radio receiver[48] or set up an aerial. Yet very little of the theoretical knowledge underlying this practical activity was explicated, leaving articles which in this respect resembled cookery recipes. Other periodicals included far less of this type of material than did Conquest.

Real participation in physics was thus at an extremely low and superficial level. Yet another type of participation was of great significance in these periodicals. I have termed this 'pseudo-participation'. It acted as a substitute for real involvement in the practice of science by creating the illusion of genuine participation among the readership. This has a tradition in the history of science. Steven Shapin has described a technique which he calls 'virtual witnessing' and which Robert Boyle employed in the seventeenth century to convince his readers of 'matters of fact'.[49] By depicting experimental methods, procedures and apparatus in some detail, and by printing a greater than usual number of illustrations, Boyle persuaded his readers that experiments had occurred as he claimed. In a parallel fashion, general science periodicals frequently described experimental practices and circumstances at considerable length, but never in enough detail to allow the reader actually to conduct the experiment.

The use of a certain kind of language complemented such descriptions of practice. A typical example was the article by Walter Rosenhain (Superintendent of the metallurgy and metallurgical chemistry department at the National Physical Laboratory, 1906-1932) on metals, which appeared in Conquest during 1919.[50] Rosenhain made extensive use of the pronoun 'we' in such phrases as 'the pattern we see', thus drawing the reader into the experiment and guiding him/her throughout its successive stages. The same style of expression was also effective in conveying the idea that the knowledge produced by physicists was public and shared. For instance, 'we already know a great deal about the architecture of the atom'.[51] This was even taken to the extent where unsolved scientific problems could be laid at the door of the wider community.[52]

Implicit or explicit accounts of scientific method in an inductive framework also suggested that scientific knowledge was public. If the practice of science depended on rigorous application of method (collecting observations and deducing laws from a sufficient number of these), and not on that elusive inborn capacity of genius, then in principle almost anyone could become a capable practitioner in a Republic of Science. It was claimed in an article on the subject of 'Matter' that:

> 'In the long run science is concerned with the probing of Nature's secrets, in classifying the facts... and piecing them together to form a connected story'.[53]

Science and technology were presented together as aspects of one single enterprise. It is almost impossible to separate the two in the context of the general science periodical. Talking technology has long been a means of persuasion as to the value of science. Utilitarian rhetoric was one of the journals' major assets in their justification of government expenditure. Technology can be interpreted as a mode of participating in the unseen,[54] that is, technology seen as a visible and tangible embodiment of esoteric scientific work and theories, a part of everyday life and experience derived from and dependent upon the remote activities of scientists. The myriad of articles dealing with technology and applied science were used in this way to engender a sense of participation. Technology was presented as affecting the lives of readers directly, thereby involving them in the products of scientific activity. This theme ran through nearly all the periodicals.[55] Conquest, however, displayed a particular fondness for this approach, with its 'technological'[56] content varying between around twenty-five and fifty percent. The concern exhibited by the journal is highlighted by the case of relativity theory, when a desperate attempt was made to find some practical benefit which might have arisen from the theory. Reference was made to its 'considerable effect on astronomical predictions - so that they who 'go down to the sea in ships' may now feel more assurance in the navigation of their boats'. This remark is extracted from an article with the intriguing title of 'What is the use of Einstein?'[57]

Although fewer in number, articles devoted to demonstrating the utilitarian benefits to be derived from physics (e.g. wireless and televison) were also a significant feature of Discovery. Some speculated on future possibilities such as J. Thomson's 'Using the energy of atoms in industry'.[58] Knowledge saw the utilitarian aspect of science introduced with articles on physics and chemistry in 1904. Although applications of science were similarly used to 'involve' readers, on occasion arguments and aims were made somewhat more explicit. (Differences in modes of presentation are discussed in Chapter 5 below). One of the earliest pieces was devoted to the National Physical Laboratory.[59] This 'public institution maintained by taxpayers' money' was a place where '...a great work is unobtrusively going forward, whose benefits spread themselves far and wide'. After describing the achievements of the laboratory, it was argued that:

'...unless adequate funds are provided to meet the national purposes of the foundation, the institution must fail in accomplishment, and a starved laboratory would probably be a worse evil than none at all.'

The question naturally arises as to how far these practices were conscious attempts to reach the desired ends. As argued below,[60] many of the periodicals were intentionally endeavouring to achieve well-articulated objectives. Yet not all of the means to those ends were deliberately and consciously undertaken. The issue of language provides a case in point. Where a periodical addressed itself to a wide range of readers it was inevitable that the use of technical language in articles designed for professional scientists (and those with a high level of scientific education) would of necessity exclude elements of the readership. When juxtaposed with simpler modes of expression, however, the result (i.e. distinct identification of the professional élite and alienation of the non-professional readership) was the same, and reinforced more calculated efforts. For instance the high profile of technology and the encouragement of a sense of participation were active attempts to secure support for science in a democratic society.[61]

4. Chemistry

a) Background

The science of chemistry developed during the nineteenth century in ways which resulted in the gradual exclusion of practically all amateur participation. Specialisation meant that contributions to new knowledge were largely the responsibility of those who had undergone a special course of training. More difficult formal modes of expression (especially in organic chemistry, with the introduction of structural formulae from about 1860), increasingly complicated yet fundamental theory (e.g. thermochemistry) and the emergence of a wholly new branch of the subject, i.e. physical chemistry, meant the face of the discipline had changed substantially by the turn of the century, and made specialised training more and more of a necessity.

The intimate relationship between theory and experiment left no obvious role for the serious amateur, no observational tasks which he/she could undertake with professional guidance. Amateur experimenters did nevertheless linger. Typical was William Ashwell Shenstone, a contributor to Knowledge. Made an F.R.S. in 1898, Shenstone was senior science master at Clifton College from 1880. His main hobby was experimental work and by 1908 when he died, the type Shenstone represented was becoming increasingly rare.

It has previously been noted that the majority of professional scientists employed in Britain in 1900 were chemists, just as the most popular degree course in the universities etc. was in chemistry. Available positions were not limited to those in universities and similar institutions. In fact, practical application of chemical knowledge provided the main source of employment and included opportunities for chemical analysts and consultants (in industry). Although chemists were among the earliest members of a scientific discipline to organise themselves in the sense of creating a professional scientific body, the Institute of Chemistry (1877), this had limited effect and little power for some considerable time: it was dogged by internal disputes and membership was slow to rise.[62] The organic chemical industry was one area in which the practical value of the science had been demonstrated (e.g. in dyestuffs). Wider recognition of the utilitarian significance of chemistry came about because of the War. In particular (and as referred to above),[63] Britain encountered severe problems at the outset of war due to previous heavy reliance on German chemical expertise for a variety of important materials, e.g. dyestuffs, optical and laboratory glass, and a number of reagents necessary for (among other things) the manufacture of explosives (e.g. acetone).

More important, however, in terms of greater public recognition, was the widespread perception of chemistry as powerful and of practical value generated by the use of chemical weapons (i.e. poison gas).[64] After the War, although chemists were required to justify their activities even more than before because of an element of hostile public reaction, they had nevertheless acquired a greater degree of public recognition than those members of other disciplines then aspiring to professional status. Crucially, financial rewards were also forthcoming: a considerable amount of the finance provided by the D.S.I.R. (along with industrial contributions) and channelled through the Research Associations, was directed into chemical research projects. As the chief beneficiaries, the burden of justification was laid largely at the chemists' door.

Despite the relatively advanced stage the discipline had reached in the transition to profession, chemistry retained one major problem. It was not until 1933 that its members were officially (i.e. legally) allowed to call themselves 'chemists'.[65] The term was previously confined to pharmacists. Chemists themselves perceived the issue as an important one, as evidenced by contributions to Nature on the subject. Gregory devoted a leader to the subject in 1919.[66] Towards the end of this article, reference was made to the 'recent establishment of a Federal Council for Pure and Applied Chemistry'. This was, apparently, 'urgently called for to give dignity to the profession of chemistry and to secure for it the recognition it may justly claim from the public'. Responding to Nature's call for the restriction of the title 'chemist' to appropriately qualified chemical scientists,[67] M.O. Forster, director of the Salters' Institute of Industrial Chemistry and former assistant professor of chemistry at the Royal College of Science, wrote a letter[68] in which he stated:

> 'The admirable article... will be welcomed by all who cherish the belief that active development of chemical study is vital

> to the welfare of the state, and modestly hope that public recognition of this fact, so long deferred, may be acknowledged before it is too late. I am convinced, however, that this recognition will not be accorded until the question of nomenclature, to which you refer, has been arranged satisfactorily.'

He continued by emphasising the 'persistent and universal' influence of the street and complained that 'every day... we are told by the street that a chemist is identical with a pharmacist and principally occupied in dispensing medicine and toilet requisites'. The concern exhibited over this difficulty of title illustrates the value placed on public recognition by the emerging professional group.

b) The periodicals

(i) Two contrasting trends

Just as was the case in physics, chemistry texts in general science periodicals between 1870 and 1939 displayed two apparently contradictory conceptions of science. That is, the presentation of chemistry supported the view that science was essentially democratic, open and accessible and that scientific knowledge was public, and alternatively the notion that science was just the opposite, i.e. élitist, isolated and privileged. Differences in the modes of presentation between physics and chemistry derived from differences in their respective degrees of professionalisation (including, crucially, public attitudes) as well as from dissimilarities in the subject matter itself.

These two trends were evident in the chemistry material in Nature. The construction of an élite was similar to that which occurred in physics, but additional aspects emerged. These may be attributed to the prevailing circumstances with which chemists necessarily interacted. Furthermore, within Nature's chemical presentation are to be found suggestions regarding the character of the relationship which existed between this and the other journals in this study and clues to the machinery by means of which the emerging professional community as a whole manipulated and exploited the general science periodical as a tool in the accomplishment of its objectives. Chemical articles in a range of these periodicals displayed a degree of explicitness with regard to motives, aims and objectives absent in their physics equivalents. It is possible to discern the pivotal position occupied by Nature in the spectrum of journals and its crucial organisational and professionalising function by expansion of the study of certain elements present in the chemical material. As a precursor to this wider analysis, it is first of all necessary to consider how professional scientists used chemistry in general science periodicals to extend their professional status beyond the confines of the discipline itself. Procedures similar to those followed in physics ensured this analysis was based on representative material.

(ii) Nature

The overwhelming impression Nature conveyed to its readership was again of an isolated élite of highly trained specialists. The community of chemists gained a coherence and sense of identity, just as did physicists. Yet the non-specialist readership for chemistry exceeded that for physics. Furthermore, attempts were made to motivate chemists to concerted action.

At the beginning of the twentieth century, by far the greatest amount of chemistry in Nature was confined to the 'Societies and academies' column: that is, extremely brief summaries of papers delivered at meetings of professional, often foreign societies. This column was a means by which professional scientists could keep up to date with the latest researches in their own discipline. Weekly publication conferred a unique position on this journal. Nature provided the very latest news, something which the far less frequent specialised periodicals could not. Most of the entries were concerned with pure chemistry, for example 'Interactions of ketones and aldehydes with acid chlorides',[69] as was the rest of the material. Textbooks and laboratory handbooks were reviewed.[70] The 'Notes' were more widely accessible; they were clearly not intended to be read merely by specialists of one field, but by members of all disciplines and the more general reader. Here were reported professional activities like new appointments, articles recently published (again, often in foreign periodicals) or significant events such as international groups, meetings and organisations.[71] Obituaries featured, as with other disciplines. The effect for the (decreasing numbers of) general readers was the presentation of an isolated, inaccessible and possibly somewhat esoteric community. Within science as a whole, chemists by these means asserted their identity and claim to professionalism.

In the years which followed, and before the outbreak of the First World War, this situation underwent considerable change. Most notably, applied chemistry became much more prominent. The different format of the (expanded) index illustrated this. The index for volume 91 (1913) divided the chemistry heading into sections which included agricultural, applied and pharmaceutical. Once the War broke out, this industrial and applied bias strengthened, as Nature was addressing a broader cross-section of society directly, but mainly indirectly.

> 'Chemistry is a comparatively young profession, which is gradually establishing itself in the knowledge and good opinion of the community. ...As it gains in strength, its services will become more widely recognised and will meet the same appreciation as that accorded to the older learned professions.'[72]

Nature was the journal of the professional. Although the public the journal hoped to influence was represented among its readership, by far the greatest proportion had to be communicated with indirectly. Much space and effort was invested in the aims outlined in the previous quotation, which was taken from a summary of the speech made by the President of the Institute of Chemistry at the 1916 annual general meeting. Addresses such as these came by this time to be frequently summarised, reported in part or in full. For example, the issue of 10 February 1916 contained an article 'Chemists and manufacturers',[73] taken from the presidential address given to the Society of Public Analysts and other Analytical Chemists. The following month saw an abstract of Frederick Soddy's address to the Aberdeen Chamber of Commerce, 'Chemistry and national prosperity'.[74] This reflected the trend away from the technical, specialised and abstract world of the pure scientist. Practical articles, dealing in, say, the nature of specific industrial processes, as well as those of a more general type which commented on the more universal aspects of the subject (namely how important chemistry had been to Britain in the past and how it would be even more so in the future) constituted the mainstay of chemical literature in Nature between 1914 and 1918.

During these years of conflict, Nature, still nominally edited by Lockyer but practically by Gregory, clearly tried to extend the readership of its chemical material beyond that of 1900. The general increase in articles on chemistry and technology offers the most obvious starting point. More readers would be interested in that which affected their own lives and, moreover, afforded a sense of participation. To be specific, groups such as chemical manufacturers were aimed at with messages like this:

> '...we would wish to see the same signs of intelligent and organised effort on the part of the general body of chemical manufacturers in this country as we are now witnessing on the other side of the Atlantic.'[75]

Book reviews with titles such as 'Rudimentary science for coal miners'[76] show that it was hoped to reach beyond scientists, industrialists and the professional middle classes with the message of chemical research. Nature was realistic in its attitude: a journal with its own limited appeal and narrow circulation could not fullfil the task efficiently. Indirect methods were necessary. Education was, in fact, one of the key topics in this programme of persuasion. The following complaint was frequently articulated:

> 'The ignorance of the value of scientific knowledge shown by people is very great, and, unfortunately, many of our rulers are little, if at all, better informed.'[77]

A typical expression of the professional attitude was that

> '...experimental science in general, and chemistry in particular, is not merely an interesting intellectual occupation, but one of the foundation stones on which national progress rests, and that its continued neglect could only lead to disaster.'[78]

Previous funding for chemistry had to be justified. Further, there was the necessity of urging the case for further investment. Reference was made to

> 'the vast and multifarious services rendered to the state by professional chemists and... the extent to which the welfare of the nation depended on the adequate utilisation of their services.'[79]

More concrete expression of these 'services' was seen to be given in the printing of extracts from reports on the research associations' activities. On at least one occasion these researches were described as 'remarkably successful'.[80]

Foreign competition was a consistent bogey, so much so that it was used as an argument for even greater social (and ultimately political) status to be accorded to the profession. Thus:

> 'It is the expert, and the expert only, who can forsee the course of development, who can keep in touch with the progress of research, and direct with intelligence the campaign against competitors.'[81]

This was put more strongly in a leader of 1915:

> 'Today, considerably more than a million of our fellow countrymen, drawn at an impressionable age from every station in life, are pursuing their scientific studies at an open-air German university under conditions which compel their undirected attention. Many of them realise very forcibly that the advantages possessed by their enemy instructors are due entirely to scientific organisation. When our soldier-students return to civil life will they insist upon scientific control of all national affairs? In that possibility lies our strong hope.'[82]

Many contributors to Nature (including Gregory himself) saw beyond the status and rewards of professionalism. For them it was desirable that the authority brought by recognition should mean, variously, that scientists be elevated to occupy positions of power and responsibility in all aspects of society,[83] that scientific methods be applied to all social, political and economic organisation and even that the scientific ideology should eventually become a fundamental basis of Western culture.

Professional scientists were urged to act positively in the advancement of the chemical cause. For example, university professors were encouraged to mediate between chemical manufacturers and their potential graduate employees,[84] i.e. to lobby for more jobs and funds and to work towards reshaping attitudes towards science and scientists. Although the changed chemical material was accessible to a greater range of reader than had been the case a decade earlier, the immediate concern was to motivate regular readers (i.e. professional chemists and their staunch supporters) into various types of action. The texts provided arguments and something of a model.

It must be remarked that the chemical community maintained its distance from the reader who did not belong, rather as it had in 1900. The members were 'trained chemists with chemical insight'.[85] One professional chemist, reviewing a popular book, praised its inclusion of 'mystic symbols'[86] (i.e. chemical formulae) on the grounds that they conferred scientific authenticity on the text. He commended their use in cases where the readers were unfamiliar with and would not hope to understand them. This reviewer was here consciously, deliberately and conspicuously advocating the process of mystification evident in both physics and chemistry material described in this chapter. He openly endorsed the incorporation of such hieroglyphics in chemical texts for wide readerships and approved the association of the incomprehensible with science. Furthermore, his rationale for the use of this technique supports the conclusions regarding the presentation of science in general science periodicals reached below (section 6, synthesis).

During the 1920s, the situation was essentially unchanged. Explicit expression of objectives and arguments continued. So too did discussions of practical chemical achievements. Scientists were encouraged to pursue these aims by featuring examples of gains already made. Typical was a 1924 article on the new chemistry building at Edinburgh University.[87]

One article was particularly revealing. Entitled 'The chemist as propagandist',[88] it was ostensibly a review of a group of chemical industry pamphlets, produced in connection with the British Empire Exhibition by the Association of British Chemical Manufacturers and the Society of Chemical Industry. The opening complaint was not unfamiliar:

> '...those who depend upon science for their daily bread are unanimous in thinking that their position in the social scale is unduly low and incompatible with the value of their work for the community.'

The anonymous reviewer then summarised the position of the chemical profession as he perceived it:

> 'It may, however, now be said that chemists have passed through the first stage in their social evolution, inasmuch as they are fully cognisant of their unmerited status. They have entered upon the second stage, which is combination for a common purpose; but they have yet to negotiate the difficult final stages, which comprise the selection of competent leaders and <u>the conversion of their fellow citizens</u>.'[89]

How precisely these 'difficult final stages' were to be achieved was clarified in the succeeding paragraphs which set out instructions on how to write popular science. Popular writing was encouraged, for

> 'to convince the man in the street of the vital importance of chemistry, and inferentially of the vital importance of the chemist, is also difficult, as the means available for this purposes are limited.'

One of the few avenues open to the scientific community for such purposes was provided by the general science periodical.

(iii) Chemistry in the wider arena

In view of the relatively advanced state of professionalisation reached by the discipline of chemistry at the end of the First World War, it is not surprising that less space was devoted to it in general science periodicals than other subjects (e.g. physics, astronomy, biology) or, for that matter, than had been prior to the conflict.[90] From 1918, the tasks were rather of justification and consolidation. The authors appeared to have followed *Nature's* lead and concentrated on applied chemistry and chemical technology.

Before 1918, the most sustained example of an attempt to employ the two opposite modes of presentation in convincing a widening readership of the value of chemistry and reshaping attitudes towards it could be found in *Knowledge*. Under the editorship of Baden-Powell (who was also the proprietor) and Grew, the chemical content of the journal increased gradually. The articles were mostly written by professional chemists. In his 'Modern views of chemistry',[91] H.J.H. Fenton wrote for 'readers who are interested in the study of chemistry but who have not had the time or opportunity of following the very rapid and important advances which have been made in the science, especially in the departments of physical and organic chemistry'. Some discussion of the theory of solutions ensued but a considerable familiarity with chemical language and concepts was assumed. The methods by which Fenton encouraged a sense of participation are interesting. At one point, some instructions were given for combining certain salts in solution to produce colour changes illustrating the ionic dissociation hypothesis. It would have been possible to procure most of these salts from pharmacists or hardware shops. This simple demonstration of a theory was an unusually close approach to genuine participation, although the theory was only partially explicated (and, of course, no new contributions to knowledge were being made either).

The same author made extensive use of that style of writing which implied a sharing between the reader and the scientist:

> 'We can compare the molecular weights of gaseous elements or compounds by weighing equal volumes of them under the same conditions, and now by extending this hypothesis to substances dissolved in liquids we can compare their molecular weights in the same way'.

One of the explanations offered by the editors for the greatly extended coverage of physics, chemistry and applied science was

> '...because they were convinced that in the new significance and importance which applied science is now recognised as having in every department of the national life, there was a real demand for an organ which should deal with such subjects in a manner that was at once authoritative, comprehensible and interesting.'[92]

Numbers of applied chemistry articles appeared: technology was presented as a kind of scientific corollary, thereby offering a way of participating (in the sense described above) in that which was, contrastingly, otherwise distant and isolated. Representative of this type of piece was the article 'Indigo',[93] by Dr. F. Mollwo Perkin. Perkin was at that time head of the chemistry department at the Borough Polytechnic Institute (London). Crucially, he subsequently became honorary secretary of the British Science Guild (see below) (1908-16). The article outlined traditional methods of indigo production and the introduction of the synthetic product. The 'waning industry' was, according to Perkin, attributable to the unwillingness of the traditional producers to adapt to scientific developments:

> 'The subject of indigo cultivation and manufacture has been brought before readers of Knowledge in order to bring home

the absolute importance of scientific knowledge and scientific research.'

Other articles dealing with the practical results of science were similarly persuasive. C. Ainsworth Mitchell was a prolific contributor to sundry general science periodicals of which Knowledge was one. A forensic chemist and fellow of the Institute of Chemistry, he subsequently became secretary to the Society of Public Analysts. On occasion he incorporated his forensic work into his articles. 'The chemistry of inks in handwriting',[94] for instance, told how chemical analysis of the inks of several signatures solved a murder. This type of story was an example of chemistry at work which had a wide appeal. Once again, however, the antithetical element was present. Chemical formulae and the titles of professional German periodicals appeared incongruous in an otherwise simple and descriptive text.Their introduction served to distinguish the various classes of interested reader from the professional scientist. Mitchell was also responsible for the 'Chemical notes': his typical procedure was to juxtapose (usually) two kinds of text in each item. The first would be a widely intelligible general account of the new ideas/events; the second would enter into greater detail, technical language was habitually employed and professional journals named.

Despite this strong pseudo- participatory aspect, the portrayal of chemistry in Knowledge was in overall terms of an élite activity. This was exemplified by a series of articles by Herbert H. Hodgson, then head of the chemical department at the Northern Polytechnic, London, on 'The triphenylmethyl problem'.[95] These were intelligible really only to fellow organic chemists. All types of chemical formulae and technical expressions abounded. The critical status of language as a factor in the definition of the professional group and its vital importance to professional identity, authority and control have been outlined in the preceeding chapter.[96] Hodgson's use of professional terminology and formal mode of expression reinforced the notion of a remote and esoteric coterie of experts, alienating those beyond its boundaries and erecting a barrier against accessibility. For example:

> 'Bayer and others have established that the hydroxyl group in triphenylcarbinol $(C_6H_5)_3$ C-OH is even more mobile than hydrogen in triphenylmethane, since it readily condenses with such bodies as phenol, aniline and phenylhydrazine , and still more noteworthy, is replaced by chlorine if a stream of hydrochloric acid gas is merely passed into a solution of triphenylcarbinol.'[97]

In the two decades following the armistice, as remarked above, the chemical profile in general science periodicals was low. (Discovery, for instance, never featured more than three chemical articles per year during the 1920s). This was particularly true of pure chemistry. Conquest contained a profusion of articles concerned with applied chemistry. Technology and industry were focal points of interest. Utilitarian aspects were stressed and subjects chosen which made contact with the lives of everyday folk.

'Juggling with air'[98] described the fixation of nitrogen, but most of the article was given over to expounding the benefits the process had brought to society. Particularly emphasised was its use as a fertilizer. 'Clearer swimming baths'[99] recounted how a public swimming baths in South Lancashire had been made more hygienic by the addition of chlorine to water. This type of article ably demonstrated the utilitarian value of chemistry and the universal benefits to be derived from it, as well as provoking a sense of sharing in science, i.e. a means of participating in the invisible. Even closer to home, 'A wonderful chemical'[100] told how to prepare a liquid which acted as an all-purpose household cleaner and disinfectant. There were those articles also which encouraged certain activities for the purposes of entertainment. The type of novelty effect achieved with 'A chemical toy'[101] in no sense approached participation in the scientific enterprise. Chemists even promised wealth and prosperity in return for their recognition and rewards: 'Synthetic sapphires'[102] dealt with the manufacture of artificial jewels. These articles induced an illusory perception of sharing.

The contrasting strand in chemical presentation was far less prominent. Yet it was nevertheless an element of these texts. One instance is the use of biography which, merely by writing about an individual, marked that individual out as special. Although the form was not a popular one with Conquest, an occasional example entered its pages. 'Scientist and inventor',[103] a reprint of a radio broadcast by J.A. Fleming, was an account of the life and works of Sir James Dewar. Dewar was described as

> '...one of the greatest of our experimental philosophers whose discoveries and inventions have inscribed his name high up on the roll of fame.'

5. Astronomy and natural history

In astronomy, the majority of articles proper shared a readership (beyond the emerging professional scientific community) of amateur scientists and non-scientific readers of various kinds. The perception of professional astronomers as a distinct élite, which these texts generated amongst amateurs, extended to the broader readership of these periodicals. Just as amateurs were alienated (by, for example, historical reconstructions of particular types, the importance of instrumentation, etc.),[104] so too was the more general reader. Conversely, the amateur activity directed by professional astronomers through general science periodicals (among other channels) demonstrated that participation in the scientific enterprise was not confined to a highly trained group of specialists with access to expensive equipment and facilities. This second-hand participation in astronomy meant there was less need for recourse to the techniques employed in physics and chemistry to induce a sense of participation.

The situation in natural history[105] differed in several respects. Elements of the two apparently contradictory trends found in physics and chemistry material were present in natural history articles which also shared their readership between amateur naturalists and the interested spectator. During the 1920s, for instance, articles in Discovery concerned with plants and animals fell basically into two categories, which in itself served to set the professionals apart. There was firstly that class of descriptive material largely devoted to accounts of the life histories and behaviour of various species of living organisms. This type of article most commonly afforded opportunities for involvement. These included the professionally controlled kind, as well as those at an even lower level and of a less genuine nature. For instance, many of the species described were to be found in Britain which allowed for the possibility of the reader personally seeing examples.

The second class of article concentrated on what are more properly termed the biological sciences: in particular, the professional preserve of theory. Whilst serving to emphasise the élite nature of the professional scientist and his knowledge, on occasion features of the presentation belied this impression. For example, the not uncommon depiction of scientific method as inductive fuelled the 'democratic', Baconian conception of science. Theoretical articles in both Discovery and Conquest, in a manner analgous to their counterparts in physics and chemistry, pointed to the applications, potential and realised, of the knowledge they presented. Furthermore, just as technology material provided a way of participating in the unseen in those areas, so too did, for example, medical, health and agricultural oriented material enable the readers to extrapolate from that which made up part of the fabric of their own lives to that which self-evidently did not.

Conquest, in contrast with Discovery, offered virtually no incentive to genuine participation in the scientific enterprise. Its numerous articles on animals at the London Zoo in Regent's Park (contributed by R.I. Pocock, Superintendant of the Zoological Gardens, 1904-23) were little more than exercises in pseudo-participation. The journals attempts at instructing its readership to utilise natural history subjects for photography were similar, the overall emphasis being on entertainment.

The extent to which the pseudo-participatory mode of presentation entered into these periodicals is therefore seen to vary according to the degree of genuine participation on offer. The former was particularly evident in physics and chemistry, where genuine participation was largely precluded by their very nature (virtual witnessing was especially noticeable in physics articles). The latter was, however, far more prevalent in astronomy and natural history where pseudo-participation was decreased accordingly. Further, when comparing Conquest and Discovery, participation (for amateurs or others) was largely excluded from Conquest, which journal consequently contained a higher rate of pseudo-participation. Similarly, in Armchair science, a voyeuristic publication with a high circulation, but far fewer amateur readers and no encouragement to involvement, the illusory aspect dominated. This can be illustrated by an instructive comparison between two articles on poisonous mushrooms. The first appeared in Knowledge of 1912[106] and dealt with the various colours, shapes and smells from the point of view of the evolutionarily successful organism and provided encouragement to actually observe. The second, an Armchair science effort of

1934,[107] was concerned with the point of view of the hungry or thrifty wanderer through the countryside.

6. Synthesis

The presentation of physics, chemistry, astronomy and natural history in general science periodicals revealed the existence of two elements which seem to be in conflict. It is useful to regard these elements in dialectical terms as thesis and antithesis, and possible to unify them into a synthesis. Location in an historical context is essential to the attainment of such a synthesis which in turn constitutes an interpretive framework for the activities of the individuals and groups involved in general science periodicals and the functions of those periodicals.

Firstly, there was that picture according to which science was seen to be essentially 'democratic' and egalitarian. Scientific method was inductive, 'a method which consists in collecting and weighing evidence, organising its facts, and generalising them to a clear conclusion'.[108] Dedication and commitment to this method of laborious observation (the results of which were then formulated into some kind of law or theory) were all that were required for the successful prosecution of scientific activity. Science was, therefore, open to all. The knowledge it produced was public and based on techniques which were objective, non-personal, and in principle reproducible by anyone. This view found support in the general science periodicals most particularly via the encouragement of a sense of participation at various levels, and which has here been called pseudo-participation. The utilitarian rhetoric, as shown above, constituted an important part of this picture of science. Similar versions of what may, somewhat loosely, be termed 'Baconianism' have a long history as useful scientific rhetorics.[109]

The tradition of the gentleman amateur[110] had to be usurped to allow for the transformation of science into a profession. Not only had the amateurs themselves to be controlled, but wider public attitudes had to be reshaped. This process was begun by general science periodicals in the 1860s.[111] The idea of the scientist as amateur was challenged by an alternative conception. Science became an élite activity; it required special skills, techniques and even inborn talent. Scientists were different, they were a closed group. The new relationships constructed between scientists and the wider society were necessary to the creation of a professional identity which would be acceptable in a wider context. On this model, scientific knowledge was no longer public and shared, but the property of the new scientocracy.

The second view of science did not supplant its predecessor.[112] An uneasy coexistence between the two was maintained in the general science periodicals. This was a necessary stage in the establishment of science as a profession. Whilst the distinguished élite was an essential part of the image of science as a profession, recognition outside the 'scientific community' demanded more. To be acknowledged as professionals in a democratic society, to be granted the desired recognition and rewards, it was crucial that science be regarded as a democratic, sharing enterprise in which anyone could participate and from which everyone would benefit. At the very least these two contrasting elements, in combination, prevented the general science periodicals from being used as critical weapons to attack the new professionals (rather as appears to have been the case in nineteenth-century France).[113] More positively, they contributed to the modification of attitudes towards science: to the acceptance of the status of science as a profession and of the authority which was part of its professional identity. Together, they in fact constituted the persuasive means through which the passive, non-participatory support of the readership was assured.

7. Recognition and rewards: persuading the general public

Although the construction of an image of science, by employing the various modes of presentation described above, encouraged wider recognition of professional status for the scientist, the role of the general science periodical went further than this in the transition to professionalism. The aim was to extend this vital recognition to a broader cross-section of society than would read articles, the subject matter of which was largely defined by disciplinary boundaries. The medium for this extension was a particular class of article which was invariably the most easily understandable in any one journal. Primarily targetted at the total readership of each periodical, the sphere of influence of these articles, often editorials, swelled beyond this largely by indirect channels.

Before the middle of the nineteenth century, the scientific worker did not regard himself as belonging, in relative isolation, to a more or less well defined specialism. The general science periodicals of the late nineteenth century arose, at least in part, as a response to increasing specialisation.[114] There was perceived a need to present an overview of science, a kind of picture of science as a whole. This was done in two ways. Firstly, by including material from different scientific disciplines. This aspect of the 'general' has been referred to extensively above. Secondly, articles which discussed science as a whole and its relationship to the wider society constituted the other level of the 'general'. The subject of these articles was 'science', not physics or botany or astronomy. They concerned the nature of science, the relationship between science and industry and so on. Moreover, they furnished the vehicle for attempts to persuade society at large (i.e. public opinion) of the right of science to professional recognition.

The new professional scientists wanted recognition and rewards. The two notions themselves overlap; their degree of interdependence in fact justifies their being subsumed under the collective concept of 'support'. In this thesis, recognition beyond its own boundaries has been adopted as an important criterion in the identification of a profession.[115] The emerging professional group themselves regarded it as such. Rewards occupied a similarly pivotal position. Intimately connected with recognition, rewards (i.e. financial, employment, honours, etc.) were its tangible embodiment. At various times financial support from the state was demanded, for science as a whole or for individual scientists. The financial element bore relevance to one particularly difficult aspect of professional identity.

In attempting to convince increasingly greater sections of society of their right to professional recognition, scientists faced the problem of the client. In the well-established professions with which they compared themselves, the 'expert'/client relationship was a central feature. This was notably absent in science, apart from consultancy work. Nature, however, claimed that 'most scientific work is done for the good of the community'.[116] Conquest lamented that 'service to the community'[117] seemed to count for little when it came to honours and added 'Many of the most famous scientists, however, have failed to receive the slightest recognition from the nation'.[118] The presentation set up the 'community' as the client. Hence it followed that the fee which the professional traditionally received for his services was in this case to be paid by society as a whole. It was argued in general science periodicals that service to the community demanded payment from the community, i.e. recognition and rewards, most particularly in terms of state financial support for the scientific enterprise.

Reminiscing in the Jubilee issue of Nature in 1919, Norman Lockyer recalled:

> 'It was the hope that a more favourable condition for the advancement of science might be thereby secured that led

Mr. Alexander Macmillan to enter warmly into the establishment of Nature in 1869.'[119]

The meaning of the phrase 'advancement of science' is ambiguous. On the basis of what has already been said about the journal, it is possible to draw a distinction between the advancement of scientific knowledge and of the scientific profession. Various interpretations of the latter have been described above,[120] and were not unique to Nature but appeared in several other general science periodicals. Ambiguity in the rhetoric served a purpose in strengthening and protecting the position science (i.e. its institutions and practitioners) was growing to occupy in society. This confusion between the two objectives of knowledge and power, a feature of these periodicals during this period, proved distinctly advantageous to the scientific profession.[121]

Nature was of particular importance in this process of persuasion. Moreover, as late as 1919, the view that 'Science is, not yet at least... a profession',[122] was openly stated in an editorial. The journal had campaigned for professional recognition in a number of ways since its inception, the most notable being its concern with scientific education. Efforts had been on the increase since the 1890s, but 1903 marked something of a turning point. This was the year in which Norman Lockyer delivered his famous address as President of the British Association entitled 'The influence of brain power on history'.[123] Lockyer argued that Britain's lack of success in international economic competition with other countries was due to a neglect of science in the conduct of national affairs and in industry. He advocated greater state support for education in general and for scientific education in particular as a solution to the nation's problems.

January 1901 saw the appearance of an editorial in which Lockyer set out what was to be his programme and that of Nature until the outbreak of war in 1914.[124] He encouraged a new attitude in the country at large:

'The scientific spirit must be applied as generally in England as elsewhere'.

He continued:

'The increasing complexity of industrial and national life requires a closer adjustment of means to ends, and this can only be attained by those who have had education on a scientific basis, and have therefore acquired the scientific habit'.

Lockyer was in effect saying that a recognition and appreciation of the professional expertise of scientists and a spreading of the influence of science could very well be the salvation of Britain.

One important consequence of Lockyer's presidential address at the British Association was the formation of the British Science Guild (B.S.G.). Nature was very closely involved with this organisation indeed. Both Lockyer himself and his successor in the editorial chair, Richard Gregory, were exceedingly active members. An announcement of the Guild's inaugural meeting was published in Nature on 12 October 1905.[125] The main purpose of this meeting, to be held on 30 October, was publicity.[126] The article set forth the Guild's objectives which were:

'...to convince the people, by means of publications and meetings, of the necessity of applying the methods of science to all branches of human endeavour, and thus to further the progress and increase the welfare of the Empire.'[127]

and further 'To promote and extend the application of scientific principles to industrial and general purposes' as well as 'To promote scientific education'. It was added that the fundamental resolution of the Guild was

'... to stimulate, not so much the acquisition of scientific knowledge, as the appreciation of its value, and the advantage of employing the methods of scientific enquiry... in affairs of every kind.'

These aims also informed the policy of Nature for many years to come.

The central position of education in the drive towards greater recognition for science was highlighted by a series of leading articles, 'The university and the modern state',[128] which appeared in Nature in 1903. Lockyer was once again placing the country's difficulties at the door of the neglect of scientific spirit. This neglect, he contended, was the responsibility of the state for failing to provide adequate endowment for the universities. He embarked on lengthy comparisons of the universities of Britain, Germany and the U.S.A. One (large) German university was found to receive as much in the way of state financial support in one year as did all Britain's universities and university colleges put together. The unfavourable comparisons were linked with the widely perceived decline of Britain in the economic and military departments.

The concept of 'scientific education' had several meanings for Nature between 1890 and 1939. It was intertwined with rhetoric about recognition and rewards. Firstly, it was interpreted in terms of the question of higher education for those mostly wishing to pursue careers as practising scientists. Increased provision of resources in this area would (and in fact did) indicate growing state recognition, not only of professional status but of cultural, economic, political and social importance.

Secondly, there was the issue of a much broader scientific education. The aim was for science to become an integral part of general education. This circumstance would have, it was assumed, ensured a greater 'appreciation' of science - in other words, establish a broad base of support. It would have widened the influence of sicence and scientists. Nature desired that this education extend to 'the [future] statesman, the official, the merchant, the manufacturer, the soldier and the schoolmaster'.[129]

The first president of the B.S.G., R.B. Haldane, had his pamphlet 'The executive brain of the British Empire' reviewed in Nature during 1905.[130] Richard Gregory wrote of Haldane:

> 'He is a thorough believer in the policy which has been advocated consistently by Nature, that the surest and best way to secure national efficiency is to educate our manufacturers and merchants liberally along scientific lines, and to enlist the cooperation of distinguished men of science in the work of national administration'.

The journal continued to press the case for greater recognition of science consistently up to the First World War, arguing for increased funding of scientific research, more (scientific) education and closer relations between science and industry.

The War saw a marked increase in Nature's efforts to secure this wider recognition. MacLeod considers the success of the British Science Guild and Nature to have been 'severely limited'.[131] Whilst it was undoubtedly extremely difficult for the journal to reach the eyes and ears of the powerful, the less direct approach it adopted was ultimately far more effective. Nature issued what amounted to directives to its readers to go forth and propagandise.

Three remarkable leading articles, published in quick succession at the end of 1915 and the beginning of 1916 outlined Nature's position. Although the readership was by that time composed mainly of professional scientists, it was not exclusively so. Furthermore, this kind of widely intelligible material could have been commented upon by other more widely read publications. This was simply not good enough. What had previously been implicit was now precisely spelled out in order that the journal's circle of influence be widened. The titles of these three articles are revealing: 'Science for all',[132] 'Science and the public',[133] and 'Merit and reward'.[134]

It was complained that 'Always, and ever, and again, science is despised and ignored',[135] and that 'little attention is given to science in education and in the public mind'.[136] The consequences of neglecting science, as well as the benefits it had already brought, were emphasised. Comparisons were made with other, well-established professions, especially law, some members of which received payment from the state for their services. It was pointed out, in contrast, that scientists' services were offered freely (i.e. without financial reward). Sir William Crookes's presidential address to the Royal Society was quoted in a leader arguing for a Ministry or Board of Science which would

> '...make scientific research an invaluable profession, with a status of its own at least on a level with that of other learned professions'.[137]

Nature desired 'definite public recognition of the national importance of science' but was

> 'Painfully aware of the apathy of British statesmen and of the British public towards the claims of science for truer recognition'.[138]

Suggesting a means by which this state of affairs might be ended, the periodical stated:

> '...we believe that when the public has been sufficiently

> enlightened as to the relative values of national work in law and science, a readjustment of the rewards made for it will be demanded.' [139]

In these important leading articles, aims and a plan of action were mapped out:

> 'Our claim is that everyone - from elementary school pupil to college don - should be made acquainted with appropriate outlines of scientific work and thought. We want science to be a part of every general education, and we urge that the times demand this recognition of its influence and potentialities. When this modernisation has been accomplished, facilities for scientific work will be increased a hundredfold, and the public will not be deceived by sensational announcements in the daily Press, or tolerate official indifference to the growth of natural knowledge.'[140]

Appeals to 'public opinion' were prominent. It was openly stated that it was 'the public which elects our Parliamentary representatives and rules most of our national institutions'[141] (as H.G. Wells had appreciated twenty years earlier). Nature wanted its readers to go out and penetrate the press, thereby reaching this public. Gregory (acting editor during the war) believed in 'the pressure of public opinion'[142] as the only way to achieve what professional scientists were demanding.

Nature advocated the use of popularisation as an instrument for the acquisition of professional recognition. Professional scientists were berated for neglecting this means of communication with the public, and reminded that 'popular interest means increased support for their work and greater use of the results'.[143] The non-specialist writings of Ray Lankester were cited as a commendable example, and it was added that

'We believe the influence of such literary work upon the public mind is much greater than in generally understood, and we should like to see many equally attractive efforts of a similar kind in other scientific fields.'[144]

A significant comment on the desired recognition which provides explicit evidence for that which, it has been argued, was mostly implicit in the presentation of physics and chemistry, was also made at this time:

'Science can only secure its rightful position in a democratic state when its work and worth are widely known and understood.'[145]

The War was not a typical situation, but it was precisely this which drew Nature out. Not only were the opportunities greater than those which had previously been available but the journal had to speak out in defence of science which was being associated with the evils of war (because of the identification of science with Germany, the aggressor).[146] Persuading the public of the value of their case (by means of education in the broadest sense of the term) was recognised as the best hope of achieving what the journal had been fighting for since its foundation. Its readership of scientists in all fields, science graduates and a remaining element of the non-scientific professional middle classes was exhorted to spread the word.

Beyond advocating the necessity of communicating to the public the value and importance of science and the expediency of its recognition, Nature offered practical advice. Lockyer, Gregory and their associates at the British Science Guild wanted scientists 'to convince the people, by means of publications'[147] of these things. As early as 1911, extracts from an address given by Henry Miers, principal of the University of London, and also contributor to Knowledge, were printed, advocating 'The cultivation of lucidity in scientific writing'.[148] Miers complained that 'much scientific writing of the present time is loose and unintelligible in its expression'. He suggested that those writing on scientific subjects look to the example of the 'great expositors' of the previous century and emphasised the importance of clarity over style.

In a 'comment on popular scientific literature in general'[149] several more suggestions were made. Of particular significance was the following:

> 'Further, our man in the street dislikes being preached at. He has little regard for unembellished statements of fact. He must see their bearing, actual or potential, on his daily life.'[150]

It was regarded as essential that 'the public' believe society as a whole and each of its individual members benefitted form science for it to support the scientist's claim for recognition.

One of Nature's initial objectives upon its foundation in 1869 was 'to place before the general public the grand results of Scientific Work and Scientific Discovery, and to urge the claims of Science to a more general recognition in Education and Daily Life'.[151] At the end of the century it was apparent that the general element of the readership was diminishing. By the close of the First World War the situation had become decidedly worse, and Nature could no longer hope to fulfil its stated aim directly. Upon Gregory's official assumption of the editorial chair (1919), a policy was instituted whereby the journal itself largely concentrated on communication between scientists. Responsibility for communication with the 'general public' was delegated. In respect of this latter task, the growth of the potential 'general public' generated an impulse and a combination of prevailing circumstances imparted a sense of urgency.[152] Gregory replaced leader reviews of scholarly works with regular leading articles which commented on some particular issue. These articles, usually containing a clear message, were designed to be widely intelligible. They became the chief vehicle through which Nature attempted to persuade its readership to work for the greater social recognition of science by making use of other communication channels.

That Nature's exhortations and influence produced results was most obviously manifested in the case of the foundation of Discovery. In his 1917 Presidential address to the Royal Society (reproduced in edited form in Nature), J.J. Thomson spoke of the need 'for a periodical which would appeal to a much wider circle'[153] than those already in existence. Crucially he declared:

> 'We should encourage and develop efforts to bring to the notice of the public those results of science which are of general interest... [and] do everything in our power to increase appreciation and interest in science among our citizens; without such appreciation, a full utilisation of the resources of science and adequate encouragement for its development are impossible in a democratic country.'[154]

Thus the voice of the President of the Royal Society was added to that of Nature. Thomson was representative of a considerable body of opinion within the scientific community which had come to recognise that the position of science required that they themselves communicate with the citizens of a 'democratic' society. As was argued in the previous section, there was a growing awareness among scientists that public recognition of, and support for science were vital to the final stages of professionalisation in a 'democracy'.[155]

Nature constituted a powerful and respected voice within the professional scientific community. The journal had argued that its readers should themselves propagandise on behalf of science, helping to persuade the public of the importance of science and its consequent right to recognition. Further, guidelines and motives were provided. Many of the contributors to Discovery and Conquest also wrote for Nature (both the two former journals made much of their 'expert' contributors;[156] examples of writers common to all three were Julian Huxley, J.A. Thomson and A.C.D. Crommelin.) It is likely that even more of Nature's readers followed the same path, taking the journal's advice, they adopted its arguments and worked towards their infusion into the popular perception of science.

A number of Nature's themes were reiterated in the periodicals of the inter-war years. J.B.S. Haldane (nephew of R.B. and another contributor to Nature, Discovery and Conquest) wrote an article for Discovery in 1926 entitled 'Should scientific research be rewarded?'[157] He discussed the question of rewarding individual researchers, as had been advocated by Ronald Ross. Preferring that 'all scientific work is recognised as a public service to the state', and avowing that 'the prospect of becoming a street name is a better incentive to effort than a rise of salary', Haldane argued for recognition. Yet he still made much of the low salaries of research scientists and concluded:

> 'But it is not only unjust but contrary to the public interest that scientific research should be, as it is, the worst paid of all the intellectual professions'.

Haldane, along with those of his scientific colleagues involved with general science periodicals, perceived of recognition and rewards as closely related and presented them as such.

Conquest concerned itself with scientific education. The editor hoped that scientists would be 'invited - as perhaps they will be in a more enlightened future - to join in the work of government.'[158]

It was also urged that boys entering a career in commerce or industry should have a degree of scientific education (as part of the process of introducing 'science' into all walks of life).[159] The journal was not, however, exclusively interested in broader scientific education. The September 1925 editorial was sub-headed 'Science as a profession'.[160] The rise in numbers of university science students, as recently issued in a report by the British Science Guild, was seen 'as an indication that we are awaking to the responsibilities of our position in the world'. This 'encouraging' state of affairs was, nevertheless, contrasted with the situation in the United States where private endowment of research was on a huge scale relative to state financial support in Britain. It was further lamented that

'it is only when we come to warfare that the state gives with an ungrudging hand'.

Again, following Nature, the technological aspect was prominent, especially in Conquest, as has been noted previously. The benefits which both the individual and society in general derived were a constant theme. Yet the dependence of techological advance upon 'pure' scientific research was consistently articulated, and its primacy underlined. Frequent references to the 'economic importance'[161] and 'indispensability'[162] of such research were made. This attitude was exemplified in 'The union of science and industry'[163] by E.H. Griffiths, who enjoyed considerable status in the scientific community (he was, for example, a member of the Council of the Royal Society, 1909-11). Pure researchers, 'men seeking after knowledge for its own sake', were behind 'some of our greatest industries'. Griffiths noted many examples, including the standard in articles of this type, that is, Faraday's work on electromagnetism:

> 'Our great electrical industries are based on this discovery - the dynamo, the motor, the electric light, the telephone, the tramway systems are all built upon the foundations laid by Faraday when he established the laws of electromagnetic induction'.

The delay in application was laid at the door of 'our educational system'. As Nature advised, pure research was linked explicitly to applied science and technology, and the benefits accruing to all abundantly emphasised. The primacy of the pure element was, of course, compatible with the élitist element contained in the presentation of material from individual disciplines.

Furthermore, science was presented as a crucial factor in national prosperity. Comparisons with Germany were fewer than they had been in other general science periodicals before the First World War,[164] but they did appear occasionally. For instance, the editorial in Conquest for January 1926 discussed the history of the awards of the Nobel prizes in national terms. Germany had received more than any other country:

> 'The moral may be drawn that ultimately all national prosperity depends on research in pure science: for it is the application in the factory and in common life of the results obtained by the scientist in his laboratory which has led to nearly all the industrial successes of recent years.'[165]

Notes and references

1. See Chapter 3, section 2.

2. H.G. Wells, 'Popularising science', Nature, 50(1894), 300-301, p.300.

3. R. MacLeod, 'Resources of science in Victorian England: the endowment of science movement, 1868-1900', in P. Mathias (ed.), Science and society 1600-1900 (Cambridge, 1972), 111-166, p.160.

4 Christine H. Shinn, 'The beginnings of the University Grants Committee', History of education, 9(1980), 233-43, p.233.

5. D.S.L. Cardwell, The organisation of science in England (London, 1972), pp.202-3.

6. MacLeod, op.cit. (note 3), p.161.

7. MacLeod, op.cit. (note 3), p.161.

8. Richard Proctor quoted in MacLeod, op.cit. (note 3), p.159.

9. Wells, op.cit. (note 2), p.300.

10. Wells, op.cit. (note 2), p.300.

11. See chapter 3.

12. See chapter 3.

13. See below, section 4, also Chapter 3, section 6.

14. Wells, op.cit. (note 2), p.300.

15. Russell Moseley, 'Tadpoles and frogs: some aspects of the professionalisation of British Physics, 1870-1939', Social studies of science, 7(1977), 423-46.

16. MacLeod, op.cit. (note 3), p.163.

17. Ibid.

18. MacLeod, op.cit. (note 8).

19. Wells, op.cit. (note 2).

20. Lawrence Badash, 'Radium, radioactivity and the popularity of scientific discovery', Proceedings of the American Philosophical Society, 122(1978), 145-54.

21. Marshall Missner, 'Why Einstein became famous in America', Social studies of science, 15(1985), 267-91.

22. 'Is it safe to look back?', Nature, 224(1969), 417-22.

23. E.g. 'Notes', Nature, 58(1898), 230.

24. E.g. Sir William Crookes, 'The action of radium emanations on diamond', Nature, 70(1904), 209-10; Ernest Rutherford, 'The succession of changes in radioactive bodies', Nature, 70(1904), 161-2.

25. J.J. Thomson, 'Radium', Nature, 67(1902-03), 601-2.

26. Frederick Soddy, 'A method of applying the rays of radium and thorium to the treatment of consumption', Nature, 68(1903), 306.

27. 'Einstein's exposition of relativity', Nature, 106(1920-21), 336-7, p.336.

28. See Chapter 5, section 3.

29. Dr. Alfred Gradenwitz, 'Artificial gold. The dream of the alchemist come true', Conquest, 5(1923-4), 441-2, p.441.

30. 'Matter an illusion. The structure of the atom', Conquest, 5(1923-4), 11-12, p.12.

31. A.S. Russell, 'The new experiments on the atom', Discovery, 13(1932), 173-4, p.173.

32. Op.cit. (note 30), p.11.

33. 'Elements and atoms. Recent facts and theories', Conquest, 5(1923-4), 117-20, p.117.

34. 'Editorial notes', Discovery, 1(1920), 292.

35. D.N. Mallik, 'An interview with Dr. Einstein', Conquest, 3(1921-2),464-6.

36. 'Scientists in undress. Kelvin and his associates', Conquest, 7 (1925-6), 68-9.

37. G.B.B.M. Sutherland and H.E. Howard, 'Einstein on the evolution of physics', Discovery, ns1(1938), 88-90.

38. 'Radium, the cause of the earth's heat', Knowledge, ns2(1905), 61.

39. P.J. Risdon, 'Radium, the breaking up of an element', Conquest, 6 (1924-5), 145-8, p.145.

40. 'How atoms are arranged. New knowledge of the constitution of matter', Conquest, 2(1920-21), 474-7.

41. A.S. Russell, 'The discovery of the neutron', Discovery, 13(1932),139-40.

42. Op.cit. (note30), p.11.

43. See Chapter 3.

44. 'To our readers', Knowledge, 1(1881), 3.

45. See Chapter 5, section 3.

46. 'Electrical wave measurement', Knowledge, ns1(1904), 244-5.

47. The journal was originally owned by the Marconi Company.

48. 'Make your own wireless set', Conquest, 4(1922-3), 65-7.

49. Steven Shapin, 'Pump and circumstance: Robert Boyle's literary technology', Social studies of science, 14(1984), 481-520.

50. Walter Rosenhain, 'The internal structure of metals', Conquest, 1(1919-20), 19-24.

51. Op.cit. (note 33), p.117.

52. R.W. James, 'Spectra and the structure of the atom', Discovery, 5(1924), 64-7.

53. E. Blake, 'Matter, the deceptive "stuff" of which the universe is made', Conquest, 1(1919-20), 348-50, p.348.

54. E.g. Yaron Ezrahi, 'The authority of science in politics', in Thackray (ed.), Science and values (New York, 1974), 215-51.

55. See Chapter 5 for an account of changing modes of presentation, etc. over time.

56. Technology is here interpreted loosely to include industrial and some applied science.

57. L.G. Brazier, 'What is the use of Einstein?', Conquest, 3(1921-2), 123-4.

58. John Thomson, 'Using the energy of atoms in industry', Discovery, 15(1934), 124-6.

59. 'The National Physical Laboratory', Knowledge, ns1(1904), 72-3.

60. See this chapter, section 7.

61. See this chapter, sections 6, 7 and 8; also Chapter 5, sections 6 and 7.

62. See Colin A. Russell, Noel G. Coley and Gerrylynn K. Roberts, Chemists by profession (Milton Keynes, 1977).

63. See above, section 3.

64. See Chapter 5, section 5.

65. Russell et al., op.cit. (note 62), p.244.

66. 'The profession of chemistry', Nature, 102(1918-19), 501-2.

67. I.e. those satisfying the requirements for admission to the Institute of Chemistry.

68. M.O. Forster, 'The profession of chemistry', Nature, 103(1919), 24-5.

69. 'Societies and academies', Nature, 67(1902-3), 117.

70. E.g. J.W., 'Our bookshelf. Textbook of electrochemistry by Svante Arrhenius', Nature, 61(1902-3), 437.

71. E.g. a report on the annual report of the international committee on atomic weights, 'Notes ', Nature, 67(1902-3), 424.

72. Sir James Dobbie, 'Chemists and their training', Nature, 97(1916), 47-8, p.47.

73. Mr. A. Chaston Chapman, 'Chemists and manufacturers', Nature, 96(1915-16), 662-3.

74. Professor Frederick Soddy, 'Chemistry and national prosperity', Nature, 97(1916), 111-2.

75. 'Sulphuric acid in America', Nature, 97(1916), 60-61.

76. 'Rudimentary science for coal miners', Nature, 96(1915-16), 198-9.

77. Chapman, op.cit. (note 73), p.662.

78. Chapman, op.cit. (note 73), p.662.

79. Chapman, op.cit. (note 73), p.662.

80. Op.cit. (note 66), p.47.

81. Professor Raphael Meldola, 'Professional chemists and the war', Nature, 95(1915), 18-19, p.19.

82. 'Scientific research and chemical idnustry', Nature, 96(1915-16), 475-6, p.476.

83. For example, a leading editorial of 1919 argued for the entry of scientists into parliament: 'Science in parliament', Nature, 102(1918-19), 421-2.

84. Chapman, op.cit. (note 73), p.663.

85. op.cit. (note 82), p.475.

86. T.M.L., 'Chemistry for students and general readers', Nature, 97(1916), 257-8, p.258.

87. 'New chemistry department, University of Edinburgh', Nature, 114(1924), 875-6.

88. 'The chemist as propagandist', Nature, 114(1924), 491-3.

89. My emphasis.

90. See Chapter 5, section 4.

91. H.J.H. Fenton, 'Modern views of chemistry', Knowledge and illustrated scientific news, n.s.1(1904), 35-6, 79-80.

92. 'Editorial', Knowledge and illustrated scientific news, n.s.2(1905), 23.

93 F. Mollwo Perkin, 'Indigo', Knowledge and illustrated scientific news, n.s.1(1904), 253-5.

94. C. Ainsworth Mitchell, 'The chemistry of inks in handwriting', Knowledge and illustrated scientific news, n.s.7(1910), 387-90.

95. Herbert H. Hodgson, 'The triphenylmethyl problem', Knowledge and illustrated scientific news, n.s.7(1910), 50-51, 90-91, 131-3, 347-9.

96. See Chapter 3, also this chapter, section 3b.

97. Hodgson, op.cit (note 95), Part I, 'General theory of triphenylmethane derivatives', 50-51, p.50.

98. Arthur R. Burrows, 'Juggling with air', Conquest, 1(1919-20), 103-10.

99. 'Cleaner swimming baths', Conquest, 6(1924-5), 246.

100. 'A wonderful chemical', Conquest, 4(1922-3), 235.

101. 'A chemical toy', Conquest, 6(1924-5), 80.

102. 'Synthetic sapphires', Conquest, 1(1919-20), 138-9.

103. J.A. Fleming, 'Scientist and inventor', Conquest, 4(1922-3), 310-11.

104. See Chapter 3, section 3.

105. See Chapter 3, section 4.

106. Somerville Hastings, 'Edible and poisonous toadstools', *Knowledge*, n.s.*9*(1912), 465-70.

107. S.H. Jones, 'Beware of death mushrooms', *Armchair science*, *5*(1933-4), 285-8.

108. 'Editorial notes', *Discovery*, *3*(1922), 169.

109. Richard Yeo, 'Baconianism in nineteenth-century Britain', *History of science*, *23*(1985), 251-98.

110. See Chapter 3, especially section 2.

111. Susan Sheets-Pyenson, Low scientific culture in London and Paris, 1820-1875 (University of Pennsylvania Ph.D. thesis, 1976).

112. At least not before 1939.

113. Sheets-Pyenson, *op.cit.* (note 111).

114. See Chapter 2.

115. See Chapter 3, section 2.

116. 'Merit and reward', *Nature*, *96*(1915-16), 503-4, p.503.

117. 'Science notes', *Conquest*, *5*(1923-4), 114.

118. *Ibid*.

119. Sir Norman Lockyer, 'Valedictory memories', *Nature*, *104*(1919-20), 189-90, p.189.

120. See above, section 4(b)(ii).

121. See chapter 5, section 5.

122. *Op.cit.* (note 83), p.421.

123. Norman Lockyer, 'Presidential address', *Report of the British Association for the Advancement of Science* (1903), 3-28.

124. N. Lockyer, 'The new century', *Nature*, *63*(1900-01), 221-4.

125. 'The British Science Guild', *Nature*, *72*(1903), 585-6.

126. A.J. Meadows, *Science and controversy* (London, 1972), p.273.

127. My emphasis.

128. 'The university and the modern state', *Nature*, *67*(1902-3), 193-6; 433-5; *68*(1903), 25-8, 241-3, 337-8.

129. Op.cit. (note 125), p.586.

130. 'Science and the state', Nature, 72(1905), 184-5.

131. R.M. MacLeod, 'Into the twentieth century', Nature, 224(1969), 457-61, p.458.

132. 'Science for all', Nature, 96(1915-16), 307-9.

133. 'Science and the public', Nature, 96(1915-16), 335-6.

134. Op.cit. (note 116).

135. Op.cit. (note 183), p.336.

136. Op.cit. (note 132), p.307.

137. 'National needs', Nature, 96(1915-16), 391-2, p.391.

138. Op.cit. (note 133), p.335.

139. Op.cit. (note 116), p.503.

140. Op.cit. (note 132), p.307.

141. Op.cit. (note 133), p.335.

142. Op.cit. (note 116), p.504.

143. Op.cit. (note 132), p.309.

144. Op.cit. (note 132), p.309.

145. Op.cit. (note 132), p.209. My emphasis.

146. See Chapter 5, section 5.

147. Op.cit. (note 125), p.585.

148. Henry A. Miers, 'The cultivation of lucidity in scientific writing', Nature, 87(1911), 465.

149. Op.cit. (note 88).

150. Op.cit. (note 88), p.492.

151. Nature, 1(1868-70), 66.

152. See Chapter 5, section 6.

153. 'Anniversary meeting of the Royal Society', Nature, 100(1917-18), 275-7, p.276.

154. Ibid., p.276.

155. See Chapter 5, sections 6 and 7.

156. See Chapter 5, section 3.

157. J.B.S. Haldane, 'Should scientific research be rewarded?', Discovery, 7(1926), 65-66.

158. 'Notes of the month', Conquest, 6(1924-5), 213.

159. 'Editorial notes', Conquest, 5(1923-4), 439.

160. 'Notes of the month', Conquest, 5(1924-5), 409.

161. 'Notes of the month', Conquest, 7(1926), 478.

162. 'Notes of the month', Conquest, 7(1926), 260.

163. E.H. Griffiths, 'The union of science and industry', Conquest, 2(1920-21), 447-8.

164. See above, sections 3 and 4, also Chapter 5, sections 4 and 5.

165. 'Notes of the month', Conquest, 7(1926), 28.

CHAPTER 5

THE CHANGING FACE OF THE GENERAL SCIENCE PERIODICAL

1. Introduction

The period 1890-1939 divides into two phases of similar duration, separated by the First World War. The first (1890-1914) was characterised by hectic periodical activity, with many journals being established and many failing. Several were short lived, and the review type journal was typical. Professional scientists attempted to gain control of the general science periodicals as well as the amateur scientists who were involved in them, and were largely successful on both counts.

During the second phase (1919-39), the general science periodicals, now largely under professional control, adapted to a different socio-cultural environment. These new circumstances allowed and facilitated the expansion of the readership, drawing readers from all classes of society. The Franchise Acts of 1919 and 1929 gave women and the working classes a new political significance. New readers from these groups were attracted by the periodicals. The existing readers were largely kept (i.e. mainly male middle classes, professional classes). A larger, more heterogeneous audience were thereby drawn into a passive, non-participatory acceptance of scientific authority and support for the scientific enterprise as a whole.

2. Two phases

The fifty years between 1890 and 1939 divide into approximately equal periods separated by the First World War. Before the War, as shown above in chapter 2,[1] ten new periodicals were founded, nine ceased publication and eighteen were published in total during the period. In contrast, the years between the two World Wars saw only three new periodicals founded, three ceasing publication and a total of seven being published.

The role of social, political and economic factors in these different rates of activity has been discussed above[2]. Expansion of education, public libraries and publication itself were important. So too were the competition the journals faced from each other and from alternative recreational activities as well as the general economic context. The marked difference between the two periods in the shift from intense and varied activity to something approaching a steady state was, however, part of a more fundamental and far-reaching change in the nature of the general science periodical. During these fifty years a gradual transformation of content, organisation, presentation and readership was effected. Attempts were made to impart a new cultural significance to the general science periodical.

3. Control of the general science periodical

Susan Sheets-Pyenson has described the development of the general science periodical in the first two-thirds of the nineteenth century[3]. Until around 1860, the norm was editorial encouragement of independent enquiry by amateurs. The original results of such researches would be published in these journals, readers were encouraged to join local scientific societies and the image of science promoted was essentially 'democratic' and egalitarian. There were no prerequisites for making contributions to scientific knowledge. The periodicals were in this way instrumental in encouraging and moulding a 'low scientific culture'. The proponents of this culture, with the democratic, inductivist and experimental science it expounded, although sometimes critical of the scientific orthodoxy, nevertheless provided extensive support for science and a reservoir of talent and ideas.

The importance which the professionalisation of science had for the development of general science periodicals with respect to both their form and function, has been demonstrated in the two previous chapters. By the 1890s emerging professionals had reached a crucial stage in their fight for the control, status, authority, recognition and rewards essential to a profession. General science periodicals were both a threat to professional advancement and a potentially useful tool.

British professionals had before them the nineteenth-century French example in which an élite 'high science' was almost entirely separate from 'popular science'[4]. There, the absence of such an amateur democratic tradition had resulted in 'high science' suffering from the attacks it received at the hands of 'popular science' through some general science periodicals. Furthermore, the British scientific élite enjoyed a positive and constructive support lacked by their French counterparts. Nevertheless, the situation in France was accompanied by certain benefits. Most notable was the autonomy and authority of the high scientific élite bolstered by the many general science periodicals which were little more than a mouthpiece for that élite.

It seems likely, moreover, that the emergent British professionals were aware of the position in France. Nature kept the scientific community in touch with devleopments overseas. Between 1905 and 1914 the 'International science' content of the journal soared[5]. Substantial interest in German developments has already been noted. Furthermore, the 'Societies and academies' column carried what amounted to weekly reports of the Paris Academy of Sciences, and the 'Notes' regularly reported French scientific events, as well as those occurring in other European countries. Finally, the importance of Lockyer's personal contacts must not be forgotten. Not only did he number many prominent British scientists among his friends and acquaintances, he was also on friendly terms with several continental men of science, such as Janssen, the celebrated French astronomer.

On this side of the Channel professionals sought to use this 'democratic' tradition to their own advantage. Without alienating this culture (as in the French model), they subordinated it to their own new professionalism. Its strength was forced into a controlled, non-challenging support. Active amateur participation largely became passive, non-particpatory acceptance. A vital first stage in this process was, however, the infiltration of and attempt to acquire control over the medium itself.

That such encroachment on what was, essentially, an amateur preserve should produce a reaction was inevitable. Richard Proctor's tirade against the new professionalism was by no means unique[6]. His own journal, Knowledge, offered the greatest resistance to professional control. By the 1890s, some professional scientific workers (possibly inspired by the example of Nature) began to found general science periodicals. These new publications exhibited variety in many respects (e.g. content, readership, etc.) but most were short lived. Not only did the scientists write for and edit the journals, in some cases they even provided the finance. One such was Natural science (1892-99). Its first editorial explained that it had been launched because professionalisation and specialisation had led to loss of 'the stimulus of popular sympathy and criticism' and the consequent 'contraction of recruiting ground' meant 'fewer unattached workers upon whose efforts progress in certain departments ultimately depends'[7]. The editors of this periodical were clearly aware of the value of the 'democratic' amateur tradition, the disadvantages accompanying its increasing separation from the new élite and the potential offered by the general science periodical as a resolving agent.

Another journal founded, conducted and controlled by professional scientific workers was Science progress. In both its manifestations[8] between 1894 and 1939 the proportion of identifiable professional contributors never fell below 70% but was more commonly around 90%[9]. Other journals attempted to increase the nubmers of professionals writing for them. In the case of The Scientific review an appeal for such contributors was made in the pages of the journal itself. E.J.M. Hudson wanted 'red hot facts straight from the men who are doing the work' to make up the 'authoritative articles written by experts' he promised his readers[10].

It has been shown in previous chapters that disciplinary differences were significant in the way relationships were redefined in general science periodicals, and that natural history and astronomy were the areas with greatest amateur strength. They were also the areas which made up the bulk of Knowledge. At the death of A.C. Ranyard in 1894,

	1890-1903	1904-10	1910-17 [11]
1	29	56	40
2	13	5	13
3	4	7	8
2+3	0	0	3
4	25	17	12
5	0	0	0
6	28	15	24
Total	100	100	100

Figure 5: Table showing percentage distribution of different types of contributor to Knowledge, 1890-1917[12]

KEY

1. Identifiable professional scientific workers (including members of the medical and engineering professions)[13]
2. Those with degrees[14]
3. Members (i.e. fellows) of national scientific societies (e.g. Linnean, Zoological, Entomological, Astronomical, Chemical, Geological, etc. societies)
4. Individuals identifiable as not being professional scientific workers
5. Those with scientific degrees employed other than in the practice of science (e.g. as schoolteachers)
6. untraceable[15]

Note: Categories 2 and 3 exclude those cases which belong to both - these are in the row 2 + 3.

the journal had had an amateur astronomer as editor for more than twenty years. Upon the appointment of Harry F. Witherby, the amateur ornithologist, E.W. Maunder became astronomical editor. Under Maunder, professional contributions increased. For instance, Alfred Fowler wrote the monthly astronomical column. As the table shows, between

1890 and 1903 the professional profile in Knowledge was significant. Equally so, however, was that of the contributor who was not a professional scientist. Most of these were serious amateur scientists such as those discussed in chapter 3.

In 1904, editorial control of the periodical was assumed by Major B. Baden-Powell and E.S. Grew. Baden-Powell, a military man with great interest in aeronautics was the proprietor; Grew was the editor. Although neither were themselves professional scientific workers, their policy was to strengthen the professional position. Physical science and technology were accorded a higher profile than had been the case previously, at the expense of the two traditional staples of thejournal: natural history and astronomy. The proportion of professional contributions increased.

Baden-Powell was replaced by Wilfred Mark Webb, who assumed editorial responsibilities in May 1910. Webb had previously been employed as a biology lecturer. He instituted a cooperative approach between professional and amateur workers. Yet professionals controlled the periodical. They were responsible for most of the 'Notes' columns (e.g. 'Zoological notes', 'Astronomical notes' etc.) which by then made up the bulk of the material in the journal. Such cooperation was possible because the Baden-Powell era had firmly established the professional hold on Knowledge. It was, however, something of an exception in the world of the general science periodical and may be attributed to Webb's commitment to the Nature Study movement.

These conclusions are supported by the quantitative data presented in the table above, despite the proportion of untraceable names. The percentage of identifiable scientific contributors can be seen to have almost doubled during the Baden-Powell/Grew era and thereafter to have declined. It must be borne in mind, however, that the membership of national scientific societies was also becoming professionalised at this time[16]. Furthermore, the consistent decline in amateur contributions must be noted (i.e. category 5).

The three periodicals founded between the two World Wars differed from their predecessors. Discovery was in full professional control. The way in which this journal was founded and conducted has been described above[17]. It was originally the idea of a senior professional scientist. This idea was nurtured, encouraged and acted upon by the Royal Society and its president and a number of eminent professional men of science. The Trustees and Organising Committee were drawn mainly from the ranks of the scientific profession and the academic world. Contributions were vetted by 'authorities' and contributors found by scientific societies which were themselves, as remarked above, increasing their professional membership as their traditional amateur composition altered.

	1(1919-20)	3(1921-2)	7(1926)	average
1	29	31	33	32
2	8	11	15	11
3	8 =45	9 =53	9 =59	8 =52
2+3	0	2	2	1
4	2	6	9	5
5	0	2	0	1
6	53	39	32	43
Total	100	100	100	100

Figure 6: Table showing the percentage distribution of different types of contributor to Conquest, 1919-1926.

Considerably less is known about the organisation of Conquest. The same method was used in this survey as in that conducted for Knowledge. Unfortunately the figure for untraceables is even higher in this case. In fact it is the greatest single category. Nevertheless, if the figures for identified professionals, those with scientific degrees and members of scientific societies are totalled, the average is over 50%. It was becoming increasingly likely that such contributors were either actually professionals or supported the professionals' objectives. This applied particularly to those with scientific degrees who had undergone a substantial part of the process of induction into the profession and who had a particular self-interest in the advance ofprofessionalisation. As regards the "unknowns", although it is likely that a proportion of these were not professional scientists, the possibility that they were increases with the passage of time. That is, as more scientific positions were created, the less likely the growing rank and file professionals would be entered in the standard biographies used in this study.

A final qualitative point concerns the notion of expertise: a crucial concept in the idea of a profession and also in the creation and maintenance of barriers within and around science. The practice of printing letters after contributors' names, be they F.Z.S. (Fellow of the Zoological Society), B.Sc. or Ph.D.[18], conferred a notion of expertise upon the author. Furthermore, both Conquest and Discovery emphasised this concept continuously in editorials. Discovery promised, for example, 'specialised expert knowledge written in a clear and popular manner'[19]. Conquest's contributors similarly were 'experts', 'eminent contributors' who 'whilst writing authoritatively, are able to express themselves in plain, everyday language'[20]. The journals of the 1920s placed an evidently greater emphasis on what was already a feature of the medium at the end of the nineteenth century when professional scientific practitioners began their attempts to control the general science periodicals[21]. By the late 1920s these attempts had proved largely successful: even in those cases where control had not been secured, professional influence was strong[22].

4. Content[23]

General science periodicals adapted in a variety of ways to their changing social, political, economic and cultural context. This was commercially valuable in that the content and presentation of the journals could be changed to meet audience interests and demands. Editors and contributors responded to new attitudes, beliefs, events, etc. as a necessary condition of achieving their aims. Such responses could mean addressing new types of reader. One important way in which general science periodicals reacted to the prevailing socio-cultural climate was by changing their content. Several consequences could result, not least of which was the significance of this changing content for the constitution of the readership. Consideration of this one way of response shows that others were possible. The periodicals also reacted to the situation within science itself and, of course, developments in the process of professionalisation.

From 1870 the birth rate among the upper and middle classes had been declining. They were increasingly practising birth control. The end of the nineteenth century presented them with the option of an improved standard of living. Improved medical care, for example, was available. Many chose to restrict the size of their families because of social and economic ambitions. Later marriage was also a contributing factor. The birth rate among the working classes did not suffer a similar decline. This led, by the turn of the century, to a widespread concern among the middle classes over racial degeneration. The broad currency of social Darwinism exacerbated this concern. Eugenic ideas became increasingly popular. Nature's coverage of the subject increased markedly and the journal adopted a pro-eugenic position, especially over the controversy between Bateson and the biometricians. It was the changing political situation which allowed for this: the decline of laissez-faire values and liberalism; a new concept of state and an increased acceptance of state intervention.

Interest in racial degeneration was heightened by Britain's poor performance in the Boer War (1899-1902). The dismal physical condition of many army recruits provoked considerable discussion of the problem. Fear of being overrun by the working classes at home and doubts about the suitability and capability of the British to control a vast empire ran side by side. There was fear too of being swamped by other, more prolific races - most notably the Chinese: the 'yellow peril'. There arose therefore, a desire for legitimation and justification of Britain's position as leader of an Imperial world. In addition, worries over competition from the United States and Germany and Britain's (then) perceived economic decline brought an interest in arguments asserting Anglo-Saxon superiority. Nature responded to these needs and interests by significantly increasing anthropological articles during the first years of the Edwardian era[24]. Numerous, mainly Imperial, races were examined and described in social Darwinian terms.

Commercial considerations were clearly relevant to these decisions over content. The mainly middle class audience of Nature was greatly interested in these issues and would therefore be more likely to buy the journal. The scientific community was itself largely drawn from the ranks of the middle classes and a degree of identity of interest was inevitable. Further, by providing the middle classes with what they demanded, namely,scientific legitimation of their existing positions and activities, and scientific ideas and suggestions for solutions to existing difficulties, Nature was cultivating the sympathy and support of an important and influential section of society.

Towards the end of the Edwardian period, the journal reduced the attention it devoted to anthropological articles[25]. This coincided with something of a decrease in the wider social preoccupation with race, due to the realisation that the future of the Empire would depend ultimately on the loyalty of and cooperation with its non-white peoples. Another factor was the appreciation that many Americans were not Anglo-Saxon. Although audiences of Nature could still read of the 'lazy lascivious negro' [26] with 'repulsive'[27] habits, a more moderate tone permeated the journal with remarks such as 'Anthropologists have exaggerated the evolutionary gulf between civilised and uncivilised peoples'[28].

The eugenics issue came to prominence once again in the 1920s and 1930s. Sir Richard Gregory, prompted by personal concern, initiated a pro-eugenic policy in 1924 when he published the journal's first of many leading pro-eugenic articles. This continued for more than a decade. The rise of Hitler in Germany and that country's legislation on compulsory sterilisation was an influential factor in Gregory's decision to abandon the policy in the mid 30s[29].

Agricultural articles more than doubled between 1900 and 1914. The great depression of the late nineteenth century had seriously damaged British agriculture. Imports of cheap American corn forced many farms out of business or to meat and dairy farming. The dismal rural situation prompted many to abandon the land for the attractions of the towns. The Edwardian years saw an upsurge of concern over the problem, culminating in Lloyd George's land reform campaign of 1913. Nature wanted to demonstrate the usefulness of science.

In fact publishing articles on agricultural research was but one means by which Nature highlighted the potential value of science to the nation. The previous chapters showed how professional scientists were attempting to persuade a wider public of this value. From 1890 onwards, greater emphasis was placed on both industry and education. Between 1900 and 1909, the amount of space devoted to these two areas was almost doubled[30]. Industrial articles were further increased until 1914. Lockyer was responding to challenges to Britain's economic and industrial position, particularly from Germany. He hoped to persuade his readership (and others) of the benefits which Britain would derive from greater financial and moral support of science. He took advantage of the national anxieties which characterised the years leading to the First World War; he adapted the content of Nature in the hope that this would contribute towards securing his main aims for the scientific profession.

The last decade of the nineteenth century saw a decline in the amount of natural history material contained in Nature. By 1900 the percentage of natural history articles had fallen to less than half its previous level. From 1900, there was an increase in general biology (i.e. theoretical), as well as the more professional type of zoological and botanical material[31]. A much greater emphasis was placed on international science after 1905[32]. This indicates a move away from the amateur (who was often associated with a local perspective) and general non-scientific readership.

Nature changed greatly during the First World War. In fact it was never again the same journal. Taking advantage of the War situation to provoke a wider interest in, appreciation of and support for science, meant considerable alteration in content. In particular, articles on scientific education, scientific reform and industrial and social matters showed a marked increase[33]. With Richard Gregory officially appointed as editor in 1919, policy changes were inevitable. Most significantly, the leader articles became a weekly forum for editorial views on social questions. Education, industrial research, the social relations of science, the relationship between science and government: these were favourite topics in the 1920s. Gregory had to consider the new position of science in the wider culture. The War had brought a widespread concern about science and a degree of government recognition and financial support which required justification.

Several changes which Conquest saw in its content during the 1920s are revealing in terms of the journal's readership. They also serve as a reminder that commercial factors were very influential in determining editorial policy. The numbers of articles on psychology rose markedly between 1919 and 1926. In fact there were none at all in the first volume of the journal (i.e. November 1919-October 1920). Psychology had never really enjoyed very much popularity in Britain either as a subject of public interest or as a serious scientific research discipline. It was only with the successes and publicity that Freudian psychoanalysis achieved in treating the many troops who returned from the front with frequently severe psychological problems and mental illness that any significant interest in and recognition of the value of the subject came. This was reflected in Conquest's growing coverage.

The discovery of the tomb of Tutankahman by Howard Carter in 1922 evoked tremendous public interest, leading, in fact, to an Egyptian craze in fashion, design etc. This coincided with the introduction of archaeological articles to Conquest in 1923. The archaeological content of Discovery also increased from 1922, and continued throughout the 1920s. The development of wireless during this decade met with a similar although more impressive response. Whereas in its early stages the journal gave it little coverage - during its first year of publication only one article on wireless was included - by 1922 articles on the new means of communication and source of information were becoming a characteristic feature. In response to the formation of the British Broadcasting Company at the end of 1922, Conquest began, in January 1923, to offer practical instructions to potential wireless amateurs. The first article in this vein described how a wireless receiver could be constructed[34].

The variation in content in general science periodicals can be analysed at another level. Beyond these important vicissitudes which occurred within individual organs, there is the question about the nature of change in the content across the entire period under study. Whilst it is difficult to generalise, the chief features appeared to have been an increase in technology and in material directed particularly at a female audience during the second phase of the periodicals' develoment. Discussion of these characteristics, however, belongs more properly in that section below entitled readership. Variation in subject matter was often intimately connected with readership. It has already been shown above[35] how Knowledge under Baden-Powell and Grew attempted to exclude the amateur from participation and transform him/her into a passive supporter of the professional scientific élite. The editors went some way towards effecting this transformation by increasing physics, chemistry, technology and biography but decreasing natural history. This close connection between content and readership was not exclusive to content but was shared with presentation which is examined below.

5. Presentation

It is in terms of presentation that the sharpest differences between general science periodicals in the two periods are evident. The term 'presentation' refers to a group of elements elucidated below which, together with 'content' (see previous section) provide crucial evidence regarding policies and attitudes of periodical producers, particularly in terms of their perceptions of readership.

The War changed several facets of British society in fundamental ways. Many of these changes had, of course, begun before the conflict and were exacerbated by it. Some were new. All combined to present a picture of a society inexorably altered by the experience of the Great War. This was perceived by many at the time. For instance, the chemist T.E. Thorpe, in his presidential address to the British Association in 1921, declared:

> 'The whole complexion of the world - material, social, economic, political, moral, spiritual - has been changed, in certain aspects immediately for the worse, in others prospectively for the better'[36].

The new situation demanded responses from the general science periodicals.

The War had in addition affected science itself: specifically in its organisation, its relationship to society and in public perceptions of its nature, its applications and effects, and its influence on everyday life. The transformation of the context in which these periodicals functioned meant that adjustment was necessary in order to survive and to hope to achieve their aims.

In his first editorial after taking over from A.S. Russell as editor of Discovery in August 1921, Edward Liveing stated that the War had meant that '.. all of us had to live or to think beyond the horizons of our offices, our workshops, or our villages; and this has left its mark upon us'[37]. Liveing selected certain aspects of the situation and interpreted these with the interests of Discovery and science at heart. He found similarities between his contemporary situation and the Renaissance of the fifteenth and sixteenth centuries:

> 'But whereas that Renaissance was confined only to the more wealthy and powerful classes and the intelligentsia of Europe, the spirit of our own age is affecting all classes of our social complex. Signs of this new spirit were not wanting before the war; but if the war did not create it, it matured its growth in remarkable fashion. It is a restless spirit; it questions the value of existing social and international conditions and of many ethical and religious doctrines placidly accepted by the Victorian millions; it asks for more definite and accurate knowledge of scientific discoveries... than is given to it by the daily Press. It is a spirit which thirsts for education, and whose thirst must be satisfied'[38].

There was a new interest in science, changes at least in the perceptions of social stratification had occurred, and a new questioning spirit was rife.

Public perceptions of science were altered by the War because of the association of science with Germany and the many scientific applications and innovations brought to the conflict. T.E. Thorpe had been one of Nature's major leader writers between 1880 and 1919. He was, in fact, the most prolific during the final decade of this period (and of Lockyer's editorship)[39]. In addressing the British Association which was, essentially, a public forum, he paid great attention to the question of the War and its relationship with science. He remarked that 'The Great War differed from all previous internecine struggles in the extent to which organised science was invoked and systematically applied in its prosecution.'[40] Thorpe expressed his opinions most forcefully. He clearly felt it was his responsibility to respond to the new attitude to science. This was of great significance as the annual presidential address was widely noticed. He condemned the use of chemical weapons as 'bestial' and warned that

> '...'an educated public opinion' will refuse to give credit to any body of scientific men who employ their talents in devising means to develop and perpetuate a mode of warfare which is abhorrent to the higher instincts of humanity.'[41]

He urged the Association to 'set its face against the continued degradation of science in thus augmenting the horrors of war'.[42] Nevertheless, Thorpe, speaking to an audience much wider than the Association's membership, also pointed to 'an element of good'[43] which the War had brought.

Public perceptions of science had been radically altered by the Great War. The use of aeroplanes, tanks etc. are examples of the numerous technological applications introduced into the conflict. The one which had the greatest effect on public opinion was, however, chemical weaponry. A recent history describes how gas 'remained in the forefront of public concern for many years after its end'[44] and how:

> '... anti-gas attitudes, which, feeble or suppressed in 1915-18, coalesced, gained strength, and attracted considerable attention in the inter-war period'.[45]

The press devoted much attention to the issue as did authors, playwrights, film proucers and other intellectuals:

> 'the mixture of bizarre fantasies and plausible scenarios, together with the common experience shared by thousands of ex-soldiers had an enhancing effect so that poison gas held public attention throughout the 1920s and 1930s.'[46]

The recollections of those who had been at the front were of considerable significance. Winter has described how eager were those not actually involved in the fighting to learn what had gone on[47]. Apart from first hand oral accounts, the literature produced by ex-servicemen enjoyed great popularity. Coupled with this was the psychology of gas. The soldier's fear was unique (partly because of the mysterious element) and once the experience was over, many compensated for their fear by exaggerating the consequences of gas attack[48].

The scientific community had to respond to these attitudes towards science. The use of chemical weapons by the British as well as the Germans worsened the outlook for science. One of the most memorable defences of the use of chemical warfare was J.B.S. Haldane's Callinicus[49] of 1925. Haldane himself had been involved. The book sold over 6,000 copies[50]. General science periodicals responded by focussing on peaceful uses of science and technology in a way quite different from anything which had appeared in pre-war publications of this type. Articles on air transport, wireless etc. abounded but chemical warfare was a subject mostly ignored. Even material concerning, for example, the fixation of nitrogen, failed to refer to Haber's role in the German development of such weapons.

Very occasionally, however, the issue was addressed directly. A Conquest editorial of 1925 admitted that 'the universal horror of this intensive chemical warfare has not abated since [the War] but has, indeed, increased'.[51]. The remark was made by way of an introductory comment to news of the publication of Haldane's Callinicus. It was argued in one article of 1922 that

> 'the use of poison gas by the Germans at Ypres in 1915 may have been a crime against humanity; but chlorine, the gas then discharged, had been employed for the useful purpose of bleaching for more than a century.'[52]

Such emphasis on positive and beneficial technologies typified the general science periodical of the 1920s.

The utilitarian value of science was important to the interwar scientific community for several other reasons. The establishment of the D.S.I.R. in 1916 and the contributions made by the state through it towards scientific research required justification (particularly in view of the ambivalent attitudes prevailing towards science generally). This was mostly attempted by indirect persuasion. In particular, the increase in what may broadly be described as technological material. For example, the proportion of such articles in Conquest never fell below a quarter and at its peak approached a half.[53] The editor himself stated in December 1925:

> '... there is a danger in being too modest about national achievements, especially in these days of economic stress, when national propaganda is a necessity. Our people cannot

> be told too often that most of the great modern industries of the world have been built upon the pioneer work of British scientists and inventors'.[54]

Typical of such articles would be those describing the work of the N.P.L.[55] or British industries such as margarine manufacture. One article 'Rustless iron and stainless steel: science to the relief of household drudgery', would, it was declared, 'tell you the secret of this remarkable steel, which, incidentally, is a British invention'.[56] A trend towards including details of actual applications, or speculations about possible ones, placed usually towards the end of more theoretical articles, was also evident.

In Nature, Richard Gregory chose to address the problem directly. An editorial of 1922 commented that in the view of many people 'science is associated with the transformation of beautiful countrysides into the slums of industrial centres, with high-explosive shells and clouds of poison gas'[57]. It was denied that 'these debasing aspects of modern civilisation are necessary consequences of scientific progress'[58]. To combat this attitude a view of scientific activity as disinterested, an objective search for knowledge was propounded:

> 'The end of all scientific investigation is the discovery of truth in the realm of animate and inanimate Nature, including man, his instincts and impulses and his social organisation'[59].

Furthermore, Gregory's portrayal of science was in terms of 'its moral and intellectual influence' thereby detracting from the 'materialistic things' (i.e. applied science) due to which it was under attack in the public arena. This strategy of emphasising an aspect other than the utilitarian (which had long been the favourite rhetoric of the advocates and publicists of "scientific advancement") prompted Gregory to enthuse:

> 'It [science] represents knowledge as opposed to ignorance, light as against darkness, the beauty of truth and the truth of beauty'.

This philosophy had previously been enunciated by Gregory in his 1916 work, Discovery (subtitled 'Or the spirit and service of science'), the professed aim of which was 'to promote a more sympathetic attitude towards those who are engaged in the pursuit of scientific truth'[60]. This objective also motivated Gregory's editorship of Nature, his work with the British Science Guild and with the British Association.

During the 1920s, Discovery, the periodical, also accentuated the moral and cultural aspect of acience. This journal was named after Gregory's influential book, and subscribed to its philosophy. The theme of science as a cultural force was maintained, not least by the combination of scientific material and that from other fields of knowledge (art, classics etc.). This journal also found it necessary to offer a defence of science in the face of the antagonistic attitudes towards it which succeeded the First World War. The editor (Liveing) perceived that 'In certain quarters there is a semi-conscious hostility towards "scientists" in general for the horrors which they contributed to the recent war'[61]. He attempted to counter this hostility by arguing that the scientists' role in the war was ethically equivalent to that of the soldier, for 'both believed they were acting for the best, in the interests of their country, or in those of civilisation'[62].

Attention was focussed on the benefits to be derived from science in other ways, most notably by a concern with the future. Much emphasis was placed on what science could do. As it was expressed in a Conquest editorial of 1924: 'our business is mainly with the future'[63]. This tendency increased throughout the 1920s. It was exemplified by a series run in Discovery during 1929 entitled 'The next step', in which the prospects for a number of different disciplines were considered by experts including Sir Oliver Lodge and J.A. Thomson[64]. In April 1934 the future theme was reiterated. A whole issue was devoted to 'Science to-day and to-morrow', where once again a number of disciplines were examined individually in terms of their prospects for the future. Contributing luminaries included James Chadwick and Lord Raglan[65]. Concentration on the future in this way distracted attention from the past, particularly the role played by science in the War.

Looking to the future offered other benefits to scientific professionals. Additional justification could thereby be provided for the state's financial contributions to the scientific enterprise. The public image of science was further damaged in the 1930s, not only because of a heightened public interest in the gas issue, but also because of the charge that science and technology were at least in part to blame for the large scale unemployment which accompanied the depression. As Nature expressed it in 1933:

> '.. the present economic dislocation and unemployment are commonly regarded as due to the application of science to the improvement of the technique of production, which has displaced labour and led to overproduction'[66].

Many scientists themselves came to agree with this view[67]. Sir J.A. Fleming conceded as much in his article 'Television and national welfare'[68], although he attempted to emphasise the greater benefits which inventions such as the motor car and the wireless had brought.

An additional problem scientists had to face was the expiry of the so-called million fund in the early 1930s. Any further state aid then had to be voted each year by Parliament. The task of justifying state support and attracting it assumed new proportions. The noticeable trend towards future thinking virtually coincided with this development. The situation was all the more acute because of the depression and the severe economies in government expenditure during the early years of the decade. Discovery commented explicitly:

> 'The expenditure of public money unfortunately merits too often the criticism it receives. But there is at least one form of public expenditure which gives a good return: the figures quoted in the latest report of the Department of Scientific and Industrial Research should find few serious critics'[69].

It was pointed out that at that time industry was contributing nearly three times the amount to scientific research as was the state. Further, the firms making up the membership were claimed to cover industries which provided around half of Britain's total exports. As well as responding to these developments by stressing potential benefits such as the possibility of 'Using the energy of atoms in industry'[70], Discovery further stepped up its 'technological' presentation. For example, the journal ran a series of eight articles in 1932 'in which experts discuss the part played by science in modern industry'[71]. This series coincided with the expiry of the million fund.

During the 1930s, through the economic crisis, Discovery and Nature adopted a new rhetoric of justification. Rather, it constituted an abdication of responsibility. Both journals refused to accept that science was in any way responsible for its non-beneficial applications. Nature shifted liability onto society: 'Science has provided rich treasures, but the community has not made the best use of them'[72]. Science was a value-free enterprise which produced 'true information'[73]. Whilst editor of Discovery at the end of the 1930s, C.P. Snow wrote:

> 'Science itself is a non-moral activity... whether either or none of these applications [good or bad, as described in the text] is carried out, depends on society and not on science. Science can no more prevent itself producing poison and high explosives than a cure for diabetes, or the steam engine. It can no more prevent itself making possible the bombing aeroplane than the ordinary motor-car'[74].

The previous approach had been to describe the beneficial applications of science, whilst keeping references to those which were dangerous or damaging down to a minimum. The inconsistency of claiming credit for the "good" but denying responsibility for the "bad" was pointed out by a critic in a subsequent issue. In his reply Snow could not but accept the logic of the argument but still claimed that on the whole mankind had benefitted and that for this science deserved the credit. Snow's argument had been developing in general science periodicals since Gregory first used it in Nature during the 1920s.

The rhetoric employed by the general science periodicals of the interwar period altered in response to a range of circumstances. The current public attitude towards science was clearly crucial. The aims of the professional science community also changed slightly. The increasingly greater extent to which science was state funded and the social and economic conditions of crisis led scientists towards a reappraisal of their position. Richard Gregory was a key figure in these developments. Gregory's beliefs and objectives of the 1920s came to be modified in ways which have been described by his biographer, Armytage[75], by Gary Werskey[76] and by William McGucken[77]. He managed to persuade the majority scientific opinion, through his work with the British Science Guild, the Association of Scientific Workers and the British Association to agree with him that society was far more influential in social and scientific change than was science itself. His crusade to persuade intensified after he was made a Fellow of the Royal Society (1933) and 'his great talent for persuading people to act in concert'[78] became even more evident than it had been in his popularising efforts of the 1920s. Nature was an important vehicle for this persuasion.

Gregory's efforts culminated in the establishment of the British Association's Division of the Social Relations of Science (1938). The new outlook meant not only that responsibility for certain applications of science was transferred from science, but also that scientists should fight for a greater say in society. Political power for scientists had been advocated by Gregory in the 1920s[79]. During the '30s, social change and Gregory's work meant this aim became widely accepted by scientists. Hence the shift in rhetoric can be seen as a response to changing public attitudes towards science.

J.R. Ravetz has analysed the causes and consequences of the rhetoric which enables scientists to accept the credit for beneficial applications of science but not the blame for those of a less desireable nature[80]. Although his is not an historical analysis, it is nevertheless a useful interpretive device for consideration of the events described above. The confusion between the two goals of knowledge and power (corresponding with the cognitive and social barriers with which this thesis has been concerned) allowed 'a very convenient false consciousness among scientists and their propagandists'[81] to grow up and which has been maintained ever since. The main advantage of this rhetoric was (and still is) its ability to stave off criticism. Arising out of scientists' response to a hostile environment, it means that both what is attacked and what scientists actually practise falls beyond the bounds of the public perception of science.

Visual presentation in general science periodicals also underwent developments during the period of this study. Before 1890, a number of processes were available to the printing industry for the purpose of reproducing illustrations[82]. Engraved blocks of wood and plates of copper or steel were widely employed. From 1850, however, the process of electrotyping[83] came into widespread use. This largely replaced copper and steel engraving as it combined the subtleties of the former with the strength of the latter. It also came to be used to copy woodcuts. Despite this innovation, illustrations remained expensive and time consuming to produce. Hence they appeared infrequently in general science periodicals.

Between 1880 and 1890, two new processes were invented which changed the face of book and periodical illustration. One of these, the 'half-tone' process, made it possible to reproduce photographs. It was cheap and, crucially, extremely quick. A block could be made on the same day it was ordered and furthermore could be printed just as speedily as type. Nature first published photographic illustrations in the early 1890s. These remained few in number. One reason for this was probably that the production of a quality print required a smooth and glossy paper which would have been out of place with the rest of the paper on which the journal was printed and would in addition have cost more. In the late 1890s Knowledge began producing high quality astronomical photographs. These were printed on individual sheets of the glossy paper and the remainder of the journal was printed on the matt paper used previously. From 1904, the new editors decided to print the entire journal on glossy paper. This allowed a greater number of photographs to be inserted in the text. The old system of glossy paper for photographs and buff paper for the bulk of the periodical was reverted to in 1910 for combined reasons of economy and readers' complaints (the glossy paper reflected the light and was more difficult to read under some conditions because of this).

Other improvements in these processes and inventions of new ones came with the twentieth century. These (especially the offset and pantone processes, the former of which was first introduced to Britain as early as 1907) enabled more rapid printing of photographs and eventually meant that quite coarse ordinary buff paper could be used. The general science periodicals appearing after the War were profusely illustrated. The number of illustrations in Conquest, for example, was never less than one per page on average[84]. Many of these were extremely large - a single one taking up a whole or even a double page. Discovery usually included several illustrations (a mixture of photographs and engravings) in each article. This was radically different from the pre-war situation. Neither was it purely a product of economics and available technology. Nature, for instance, never approached anything like the level of illustration of the other periodicals. These considerations have implications for the readership which are discussed below.

Another crucial respect in which the general science periodicals which followed the Great War diverged from those which preceded it was in the role of correspondence. Most of the late Victorian and Edwardian journals had a prominent and lively correspondence column. Not so in the interwar years. Conquest rarely published any letters, beyond those which made up the highly formalised 'Questions and answers' page. Discovery did have a more or less regular column, although it usually only comprised one or two letters and the type of often prolonged and heated debate which had frequently occurred in these journals during the first half of the period under consideration was less evident. In a parallel manner, the correspondence in Nature underwent a significant change, although this had been developing since well before 1914. The typical letter to Nature had been losing its anecdotal mode of expression even before 1890. The growth of the scientific profession[85] after 1900 explains the increase in such letters as well as their nature. Between 1909 and 1912 three volumes a year were required rather than two. The pressure on space was largely due to the growth of the correspondence column. By the 1920s the letter to Nature was well on the way to becoming a formalised means of announcing results, assuring priority, rapidly publishing a preliminary claim as a precursor to a scientific paper proper.

Finally, one further development occurred in the presentation of general science periodicals over the two phases in question. This was particularly fundamental and revealing. The existence of two themes, two apparently conflicting modes of description which permeated the texts in these periodicals from around 1860 onwards, is a central element in this thesis. These were the 'democratic' and 'élitist' trends discussed extensively in the previous chapter. It is significant in this context that in the years following the First World War, explicit articulation of the two conflicting ideas increased, in particular the 'democratic' element. T.E. Thorpe, in the presidential address to the British Association in 1921, which was quoted above, reminded the scientific community of the nature of the context in which they were working:

> It must be recognised that modern ideas of democracy are adverse to the creation of places to which definite work is not assigned and from which definite results do not emanate'[86].

Thorpe was speaking of the D.S.I.R. and its Government funding.

The democratic rhetoric acquired a new prominence from 1919. References to 'democracy' in Discovery editorials were numerous throughout the 1920s[87]. The relationship between science and democracy was taken even further in Conquest. An article entitled 'How science has influenced civilisation'[88] attempted (in the wake of the War and the hostile cultural element which followed it) to show that science had brought major improvements to society. It attributed the overthrow of the feudal system and its replacement with an absolute monarchy to the support of the people. It described how 'in turn, after a long, fierce struggle, the monarchy was forced to yield its pretensions and surrender to the demands of democracy'. The rise of democracy was, it was claimed, due to science. The key to this lay in gunpowder: 'essentially a democratic invention'. This was then explained:

> 'Science placed gunpowder in the hands of the people. Gunpowder put political power within their grasp. They have seized that power, and now hold it firmly'.

This tale served a dual purpose. Clearly, by analogy, it helped to justify the actions of scientists during the War. Furthermore, it had implications for the readership which are explored below.

Although this instance was unusual, it was by no means unique. Lest it be considered extreme, a Nature editorial of the same year (1922) which argued a similar point must be taken into account. Nature too was claiming that democracy was a derivation of science:

> 'the principles of self-determination and self-government have been responsible since the Armistice for many political changes, but these are as nothing compared with the social effects of the independence of scientific enquiry typified by Galileo's life and work.... The freedom of thought and action now possessed by progressive peoples are direct consequences of the work of Galileo and other scientific pioneers'[89]

6. Readership

The factor which serves to distinguish most clearly between general science periodicals in the two phases described above is readership. Further, it is the key to understanding changes in the nature and socio-cultural significance of the general science periodical. Something of the way in which these periodicals defined and redefined relatiohships between participant groups has already been discussed. So too, in general terms, has the constitution of their readership. Here, overall tendencies in the evolution of this constitution are analysed, and a number of possible influencing factors suggested.

Between 1890 and the First World War general science periodicals were mostly intended for a relatively small proportion of the population. These readers were largely drawn from the ranks of the middle classes, including scientists themselves and other professionals.[90] The post-war journals were radically different in this respect. They appealed to a much larger and heterogeneous readership and their editors were aiming to reach a much broader cross-section of the public than had previously been the case. These conclusions were reached by consideration of both direct and indirect evidence.

In the preceding section it was remarked that general science periodicals of the second phase were characterised by their comparative abundance of illustrations, mainly photographs. The developments in technology which made this possible have been outlined. Yet these technological innovations do not completely account for the change in the periodicals. Nature, for example, did not follow the trend towards increased illustration: the journal had other concerns. The use of profuse illustrations in publications from the Northcliffe stable (e.g. the Daily mirror) was partly responsible for its appeal to a mass audience. The postwar journals were attempting to follow a similar path. The interwar years were those when mass communication came of age.

A number of other factors combined with this use of illustration in identifying the readership. One crucial indicator was the type of advertising. Before 1914 advertisements in these periodicals were chiefly confined to scientific instruments, experimental materials, books, magazines, pens etc. In contrast, the postwar periodicals Conquest and Armchair science included a much greater variety which anticipated and would have interested many more readers. Conquest, for example, advertised Bovril, cocoa, condensed milk, tobacco, hypnotism, patent medicines and correspondence courses in a huge range of areas, particularly commerce and accounting. Armchair science's advertising was even more diverse and furthermore was well organised. For instance, dog food was advertised directly beneath an article about the electric hare[91] in the first issue. Other products featured included cruises, shaving soap, eggs, house insulation, shirts, pyjamas and typewriters. These advertisements were numerous in comparison with those of the journals' predecessors.

Article length had been reduced - Conquest's articles, for example, were on average between two and three pages long and those of Discovery four pages long. This compared with Science progress, Bedrock, etc. which featured articles of far greater length, extending up to twenty-eight pages. In terms of word length, this translates into an average of just under one thousand for Conquest, and around five thousand for Bedrock. The print was larger, the text interrupted more freqently with large illustrations, there were many more much shorter items, sentences reduced in length and technicalities occurred less often. These features combined to increase variety and readability and indicate a much broader and less well educated readership than the earlier periodicals. The usual editorial policy in cases of broad, heterogeneous audiences was to take the lowest common denominator.

Of the general science periodicals published between the two World Wars, Discovery was one of the less accessible (excepting Nature and Science progress which were by this time mainly directed at working scientists). Yet in 1924, its editor, Hugh Pollard, in a piece on the British Empire Exhibition, claimed:

> 'Discovery is read by professors, by scientists outside academic circles, by teachers, doctors and all sorts of

> professional men, yet more than half the best and most encouraging letters we receive are written by working men; miners, artisans and mechanics. Men whose opportunities have been few but whose intellectual courage is indomitable. Their desire for knowledge is no mere dilettantism, no pleasing hobby of a well-educated man, but a living ardent passion as vigorous and fundamental as any spiritual element in man.'

He continued:

> '... we find the best scientific brains saying to the masses come, look - and do not be content with marvelling but set out to learn. We will do all we can to help you. That is the spirit of science.'[92]

Conquest was less specific: 'The man-in-the-street' was referred to quite often [93] as the typical reader the journal hoped to reach. More telling was the sympathetic attitude towards the working classes adopted in editorials. For instance, the journal's editorial comment on the British Empire Exhibition bemoaned the facts '.. that the habitations of even Great Britain are mostly slums; that not one thrifty man in hundreds could hope with a lifetime's savings to buy even one unpretentious house'[94]. Further, 'bringing home to all classes the great importance of this branch of human knowledge'[95] (i.e. science) was emphasised as one of the journal's objectives. That Armchair science included a working class element in its readership is demonstrated by the correspondence. For example, the journal received a letter from a working miner which was published in the issue for March 1934.[96] Even Science progress ran a series entitled 'Popular science' through the 1920s.[97]

Therefore the pool of potential readers which the editors of general science periodicals hoped to harvest had extended to include the working classes. Another development, however, was a newly acquired concern with women readers. Women as a separate audience had been largely ignored by these periodicals before the Great War. There were, of course, occasional exceptions. In 1911, for example, the Rev. H.N. Hutchinson commented that '...doubtless the readers of Knowledge are not all men'.[98] Significantly, however, it soon became clear that he was speaking of 'women of the upper and middle classes'.[99] On the whole, these journals made no attempt to attract women readers, to provide for their interests or accommodate them in any way whatsoever.

From 1919, all this changed. Where women were concerned a marked development in editorial policy took place. Conquest included material relating to matters which traditional perceptions regarded as the proper sphere of female activity i.e. the home and in particular, the kitchen. Articles described new electrical domestic applicances such as vacuum cleaners[100] and dishwashers. Technology was also brought into the lives of women by means of accounts of the manufacture of perfume, artificial silk, margarine[101] and so on. The 'Home hints' and 'Novel patents and new ideas' sections regularly addressed women readers, usually with advice or devices to help with cleaning and cooking. It is even possible to identify an occasional correspondent (to the 'Questions and answers' column) or competition winner as female.

Armchair science was more involved with the female element of its audience. Its policy regarding women was stated in its very first editorial:

> 'We believe that the discoveries of the men of Science are of equal interest to the woman in her home as to the officers of the British Association, but we realise that it is the

manner in which the subject matter of the discoveries is served up that is of vital importance'.[102]

Articles directly addressed to women were frequent. For some time the journal ran a feature 'Science in the home' which normally contained two articles, often dealing with food and clearly aimed at women. The emphasis was again focussed on the domestic role of women. Even 'Ruling the world'[103], an early article of 1929, located women's power, their political and social involvement, in the kitchen.

During its first few years of existence, Discovery did not make any explicit concessions to its female readership. Around the mid-1920s, however, some changes in attitude may be detected. Most significantly, a few womens' names began to appear in the journal as contributors. Into the 1930s, issues of specific concern to women received some attention. Of course material relating to nutrition and health, an issue which was of great public interest, would most likely be aimed at women, but maternal mortality, for example, was of particular relevance to women.[104]

These three periodicals were all established after the First World War. They may be compared with Science siftings (1891-1927). This periodical had been aware of the female element of its readership even during the 1890s, but after the War a marked change occurred, Instead of the occasional article on a subject such as "love a disease": what hypnotism can do'[105], Science siftings set out to attract and retain a female readership which had evidently assumed a new significance. 'Diseases which are fatal to women'[106] was a typical title for an article. Female readers would no doubt have been interested to learn of 'The spider world. Where woman rules'.[107] Regular series were instituted for their benefit: 'Feminine science' and 'Domestic science'.

Here once more the emphasis was on women's traditional role. Science for women was defined in the context of the home. It meant domestic science in general science periodicals just as it did in many schools for girls.[108] Women's rights actually surfaced as an issue:

> 'The spiders have long had "women's rights". The females run things and do all the work. The males don't amount to anything, and, being smaller than the females and not so strong, they have to look sharp not to be eaten up, for the mother spider likes nothing better than a juicy male spider for dinner.'[109]

Such a presentation supported the existing social framework, for not only was the issue trivialised, but the situation described would have been undesirable to both female and male readers.

All the periodicals which adopted a new approach to women after 1918 by and large supported the traditional sexual hierarchy within society. In this way the general science periodicals acted politically. At a time of changing attitudes towards women, these periodicals took the part of the orthodoxy. Pollard described technological applications as 'offspring of Nature sired by Science'.[110] In terms of the rhetoric of control, which was very important to these journals, nature was controlled, science controlled. Nature was by tradition female and a number of these journals, including Nature, referred to it as 'she'. Science was similarly male. Two parallel rhetorics were mutually supportive. Just as males controlled females, so did science control nature. This relationship brought benefits (i.e. children, technology). A model which enabled science to be understood in terms of familiar social institutions and which was at the same time supportive of those institutions was important to the social acceptance and authority of science. By analogy, the authority of tradition strengthened the authority of science.

It is therefore clear that after 1918, general science periodicals drew their readership from a much wider, diverse public than they had previously. These readers were being drawn from the working class and female populations as well as from the largely male and professional classes. This was, in part, a response to changing social, political and economic circumstances.

Reference has already been made to Discovery's description of the 1920s as a kind of Renaissance.[111] Liveing wrote of a new 'spirit', a questioning, restless attitude which 'asks for more definite and accurate knowledge of scientific discoveries'. By 1934, the journal was still able to claim that 'Public interest in the progress of science was never keener than it is today'.[112] Mowat's history of the inter-war period also points to a widespread interest in science during the 1920s and 1930s.[113] As noted above, concern with science in a negative sense had arisen in part because of the role science had played in the War and the 'public obsession with gas'[114] which followed. Interest was sharpened in the 30s by suggestions that technological developments had contributed to the unemployment which characterised the depression. Later in the decade, fears of war further heightened this interest. Mowat explains the popularity of science in terms of actual scientific developments. He points to relativity as crucial. This was in fact the case: the theory and its creator aroused massive public and press attention and generated a wide interest in astronomy. Science acquired visibility and drama. Conquest featured several relativity articles and was inundated with postal queries on the subject. Mowat also points to research in biology, particularly that on ductless glands, genetics and sex.

In addition, a positive interest in science was advanced by the technological innovations entering everyday life. Science was given a new tangible meaning via the introduction of wireless, the internal combustion engine (cars and buses), electrification and so on into the lives of an ever-widening circle of people. The car, for instance, ceased to be the prerogative of the extremely rich. The ownership of wireless sets spread rapidly. Cinema gained more and more in popularity. These provide merely a few examples of the way science was seen to enter into everyday life on a hitherto unknown scale and to improve the quality of life for many.

This flowering of interest in science was also reflected in book sales. Discovery referred to the 'unprecedented popularity of scientific books by Sir James Jeans and other modern writers'[115] and commented upon the sales of Jeans's The universe around us which apparently amounted to more than 18,000 in the first week of publication. Other books sold massively. For example, J.B.S. Haldane's Daedalus (of the 'Today and tomorrow' series) sold in excess of 20,000.[116] Books proliferated. But, crucially, their readership expanded in a manner analogous to that of periodicals. Reduced prices, greater print runs and increased availability all meant that the readership of scientific books also changed to include new elements, most notably by attracting working class readers.[117]

The War brought with it a new democratic consciousness. The large numbers of men who served and died during the conflict[118] brought about a widely-held view that the survivors deserved a voice in how their country was to be run. The War had created a sense of unity among the people of Britain - all had pulled together in the crisis and the argument, therefore, extended to everyone: all had a right to a say. Further, enlisted men and officers had come to know each other in the trenches which added to this democratic mood. Constitutional reform was urgently required because the existing residential requirement (under the Suffrage Acts of 1867 and 1884) disqualified many of those who had served at the front from voting. The 1918 Representation of the People Act resulted and gave the vote to all but 5% of the male population. The War had also narrowed the gap between rich and poor. Working class standards of living improved, largely due to an increase in real wages and more equitable distribution of food. Other factors contributed to the prevalent 'democratic' climate, including the sale of many country estates by the landed gentry who could no longer afford to keep them. More leisure time and things with which to fill it (widely perceived as the fruits of science, such as wireless, better transport, etc.) also helped bolster this sense of equality. So too did the wide availability of cheap clothes which imitated the fashions of the well to do.

The 1918 Act also gave the vote to women over 30. During the War, the suffrage agitations which had characterised the Edwardian era were replaced by action. Women took over men's jobs: they were bus conductors, agricultural workers, munitions workers; they did hard work which was vital to the war effort. Perceptions of women's role and status began to change and their reward was the granting of the vote. Other significant changes followed in the 1920s. Despite this, however, after the War many women returned to their former role. The creche facilities which had been made available during the War were withdrawn. The prevailing attitude, not least because of continued concern over the birth-rate, was to keep women in the home or in suitable, low-paid work. The emphasis was on the domestic/childbearing situation. Yet some gains had been made for the work participation rate among women was maintained up to 1931, whereas that among men declined.[119]

Further, female suffrage was extended to all women over 21 in the Suffrage Act of 1929.

In summary, certain economic factors are vital in any attempt to explain how the readership of these journals could have expanded in this way. In particular, a market emerged for higher circulation magazines of this type. The interest generated in science by the War and by the increasing visibility of technology both contributed. So too did improvements in educational standards throughout society and in standards of living, especially among the lower classes, which accompanied the war. Technological innovations provided an additional impulse, greatest in the area of illustration where relatively cheap production of large numbers of good quality photographs became possible. Coupled with this, the existing (and proven commercially successful) well-illustrated mass circulation newspapers pioneered by Northcliffe offered further stimulus.

Economic considerations were by no means the exclusive determinants of the trend towards diversity in composition and increase in size of the readership. Purely economic factors such as the availability of a market were shown in chapter 2 to be insufficient to explain the new situation in general science periodicals after 1918. Whether that additional and crucial motivation stemmed from the 'democratic' mood of the age and a desire on behalf of the scientists to inform their fellow citizens of a 'democratic' state is a significant question. It is shown below that this was manifestly not the case.

The readership of general science periodicals can be seen to have expanded considerably after the Great War to incorporate types of reader which it had not previously covered. It has also been shown how this was accompanied by an increase in democratic rhetoric.[120] Typically, Richard Gregory was quoted in Discovery:

> 'The time has come for a crusade which will plant the flag of scientific truth in a bold position in every province of the modern world.. It is not by discoveries alone, and the records of them in volumes rarely consulted that science is advanced, but by the diffusion of knowledge and the direction of men's minds and actions through it. In these democratic days no one accepts, as a working social ideal, Aristotle's view of a small and highly cultivated aristocracy pursuing the arts and sciences in secluded groves and maintained by manual workers excluded from citizenship'.[121]

Despite such rhetoric and a broadening of readership, it is necessary to conclude that science was, nevertheless, not democratised during this period. If Richard Gregory's public rhetoric be contrasted with the editorial line adopted by his own journal Nature, it can easily be seen that his message to scientific professionals was very different.[122] There he was encouraging scientists to respond to the new situation, to take advantage of the new powerful force 'public opinion' and propagandise on behalf of science. This, of course, virtually coincided with Nature's own change in readership. After the First World War non-professional readers were increasingly excluded from the journal. The responsibility now lay elsewhere - in those other general science periodicals which professionals had worked so hard to control.

Gregory's talk of the rejection of a scientific aristocracy is also belied by other considerations. It has been shown above how an ideology of élitism was fundamental to the professional programme.[123] This permeated the periodicals to the extent where it informed even the choice of analogy. In his article 'The differentiator' Julian Huxley, explaining the role of particular cells in growth, likened the situation to human society:

> 'What more familiar than the fact in the nations a few exceptionally active minds, whether in art or science, politics or business, determine the way in which other less active minds shall employ themselves, shall build their lives - the way in which the community's differentiation shall proceed?'[124]

Huxley was but one contributor among many who injected an élitist element into the portrayal of science in general science periodicals during the interwar years. Paraphrasing his famous grandfather, he wrote in 1921:

> 'One of the great scientists of last century declared that Science was organised common sense. In a way it is; but in another way how emphatically it is not! Perhaps we might say that it is a continual upsetting of the judgements and most firmly-held doctrines of common sense'.[125]

Although political, social, cultural and economic concerns informed the changes in general science periodicals which have been described, especially the emergence of a market and the necessity of attracting a large readership in order to maintain financial solvency, the most significant factor underlying the particular forms and functions adopted by general science periodicals was the professional advancement of science and the securing of a wide public recognition of status, authority and position.

That a 'democratic' motive was not the main impulse behind these developments is further supported by the different ways in which the readership expanded from journal to journal. Discovery, for instance, only responded gradually to the potential female audience. Commercial difficulties appear to have prompted a move in this direction, as well as an attempt to broaden the readership further. Armchair science, founded hot on the heels of the 1929 Act, concentrated on women of the expanding middle classes. The working classes were no longer as important as they had been in the preceding decade; hence that journal's concentration on the middle class physical culture of the 1930s. Discovery, on the other hand, in what was undoubtedly a mixture of audience related and practically motivated social awareness focussed on the importance of adequate nutrition for all classes of society.

The climate of democracy which descended upon the nation after the First World War profoundly affected these general science periodicals. Science progress featured a series of articles on the subject of 'Scientific politics' in the early 1920s which included discussions on '"The will of the people"' and 'Public opinion and propaganda'.[126] That the journal was aware of the need to reach a widening public is evidenced by its introduction of a 'Popular science' series towards the end of the War, and which ran until the early 1930s. Of particular interest is the article in this series entitled 'The encouragement of discovery'.[127] This took the form of a conversation[128] between a 'scientist' and a 'statesman', and argued for more recognition and rewards for scientific practitioners. The article can be interpreted on two levels: a direct appeal to an expanding readership[129]; or an exemplar aimed at the majority of the established readership of practising scientists. Although the series itself demonstrates an awareness of the necessity of communication with a wider public, certain factors count against a genuinely 'democratic' rationale for its introduction. It virtually coincided, for example, with the introduction of a regular feature, 'Recent advances in science', which occupied the first pages of each issue and was a kind of abstracting service for working scientists. The polarising effect generated by the presence of these two very different features established a barrier between two equally different audiences.

General science periodicals utilised a democratic rhetoric in order to maintain a sound basis for support and to impart legitimacy to the authority, status and recognition they were gradually acquiring. This became all the more vital in an age preoccupied with the idea of democracy. Moreover, the establishment of the D.S.I.R. during the War meant that science had to be seen to be compatible with the political climate as it was receiving funding from the nation's purse. The 1918 and 1929 Acts brought political significance to newly enfranchised groups within society. These were precisely the groups which the post 1918 general science periodicals set out to attract. Professional science simply needed the support[130] or at the very least the acquiescence of women and workers because they had assumed a new cultural and political significance. The periodicals were adapting to socio-cultural imperatives. Their talk of democracy was little (if anything) more than rhetoric, it underlay the claim of professional scientists to élite and privileged status, and provided a cloak which facilitated public acceptance of this claim. Science was not democratised: its rhetoric was. As it was expressed in Nature:

'In a democracy one must appeal to the people'.[131]

Notes and references

1. See chapter 2, figures 1 and 2.
2. See chapter 2, sections 4 and 5.
3. Susan Sheets-Pyenson, Low scientific culture in London and Paris, 1820-1875 (University of Pennsylvania Ph.D. thesis, 1976).
4. These are Sheets-Pyenson's terms.
5. R.M. MacLeod, 'Into the twentieth century', Nature, 224 (1969), 457-61, p. 458.
6. See chapter 4, section 2.
7. 'Introduction', Natural science, 1(1892), 1-2, p.2.
8. See critical bibliography. The journal ceased publication in 1898 and new series started in 1906.
9. The quantitative data was obtained by using methods also employed in the analyses described below.
10. E.J.M. Hudson, 'The wheels of time', The Scientific review, 1(1914), 1.
11. It is unlikely that the war affected these figures very much. The figures are derived mainly from the years 1910-15. For the first two years of the War the journal was virtually unaffected. In 1916, however, events began to catch up with Knowledge, particularly, and of most relevance to this discussion, the introduction of conscription in that year. Only one slim volume could be managed for both 1916 and 1917 combined.
12. Samples of approximately equal size were chosen for each period, and each numbered around 100. The sample was random apart from ensuring that consistent contributors (i.e. those with regular monthly columns) were included. Similar procedures were adopted in the surveys of Conquest and Armchair science.

13. The information was derived from biographies, histories of particular scientific disciplines etc. but in many cases from the general science periodicals themselves where occupations or titles were often given. Of particular help were indications of membership of professional bodies like the Institute of Chemistry or the Institute of Physics.

14. B.A. degrees were in a minority and, moreover, could have been obtained in science subjects (e.g. at Oxford and Cambridge).

15. The standard biographical sources were used: Who was who, 5th ed. (London, 1962) and supplements; the Dictionary of national biography (Oxford, 1959-60) and supplements; and the Dictionary of scientific biography (New York, 1970) and supplement. Also disciplinary and institutional histories.

16. See S.A. Neave, A history of the Entomological Society of London, 1833-1933 (London, 1933), especially chapters 6 and 7, p.p. 47-63.

17. See chapter 2.

18. These letters were not always printed after contributors' names.

19. 'Editorial notes', Discovery, 5(1924), 29.

20. 'The editor's chair', Conquest, 2(1920-1), 14.

21. Hudson, op. cit. (note 10).

22. It is unfortunately difficult to draw conclusions with regard to Armchair science. A survey of contributors carried out along the same lines as those above showed that nearly two-thirds of contributors were unidentifiable. Yet one quarter were identified as professionals, including the editor, Bradley, a professional engineer. Moreover, the journal committed itself to support for professional science in its introductory editorial '"Ourselves". What we are and what we hope to be', Armchair science, 1(1929-30), 11, where it was stated that 'it is our intention to give

the public that respect and liking for the man of science which heretofore has been lacking'. The journal's domestic presentation encouraged passive, non-participatory support for the scientific élite. Later in its life, articles such as A.M. Low, 'Chemical experiments at home', Armchair science, 12,(1939-40), 20-23, added a pseudo-participatory dimension. The journal's one genuine venture into the area of reader participation, the Amateur Astronomer's League of 1938, was organised under the direction of members of the British Astronomical Association which was itself under professional control (see chapter 3, section 3). Ralph Stranger, 'The Amateur Astronomer's League', Armchair science, 11,(1938-9), 69-70.

23. The quantitative data in this section are derived from analyses conducted by the present writer and the survey of Nature in MacLeod, op. cit. (note 5). For Nature, the larger period of 1890-1925 was divided into smaller periods of 5 years each. 400 randomly selected articles of at least one column in length for each 5 year period were classified according to 34 different categories (four of which were subdivided further). These categories were those considered approriate to the contents of the journal. It is, of course, inevitable that to a certain extent decisions of classification will be arbitrary. For Conquest and Discovery, all articles in alternate volumes were classified according to similar categories.

24. Between the early 1890s and the early 1900s the percentage of anthropological material doubled.

25. By the end of the Edwardian era the percentage of anthropological articles had been almost halved from its high point at the turn of the century.

26. 'The negro of the New World', Nature, 85(1910-11), 172-3, p. 172.

27. 'Anthropology in southern India', Nature, 89(1912), 530-1, p. 531.

28. 'The Yuchi indians', Nature, 82(1909-10), 191-2, p. 191.

29. See Gary Werskey, 'Nature and politics between the wars', Nature, 224,(1969), 462-70, p. 467.

30. MacLeod, op. cit. (note 5), p. 459. The survey conducted by present writer agrees with MacLeod's conclusions except that the increase in educational material was found to be slightly less than he claims.

31. Natural history 1890: 14%   biology 1890: 4%
    1900: 4%   1900: 10%

    See chapter 3 section 4 for detailed explanation of the difference between natural history and biology. This has been used as a basis for classification and owes its value as a criterion of definition to its historical origin.

32. MacLeod, op. cit. (note 5), p. 459.

33. MacLeod, op. cit. (note 5), p. 459.

34. 'The "Conquest" wireless receiver', Conquest, 4(1922-3), 99-103.

35. See chapter 3.

36. Sir T. Edward Thorpe, 'Presidential address', Report of the British Association for the Advancement of Science, Edinburgh, 1921 (London, 1922), 1-24, p. 22.

37. 'Editorial notes', Discovery, 2, 193-5, p. 193.

38. Ibid.

39. R.M. MacLeod, 'Private army of contributors', Nature, 224(1969), 445-9, p. 449.

40. Thorpe, op. cit. (note 36), p. 22.

41. Thorpe, op. cit. (note 36), p. 24.

42. Thorpe, op. cit. (note 36), p. 24.

43. Thorpe, op. cit. (note 36), p. 22.

44. L.F. Haber, <u>The poisonous cloud</u> (Oxford, 1986), p. 285.

45. <u>Ibid.,</u> p. 282.

46. <u>Ibid.,</u> p. 289.

47. J.M. Winter, <u>The Great War and the British people</u> (London, 1985), especially chapter 9, pp. 279-305.

48. Haber, <u>op. cit.</u> (note 44), pp. 288-9.

49. J.B.S. Haldane, <u>Callinicus</u> (London, 1925).

50. Private communication, Ms. K. Ring. From Kegan-Paul quire stock book (1908-35), item 55. Routledge and Kegan Paul archive, University College, London.

51. 'Notes of the month', <u>Conquest</u>, <u>6</u>(1924-5), 213.

52. J.A. Brendon, 'How science has influenced civilisation', <u>Conquest</u>, <u>3</u>(1921-2), 507-10, p. 507.

53. Figures based on quantitative survey of <u>Conquest</u> (see above, note 23). This showed that volume <u>1</u> (1919-20) contained 46.4% technological material and volume <u>7</u>(1926) contained 25%.

54. 'Notes of the month', <u>Conquest</u>, <u>6</u>(1924-5), 539.

55. E.g. Walter Rosenhain, 'The internal structure of metals', <u>Conquest</u>, <u>1</u>(1919-20), 19-24.

56. 'Rustless iron and stainless steel', <u>Conquest</u>, <u>1</u>(1919-20), 34.

57. 'The influence of science', <u>Nature</u>, <u>109</u>(1922), 801-3, p. 801.

58. <u>Ibid.</u>

59. <u>Ibid.</u>

60. R.A. Gregory, <u>Discovery, or the spirit and service of science</u> (London, 1916), p.1.

61. 'Editorial notes', <u>Discovery</u>, <u>3</u>(1922), 141.

62. <u>Ibid.</u>

63. 'Notes of the month', <u>Conquest</u>, <u>6</u>(1924-5), 1.

64. 'The next step': I J.A. Thomson, 'What is ahead in biology', Discovery, 10(1929), 7; II Sir J.C.W. Reith, 'The future of wireless broadcasting', Ibid., 37; III A.C.D. Crommelin, 'Astronomy widens its vision', Ibid., 78; IV Sir Oliver Lodge, 'The new outlook in physics', Ibid., 109; V O.G.S. Crawford, 'The archaeology of tomorrow', Ibid., 145; VI F. Debenham, 'Farther afield in exploration', Ibid., 187; VII V.E. Pullin, 'The future of radiology', Ibid., 214; VIII The Master of Sempill, 'Aviation spreads its wings', Ibid., 247; IX J.F. Thorpe, 'The synthetic chemistry of the future', Ibid., 299; X A.E. Boycott, 'Next steps in medicine', Ibid., 326; XI Sir John Russell, 'The future of agriculture', Ibid., 335; XII William Kerr, 'Some possibilities in engineering', Ibid., 404.

65. 'Science to-day and to-morrow': Lord Raglan, 'Anthropology to-day and to-morrow', Discovery, 15(1934), 89; J.L. Myers, 'Archaeology to-day and to-morrow', Ibid., 90; Herbert Dingle, 'Astronomy to-day and to-morrow', Ibid., 91; Charles Singer, 'Biology to-day and to-morrow', Ibid., 91; Sir Percy Sykes, 'Exploration to-day and to-morrow', Ibid., 92; A.C. Seward, 'Geology and plant-life to-day and to-morrow', Ibid., 94; James Chadwick, 'Physics to-day and to-morrow', Ibid., 96.

66. 'Science and social problems', Nature, 132(1933), 653-5, p. 655.

67. William McGucken, Scientists, society and state. The social relations of science movement in Britain 1931-47 (Columbus, 1984), pp. 45-6.

68. Sir Ambrose Fleming, 'Television and national welfare', Discovery, 15(1934), 106.

69. 'Notes of the month', Discovery, 15(1934), 27.

70. John Thomson, 'Using the energy of atoms in industry', Discovery, 15(1934), 124-6.

71. Sir E. John Russell, 'Modern research in agriculture', Discovery, 13(1932), 71-4, p. 71. The other articles in the series were II Sir William B. Hardy, 'New Knowledge of food', Ibid., 115-8; III Sir Harold Carpenter, 'The age of metals', Ibid., 141-6; IV G. Shearer, 'X-rays and new methods', Ibid., 189-92; V O.F. Brown, 'The development of wireless', Ibid., 215-18; VI Morris W. Travers, 'Some aspects of fuel research', Ibid., 245-8; VII S.O. Rawling, 'The new photography', Ibid., 289-92; VIII W.H. Gibson, 'The search for new fabrics', Ibid., 320-24.

72. Op. cit. (note 66), p. 655.

73. Op. cit. (note 57), p. 803.

74. C.P. Snow, 'Science and war', Discovery, n.s. 1(1938), 318-9, p. 318.

75. W.H.G. Armytage, Sir Richard Gregory: his life and work (London, 1957).

76. Gary Werskey, The visible college (London, 1978).

77. McGucken, op. cit. (note 67).

78. Armytage, op. cit. (note 75), p. 121.

79. The point was cautiously made in the 1925 article 'Science and the community', Nature 115(1925), 4-5. As early as 1915 the journal was complaining about the lack of scientific representation in both the Commons and the Lords, 'Science and the public', Nature, 96(1915-16), 335-6.

80. J.R. Ravetz, 'Anti-establishment science in some British journals', in Helga Nowotny and Hilary Rose (eds.) Counter movements in the sciences Sociology of the sciences yearbook 3 (Dordrecht, 1979), 27-37.

81. *Ibid.*, p. 29.

82. Marjorie Plant, *The English book trade* (London, 1939), pp. 307-18, also John Feather, *A dictionary of book history* (London and Sydney, 1986).

83. See Plant, *op. cit.* (note 82) p. 312 for explanation.

84. The illustrations in all 7 volumes of *Conquest* were counted and an average found by dividing by the number of pages.

85. See chapter 2, section 4(vi) and chapter 3, section 2.

86. Thorpe *op. cit.* (note 36), p. 24.

87. E.g. 'Editorial notes', *Discovery*, *2*(1921), 277-8, p. 277.

88. Brendon, *op. cit.* (note 52).

89. *Op. cit.* (note 57), p. 802. My emphasis.

90. See chapter 2, section 4.

91. 'The electric hare', *Armchair science*, *1*(1929-30), 50.

92. Hugh Pollard, 'The Royal Society's demonstrations of pure science at the British Empire Exhibition', *Discovery*, *5*(1924), 53-4, p. 53. My emphasis.

93. E.g. 'The editor's chair', *Conquest*, *2*(1920-1), 14.

94. 'A Martian at Wembley', *Conquest*, *6*(1924-5), 246.

95. 'Notes of the month', *Conquest*, *6*(1924-5), 539.

96. *Armchair science*, *5*(1933-4), 804.

97. The first article in the series appeared in July 1916. 'Popular science' articles became a regular quarterly feature throughout the 1920s, and gradually disappeared from the journal in the early 1930s.

98. Rev. H.N. Hutchinson, 'Science in everyday life', *Knowledge*, n.s. *8*(1911), 89-91, p. 89.

99. *Ibid.*, p. 90.

100. E. Austin, 'Our housemaid electricity', *Conquest*, *1*(1919-20), 112-8.

101. E.g. 'What is margarine?', Conquest, 1(1919-20), 55-61.

102. Op. cit. (note 22). My emphasis.

103. Miss E. Proctor-Gregg, 'Ruling the world', Armchair science, 1(1929-30), 23-4.

104. E.g. John Yudkin, 'A new medical discovery', Discovery, n.s. 1(1938), 55-9.

105. '"Love a disease": what hypnotism can do', Popular science siftings, 69(1926), 293-4, 307-8.

106. 'Diseases which are fatal to women', Popular science no. 1799, 69(1926), 17.

107. 'The spider world', Popular science siftings, 69(1926), 286.

108. David Layton, Interpreters of science (London, 1984), pp. 33-6.

109. Op. cit. (note 107).

110. Pollard, op. cit. (note 92), p. 53.

111. Liveing, op. cit. (note 3).

112. 'Editorial notes', Discovery, 13(1934), 57-8, p. 58.

113. C.L. Mowat, Britain between the wars, 6th ed. (London, 1966) p.p. 220-3.

114. Martin Ceadel, 'Popular fiction and the next war', in Frank Gloversmith (ed.) Class, culture and social change (Brighton, 1980), 161-84, p. 169.

115. 'Notes of the Month', Discovery, 12(1931), 1-2, p. 1.

116. Op. cit. (note 50).

117. Private communication, Ms. K. Ring.

118. J.M. Winter, The Great War and the British people (London, 1986), p. 75. Nearly three-quarters of a million men from Britain and Ireland died.

119. Jane Lewis, 'Women between the wars', in Gloversmith, op. cit. (note 114), 208-39, p. 210.

120. See chapter 4, section 7.

121. 'Editorial notes', Discovery, 2(1921), 277-9, p. 278.

122. See chapter 4, section 7.

123. See chapters 3 and 4.

124. Julian Huxley, 'The differentiator', Discovery, 5(1924), 76-7, p. 77.

125. Julian Huxley, 'Living backwards', Discovery, 2(1921), 28-31.

126. 'Notes. Scientific politics: I Self determination', Science progress, 16(1921-2), 437-41; 'II Labour and the Labour Party', Ibid., 628-32; 'III "The will of the people"', Science progress, 17(1922-3), 130-5; 'IV Public opinion and propaganda', Ibid., 283-92; 'V The election analysed', Ibid., 439-42; 'VI The theory of the state', Ibid., 630-5.

127. Ronald Ross, 'The encouragement of discovery. A proconnary', Science progress, 19(1924-5), 296-306.

128. This form of presentation was unusual in general science periodicals between 1890 and 1939, but does have a tradition in the popularisation of science. E.g. Jane Marcet, Conversations on chemistry, 3rd ed. (London, 1809).

129. The journal's circulation had been increasing since the end of the War. It rose from 739 in January 1918 to a peak of 1,187 in January 1922, remaining above a thousand (per issue) until mid-1925. (John Murray archive).

130. As defined in chapter 4, section 1.

131. Op. cit. (note 79), p. 5.

CHAPTER 6

GENERAL SCIENCE PERIODICALS IN THE UNITED STATES: A COMPARATIVE ANALYSIS

1. Introduction

The present chapter is devoted to a comparison between American and British general science periodicals. It was undertaken with a view to providing further insights into the nature and functions of those periodicals which are the main subject of this study. Specifically, it was hoped that comparative analysis would reveal something of the significance of professionalisation for the popularisation of science in general science periodicals, and the role of these periodicals in developing relationships and interactions (which proved so interesting in the British context) and in constructing social and cognitive barriers.

In the quest for a deeper understanding of any problems, one possible approach is to broaden the perspective. The objective in this instance was to escape the limitations imposed by national frontiers, thereby moving towards an improved appreciation of the nature of the process of popularisation of science and its impact upon the constitution and activities of the scientific community.

2. The professionalisation of science in the U.S.A.

Locating American general science periodicals in context is essential in explaining the differences and similarities they exhibit when compared with their British counterparts. In view of the crucial significance that the professionalisation of science has been shown to have had for these periodicals in Britain, an examination of the American process presents itself as an obvious starting point for this analysis.

The available literature is diverse and often contradictory. Rosenberg wrote despairingly several years ago:

> '...no currently available formulation of the stages and characteristics of the professionalization of knowledge is based on an adequate historical investigation'.[1]

and little has altered since then. This difficulty proves to be more acute in the American than the British context. Rosenberg's solution is to adopt a particular rather than a general approach. That is to examine the changing relationships, needs and identities of specific disciplines in a detailed way. The discipline is chosen as the basic unit of analysis because, despite differing institutional contexts, (e.g. university and industrial research laboratory), those who identified themselves with any one discipline obtained thereby a sense of community, of belonging, and ultimately of professional identity.

This is an important point as much of the literature tends to separate groups of scientific practitioners into, for example, those working in industry and those at universities. This sense of unity, however, demands that scientists working in all contexts be considered. Without specific articulation, Rosenberg's procedure was in effect followed in the discussions of British professionalisation. Here, the most significant features in those discussions are examined in relation to the American situation. These include the existence of agreed standards, a process of induction into the group, the existence of employment (on which the members of the profession are dependent for their livelihood) and recognition beyond the profession itself.

Nathan Reingold, in his article 'Definitions and speculations: the professionalisation of science in nineteenth century America'[2] separates the scientific community into three groups: 'researchers', 'practitioners' and 'cultivators'. The last named roughly corresponded to the British committed amateur. 'Researchers' and 'practitioners' made up the emerging professional community as they shared education, training, membership of the same professional institutions and so on. Reingold himself admits the high degree of overlap between his categories.

Significant changes in the nature, organisation and perception of American science of the sort associated with professionalisation really began after the Civil War. As in Britain, these changes were slow and gradual. Reingold also argues that the transition to professional status was characterised by a marked decline in the numbers of 'cultivators'. The emerging professional community was 'struggling to differentiate itself from amateurs'.[3] One means by which this differentiation was effected was by the creation of professional institutions. It can also be said, in a somewhat general sense, that the increasing complexity of science, particularly its language, tended to exclude the possibility of self-education. Meaningful participation in science came increasingly to depend on specialised training.

The last years of the nineteenth century and the early years of the twentieth witnessed the establishment of societies from which the amateur was completely excluded or at least discouraged from joining. In 1891 the American Chemical Society was reconstituted and became a national professional society. The American Physical Society and the Astronomical and Astrophysical Society of America were both founded in 1899, the American Anthropological Association in 1902 and the first biochemical society in 1906. These institutions encouraged a sense of community especially important to the United States. A sense of unity was a long time coming to individual scientific disciplines and science as a whole due to American geography: the country was simply too large and scientists had to work hard to achieve it.

These societies were also a means to the improvement of standards. The quality of research in several disciplines compared unfavourably with European work. The creation of periodical publications largely concerned with original work of professionals also contributed to the improvement of standards. For example, the Journal of the American Chemical Society was revitalised in the 1890s and in 1893 the Physical review was established. The chemical journal, although much improved, continued to publish poor quality research in order to avoid dissent and disagreement among local sections of the national society. This illustrates the prime importance of creating and maintaining a sense of unity for the American scientific community on the road to professionalisation. Journals as well as societies contributed towards this achievement. The Physical review was not all that could be desired of a national, professional publication. Before 1910 material on the 'new' physics was in short supply. The periodical was taken over by the American Physical Society in 1913 when standards were raised and the cause of unity advanced. Other similar disciplinary journals were launched in the early years of the century. The Transactions of the American Mathematical Society (1900) offered a model to be followed. Earlier scientific periodicals had accepted much poor quality work or republished European work. Moreover, many of the best American papers had appeared in more prestigious European journals.

The American scientific community was, by the turn of the century, moving towards the independence, autonomy and acceptance of standards necessary to a profession. Certification within the individual disciplines was provided by the universities which played a crucial role in the professionalisation process. Graduate training was offered at first only by a small number of schools, the first one being Johns Hopkins, founded in 1876. In the early days, the fact that such training was available at relatively few centres engendered a sense of cohesion, identity and community among America's scientific practitioners. Thus the universities, societies and periodicals developing at the end of the nineteenth century constituted an essential framework for the profession of science.

The universities were important to emerging scientific professionals. Crucially, they provided the majority of available employment for newly qualified scientists. The universities were growing swiftly during this period. Their response to the rapid increase in numbers of graduate and undergraduate admissions was to appoint more staff. (The number of graduate students enrolled in 1900 was 6,000; this rose to 47,000 in 1930).[4] Unlike Britain, a glut of newly qualified science students (at various levels) did not emerge from the universities with little or no prospect of scientific employment. Those with doctorates were mostly reabsorbed into the higher education network. Whilst the numbers of the scientifically qualified increased substantially at the beginning of the new century, they did not constitute the type of 'pressure group' for status, recognition and rewards that was evident in the British context. A limited amount of employment was available in industrial research laboratories. Yet, as Edward Shils has described them, these laboratories did not present a particularly appealing prospect for most scientists:

> 'Not only were they very few in number, relatively small in size, and specialised within a narrow range, but they did not accord freedom of publication to their scientists and were,

> for the most part, devoted to applied or practical research'.[5]

Beyond the greater number of posts on offer, the university jobs were much better suited to emerging professionals striving for national and (particularly) international status and recognition, autonomy and self-regulation. Similar disadvantages accompanied the more numerous posts at agricultural research stations. Industrial research only became a major feature of American science in the second decade of the twentieth century, although the conditions which made this possible had been enduring for a number of years previously.[6]

Science funding from 1890 originated in a diverse variety of sources. University departments relied heavily on tuition fees, but also obtained income from state government funds, endowment and direct philanthropy. Industry also provided some support. It used university scientists as consultants and in 1881, the American Bell Telephone Company gave Harvard the money to build a new physics laboratory. In return the company received the assurance that the university laboratories would be put at the disposal of professors undertaking work for private companies.[7]

Private philanthropy was particularly important to American science. Much attention has traditionally been paid to the huge philanthropic organisations and contributions of the likes of Rockefeller and Carnegie. The early years of the twentieth century saw the creation of a number of massive foundations committed to 'the advancement of knowledge and human welfare'.[8] They proposed to achieve this by supporting research. Although separate institutions such as the Rockefeller Institute for Medical Research (1901) were set up, they were few and themselves depended on the universities. Most foundation donations, however, went to existing universities to support large-scale projects, erect buildings and buy large, expensive equipment such as telescopes. Awards were infrequently made to individual researchers until the 1920s.[9] The powerful foundations were not alone in their support of science during this period. A larger number of individuals made a greater number of smaller donations of considerable significance. In effect, this meant that the emerging professional community not only could but had to appeal to a public directly for support.

Even more so than in Britain, public opinion was crucial in the professionalisation of science in America. Public support in the broader sense was a vital factor in the development of American science. This was particularly true of financial support, be it from industrial, philanthropic or federal sources. The ways in which the scientific community adapted to the climate of public opinion in constructing an image of science in the public domain, and the popular response to this, had important consequences for the organization and pursuit of science.

At the beginning of the nineteenth century, American science did not enjoy much public esteem. During the early 1800s a strong anti-science current prevailed. The second quarter of the century, however, saw an increasing amount of popularisation which capitalised on the remaining public interest in scientific subjects with dramatic, wondrous and entertaining aspects. Mid-century popularisations were especially successful because of the overwhelmingly utilitarian rhetoric they employed. Its spokesmen persuaded the American public that science had become democratised. It was widely believed that everyone could understand and make judgements about scientific questions. These popularisations generated a great deal of popular interest and support. One manifestation of this was the high profile science assumed in the curricula of the rapidly expanding college system.[10] Further, as it has been expressed by one historian, 'For its support, science, in common with other areas of national culture, became subject to popular taste and approval'.[11]

Although this utilitarian, Baconian and democratic concept virtually dispelled the hostility which science had suffered previously and placed it rather in a position of public favour, it was nevertheless accompanied by a number of serious disadvantages to the scientific community. This was most evidently and damagingly so in the case of professionalisation. Even before the Civil War difficulties began to emerge. The twin ideals of utility and social democracy were contradicted by the decline of the amateur and the rise of specialisation. In fact the concepts of professionalism and social democracy were mutually antipathetic. Daniels refers to 'the hostility of democracy to professional expertise'.[12] A crucial element in the notion of professionalism was autonomy. This was incompatible with the idea that the average citizen was capable and competent to assess and draw conclusions about scientific matters. In inculcating the idea of a democratic science, aspiring professionals had effectively conceded an important point: control over the process of knowledge production.

At first reluctant to form national professional bodies because they might not be able to maintain internal control,[13] leading professionals[14] relied on the American Association for the Advancement of Science (A.A.A.S.). From its establishment in 1847 the Association regarded the advancement of science and not its diffusion as the principal objective. The professional hold over the body grew firmer with the years, and the Association came to assume a variety of roles. One of these was to act as an authority in disputes, which prevented scientific practitioners from appealing to the public. This was an important way in which the community tried to keep control out of public hands and secure professional autonomy.

By the 1870s scientific practitioners enjoyed considerable status in American society. The majority of employment for men of science was in the Universities and Colleges.[15] University research not only provided full time employment for the new, emergent professionals but also, eventually, standards, status, recognition and rewards. It was, in fact, the chief route by which American science became professionalised.

Federal government funding was stepped up after the Civil War. The establishment of the Bureau of Agriculture and the passing of the Morrill Act which granted public lands for colleges (the 'land-grant' colleges) during the War (both 1862) set the scene for further government expenditure on science. These two events differed from their predecessors in that although the Naval Observatory, the Coastal Survey, etc., were federally funded, they had been conceived as temporary. The Civil War developments were new and significant in that Congress thereby demonstrated its support for scientific research and embodied this support in the setting up of permanent bodies for the prosecution of such research. Subsequently more federal support was obtained, more bureaux established. Successes scored by science in the Civil War encouraged these developments. One of the most notable was the passing of the Hatch Act in 1887, when the federal government made available $15,000 a year for the support of an agricultural station in each state.

Between 1870 and 1900, the American scientific community came to develop and articulate a new ideal. The proliferation of specialist and professional societies which occurred during this period has been described earlier in this section. The A.A.A.S. acted as 'an effective pressure group to promote federally funded research'.[16] The flowering of other institutions and societies which performed many professionalising functions towards the end of the century meant the Association shifted its emphasis to persuading the public on whose opinion the future course of science depended.

This new ideal to which scientific practitioners increasingly came to subscribe, was that of professionalism. Autonomy, employment, recognition, and rewards were all part of the new point of view. One particularly contentious aspect was the belief in the value of 'pure' science, of research for its own sake, for the acquisition of true knowledge, and not to serve any utilitarian ends. A more appropriate rhetoric came to replace the utilitarian democratic version in the public arena.

Several circumstances contributed to the development and expression of the professional ideal. Many young scientists studied in Germany during the 1870s and 1880s where they imbibed the professionalism and became motivated by the élitist ideology of the German academic community. Professionalism, however, also had an internal national development in the United States and was not restricted to the sciences. Science was but one field among several seeking professional status and autonomy at this time. In addition, the prevailing atmosphere of cultural nationalism provided encouragement to compete with European successes and prestige in the world of science. The change in rhetoric was made possible by the palpable successes of applied science. The need to emphasise the utility of science vanished once it became obvious and the scientific community had other concerns.

Ironically, it was precisely these demonstrations of the practicality of science and the successful and persuasive utilitarian rhetoric which hindered the professionalisation of American science. The colleges and universities were regarded primarily as teaching institutions. If the science professor wished to undertake research this was understood to be in an amateur-like way outside working hours. Practical science was the order of the day, not the 'pure' abstract sort esteemed and endorsed by the advocates of professionalisation. Furthermore, many of the colleges were poorly equipped, struggling affairs, and most offered no opportunities for graduate study. The scientific community, in contrast , required that such institutions serve as research centres and as training grounds for new professional scientists.

The inevitable conflict between professional élitism and egalitarian democracy also intruded into the relationship between the scientific community and the federal government. Federal financial support for scientific projects was forthcoming only if some practical results were promised. The scientists concerned found the requirement of practicality an increasingly difficult burden to bear. Those employed at agricultural stations, for example, were expected to work on economic benefits which science could bring to agriculture and advise farmers on how to put their results into practice. This was often translated into the running of a profitable farm, and the pursuit of research was often very difficult. Yet the greatest obstacle aspiring professionals had to overcome was the idea of public accountability. The ideal of a self-governing, self-reproducing, widely recognised professional community of scientists, although by no means realised by 1900, was well on the way to being so.

There is a tradition in the literature on American science in which emphasis is placed on the support given to applied science and technology. This is contrasted with an indifference to, dislike of, or discouragement of 'basic' or 'pure' research. Reingold has gone far in showing that such a simplistic categorisation fails to do justice to the situation.[17] Kevles describes the 'prevailing attitudes of indifference, if not hostility toward science in industrial circles'.[18] Before 1900 industry had little contact with science, although a few independent laboratories, scientific consultants and even laboratories attached to particular firms did exist. Throughout the nineteenth century and into the twentieth, 'American society continued to rate men of practicality as the equals of men of science'.[19] The industrial research laboratory began to make its mark on the American scene at the turn of the century but it was the First World War which gave the process of development a considerable impetus. This is indexed by the following: in 1913, industrial physicists made up one tenth of the membership of the American Physical Society; by 1920, this proportion had risen to one quarter.[20] The 1920s saw the industrial research laboratory come into its own: the number had risen to 300 in 1920 and exceeded 1,000 by 1927.[21] Large corporations could by then support laboratories with substantial research staffs. There had also grown up a realisation of a need for industrial research among the business community. The War itself, by bringing together science and industry on a hitherto unseen scale, demonstrated the real potential of cooperation, thereby escalating an already existing trend.

With the 'essentially aristocratic'[22] conception of science its practitioners were mostly expounding at the end of the last century and the beginning of the present,

> '...the scientific community may not have found much support among the industrial entrepreneurs of the day, but it did find enthusiastic patrons among a special group of college educated Americans consisting of predominantly upper-middle-

> class, well-to-do professionals, businessmen of a mercantile cast, and landed gentry.'[23]

These classes supported the scientists in their campaign for the élite and privileged professional status they desired. This included financial support. They held comparable status and wanted to keep it. A powerful group within society, they backed the growth of the universities and the research ideal.[24] (It is significant that the trustees of the great foundations entertained similar views and ensured that the weight of their organisations was behind this movement.)[25]

A sense of national pride provided further encouragement. In the context of the establishment of the state in the late nineteenth century, these ideas of the American middle classes can be seen as related to the prevailing atmosphere of xenophobia described by Eric Hobsbawm.[26] This cultural nationalism was related to the status/élite argument as was the huge wave of immigration seen in the United States at the end of the nineteenth and the beginning of the twentieth century. The scientific community and the middle classes shared interests and subscribed to the same ideology. They were mutually supportive: the middle classes paved the way for professional recognition; the scientists imparted authority and legitimacy to arguments of racial superiority. An identity of interests prevailed. These relationships were reflected in the general science periodicals.

It was not the older and more established social élite in which scientific professionalism found its principal ally. American society was in the early years of the twentieth century undergoing a number of fundamental changes which have earned the period the title of the 'Progressive Era'. These years were characterised by the rise of a new bureaucratised middle class who undertook a series of radical reforms. This new force in society shared scientists aspirations to professionalism. Furthermore, they had a deep-rooted faith in science or, rather, in something called 'scientific method', which they believed, when applied to social problems would provide solutions. Deeply impressed by successful technology and its power of control, the progressives regarded science as leading inevitably to progress, and attempted to bring a rational, "scientific" approach to many aspects of society. Although the emerging professional community were understandably wary of this tendency in the light of their preoccupation with the pure science ideal, it nevertheless did wonders for their public image and public attitudes towards science.

In the wake of the First World War, public attitudes towards science became even more favourable. The proliferation of industrial research laboratories has been described. Scientific achievements during the war (e.g. submarine detection, disease prevention and control, etc.) exacerbated the prewar trend and served to improve the status of science in society even further. This differed from the British context where scientific involvement in the war evoked a considerably less sympathetic public reaction. The authority of science was strengthened and the residual distrust of the expert all but disappeared. The 1920s became '"the golden age of scientific faith"'[27] in the United States. Science had achieved public recognition. It had acquired the status and authority of a profession, but more than that, a deep rooted and passionate belief in its capabilities.

The ascendency of science in public perceptions coincided with a new radical democracy after the Great War. A combination of wartime experience and rhetoric as well as the changing attitudes towards science led to support for a somewhat idealised direct democracy in which objective experts advised the average citizen who then made decisions. Public hostility was reserved for politicians, not scientists. Thus the American scientific community achieved a degree of professional status, authority and recognition during the interwar period which their British counterparts could not match. Their position in the public mind, in government and in society was equalled across the Atlantic only by the aspirations and dreams of a Lockyer or a Gregory.

Whilst it would be inappropriate to explore the disagreements between historians of American science in a comparative chapter such as this, the analysis of one particular historian must be questioned at this point. Nathan Reingold has stated, in comparing British and American circumstances with respect to the professionalisation of science, that 'the replacement of gentlemen amateurs by a gentlemanly professoriate [in Britain] is remote from the problem of an élite in a democracy'.[28] That he chose to interpret the differences between the two nations in precisely this way, displays Reingold's miscomprehension of the British situation. The bulk of this thesis has shown just how mistaken his contention was. Both groups of professionals had to cope with this 'problem'. Furthermore, the Americans achieved far more in the acquisition of status and authority in their own society than did their British counterparts. One task of the remainder of this chapter is to investigate why this was the case.

3. The periodicals

The preceding chapters have demonstrated that British general science periodicals arose in the first instance and took the particular form they did in response to a prevailing set of circumstances. Further, they continued to interact with this cultural context throughout the period under study. It has already been shown above how the American context differed from the British in certain respects. It is therefore clear that no American general science periodical could be expected to be closely comparable with its British counterparts. This is indeed the case, although there were some important parallels.

Two major journals have been chosen as subjects for this analysis: the Popular science monthly and Science. The Scientific American was unsuitable. The journal may be identified as comparable to the English mechanic by its 'nuts and bolts' approach, its technical engineering and practical content, its role as patent agent and its target audience (the 'nebulous community of inventors').[29] Such periodicals lie outside the scope of this study. In their classificatory scheme, Whalen and Tobin[30] do not include it under their general science periodical heading. Rather, it was in their terms a 'periodical of scientific study'.[31] By the end of the nineteenth century the Scientific American had become 'more of a general information type journal'[32] (i.e. it was not restricted to scientific and technological information). It entered into something of a decline at this time, mainly due to the adverse effect of the diversification policy pursued by the firm of Munn and Co. who owned the journal.

a) Popular science monthly

The Popular science monthly has been described by Louise Michelle Newman (in her study of the role of the periodical in the women's debate of the late nineteenth and early twentieth centuries) as 'an influential journal of the nineteenth century'.[33] The journal was founded by E.L. Youmans in 1872, and was intended primarily as a vehicle for the writings of Herbert Spencer. Youmans wrote to Norman Lockyer that it was 'a piratical concern of which I am duly ashamed',[34] as it was 'based on the reproduction of British and European articles'.[35]

Youmans represented a group of 'cultivators' and 'practitioners' (to use Reingold's terms) who 'saw a need for conveying both a sense of and a meaning for the mission of science to the public and their colleagues'.[36] The advancement of science was a primary motive underlying journal policy and Youmans saw his audience as comprising not only the 'cultivators' and 'practitioners' themselves but also the 'learned culture' or 'polite culture' (again as defined by Reingold).[37] This polite learning was an eclectic selection derived from very many fields of knowledge. It was largely restricted to the upper middle classes since 'most of the people did not possess polite learning'.[38]

Other writers have identified the readership of the Popular science monthly. Kevles has already been quoted[39] in equating the supporters of the emerging scientific profession (i.e. 'predominantly upper-middle class, well-to-do professionals, businessmen of a mercantile cast and landed gentry')[40] with this readership. According to Newman, they were 'well educated, white middle-class men and women'.[41] Under Youmans the journal was aiming to educate, provide intellectual stimulation and prove useful in readers' everyday lives by means of their application of scientific knowledge and scientific method. In relatively short, non-technical articles, the philosophical implications of science and its bearing on modern life were a significant feature.

Major changes in the nature of the periodical were made around the turn of the century. In 1900 James McKeen Cattell took over as editor and the Popular science monthly became a component publication in

Cattell's Science Press. This was probably at least in part a response to the criticism the journal had meted out to the new professional ideal.[42] Under Cattell contributors were drawn increasingly from the native professional science community. They included the most eminent, such as T.H. Morgan and Simon Newcomb, university and college professors, and government scientists working in, for example, the Bureau of Standards or the Department of Agriculture.

Each issue contained about seven essay-type articles together with a section entitled 'The progress of science'. The length of the main articles varied from four or five pages to twenty-five or more. The larger pieces required a considerable amount of commitment from the reader. The only British general science periodical to have such similarly long articles was Science progress, the review journal for inter-disciplinary communication between professional scientific specialists. In terms of technicality, a great variety was displayed. The range spanned between T.H. Morgan's long, technically and structurally difficult 'The mechanism of heredity as indicated by the inheritance of linked characters'[43] and the straightforward, non-technical prose of F.C. Brown's 'Who profits from scientific work?'.[44] Illustrations were rare in this journal and the texts continuous, in contrast to most of the British periodicals.

The effect of these and other changes as exemplified by the name change of the journal in 1915 to The Scientific monthly was to alienate much of the existing readership. Cattell phased out the correspondence column. The philosophical speculations were halted. Science was presented as an essentially professional enterprise. The 'Progress of science' section was particularly important in this connection. The main body of the section dealt with obituaries, major anniversaries, meetings, the opening of new buildings, etc. The sub-section 'Scientific items' provided a list of deaths, appointments, resignations, awards, elections to societies, honorary degrees, memorials, prizes, and so on: in other words, it was devoted to professional news. Furthermore, this section was more accessible to non-professional readers than any other part of the periodical. It included photographs which interrupted text written in clear, simple non-technical language.

The non-scientific middle class, although distanced from the world of professional science was still important to that world. Provision was made to maintain its interest (shorter articles, for example, and the topics chosen). What did change, however, was the sequence of relationships between the journal, its readership and its by now largely professional contributors. From active participation, the readership was consciously shifted to non-participatory and passive acceptance of scientific status and authority and support for the scientific enterprise. These developments, paralleled in other general science periodicals, were but one means by which Reingold's 'cultivators' were excluded from the scientific community proper. These periodicals redefined the wider perception of that community. In fact, until at least 1910,

> '...periodicals were the dominant means for conveying images of science to the public.'[45]

The readership remained restricted to the middle classes. Whalen and Tobin have remarked that

> '...the mass audience, who had never been taken into account by the editors of these general science periodicals remained in uncomfortable ignorance.'[46]

In comparison with the British situation these changing relationships and concerns are revealing. In both cases an emerging professional community took control of the medium of the general science periodical and used it to advance their own aspirations to professionalism. They used the periodicals to establish their status as an élite and its accompanying authority in the public arena. The separation of amateurs from the new professionals was furthered by the tendencies evident in these journals. In both countries, the scientists addressed the people who mattered. In Britain, as described above[47] there was an observable trend towards an extension of the audience. Apart from wider recognition and support, funding was crucial. As a mood of'democracy' swept the country after the end of the First World War and the voting public altered its size and constitution in the Suffrage Acts of 1919 and 1928, the professionals adapted their journals to cope with the changes. Funding, closely tied to recognition and support in a wider sense, depended on these voters. They had to be persuaded to lend their support to science. Without at least making an attempt, science in Britain between the wars would have had no authority, legitimacy or status.

In the United States, the people who mattered were the middle classes. The old middle classes (i.e. 'self-employed, enterpriser-workers and professionals')[48] were the original supporters of science and the Popular science monthly. The newly emerging scientific profession depended on this group for support (as described in the preceding section) in both ideological and financial respects. Private support for science was crucial in America. Without the necessary reliance on state support seen in Britain, the American scientific community could afford to concentrate its efforts on a relatively small section of the population. The rise of the new middle classes from 1870 onwards (i.e. 'white collar persons on a salary')[49] had consequences in terms of support, direct and indirect, financial and otherwise, which are explored below.

b) Science

The takeover of general science periodicals by the new professional scientists was more obvious, complete and organised in American than in Britain. Reference has already been made to James McKeen Cattell and his Science Press. Cattell built a periodical empire by systematically acquiring a number of science periodicals and transforming them in accordance with his own attempted 'radical reform of the American scientific community'.[50]

Science was founded in 1883 but after ten years ceased publication because of lack of funds. Cattell bought the journal in 1894 and somewhat after the manner of Lockyer used his contacts within the American scientific community to ensure that among his contributors numbered the most eminent men of science in the country. Science thereby became

'a central organ of news and opinion for American science'.[51]

During the 1880s Science had been clearly modelled on Nature, most obviously and immediately in its typography. Once in Cattell's hands, however, it became more like Nature in spirit by providing a means of communication between a thriving and original community of scientists. The circulation was greatly increased in 1900 when Cattell persuaded the American Association for the Advancement of Science, with which he was involved, to make Science its official organ. This, together with Cattell's reform programme, altered the readership of the journal. Such a method of removing the problem of subscription commitment was unique in this study. One attempt was made in Britain to follow a similar course. Negotiations between John A. Benn and the British Association in 1937 failed, however, to make Discovery the official organ of that organisation.[52]

The first editorial of the new series which began in 1895 was penned by Simon Newcomb. He wrote of the journal that

> 'It will have little space for technicalities which interest only the specialist of each class, and will occupy itself mostly with those broader aspects of thought and culture which are of interest not only to scientific investigators, but to educated men of every profession.'[53]

The following article, also of an editorial nature and contributed by D.C. Gilman, reinforced this idea. Science was to be

> 'adapted to many men of many minds, a newspaper, in fact, planned for those who wish to follow a readable record of what is in progress throughout the world, in many departments of knowledge. It is not the place for 'memoirs' but for 'pointers'; not for that which is so technical that none but a specialist can read it; not for controversies, nor for the riding of hobbies. It should not be maintained for the dominant advantage of any profession, institution or place.'[54]

One of the most important functions of Science was social. It helped to bring a unity to a widely scattered and traditionally quarrelsome population of scientific practioners. The remarks about 'controversies' and 'the riding of hobbies' are particularly pertinent to the American scene at this time. The journal was for a while largely free of the controversies which were a feature of Nature, particularly in the correspondence columns. The overriding theme was unity: it had to be both secured and projected. The non-scientific readership served two functions at this time. They provided a public by which the community could be recognised and they provided subscription money. Following the changes of 1900, these subscriptions were not as necessary, Cattell had acquired the *Popular science monthly* which catered for this type of reader (i.e. the more serious 'amateur', the middle class, well educated 'cultivator', which of course he ideally desired be separated from the professional community) and *Science* became increasingly a journal for a readership mainly comprising scientific professionals.

The *Popular science monthly* and *Science* have therefore been selected as the primary sources upon which the following comparison and analysis are based. Attention is focussed on the *Popular science monthly*. It facilitated interactions between groups within the scientific community and beyond it. Similar interactions are precisely what made the British situation most interesting. The remainder of the present chapter addresses the role of the general science journal in these interactions, within the American context.

4. The unity of science

In the present section, material from the two periodicals of which the subject was 'science' in general is discussed. This type of article may, as in the British periodicals, be distinguished from those dealing with particular sciences. It is from such a study that an overview of the journals' interests, attitudes and policies can be derived. The general science periodical offered the ideal forum for such discussions; in this case general meant that which took and represented science as a unity. This was of greater significance in the American context. These articles were frequent and important in promoting a sense of unity among scientific practitioners and a perception of a scientific community among the readership. Simon Newcomb referred to 'a tendency toward unification'[55] in his introductory editorial in Science (1895). With this he contrasted the trend of specialisation which was at first emphasised because of the pressing need to bring together the scattered scientific workers of America. Conversely, the growth of specialisation and the associated notion of expert knowledge were reflected in the presentation of individual disciplines as identifiable 'subspecialised bodies'.[56] This aspect is dealt with in the next section.

The two editorial articles which introduced the new Science in January 1895 were immediately followed by a piece taken from Daniel G. Brinton's introductory address to the A.A.A.S. as president. Entitled 'The character and aims of scientific investigation',[57] it described the nature of scientific activity. This description was at first Baconian and democratic. The goal of science was scientific truth - this must be tested by appeal to evidence which

> '...is that which is in the power of every one to judge - that which is furnished directly by the senses. It deals with the actual world about us, its objective realities... The only conditions which it enjoins are that imperfections of the senses shall be corrected as far as possible, and that their observations shall be interpreted by the laws of logical induction.'

Brinton then listed some of the practical benefits science had brought to everyday life. He proceeded to assert that scientific truth was

> '...absolutely open to the world ...there is no such thing

> about it as an inner secret, a mysterious gnosis, shared by the favoured few, the select illuminati, concealed from the vulgar horde, or masked to them under ambiguous terms.'

Brinton's rhetoric therefore self-evidently conformed to the beliefs and attitudes towards science then prevailing in society. This viewpoint was, however, to become increasingly rare in both the periodicals in question.

Towards the conclusion of his article, Brinton presented an alternative conception of science in which the dogmatist can be right and about which there is something spiritual which can 'satisfy the loftier yearnings of the soul of man'. In accordance with the new ideal of professionalism in science, Brinton was espousing the notion that science was a part of general culture and hence deserved to be studied for its own sake, not merely as a means to an end.[58] He attempted to synthesise these two views of science in the final paragraph:

> 'This is the mission of science - noble, inspiring, consolatory; lifting the mind above the gross contacts of life, presenting aims which are at once practical, humanitarian and spiritually elevating.'

This synthesis and its component elements bears parallels with the two modes of presentation and their synthesis used in British general science periodicals. In Science, however, it is noticeable that the democratic, Baconian and utilitarian gave way to something quite other. By the 1920s the journal painted a picture of a highly organised professional community. Much space was devoted to the columns 'Scientific events' and 'Scientific notes and news' which were concerned with, for example, meetings (both international and national, but not local), deaths, honours, appointments, the openings of new buildings and so on. Professional contributions with titles such as 'The emission of electrons from tungsten at high temperatures: an experimental proof that the electric current in metals is carried by electrons'[59] were published alongside a section on 'Scientific apparatus and laboratory methods'. Neither Science nor science were 'absolutely open to the world' by this date.

The approach adopted by Brinton at the end of his article was merely a foretaste of what was to come. The professional ideal was vigorously pursued in both journals and with the passage of time the demands for recognition and rewards escalated. From the very outset of Cattell's editorship of the Popular science monthly complaints about the status of scientists in society as a whole (or, more specifically, among its more influential sections) were voiced. One article, 'The man of science in practical affairs'[60] argued that the scientist was much like other men and that 'he may exemplify any trait of human nature except the traits of ignorance and stupidity'. The practicality of scientists was emphasised and attempts were made to dispel the stereotype, which bore more than a passing resemblance to the caricature of a German professor, of the 'elderly dreamer in spectacles with no aptitude whatsoever for practical affairs'. Particularly in the area where science and business were closely related, it was said:

> 'In our own country the importance of applied science is fully realized and its achievements are beyond dispute, but the scholar as yet receives less consideration than the commercial expert.'

Direct appeals for financial support were occasionally made. For instance, one long article of 1900 describing all aspects of the Massachussetts Institute of Technology, ended in the following manner:

> '...may we not hope that as the applications of science to the arts enrich the alumni and friends of the Institute, they may help us to make the road easy for their successors by devoting a part of their riches to the advancement of technical education?'[61]

As time progressed, emphasis on the practical aspect of science declined. Four years later, a plea for more general recognition of status was expressed in the 'Progress of science' column. Comparisons with France were made:

> 'It is probable that the conditions are more satisfactory here, where scientific work is adequately supported by the state and by private endowment, although the scientific worker is likely to be unknown outside his own circle. But reputation and fame have so long been regarded as the rewards of certain kinds of service that the homage paid in France to a man such as Pasteur may attract young men to a scientific career.'[62]

This kind of complaint or unfavourable comparison with other, specifically European nations was typical.

That same year, an explicit description of some of the professionals' main dissatisfactions was given by Professor John J. Stevenson of New York University in his article 'The status of American college professors'.[63] Reference has been made above to the importance of the university and the research ideal to the professionalisation of science in the United States. They were, in fact, the areas in which all the significant developments took place. Stevenson's complaints reflected the changed attitudes of American scientists to universities and colleges, the increased value they now placed on scholarship and their attempts to present science as part of general culture,[64] all of which sprang from the new ideal of professionalism.

He wrote:

> 'It is true that college professors have never received salaries such as to arouse envy in men of other professions, but, at one time, the calling offered great attractions to those who cared more for study than money.'

The dissatisfaction over salary can be attributed to a number of factors.[65] Academics were forced to spend an increasing proportion of their day in teaching which left less time for research; they had very little (if any) say in how their departments were organised as power lay mainly in the hands of each institution's trustees and president; and they faced new competition in the status stakes from the new middle class professionals (e.g. social workers).[66] It was remarked that scientific training was 'more exacting than that for any profession, medicine not excepted'.

Stevenson bemoaned the fact that

> '...the compensating privileges of social standing and leisure for research have been reduced to a minimum. This feeling respecting the status of American professors is... widespread.'

In the past, 'as in Germany of today', it was added, 'the calling was honourable above all others'. Among suggestions offered to remedy the situation were included 'the elimination of mimic universities' to ensure standards, and a reorganisation of the higher education institutions' administrative arrangements in order to place a greater degree of control and professional autonomy in the hands of university scientists. This latter was one of the main aspects of Cattell's previously mentioned attempted 'radical reform of the American scientific community'.[67] The journal compaigned vigorously to achieve this reorganisation and authority transfer to the profession.

This article was addressed, at least in part, to those who supported science financially. Critics of these donors were attacked and of the donors themselves Stevenson wrote that 'they have done only what everyman ought to do and they have chosen a praiseworthy method; they will be remembered as doers of good'. Further, he urged:

> 'But now, in most of our colleges, additional buildings are not the urgent need; the time has come to impress upon the community the necessity for endowments, that qualified instructors may be obtained so as to utilize properly (sic) the buildings and equipment already provided so generously.'

This appealed directly to donors, but also urged the scientific professionals themselves to publicise the situation.

At this time the Popular science monthly reprinted an address by Simon Newcomb to the International Congress of Arts and Science which was clearly intended for a wide audience and was entitled' The evolution of the scientific investigator'.[68] He concluded:

> 'It is, therefore, clear that the primary agent in the movement which has elevated man to the masterful position he now occupies is the scientific investigator. He it is whose work has deprived plague and pestilence of their terrors, alleviated human suffering, girdled the earth with electric wire, bound the continent with the iron way, and made neighbours of the most distant nations.'

He was, however, at pains to stress that although the work of captains of industry and inventors was vital, the transition undergone by society and described in the previous quotation

> 'was possible only through a knowledge of laws of nature which had been gained by men whose work took precedence of (sic) theirs in logical order.'

Namely, 'the true man of science... [who] has no such expression in his vocabulary as useful knowledge'. This propagandisation of research was a major feature of the periodical throughout the period considered. The attempt to distinguish between the scientist and inventor should be noted.

Wartime conditions proved to be particularly revealing in the case of Nature and its editorial intentions. Science was presented on both sides of the Atlantic as that which was going to win the War. Despite the escalation of cooperation between American scientists and industry during the War, the contributors to Science continued to argue for 'the pursuit of knowledge for the sake of pure truth alone'.[69]

Advantage was taken of the unusual circumstances to press the cause of science, just as occurred in Britain. One article in Science was typical.[70] It was complained that 'In the past botany has failed to receive the full measure of popular appreciation it deserves' but the war offered a 'wonderful opportunity' to rectify the situation. The following was suggested:

> 'Let us by spoken and printed word and by demonstration strive to instill into the public mind a greater respect for botanical research and a more ready acceptance of its results, thus doing our bit toward ensuring both scientific and material prosperity in the future.'

Elsewhere the use of publicity was advocated 'to get... information to the public which is now interested in the subject on account of war conditions.'[71] Thus Science acted in a similar way to Nature during the First World War, by mobilising scientists to make the best possible use of the situation and the extent to which science had become involved to promote their case for recognition in the public arena.

The 1920s saw the scientific profession approaching the kind of appreciation the general science journals had been aiming for. Science showed clear understanding of this: 'Science is becoming recognised as one of the important professions'.[72] Problems persisted in certain areas of the country. A letter from a scientist employed by the Bureau of Plant Industry in 1927 complained of the situation in some of the south west states.[73] The situation was compared with that experienced by 'real estate operators' a few years previously. In both cases, bona fide professionals were 'being hampered in their chosen field by a motley array of amateurs of a low order'. A code of ethics was suggested 'that should go far toward making the profession respectable - at least in the eyes of the public'.

During the decade following the First World War the American scientific community increased its efforts to secure professional status, recognition and rewards. James Rowland Angell, chairman of the National Research Council, argued in an address of 1919 (reprinted in the by now renamed Scientific monthly of 1920)[74] for the encouragement of research:

> 'This encouragement should be in part in the form of public recognition, both inside and outside the academic circle, and in part should take the form of increased opportunity for productive work.'

He continued:

> 'In my judgement this particular association can hardly do any one thing more useful for the safeguarding and developing of research interests than by setting its face energetically to nation-wide propaganda for the speedy betterment of the conditions of research workers and the trainers of research workers in universities.'

It is significant to note at this point that 'Nature's leading articles did have a strong influence abroad'.[75] In fact George E. Hale, one of the founders of the National Research Council, wrote to Lockyer that he had 'followed with great interest'[76] the journal's wartime leaders.

America's general science periodicals, moreover, appear to have followed some of Nature's advice, just as their British counterparts did. Particularly reminiscent of the British journals were their calls for recognition and propaganda on behalf of science, as typified by the above quotations from Angell's address.

The most significant features of the 1920s in The Scientific monthly were a strengthening of democratic rhetoric and a heightened sensitivity to the attitudes and perceptions of a larger audience than that composed largely of the middle class readers which the journal had traditionally courted. During this decade federal funding assumed a new importance for the scientific profession. As one historian has expressed it '...the folklore of scientific independence... was rapidly being eroded by raw economics'.[77] Although traditional philanthropy was still important, and this was reflected in The Scientific monthly (e.g. 'The Steinhart Aquarium of the California Academy of Sciences'),[78] both science and government began to realise that cooperation would be mutually beneficial. Receipt of financial support required public justification, not merely appeal to a restricted and privileged élite.

Because of this changed state of affairs, articles with titles such as Austin H. Clarke's 'What science owes the public'[79] began to appear. Here it was asserted that 'Science has become democratized'. This new expansion in democratic rhetoric was necessary because of the changing relationship of science to the larger society and the new mood of radical democracy which swept the country after the War. It was possible because science had largely achieved the status and recognition among those sections of American society to which emerging professionals had previously been addressing themselves. According to Austin Clarke of the Smithsonian

Institution 'Science is and always has been dependent on the active appreciation of an interested public'. In appealing to a wider cross section of society and urging scientists to do the same he asserted

> 'In the old days science in America was for the most part the recreation of the rich or well-to-do, and these were the only classes interested. Conditions are quite different now.'

Revealingly, he referred to an increased interest in science created by scientists themselves and commented:

> 'But by doing this science has brought upon itself a grave responsibility, that of satisfying the interest it has itself created. Why is this true? Because of the dependence of science on intelligent popular appreciation. This dependence is at once apparent in all those institutions that are supported by federal or state appropriations. It is at once apparent also in the great industrial concerns that sell their products to the public... though not so obviously or so immediately responsive to the popular will, endowed institutions are nevertheless ultimately dependent on it.'

The Popular science monthly can therefore be seen as acting on behalf of the professional science community in essentially the same way as its British counterparts. It differed, of course, in its precise mode of action because it was the product of and interacted with a distinct and very different context. By examination of selected topics from the journal, a more complete picture of these interactions can be gained.

5. Specialised professional fields: individual disciplines in the *Popular science monthly*

a) Astronomy

The Astronomical and Astrophysical Society of America was founded in 1899. Although it initially welcomed amateurs they had only marginal status within it. Towards the end of the decade, however, the society took steps to encourage amateur astronomers in a positive way. At around the same time, one Frederick C. Leonard founded the Society for Practical Astronomy (1909). This was to be a national organisation for amateurs and it was intended to publish a journal of amateur work eight or nine times a year.

During the first two years of its existence, the Society for Practical Astronomy met with little success; by 1911 it had only eighteen members and only two issues of the journal had appeared. Leonard then sent an announcement to *Popular astronomy*, a periodical controlled and edited by professional astronomers but aimed almost exclusively at amateurs. In the announcement,[80] which was long, Leonard described his society which he wanted to be 'one of the strongest and largest amateur astronomical organisations in existence'. Such an autonomous amateur group would constitute a threat to professional status, it would have meant a considerable weakening of disciplinary control. The professionals responded appropriately: they attempted 'to define and establish more explicitly the relationship between amateur and professional'. Rather than attacking Leonard and his society, they suggested explicitly an alternative in which the amateurs would be controlled and coordinated by the professionals.

Underneath Leonard's announcement in Popular astronomy there was an editorial note by Herbert Wilson, director of the Goodsell Observatory.[81] Completely ignoring the Society for Practical Astronomy, Wilson commented on the desirability of a national organisation for amateurs. His model was undoubtedly the British Astronomical Association in which professionals directed the work of amateurs and organised them into specialised sections, some of which were headed by amateurs. The next issue of the journal announced the setting of up a variable star section of the national society Wilson had proposed.[82] E.C. Pickering (director of Harvard College Observatory and contributor to Knowledge) was aware of the value of cooperating with amateurs. For some years he had used them at Harvard as an inexpensive, controllable data-collection force. (He also employed women observers because they cost little.) The variable star section extended the existing Harvard programme - with Pickering and his staff directing operations and interpreting data. Heading the new section was one of Pickering's amateur observers, William T. Olcott. He himself was 'willing to put up with regimentation, systematization and disciplire in exchange for the opportunity of contributing to astronomy'.[83] Olcott was himself trained by Leon Campbell, one of Pickering's staff. By the end of the year the section had become independent and was known as the American Association of Variable Star Observers. The data was still interpreted by professionals and the Association remained closely associated with Harvard for many years despite being incorporated into the national professional society (renamed the American Astronomical Society in 1914) in 1918.

Through Popular astronomy it was not long before another amateur organisation, the American Meteor Society was established. By these means professional astronomers assured themselves of disciplinary control, with the added advantages of a low cost and willing labour force to do routine work and a loyal group of supporters. Leonard's society, although showing early promise, was beaten by professional power, and collapsed during the First World War. Amateurs chose to join the societies controlled by the professionals as these had more status. Whereas in Britain these relationships were redefined to a certain extent in the general science periodical, this medium was not used in the American context. They had an already existing, well established journal for amateurs which was adequate to do the job. Before the 1920s, the Popular science monthly adopted the non-participatory approach. This did not even include 'pseudo-participation'. It did not need to. Professionals were seeking rather to dispel the democratic image of science which was well entrenched in American culture.

Astronomy was not a particularly well covered subject in the Popular science monthly. There was no regular astronomical column, which was a very important feature in several British general science periodicals. During the first two decades of the twentieth century astronomy articles were either historical[84] or placed emphasis on professional instrumentation, international cooperation and were often quite technical.[85] This trend continued in the 1920s, with one or two exceptions. Most notable amongst these was Leon Campbell's article 'The amateur's work in astronomy',[86] one of a series of radio talks reprinted in The Scientific monthly of May 1926. This article was reprinted with only minor changes in Discovery later in the year.[87] It dealt with the ways amateurs could and did contribute to astronomy, and paid much attention to the American Association of Variable Star Observers. Of the A.A.V.S.O. it was said

> 'Its chief purpose is to secure those observations that will be of the greatest value to the professional astronomers.'

More details of the scheme were given in the American journal, in particular, how the data was used and the fact that it was published in Popular astronomy. This article attempted to shift 'cultivators' as defined by Rothenberg[88] (i.e. those interested in astronomy but unable to do any meaningful research) from the world of passive non-participatory acceptance to the world of routine participatory activity subordinated to professionals. The attempt to involve is nevertheless significant for the Popular science monthly in view of the new set of circumstances to which it was required to respond, in terms of the post-war radical democracy and the growing importance of federal funding for science.

b) Technology

The importance of technology and applied science in American culture, the rhetoric of utility and the meaning of science within that culture have been described above. So too has the way federal government funding of bureaux and especially agricultural research stations led to exasperated scientists solving narrow practical problems. The high regard in which inventors were held by the public at large frustrated aspiring professionals. Looming large in the professional ideal imbibed by students studying in Germany were the research ethic and the strong desire to be rid of the yoke of utilitarianism.

It is therefore hardly surprising that two journals owned and edited by one of these new professionals, who was consciously out to reform the American scientific community and advance the cause of scientific professionalism, should have included very few articles on technology indeed. Conversely in Britain, where the prevailing public perception of the scientist at the end of the nineteenth century was of the gentleman amateur pursuing science as a hobby, technology was frequently a major feature. In Britain the public required to be convinced of the utility of any science. In America, they had to be persuaded of the value of pure research over applied research and ultimately of both of these over invention. Furthermore, the interests jointly shared by the scientific community and the middle class readership would not have been served by the inclusion of much technological material in these journals.

Despite the conspicuous absence of articles specifically devoted to technology in the Popular science monthly, there was a role for it within articles primarily devoted to pure research. The aim was to create a new link between the kind of élite, professional research undertaken in academic centres and the practical improvements technology had brought to everyday life in areas such as, for example, health and communication. Emphasis was, however, always placed on the research ideal. An example of this has already been seen in Simon Newcomb's article on 'The evolution of the scientific investigator'.[89] It was taken to the extreme in 'Utilitarian science',[90] in which the primacy of research was clearly articulated. This was taken to the point where it was asserted that

> 'The time must come when a man who has no learning and no experience in research will not be called educated, whatever may be the range of his erudition.'

Just like their British counterparts, American scientists, whilst willing to take credit for the beneficial applications of science, laid the responsibility for the less welcome consequences elsewhere:

> 'At the same time these defects are not to be charged to science, but to the failure to utilise it.'[91]

It was only in articles written by scientists at agricultural research stations (which were funded by the federal government) where less emphasis was placed on the singular importance of undirected research. As Rosenberg has expressed it:

> 'In their appeals for public support... would-be entrepreneurs of agricultural science had no choice but to affirm a necessary interdependence between science pure and science applied.'[92]

W.J. McGee, National Conservation Commissioner, was exceptional. He laid down a progressive scheme for the development of science in which utilitarianism was the final stage. He wrote in 1910 that science had evolved through three stages of sophistication.[93] Investigation was initially 'subjective', became 'objective' or 'Baconian', and ultimately grew to be 'directive'. The knowledge which arose from such research was, respectively, 'accidental', 'incidental', and 'a means to an end'. Not only was McGee's scheme simplistic and idealised, his emphasis on practicality was rare among contributors to the Popular science monthly. This may be explained by McGee's position as federal government official whereas most of the journal's contributors were professional scientists.

c) Medicine

Medical material became a prominent feature in The Scientific monthly following the First World War. The War itself had generated an increased interest in medicine which continued after 1918, bolstered by the campaign for medical insurance. The American Association for Labour Legislation also contributed to this heightened awareness by publishing a series of pamphlets which exposed disturbing facts about the health of the country. Even before this, however, (i.e. since the first decade of the twentieth century) movements for the conservation of national resources and national health had been growing in strength. These were characteristic of the

Progressive Era with its emphasis on efficiency, reform and the application of "scientific method". A further important element of the era was, of course, professionalism. In these respects science and medicine were allied.

Medicine had suffered throughout the nineteenth century from a surfeit of "quacks". (This story has been well documented by James Harvey Young in The toadstool millionaires).[94] Lack of standards and adequate certification saw the profession overrun and its reputation ruined. The work of Pasteur and Koch did not make itself felt in the United States to any significant extent until the 1890s. Doctors began to organise and acquire professional recognition. The American Medical Association reorganised in 1901 and its membership rose from 8,400 in 1900 to more than 70,000 by 1910.[95]

The new status of medicine was therefore dependent on the prestige of science (especially in the shape of the bacteriological work of Pasteur, Koch and their followers). It continued to be so, although the relationship was by no means unidirectional. A series of medical articles entitled 'The physical basis of disease'[96] was particularly important. The author was a medical research worker. The series took the form of a conversation in which the participating characters and their lifestyles revealed something of the nature of the audience intended. They were the well-to-do middle classes (e.g. lawyers, manufacturers), both male and female. At one stage such 'people of means and social position' were chided for being 'responsible for the commercial exploitation of the medically ignorant',[97] (reflecting the new radical democracy as well as the reforming concerns of the Progressive Era).

Several professional issues were tackled. Greater control of those licensed to practise was advocated, as many qualified medics were in fact 'frankly incompetent'.[98] Alternative forms of medicine were condemned, including religio-therapy and chiropractise. Religious sects opposed to the new professional medicine were attacked: 'African voodoism masquerading in the nomenclature of christianity. Financed by predatory commercial interests. A yearly sacrifice of ten thousand human lives (sic).'[99] Commercial interests were criticised elsewhere - they had been active in resisting the proposed medical insurance which workers' organisations were fighting for. Quacks and anti-vivisectionists posed a threat to professional autonomy, control and authority. Legal control of 'charlatans' was claimed to be 'ineffective ... so long as medical and hygienic matters are in the hands of political machines, reflecting the ideas of the ignorant.'[100] The qualified medical practitioner was an 'expert'[101] and deserved to be recognised as such.

The author ('the research worker') complained bitterly about the lack of funding received by medical research (although it did rather well out of the large foundations). Wealthy philanthropists were clearly the target. Funding of other scientific disciplines was also deplored, and astronomy singled out, as

> 'an intellectual luxury that should be supported only after pressing problems of human life have been solved.'[102]

Such sciences, it was declared in an appeal to the practical tradition, were 'of remotest bearing on human life'. In keeping with the new attitudes of the 1920s, the research worker also claimed

> 'As soon as the importance of such work is realised by the general public, adequate support will undoubtedly be provided.'[103]

The greater importance of science to medical prestige in America helps to explain this use of the general science periodical in a way which did not occur in Britain, where the medical profession was rather a standard against which the new scientific profession was to be measured. The claims of the American medical profession acquired credibility by being associated with science, particularly among that important and receptive middle class readership. Science, too, benefitted from a relationship which was mutually supportive. Medicine demonstrated the practical results of pure research. The notions shared by scientists, medical practitioners and the middle classes in terms of élites were also important in this context.

d) Eugenics

Immigration was hugely important in the history of American society. Between 1880 and 1900, 8.9 million immigrants entered the country and between 1900 and 1920 the number was 12.4 millions. (The total population was 64 millions in 1890 and 106 millions in 1920).[104] The middle classes felt threatened. The white anglo-saxon protestants who made up this group were in danger of being overrun by European peasant immigrants, many of whom were catholics. The birth rate of the well to do was declining. The middle classes became increasingly xenophobic, nationalistic and concerned about what it took to be an 'American'. This was reflected in the increase which took place in the number of immigrants deported and excluded after 1900.[105] Together with traditional concern over racial issues because of the black population, the situation was ideal for a widespread appreciation of the eugenic programme. Eugenics became far more important in American society than it ever did in Britain because of these conditions.

This state of affairs was reflected in the Popular science monthly. (Of the British journals only Nature ever made a significant feature out of it.) The middle classes adopted eugenic ideas as a means to legitimate and perpetuate their privileged status. Science (or, rather, its embodiment in a group of influential professional scientists), in return for the kinds of support (financial, ideological) described in the first section of this chapter, lent the support of its growing authority to these ideas. It was undoubtedly in the interests of the profession to do so. A commercial consideration was also important.

Throughout the period in question, eugenics was a major feature of the Popular science monthly. Concern that the established middle classes would be swamped by the poor, less well educated immigrants and lower classes was explicitly stated. The ultimate worry was that this would result in 'political control in the hands of the inferior'.[106] Arguments for the eugenic viewpoint (and its practical expression in a programme of social reform) were advanced. The majority of the articles were pro-eugenic. Authorities were quoted,[107] appeals to common knowledge made (e.g. 'everyone is familiar with the ordinary anthropological races'[108] or 'like father like son'[109]) and emotive language used. Most of the readership would have needed little convincing - they wanted their beliefs to be backed up by scientific authority and to be provided with rational arguments (or 'facts' such as the scientific 'proof' of the inheritance of intellectual factors). Analogy was also used in this way. For example, Davenport likened the inherited response to certain environmental stimuli to 'the moth [which] flies towards the candle'.[110] Analogies were most frequently cast in agricultural terms; agriculture being a central concept in American culture. In this way the eugenic programme was connected with practical everyday life. Reference to breeding experiments endowed the programme with a potential for realisation, as part of the reform agenda initiated by progressives.

The democratic rhetoric of the 1920s was not confined to the realm of scientific funding. The reform movements of the pre-war years, the rhetoric of war justification and the disillusionment which followed, had led to what one author described as 'a more radical democracy'.[111] In this context, the eugenic argument was relocated. The same author referred to

> 'certain safeguards which democracy must more and more recognize and make effective. The first of these is eugenics, which is often called the religion of the future.'[112]

Yet the underlying ideology remained the same: 'Ranks and classes are inherent in human nature'.[113] Only the mode of expression had changed. Just as was the case in Britain, American general science periodicals pursued the objectives of an emergent community of professionals, altering the mode of presentation in response to the socio-cultural context.

e) Natural history

Prior to Cattell's assumption of editorial control, articles in the Popular science monthly on 'natural history' were typified by Miss Margarette W. Brooks's piece 'Insect pests of the house'.[114] Here the author did little more than provide descriptions for the purposes of identification and instructions for the purposes of eradication. Alongside material such as this appeared discussions of evolution. Together, they provided what the middle class readership wanted: namely, practical advice, philosophical speculation and entertainment.

Cattell extended the readership to include the new middle classes. His objectives differed from those of the old editorship, but in neither case was the journal addressing amateur naturalists. They were not a necessary element of the readership in terms of financial solvency or the wider objectives of social recognition and status. Amateur naturalists had no role to play in the attempt to construct a notion of expertise acceptable to the American public. Democratic, Baconian science had to be largely replaced by the concept of the expert. Furthermore, the amateur natural history community was neither as powerful nor as estranged from the emerging professional community as was the case in Britain. (Far more opportunities existed within the higher education system to become assimilated into the professional community in America). The fascinating interactions which took place between the two groups in British general science periodicals did not occur in the Popular science monthly.

Cattell's takeover meant the journal was in professional hands and, moreover, became part of his objective for changing the nature, status and role of the scientific community. Professional control came suddenly to the Popular science monthly. Cattell bought the journal which then became one publication in the powerful group he owned. There was no gradual transition as in many British journals. Amateur naturalists were simply not part of the readership and there was no reason for participation (real or illusory) to be encouraged. Therefore most of the natural history articles were either descriptive life histories written by experts[115] or served to construct cognitive and social barriers. For example, 'The natural history and physiology of hibernation'[116] was divided into two distinct parts, and 'scientists and naturalists' were distinguished. The 'natural history' section was, predictably, a descriptive account of the habits of certain hibernating animals. The 'physiology' section was explanatory, theoretical and peppered with references to authorities. Articles on the subject of conservation were mostly dealing with the progressives' concern over efficient utilisation of resources,[117] a concern which crystallised into action with the 1908 White House Conference and the foundation of the National Conservation Commission.

6. Summary

The purpose of this comparison between general science periodicals in Britain and the United States was twofold. Firstly, it was intended to reveal something more about the nature of these periodicals. Secondly, it was hoped to support and justify some of the conclusions already reached regarding the situation in Britain. Despite being necessarily limited in scope, this comparison has brought another level of insight to the analysis of the general science periodical.

As in Britain, these periodicals were taken over by and used to further the interests of the professional scientific community. It has been shown how the different social, political, economic, cultural and scientific context of America led to different needs and desires of this community and consequently different ways of using the general science periodicals.

Of particular importance to the United States was the sense of unity these journals helped to promote among scientists themselves as well as presenting an image of community to a wider public. This was, of course, a vital step on the road to professionalisation and was made particularly difficult because of the size of the country and the large distances which separated scientific practitioners. This was not a pressing problem in Britain.

The campaign for professional status, recognition and rewards which was identified in the British journals was paralleled in the American. The audience to be persuaded was largely confined to the middle classes (both old and new) who were both influential and sympathetic. They provided philanthropic gifts and endowments and further, broadly speaking, shared an ideology of élitism. They in turn received support from scientists for their own position. These journals attempted to ensure passive, non-participatory acceptance of scientific authority and support for science, and to extend this beyond their readership and into the wider culture, much as did British general science periodicals. In this way, these periodicals contributed to the establishment of a recognised professional community of scientists on both sides of the Atlantic.

The importance of the professionalisation process to general science periodicals on both sides of the Atlantic is therefore evident. So, too, is the role they played in that process, particularly in terms of the construction of cognitive and social barriers. In both communities, and contrary to Reingold's assertion,[118] aspiring professional scientists had to face, in some form, the problem of an élite in a democracy. American scientists used the general science periodical to gain support and recognition, and attempted to reform public perceptions of and attitudes towards science, but in ways which were necessarily different from those used by British scientists. Yet despite the many dissimilarities between the two situations, at a fundamental level the similarities are striking. Of special significance was the search for a balanced image of science in which the Baconian, democratic and utilitarian concept existed in a state of equilibrium with the pure and élitist notion of expertise.

Notes and references

1. Charles Rosenberg, 'Toward an ecology of knowledge: on discipline, context and history', in Alexandra Oleson and John Voss (eds.), The organisation of knowledge in America (Baltimore and London, 1979), 440-55, p.442. One valuable work, although limited to the physics community, is Daniel J. Kevles, The physicists (New York, 1978).
2. Nathan Reingold, 'Definitions and speculations:the professionalisation of science in America in the nineteenth century', in A. Oleson and Sanborn C. Brown (eds.), The pursuit of knowledge in the early American republic (Baltimore and London, 1976), 33-69.
3. Nathan Reingold, 'American indifference to basic research: a reappraisal', in G.H. Daniels (ed.), Nineteenth-century American science: a reappraisal (Evanston, 1972), 38-62, p.58.
4. Stanley Coben, 'American foundations as patrons of science: the commitment to original research', in Nathan Reingold (ed.), The sciences in the American context: new perspectives (Washington, 1979), 229-47, p.229.
5. Edward Shils, 'The order of learning in the United States: the ascendency of the university', in Oleson and Voss (eds.), op.cit. (note 1), 19-47, p.26.
6. See Kendall Birr, 'Industrial research laboratories', in Reingold (ed.), op.cit. (note 4), 193-207.
7. See Stanley M. Guralnick, 'The American scientist in higher education', in Reingold (ed.), op.cit. (note 4), 99-141.
8. Robert H. Bremner, American philanthropy (Chicago and London, 1967),p.117.
9. Coben, op.cit. (note 4).
10. Guralnick, op.cit. (note 7), pp.99-113.
11. George H. Daniels, Science in American society (New York, 1971), p.163.
12. Ibid., p.171.

13. Because of the heterogeneous nature of the scientific community, that is, different disciplines were at various stages of professionalisation. The leading professionals feared amateur resistance to their authority.
14. The so-called Lazzaroni. See Daniels, _op.cit_. (note 11), p.266. Also Mark Beach, 'Was there a scientific Lazzaroni?', in Daniels, _op.cit_. (note 3), 115-32.
15. By 1910, three-quarters of American scientists were employed in higher education. See Guralnick, _op.cit_. (note 7), p.134.
16. Daniels, _op.cit_. (note 11), p.269.
17. Reingold, _op.cit_. (note 3).
18. Daniel Kevles, 'The physics, mathematics and chemistry communities: a comparative analysis', in Oleson and Voss (eds.), _op.cit._ (note 1), 139-72, p.141.
19. Reingold, _op.cit_. (note 3), p.58.
20. Spencer B. Weart, 'The physics business in America, 1919-1940: a statistical reconnaissance', in Reingold (ed.), _op.cit_. (note 4), 295-358.
21. Coben, _op.cit_. (note 4), p.229.
22. Chemist T. Sterry Hunt quoted in Kevles, _op.cit_. (note 18), p.141.
23. Kevles, _op.cit._ (note 18), pp.141-2.
24. Burton J. Bledstein, _The culture of professionalism_ (New York, 1976).
25. Coben, _op.cit_. (note 4).
26. Eric Hobsbawm, 'Mass producing traditions: Europe, 1870-1914', in E. Hobsbawm and T. Ranger (eds.), _The invention of tradition_ (Cambridge, 1983), 263-307.
27. Weart, _op.cit_. (note 20), p.303.
28. Reingold, _op.cit_. (note 2), p.33.
29. Matthew D. Whalen and Mary F. Tobin, 'Periodicals and the popularisation of science in America, 1860-1910', _Journal of American culture_, _3_(1980), 195-203, p.200.

30. _Ibid_.

31. _Ibid_., p.196. A periodical of scientific study is defined as 'devoted to the application of the ideal of science and scientific civilisation, as a vehicle of self- and social-reformation'.

32. Michael Borut, The Scientific american in nineteenth century America (University of New York Ph.D. thesis, 1977), p.264.

33. Louise Michelle Newman, _Men's ideas/women's realities_ (New York and Oxford, 1975), p.xxi.

34. Youmans to Lockyer, quoted in A.J. Meadows, _Science and controversy_ (London, 1972), p.30.

35. Meadows, _op.cit_. (note 34), p.30.

36. Whalen and Tobin, _op.cit_. (note 29), p.198.

37. Reingold, _op.cit_. (note 2), p.39.

38. _Ibid_., p.39.

39. See previous section.

40. Kevles, _op.cit_. (note 18), p.141.

41. Newman, _op.cit_. (note 33), p.xix.

42. See Daniels, _op.cit_. (note 11), p.287.

43. T.H. Morgan, 'The mechanism of heredity as indicated by the inheritance of linked characters', _Popular science monthly_, _84_(1914), 5-16.

44. F.C. Brown, 'Who profits from scientific work?', _The Scientific monthly_, _19_(1924), 655-60.

45. Whalen and Tobin, _op.cit_. (note 29), p.195.

46. _Ibid_., p.

47. See chapter 5, section 6.

48. Don Martindale, _American social structure_, (New York, 1960), p.462.

49. _Ibid_., p.462.

50. Dorothy Ross, 'James McKeen Cattell', _Dictionary of American biography_, supplement 3, 1941-5, (New York, 1973), 148-51, p.150.

51. Ibid., p.150.

52. Letter from John A. Benn to Richard Gregory, 29 October 1937. Macmillan firm archives.

53. Simon Newcomb, 'To our readers', Science, n.s. 1(1895), 1-2, p.2.

54. D.C. Gilman, 'Scriptoribus et lectoribus, salutem', Science, n.s. 1 (1895), 2-3, p.2.

55. Newcomb, op.cit. (note 53), p.2.

56. Whalen and Tobin, op.cit. (note 29), p.199.

57. Daniel G. Brinton, 'The character and aims of scientific investigation', Science, n.s. 1(1895), 3-4.

58. A similar move to assimilate science into general culture was made by J.J. Thomson and the founders of Discovery in 1920s Britain. This was by no means a new idea for it had been a concern of Huxley and Tyndall in the 1870s.

59. O.W. Richardson, 'The emission of electrons from tungsten at high temperatures: an experimental proof that the electric current in metals is carried by electrons', Science, 38(1913), 63-82.

60. F.W. Clarke, 'The man of science in practical affairs', Popular science monthly, 56(1899-1900), 487-91.

61. Professor George F. Swain, 'Massachussetts Institute of Technology', Popular science monthly, 57(1900), 257-84, p.284.

62. 'The progress of science: the monument to Pasteur in Paris', Popular science monthly, 66(1904-5), 191-2.

63. John J. Stevenson, 'The status of American college professors', Popular science monthly, 66(1904-5), 122-30.

64. In their attempts to be rid of the obstacles which the utilitarian ideal posed for the professional ideal, many American scientists promoted the notion that science was a part of a general culture, just as music and art were. In this they found themselves allied with classicists in universities. See Guralnick, op.cit. (note 7).

65. See Guralnick, op.cit. (note 7), pp.126-7.

66. See Robert H. Wiebe, The search for order 1877-1920 (New York, 1967), pp.111-32 and Bledstein, op.cit. (note 24).

67. Ross, op.cit. (note 50).

68. Simon Newcomb, 'The evolution of the scientific investigator', Popular science monthly, 66(1904-5), 92-6.

69. Professor Julius Stieglitz, 'The outlook in chemistry in the United States', Science, 46(1917), 321-33, p.333.

70. G.R. Lyman, 'The need for organisation of American botanists for more effective prosecution of war work', Science, 47(1918), 279-85.

71. G.R. Lyman, 'Minutes of the war emergency board of American plant pathologists', Science, 47(1918), 210-13, p.212.

72. Dr. Burton E. Livingston, 'Relations of the American Association to the National Academy', Science, 66(1927), 493-5, p.493.

73. J.H. Kempton, 'Scientors appear in the Southwest', Science, 66(1927), 354-5.

74. James Rowland Angell, 'The organisation of research', The Scientific monthly, 11(1920), 25-42.

75. R.M. MacLeod, 'Into the twentieth century', Nature, 224(1969), 457-61, p.459.

76. Hale, quoted in MacLeod, op.cit. (note 75), p.459.

77. Daniel S. Greenberg, The politics of pure science (New York, 1967),p.62.

78. Director Barton Warren Evermann, 'The Steinhart Aquarium of the California Academy of Sciences', The Scientific monthly, 18(1924), 149-58.

79. Austin H. Clark, 'What science owes the public', The Scientific monthly, 23(1926), 50-53.

80. Frederick C. Leonard, 'The society for practical astronomy', Popular astronomy, 19(1911), 455-6.

81. 'What an amateur can do', Popular astronomy, 19(1911), 456-7.

82. 'Cooperation in observing variable stars', Popular astronomy, 19(1911), 520-21.

83. Marc Rothenberg, 'Organisation and control: professionals and amateurs in American astronomy, 1899-1918', Social studies of science, 11(1981), 305-25, p.314.

84. E.g. C.L. Doolittle, 'Halley's comet', Popular science monthly, 76(1910), 5-22.

85. E.g. W.W. Campbell, 'An address on astrophysics', Popular science monthly, 66(1904-5), 297-318.

86. Leon Campbell, 'The amateur's work in astronomy', The Scientific monthly, 22(1926), 411-5.

87. See Chapter 3, section 3.

88. Rothenberg, op.cit. (note 83), p.316.

89. Newcomb, op.cit. (note 68).

90. David Starr Jordan, 'Utilitarian science', Popular science monthly, 66(1904-5), 76-91.

91. Arthur Gordon Webster, 'Scientific faith and works', Popular science monthly, 76(1910), 105-23, p.112.

92. Charles E. Rosenberg, 'Rationalisation and reality in shaping American agricultural research, 1875-1914', in Reingold (ed.), op.cit. (note 4), 143-63, p.144.

93. W.J. McGee, LLD, 'Scientific work of the Department of Agriculture', Popular science monthly, 76(1910), 521-31.

94. James Harvey Young, The toadstool millionaires (Princeton, 1974). Of course there are difficulties associated with the concept of "quack", not least in terms of definition. It is used here to convey the attitude of medical practitioners striving for professional status.

95. Wiebe, op.cit. (note 66), p.115.

96. The research worker, 'The physical basis of disease, I. Congenital structural defects', The Scientific monthly, 19(1924), 156-64; 'II. Local tissue death', Ibid., 281-9; 'III. Tissue degeneration', Ibid., 407-14; 'IV. 'Tissue overgrowth', Ibid., 520-26; 'V. Fluid accumulations', Ibid., 648-53; 'VI. Abnormal functional activity', The Scientific monthly, 20(1925), 64-72; 'VII. Curative forces of the human body', Ibid., 176-82; 'VIII. The diagnosis of disease', Ibid., 297-303; 'IX. The treatment of disease', Ibid., 416-23; 'X. Unsolved problems in research medicine', Ibid., 499-505.

97. Ibid., VIII, p.298.

98. Op.cit. (note 96), VIII, p.297.

99. Op.cit. (note 96), X, p.500.

100. Op.cit. (note 96), IX, p.422.

101. Op.cit. (note 96), VIII, p.300.

102. Op.cit. (note 96), X, p.499.

103. Op.cit. (note 96), VII, p.180.

104. Martindale, op.cit. (note 48), p.40.

105. Ibid., p.41.

106. Professor Leon J. Cole, 'The relation of eugenics to euthenics', Popular science monthly, 81(1912), 475-82. My emphasis.

107. Herbert Adolphus Miller, 'The psychological limit of eugenics', Popular science monthly, 84(1914), 390-96; Professor Chas W. Hargitt, 'A problem in educational eugenics', Popular science monthly, 83(1913), 355-67.

108. Charles Davenport, 'Heredity, culpability, praiseworthiness, punishment and reward', Popular science monthly, 83(1913), 33-9.

109. Professor W.E. Castle, 'Heredity', Popular science monthly, 76(1910), 417-28.

110. Davenport, op.cit. (note 108).

111. G. Stanley Hall, 'Can the masses rule the world?', *The Scientific monthly*, *18*(1924), 456-66, p.462.

112. *Ibid*., p.464.

113. *Ibid*., p.466.

114. Miss Margarette W. Brooks, 'Insect pests of the house', *Popular science monthly*, *37*(1890), 333-45.

115. E.g. Professor E.S. Morse, 'A bubble blowing insect', *Popular science monthly*, *57*(1900), 23-9.

116. Allen Cleghorn, M.D., 'The natural history and physiology of hibernation', *Popular science monthly*, *77*(1910), 356-62.

117. E.g. 'The conservation of natural resources', *The Scientific monthly*, *16*(1923), 337-413. One whole issue (that for April 1923) was occupied by the papers delivered at the social and economic section of the A.A.A.S. meeting of December 1922.

118. Reingold, *op.cit*. (note 28).

CHAPTER 7

CONCLUSION

At the outset of this thesis, an outline of Richard Whitley's analysis of popularisation was presented,[1] with the intention of testing his general conclusions against one specific case study. The present enquiry has proved to be largely supportive of those conclusions. In particular, by showing that the process of popularisation is most constructively viewed as a relationship between scientific fields, scientific practitioners and the readership at which general science periodicals were targeted, it has abundantly vindicated Whitley's major contention.

The length of the period 1890-1939, and the unique continuity of the periodical, allowed the historical specificity of popularisation to be amply demonstrated. This was most emphatically the case in chapter 5, in which the changes undergone by its forms and functions were examined. Investigations of astronomy and natural history in these periodicals at the turn of the century in chapter 3 established a link between popularisation and knowledge production by showing how the process directly affected the organisation and conduct of research in both areas. The contrast which these two fields present with physics and chemistry, as described in chapter 4, conforms to the view that the extent of this feedback is connected with the proximity of individual fields to 'everyday discourse and concerns'.[2]

That the forms and functions of popularisation depend on the general connections between scientists and audiences and between particular scientific fields is illustrated in chapters 3 and 5. Natural history, for example, was popularised in a manner unlike that of astronomy according to the relationships existing between aspiring professional biologists and amateur naturalists, and also relating to the field's low status when compared with that of physics. The discussion of astronomy in chapter 3 indicated the manner and extent to which the forms and functions of popularisation can be influenced by the way research is organised and controlled in a field, and by the relationships audiences have with the field. Furthermore, inclusion of intra-scientific communication in the concept of popularisation is entailed by the growth of the review journal as outlined in the second chapter, the changing readership of Nature, the journal's abdication of responsibility for non-scientific audiences, and the eventual attempt to transfer that responsibility, an account of which appears in chapters 3, 4 and 5.

The present analysis also gives rise to implications for the effect which the nature of the knowledge production system can have upon the forms of popularisation. Manifest differences between these forms (and their functions) in, for instance, chemistry and natural history, which emerged in chapters 3 and 4, affirm the importance in this respect of the extent to which the modes of discourse and practice are standardised and formalised. Contrasting the fields treated in these chapters serves additionally to highlight the significance of cognitive distance between scientific practitioners and their audiences for these differences in form and function. Developments recounted in chapter 5 reinforce this point, namely, the expansion in the readership of general science periodicals which occurred in the inter-war period, the attendant and inevitable increase in cognitive distance, and the corresponding changes in the manner and purpose of popularisation.

That the dependence of researchers on the attitudes and interests of audiences, according to the degree of control exerted by these audiences over resources, can also affect popularisation, has also been supported by the evidence contained within the present thesis, particularly that presented in chapter 5. Modifications of popularisation accompanied innovations in science funding and a cultural environment characterised by democratic attitudes and rhetoricswhich followed the First World War. These modifications involved the forms, functions and audiences of popularisation.

The social prestige and status of individual fields is the area in which the consequences of popularisation have been most clearly located. Whitley states that in attempting to heighten this status, popularisation frequently emphasises the utilitarian value of science. This was indeed found to be the case, although only in certain contexts and in response to specific sets of circumstances (Chapters 4 and 5). As a further means to this objective, Whitley advanced the idea of popularisation demonstrating 'consonance with the dominant ideological views and goals of major social groups'.[3] Both in the British and American contexts such an approach was adopted, as illustrated in chapters 5 and 6.

Although the conclusions reached in this study are largely consistent with those drawn by Whitley, there are several issues which require clarification and qualification. For example, that popularisation has a constitutive role in the formulation and reformulation of relationships has emerged as a crucial factor in its functions, most clearly in the discussions of astronomy and natural history in chapter 3, but also in chapters 4 and 5. Any emphasis on knowledge has been tempered somewhat by showing that audiences are in addition encouraged to acquire attitudes and views about the nature of science, its relation to society, the position of science in society, their own relationship to science and even the nature of science itself.

That there was not just one audience for popularisation, but several, was established in chapters 2 and 6 particularly. In addition, however, it has been disclosed in the present analysis that many of these audiences, such as military and business groups and science students were emerging during the period in question. Moreover, it is interesting to note that a great deal of the 'traditional view' of popularisation and the conception of science upon which it is grounded, permeated the presentation of science in general science periodicals, and was a factor in the new hegemony they were trying to create.

Whilst the significance of the social prestige of a field to its popularisation is indubitable, Whitley's claim that the greater this is, the more the popularisation is presented in terms of certainty and with decreasing attention to details and arguments, must be qualified. Physics (which Whitley cites as the twentieth-century scientific field with the highest level of prestige) and chemistry, when faced with difficulties in terms of social prestige, responded in general science periodicals by adopting, or rather, stepping up, a pseudo-participatory mode of presentation. One element of this was to invoke certain apparently detailed aspects of experimental procedure. Yet this was, as demonstrated above in chapter 4, in no way a genuine attempt at justification by relating the circumstances surrounding the development of knowledge to an audience capable of judgement.

The concept of social distance, which is very much related to that of social prestige, has been a considerable point of discussion in this thesis. It plays little part, however, in Whitley's account, which concentrates far more on cognitive distance. These inseparable concepts are of equal importance. A similarly partial view is offered by Whitley in respect of several other issues. For instance, his suggested classificatory framework is appropriate and useful in a number of contexts yet it is, nevertheless, but one alternative among many. A more expedient category in the present case, and of which the significance to popularisation emerged in chapter 4, might be the degree to which participation is encouraged.

Treating the issue of popularisation in terms of individual scientific fields has been shown, by analysis of the separate fields of astronomy, natural history, physics and chemistry, to be a fruitful and justified procedure. This can, however, lead to a neglect of the important consideration of the image of science as a whole, and the significance which popularisation has for this. The materials used in the present study allowed the two aspects to be considered and the importance of both has been demonstrated, particularly at a time when many such fields were emerging and establishing their identities.

That Whitley largely fails to recognise this aspect may in all probability be attributed to his reliance on contemporary as well as historical analyses of popularisation. Drawing to the extent he does on contemporary work explains the inclusion of two consequences of popularisation which Whitley claims to affect the practice of science. These relate more to the intellectual status of individual fields and of approaches within those fields. They come into play, as he himself acknowledges, only once science has achieved a considerable amount of control over resources and is recognised as 'the dominant form of understanding and controlling the environment',[4] and hence predictably do not feature in the present study.

The popularisation of science in general science periodicals was, therefore, a process through which attempts were made to redefine relationships.

Beyond the significance of economic factors, these periodicals were very much (though not, of course, exclusively) concerned with the professionalisation of science between 1890 and 1939. This concern informed their presentation, both at the level of individual scientific fields, and of science as a whole. Emerging professional scientists used general science periodicals in their endeavours to reconstruct relationships: firstly, in their quest to gain control over disciplines such as astronomy and natural history; and secondly, in striving to cultivate a wider public acceptance of their status and to secure recognition and rewards for the growing profession. The periodicals adapted their modes of presentation and their content according to the context within which they functioned, but underpinning their development lay a crucial motivation provided by commitment to professionalisation.

British science at the end of the nineteenth century inherited a strong tradition of amateurism and egalitarianism. Earlier in the century, a powerful 'low scientific culture' had provided a source of support and labour for the élite, but on occasion was able to launch independent and effective criticism of that élite, sometimes using the general science periodical as a medium of expression. This inherited tradition imparted an impulse to the direction in which the popularisation of science in these periodicals developed.

In contrast, across the Channel, the French scientific élite had long enjoyed considerable autonomy and status. Their relative isolation meant, however, that serious and damaging criticism was occasionally directed at them from outside. Again, general science periodicals provided a forum for the expression of such attacks. The American situation was characterised by a deeply-rooted democratic tradition which offered a serious obstacle to professionalisation.

The way British general science periodicals developed avoided the pitfalls evident across both the Channel and the Atlantic. Elements of both élitism and 'democracy' permeated their texts. It was from this apparently incompatible mixture that British science hoped to derive autonomy and legitimacy. The 'democratic' element, originally taken from the inherited amateur tradition, but which became increasingly significant after the First World War, gave science and its practitioners legitimacy and credibility. The élitist aspect was essential for authority and autonomy. Separately, both would have been inadequate. In combination, an ideology of élitism gained vital support from a 'democratic' foundation.

The new hegemonic class of scientific professionals attempted to acquire their authority and autonomy by securing the consent of a widening audience. The amateur ideal was replaced by a new hegemony. Further, just as nineteenth century social élites supported their own position with the erection of barriers and the creation of a concept of mass culture, so the new scientific élite of the twentieth century created their own barriers and promoted, within a pluralist popular culture, the idea of a distinct 'popular science'.

Notes and references

1. Richard Whitley, 'Knowledge producers and knowledge acquirers. Popularisation as a relation between scientific fields and their publics', in T. Shinn and R. Whitley (eds.) Expository science: forms and functions of popularisation, Sociology of the sciences yearbook 9(Dordrecht, 1985), 3-28.
2. Ibid., p. 8.
3. Ibid., p. 22.
4. Ibid., p. 22.

BIBLIOGRAPHY

(A) Critical bibliography of general science periodicals.

Armchair science, 1929-41.

Vols. 1-13, Apr. 1929-Jun. 1941. Then incorporated into Parade (London).

Monthly. Apr. 1929-May 1938 4^{o}, Jun. 1938-Jun. 1941 8^{o}.

Apr. 1929-Apr. 1930 7d., May 1930-Sept. 1933 1s., Oct. 1933-Dec. 1939 6d., Jan 1940-Jun. 1941 7d.

For the first few months of publication the number of pages averaged 64 per issue. This had, however, dropped to 56 by April 1930, but immediately increased once the price rose to 1s, to average out at 68 pages per issue over the next few years. When the price was reduced to 6d in October 1933 the number of pages remained unchanged for several months, but subsequently declined to an average of 48 between 1936 and 1938. This number later doubled to a stable 96 per issue with the move from quarto to octavo in June 1938.

Editor:	A. Percy Bradley
Technical adviser:	A.M. Low
Director:	Lt. Col. J.T.C. Moore-Brabazon

Armchair science's readership was largely composed of the expanded middle classes. The emphasis was on entertainment and material was drawn from many branches of science. Particularly prominent, however, were the concerns shared by Low, Bradley and Brabazon, that is, motoring, wireless, aviation and warfare, as well as topics which generated considerable public interest in the 1930s, most notably health, fitness and diet. The journal's domestic presentation, as exemplified by its title, discouraged participation in science. A.M. Low claimed to have 'achieved a circulation of 80,000 a month or thereabouts.'* Profusely illustrated.

* A.M. Low, quoted in Ursula Bloom, He lit the lamp, (London, 1958), pp. 97-8.

Bedrock, 1912-14.

Vol. 1, no. 1 - vol. 3, no. 1, Apr. 1912-Apr. 1914 (London).

Quarterly, 8^{o}, 2s 6d., av. 140 pp.

Acting editor:	H.B. Grylls
Editorial committee:	Sir Bryan Donkin
	E.B. Poulton, Hope Professor of Zoology in the University of Oxford
	G. Archdall Reid
	H.H. Turner, Savilian Professor of Astronomy in the University of Oxford

Bedrock, sub-titled a quarterly review of scientific thought, was a journal largely written by and for professional scientists. Its articles were often long and it provided a forum for the discussion of topics and particular modes of presentation which would have been excluded from more academic and specialist periodicals. The journal was not illustrated.

Conquest, 1919-26.

Vol. 1, no. 1 - vol. 7, no. 3, Nov. 1919-Mar. 1926. Then Modern science, vol.7, no. 4 - vol. 7, no. 12, Apr. - Dec. 1926. Then incorporated into Discovery (London).

Monthly, 4^o, 1s., av. 46 pp.

Editor:	Nov. 1919-May 1923	Percy W. Harris
	Apr. 1924-Dec. 1926	T. Barton Kelly

Subtitles:

Nov. 1919-Oct. 1920 A magazine of modern endeavour.

Nov. 1920-Oct. 1922 The British magazine of popular science.

Nov. 1922-Mar. 1924 The magazine of popular science.

Apr. 1924-Oct. 1925 The magazine of progress.

Nov. 1925-Dec. 1926 A magazine of progress, invention and discovery.

A profusely illustrated journal of the inter-war years, Conquest was published by the Wireless Press (which was owned by the Marconi Company) and included a substantial amount of material on wireless. Its variety in content (i.e. typically a mixture of physical science, natural history and technology) within each issue, as most articles were short, gave Conquest a broad readership. It specifically addressed the working classes and women, as well as the traditional middle class readership. The journal claimed its average net sales from November 1920 to April 1921 to be 15,569.*

* '"Conquest". A sound proposition for advertisers', advertisement on the cover of the issue for June 1921, Conquest, 2(1920-21).

Discovery, 1904.

Vol . 1, nos. 1 and 2, Sept. and Oct. 1904 (London).

Monthly, 8^{o}, 3d., 22pp.

Editor: George McKenzie Knight F.R.A.S.

subtitled a monthly illustrated magazine of Popular Science, Literature and Art, this journal had a strong astronomical bias. Each of its issues included only one illustration, both photographs.

Discovery, 1920-40, 1943-67.

Vols . 1-19, Jan. 1920-Dec. 1937 (London), n.s. vols. 1-2, Jan. 1938-Mar. 1940 (Cambridge). Incorporated Conquest in 1926. Incorporated into Science journal in 1966, which in turn was incorporated into New scientist in 1971.

Monthly, 4^{o}, Jan. 1920-Dec. 1920 6d., Jan 1921- 1s., av. 32 pp.

Editor:	Jan. 1920-Dec. 1920	A.S. Russell
	Jan. 1921-Dec. 1923	Edward Liveing

Scientific adviser:	Jan. 1921-Dec. 1923	A.S. Russell
Editor:	Jan. 1924-Mar. 1924	R.J.V. Pulvertaft
	Apr. 1924-Mar. 1926	Hugh Pollard
	Apr. 1926-1932	John A. Benn
	1932-4	Bernard Lintern
	1934-8	L. Russell Muirhead
	1938-40	C.P. Snow

Trustees: Sir J.J. Thomson
Sir Frederic Kenyon
R.S. Conway
A.C. Seward

A group of experts, including notable professional scientists such as J.J. Thomson, then President of the Royal Society were involved in the establishment of Discovery, as was the editor of Nature, Sir Richard Gregory. Its contributors were drawn from professional bodies, including teacher's organisations and scientific societies. The content of the journal was drawn from a wide range of scientific disciplines and although it included material from areas of knowledge such as art, literature and classics, the proportion of non-scientific material decreased rapidly after 1920. Discovery was aimed at a very wide readership including scientists, teachers, schoolchildren, the professional and the working man. During the first year of its existence the journal was poorly illustrated, featuring only a few engravings. Photographs were introduced the following year, hence the price increase.

Hardwicke's science gossip, 1865-1902.

Vols. 1-29, 1865-93, then Science gossip, n.s. vols. 1-8, 1894-1902. Then incorporated into Knowledge (London).

Monthly, 8^o, 1865-93 4d., 24pp., 1894-1902 6d., av. 30pp.

Editor:	1865-71	M.C. Cooke
	1872-93	John E. Taylor
	1894	John T. Carrington and E. Step
	1895-1902	John T. Carrington

From 1894 subtitled an illustrated monthly record of nature, country lore and applied science, Science gossip continued to focus on natural history just as it always had. Both before and after 1894 illustrations numbered 6 or 7 per issue.

Illustrated scientific news, 1902-04.

Vols. 1-16, Oct. 1902-Jan. 1904, then united with Knowledge as Knowledge and illustrated scientific news (London).

Monthly, 4^o, 6d., 1902-3 16pp. 1903-04, 20pp.

Editor: E.S. Grew

This was a glossy, well illustrated periodical. Its photographic illustrations were particularly impressive, frequently occupying a whole page and occasionally even a double page. The journal concentrated on physical and applied science.

Knowledge, 1881-1917.

Vols. 1-26, (9-26 = n.s. 1-18), Nov. 1881-Dec. 1903 Then with the Illustrated scientific news as Knowledge and illustrated scientific news, vols. 27-33, no. 4 (= 3s. 1-7), Jan. 1904-Apr. 1910. Then Knowledge, vols. 33, no. 5-40 (= 3s 7-14, no. 2), May 1910-Dec. 1917. Incorporated Science gossip in 1902 (London).

Nov. 1881-Oct. 1885 weekly, Nov. 1885-Dec. 1917 monthly, 4^{o}.

Nov. 1881-Oct. 1885 2d.-3d., Nov. 1885-Apr. 1910 6d., May 1910-Dec. 1917 1s.

Nov. 1881-Oct. 1885 av. 20 pp., Nov. 1885-Apr. 1910 av. 24pp.(after initial, brief 36pp.), May 1910-Dec. 1917 40pp. The number of pages declined, particularly during the War, and in the last issue of the journal they numbered only 20.

Founder-editor:	1881-8	Richard Anthony Proctor
	1888-94	Arthur Cowper Ranyard
	1895-1904	Harry Forbes Witherby
Conductors:	1905-10	Major B. Baden-Powell and E.S. Grew.
	1910-17	Wilfred Mark Webb and E.S. Grew

This periodical went through three distinct phases. It originally had a strong astronomical content and was aimed at amateur astronomers and interested members of the middle classes. Witherby's editorship extended the natural history coverage; dedicated amateurs both contributed to and read the journal. The merger with the Illustrated scientific news in 1904 and the new editorial team of Grew and Baden-Powell transformed Knowledge. Physical and applied science replaced much of the natural history and astronomy of the preceding régime, amateur participation was discouraged and support for what was becoming orthodox, professional science was encouraged. During its third and final phase, between 1910 and 1917, a combination of these two approaches was adopted by Webb and Grew. Natural history gained in prominence once more and something of a reconciliation of the amateur and professional elements was effected. From its early days as a monthly, when it only had 3 or 4 illustrations per issue, Knowledge increased its illustrated content during the 1890s. Between then and the First World War, each issue averaged between 8 and 15 illustrations, many of which were photographs. By 1916, illustrations had been largely confined to two glossy leaves in every number. In 1882, Proctor claimed that the first volume had achieved a circulation in excess of 20,000.*

* Knowledge, 2(1882), p. 13.

Modern science, 1926.

See Conquest.

Natural science, 1892-9.

Vols. 1-15, Mar. 1892-Dec. 1899 (London).

Monthly, 8^{o}, 1s., 80pp.

Subtitled a monthly review of scientific progress, the journal was edited by a group of experts from the Natural History Museum, including Peter Chalmers Mitchell, none of whom were paid, and who personally provided financial support for the venture. Natural science began its life with an average of 9 or 10 illustrations per issue (mostly engravings), but this declined until in its final year there were no illustrations at all.

Nature, 1869-

Vol. 1 no. 1, 4 Nov. 1869 - (London).

Weekly, 4^{o}, 1869-78 4d., 1878-1918 6d., 1918-20 9d., 1920 1s.

In 1869, the number of pages per issue averaged 20. By 1890 this had risen to 24. The first decade of the new century saw a gradual rise (to an average of 34) by 1910, a figure which had fallen to 26 by 1914. Difficulties encountered during the War forced a further decrease to 20pp. but this rapidly rose once more after 1918, to reach 32 by 1920, 36 by 1925 and 40 by 1939.

Editor: 1869-1919 J. Norman Lockyer
1919-39 Richard Arman Gregory

When established in 1869, Nature, a weekly illustrated journal of science, hoped for a readership not only of professional scientists, but drawn from among the general public as well. In this it largely succeeded for a number of years, an achievement which can be attributed mainly to Norman Lockyer's editorship. Towards the end of the century, however, specialisation and professionalisation of science contrived to make this task increasingly difficult. The correspondence column expanded, and the journal became more and more a vehicle for communication between professional scientists, particularly in terms of the results of new researches. By 1919, when Richard Gregory took over from Lockyer in the editor's chair, this process was well advanced. Gregory attempted to further this, and encouraged other periodicals to address the wider audience.

Nature was a great persuader. Campaigns were mounted throughout its history, for example for greater state support for science, greater recognition of science in society, improved relations between science and industry, and advances in scientific education. Much of the scientific community was influenced by Nature's advice and example, and this was as true in the popularisation of science as in any other respect.

Science gossip, 1894-1902.

See Hardwicke's science gossip.

Science progress, 1894-8, 1906 -

Vols. 1-7 (6-7 = n.s. 1-2), Mar. 1894-Oct. 1898. Then Science progress in the twentieth century (n.s.) vols. 1-28, Jul. 1906-1933. Then

Science progress (London).

Mar. 1894-Aug. 1896, monthly, Oct. 1896-quarterly, 8^{0}.

Mar. 1894-Aug. 1896 2s. 6d., Oct. 1896-Oct. 1898 3s.,

Jul. 1906-Mar. 1919 5s.,Apr. 1919-Sept. 1924 6s., Oct. 1924- 7s.6d.

The number of pages in each issue of the journal fluctuated. Between 1894 and 1896 it settled at around 84. Upon becoming a quarterly in 1896, the number increased to approximately 132. From 1906-1939, the average was 172, rising to 188 during the 1930s. In January 1920, setting some of the type closer together (to fit 6 more lines on each page) increased the length of the journal by about 9%.

Editor:	1894-8	J. Bretland Farmer
'Conductor':	1894-8	Henry C. Burdett
Editors:	1906-09	N.H. Alcock and W.G. Freeman
	1909-11	H.E. Armstrong and J. Bretland Farmer
	1913-18	Sir Ronald Ross
	1918-27	Sir Ronald Ross assisted by D. Orson Wood and J. Bronté Gatenby
	1927-30	Sir Ronald Ross assisted by D. Orson Wood
	1930-32	Ronald Ross in consultation with D. Orson Wood and E.J. Salisbury

Subtitles:

1894-6	A monthly review of current scientific investigation.
1896-8	A quarterly review of current scientific investigation.
1906-33	A quarterly journal of scientific work and thought.
1933-9	A quarterly review of scientific thought, work and affairs.

This periodical was largely filled with contributions from practising scientists written for practising scientists. Its articles were relatively long and it was thus able to explore issues in relatively greater detail. The correspondence column was used as a forum for debate. The emphasis lay with the biological sciences. Circulation ranged between 449 (Jan. 1907) and 1,187 (Jan. 1922)- it began a sustained rise in 1916 but lost ground consistently after the price rise of 1924. Illustrations were few and were usually graphs, tables and diagrams.

Science siftings, 1891-1927.

Nos. 1-52, 1891-15 Oct. 1892. Then Siftings, nos. 53-72, 22 Oct. 1892- 4 Mar. 1893. Then Science siftings, nos. 73-709, 11 Mar. 1893-20 May 1905. Then Popular science siftings, nos. 710-1802, 27 May 1905-1 May 1926. Then Popular science, nos. 1803-42, 8 May 1926-19 Feb. 1927. Then Popular pictorial, nos. 1843-75, 26 Feb- 8 Oct. 1927 (London).

Weekly, 4^{o}, 1891- 1 May 1926 1d., 8 May 1926-8 Oct. 1927 2d., 1891- 1 May 1926 16pp., 8 May 1926-8 Oct. 1927 first few issues 26pp., then 32pp.

Editor: 1891-1926 Charles Hyatt-Woolf

Science siftings was an entertaining collection of material from all branches of science, much of which could be described as trivia. Blatantly modelled on George Newnes's Tit-bits, it was actually subtitled The Tit-bits of popular science. Its low price, format and content assured Science siftings of a relatively high circulation and a readership broader than was usual for general science periodicals, at least before the First World War. As early as 1892, the journal itself claimed to have achieved a circulation in excess of 20,000.* Although clearly a commercial venture, once Hyatt-Woolf surrendered his editorship in 1926, the science content of the journal soon disappeared. In quantitative terms, Science siftings was well illustrated (usually at least one per page), although these were not photographs but engravings, even during the 1920s.

*'A speaking fact', Science siftings, 2(1927), 1.

Science work, 1898-9.

Vol. 1, nos. 1-3, Dec. 1898-Apr. 1899 (Manchester).

Monthly, 4^{o}, 3d., 12pp.

Editor: Walter Jeffs

Science work, a monthly review of scientific literature, aimed to keep 'students and specialists' as well as those with a more general interest in science, abreast of recent developments. It contained information about scientific events and publications (e.g. meetings of societies, forthcoming lectures, book lists and reviews etc.). Its lists of articles in periodicals (many of which were general science periodicals) were in particular poorly organised, far from comprehensive and strewn with elementary errors. Unillustrated.

The Scientific monthly, 1908-9.

Vol. 1,no.1 - vol. 2 no. 4, Jul. 1908-Oct. 1909 (London).

Monthly, 4^o, 3d., 16pp.

In 1909, the Scientific monthly became the 'official organ in England of the Alliance Scientifique Universelle'. Subtitled an illustrated journal of science, and with the emphasis on physical science, it averaged approximately 5 illustrations per issue, the majority of which were photographs.

The Scientific review, 1914.

Vol. 1, no. 1, Mar. 1914 (London).

Monthly, fol., 6d., 32pp.

Editor: E.J.M. Hudson

Subtitled A non-technical, popularly written review of all that is newest in Science and technology throughout the world. Physical and applied science dominated. Hudson was of the opinion that 'the practical results of Science will interest the larger audience', those results which had 'so altered every condition of modern life!'* He was aiming for a diverse readership which he hoped would include scientists, engineers, other professionals, businessmen and those working in industry, as well as ' the general public'. this first (and only) issue had eleven illustrations, of which

7 were photographs.

* E.J.M. Hudson, 'An introduction to science', The Scientific review, 1(1914), 28.

(B) Archival sources

Norman Lockyer papers (University of Exeter).

Macmillan archive (British Museum manuscript collection).

Macmillan firm letters (University of Reading).

John Murray archive (Private collection, John Murray publishers, 50A Albemarle Street, London).

(C) Books and articles

Allen, David Elliston, The naturalist in Britain: a social history, London, 1976.

Allen, Garland E., Life science in the twentieth century, Cambridge, 1978.

Altick, Richard D., The English common reader: a social history of the mass reading public, Chicago, 1957.

Armytage, W.H.G., Sir Richard Gregory: his life and work, London, 1957.

Arpad, Joseph J., 'Immediate experience and the historical method', Journal of popular culture, 11(1977-8), 140-154.

Badash, Lawrence, 'Radium, radioactivity and the popularity of scientific discovery', Proceedings of the American Philosophical Society, 122(1978), 145-54.

Barber, Lynn, The heyday of natural history, 1820-1870, London, 1980.

Barbour, Ian G., Issues in science and religion, London, 1966.

Barnes, Barry (ed.), Sociology of science, Harmondsworth, 1972.

Barnes, Barry and Steven Shapin (eds.), Natural order: historical studies of scientific culture, London and Beverly Hills, 1979.

Basalla, George, 'Pop. science: the depiction of science in popular culture', in G. Holton and W.A. Blanpied (eds.), Science and its public: the changing relationship, Boston studies in the philosophy of science, 33, Dordrecht and Boston, 1976, 261-78.

Bates, J. Leonard, The United States, 1898-1928. Progressivism and a society in trasition, New York, 1976.

Ben-David, Joseph, 'The profession of science and its powers', Minerva, 10 (1972), 362-83.

Benn, E.J.P., The confessions of a capitalist, 10th ed., London, 1927 (first published 1925).

Bergson, Henri, Creative evolution, New York, 1944 (first published 1907).

Berman, Morris, '"Hegemony" and the amateur tradition in British science', Journal of social history, 8(1974-5), 30-50.

Birr, Kendall, 'Industrial research laboratories', in N. Reingold (ed.), The sciences in the American context: new perspectives, Washington, 1979, 193-207.

Bledstein, Burton J., The culture of professionalism, the middle class and the development of higher education in America, New York, 1976.

Bloom, Ursula, He lit the lamp: a biography of Professor A.M. Low, London, 1958.

Bodmer, Walter, The public understanding of science. The Bernal lecture, London, 1986.

Borut, Michael, The *Scientific american* in nineteenth century America, University of New York Ph.D. thesis, 1977.

Bremner, Robert H., *American philanthropy*, 4th ed., Chicago, 1967.

Briggs, Asa, *The history of broadcasting in the United Kingdom*. Volume 2, *The golden age of wireless*, London, 1965.

Brightwell, L.R., *The zoo story*, London, 1952.

British Association for the Advancement of Science, *Reports of the meetings of the British Association for the Advancement of Science*, 107 vols., London, 1831-1938.

British Library, *Catalogue of the Newspaper Library, Colindale*, 8 vols., London, 1975.

British Museum, *General catalogue of printed books*, 263 vols., London, 1959-66, and supplements.

Brock, W.H., 'The development of commercial science journals in Victorian Britain', in A.J. Meadows (ed.), *Development of science publishing in Europe*, Oxford and Amsterdam, 1980, 95-122.

Brock, W.H., 'Advancing science: the British Association and the professional practice of science', in R.M. MacLeod and P. Collins (eds.), *The parliament of science. The British Association for the Advancement of Science, 1831-1981*, Northwood, 1981, 89-117.

Brock, W.H. and A.J. Meadows, *The lamp of learning: Taylor and Francis and the development of science publishing*, London and Philadelphia, 1986.

Bunders, Joske and Richard Whitley, 'Popularisation within the sciences: the purposes and consequences of inter-specialist communication', in T. Shinn and R. Whitley (eds.), *Expository science: forms and functions of popularisation*, Sociology of the sciences yearbook, 9, Dordrecht, 1985, 61-77.

Burnett, John, *A history of the cost of living*, Harmondsworth, 1969.

Cannon, Susan Faye, *Science in culture: the early Victorian period*, Folkestone, 1978.

Cardwell, D.S.L., *The organisation of science in England*, London, 1972.

Carr-Saunders, A.M. and P.A. Wilson, *The professions*, London, 1964.

Ceadel, Martin, 'Popular fiction and the next war', in Frank Gloversmith (ed.), *Class, culture and social change: a new view of the 1930s*, Brighton, 1980, 161-84.

Chalmers, A.F., *What is this thing called science?*, 2nd ed., Milton Keynes, 1982.

Chemical Society, *List of the officers and fellows of the Chemical Society*, London, 1916.

Chirnside, R.C. and J.H. Hamence, The 'practising chemists'. A history of the Society for Analytical Chemistry, London, 1974.

Church, A.G. et al. (eds.), 'The Association of Scientific Workers. Ten years' work', The Scientific worker, 4(1928), 83-8, 113-5.

Clair, Colin, A history of printing in Britain, London, 1965.

Clerke, Agnes M., A popular history of astronomy during the nineteenth century, Edinburgh, 1887.

Cloître, Michel and Terry Shinn, 'Expository practice: social, cognitive and epistemological linkage', in T. Shinn and R. Whitley (eds.), Expository science: forms and functions of popularisation, Sociology of the sciences yearbook, 9, Dordrecht, 1985, 31-60.

Coben, Stanley, 'American foundations as patrons of science: the commitment to original research', in N. Reingold (ed.), The sciences in the American context: new perspectives, Washington, 1979, 229-47.

Cohn, William H., 'Popular culture and social history', Journal of popular culture, 11(1977-8), 167-79.

Cole, G.D.H. and Raymond Postgate, The common people, 1746-1946, 2nd ed., London, 1961.

Coley, N. and Graham Martin, Science, technology and popular culture (2), Milton Keynes, 1981.

Collins, H., 'Certainty and the public understanding of science: science on television', Social studies of science, 17(1987), 689-713.

Collins, Peter, The British Association as public apologist for science, 1919-46', in R.M. MacLeod and P. Collins (eds.), The parliament of science. The British Association for the Advancement of Science, 1831-1981, Northwood, 1981, 211-36.

Cooter, Roger, The cultural meaning of popular science. Phrenology and the organisation of consent in nineteenth-century Britain, Cambridge, 1984.

Crosland, M.P., Historical studies in the language of chemistry, 2nd ed., London, 1978.

Crowe, Michael J., The extraterrestrial life debate, 1750-1900. The idea of a plurality of worlds from Kant to Lowell, Cambridge, 1986.

Daniels, George H., 'The process of professionalisation in American science: the emergent period', Isis, 58(1967), 151-66.

Daniels, George H., Science in American society, New York, 1971.

Daniels, George H., Nineteenth-century American science: a reappraisal, Evanston, 1972.

Darius, Jon, Beyond vision. One hundred historic scientific photographs, Oxford, 1984.

Davie, George Elder, The democratic intellect, 2nd ed., Edinburgh, 1964.

Davinson, D.E., Periodicals, London, 1964.

Dear, Peter, 'Rhetoric and authority in the early Royal Society', Isis, 76(1985), 145-61.

Dixon, Bernard, 'Telling the people: science in the public press since the Second World War', in A.J. Meadows (ed.), Development of science publishing in Europe, Oxford and Amsterdam, 1980, 215-35.

Dolby, R.G.A., 'On the autonomy of pure science: the construction and maintenance of barriers between scientific establishments and popular culture', in Norbert Elias, Herminio Martins and Richard Whitley (eds.), Scientific establishments and hierarchies, Sociology of the sciences yearbook, 6, Dordrecht, 1982.

Durbin, Paul T., The culture of science, technology and medicine, New York, 1980.

Edwards, Paul (ed.), The encyclopedia of philosophy, 8 vols., London and New York, 1967.

Etzoni, Amitai and Clyde Nunn, 'The public appreciation of science in contemporary America', in G. Holton and W.A. Blanpied (eds.), Science and its public: the changing relationship, Boston studies in the philosophy of science, 33, Dordrecht and Boston, 1976, 229-43.

Ezrahi, Yaron, 'The authority of science in politics', in A. Thackray and E. Mendelsohn (eds.), Science and values; patterns of tradition and change, New York, 1974, 215-51.

Farago, Peter, Science and the media, Oxford, 1976.

Faulkner, Harold Underwood, The quest for social justice, 1898-1914, New York, 1931.

Feather, John, A dictionary of book history, London and Sydney, 1986.

Fishman, J.A., 'A systematisation of the Sapir-Whorf hypothesis', Behavioural science, 5(1960), 323-39.

Forman, Paul, 'Weimar culture, causality and quantum theory, 1918-1927. Adaptation by German physicists to a hostile intellectual environment', Historical studies in the physical sciences, 3(1971), 1-117.

Gilbert, G.N. and Michael Mulkay, 'What is the ultimate question? Some remarks in the defence of the analysis of scientific discourse', Social studies of science, 12(1982), 309-19.

Gilbert, G.N. and Michael Mulkay, 'Joking apart: some recommendations concerning the analysis of scientific discourse', Social studies of science, 12(1982), 585-613.

Gilbert, G.N. and Michael Mulkay, Opening Pandora's box. A sociological analysis of scientists' discourse, Cambridge, 1984.

Gilligan, Carol, In a different voice. Psychological theory and women's development, Cambridge, Mass., 1982.

Gillispie, C.C. (ed.), Dictionary of scientific biography, 16 vols., New York, 1970-80.

Gingerich, Owen (ed.), Astrophysics and twentieth-century astronomy to 1950: part A, Cambridge, 1984.

Gloversmith, Frank (ed.), Class, culture and social change: a new view of the 1930s, Brighton, 1980.

Goodfield, June, Reflections on science and the media, Washington, 1981.

Greenberg, Daniel S., The politics of pure science. An enquiry into the relationship between science and government in the United States, New York, 1967.

Gregory, Richard Arman, Discovery. Or the spirit and service of science, London, 1916.

Guralnick, Stanley M., 'The American scientist in higher education', in N. Reingold (ed.), The sciences in the American context: new perspectives, Washington, 1979, 99-141.

Haber, L.F., The poisonous cloud. Chemical warfare in the First World War, Oxford, 1986.

Haldane, J.B.S., Callinicus. A defence of chemical warfare, 2nd ed., London, 1925.

Haldane, J.B.S., Daedalus or science and the future, London, 1925.

Harding, S. and M.B. Hintikka, Discovering reality. Feminist perspectives on epistemology, metaphysics, methodology and philosophy of science, Studies in logic, methodology and philosophy of science, 161, Dordrecht, 1983.

Hartley, H., 'The life and times of Sir Richard Gregory, Bt., F.R.S., 1864-1952', Advancement of science, 10(1953-4), 275-86.

Hines, Samuel, The Edwardian turn of mind, London, 1968.

Hobsbawm, Eric J., Industry and empire. An economic history of Britain since 1750, London, 1968.

Hobsbawm, Eric J. and Terence Ranger (eds.), The invention of tradition, Cambridge, 1983.

Holt, B.W.G., 'Social aspects in the emergence of chemistry as an exact science: the British chemical profession', British journal of sociology, 21(1970), 181-99.

Holton, Gerald and William A. Blanpied, Science and its public: the changing relationship, Boston studies in the philosophy of science, 33, Dordrecht and Boston, 1976.

Houghton, Bernard, Scientific periodicals. Their historical development, characteristics and control, London, 1975.

Houghton, W.E. (ed.), The Wellesley index to Victorian periodicals, 1824-1900, 3 vols., London and Toronto, 1966-79.

Hull, David L., Philosophy of biological science, New Jersey, 1974.

Huxley, Julian, Memories, London, 1970.

Illingworth, Valerie (ed.), A dictionary of astronomy, 2nd ed., London, 1981.

Jaggar, Alison M., Feminist politics and human nature, Brighton, 1983.

James, Louis, The trouble with Betsy, periodicals and the common reader in mid-nineteenth-century England', in J. Shattock and M. Wolff (eds.), The Victorian periodical press: samplings and soundings, Leicester, 1982, 349-66.

Jenkins, E.W., 'Science, sentimentalism or social control? The nature study movement in England and Wales, 1899-1914', History of education, 10 (1981), 33-43.

Johnson, Allen (ed.), Dictionary of American biography, 20 vols., New York, 1928-36, reprinted 1955-7, 10 vols., and supplements.

Kando, Thomas M., Leisure and popular culture in transition, 2nd ed., London, 1980.

Keller, A., The infancy of atomic physics: Hercules in his cradle, Oxford, 1983.

Kelly, Thomas, History of public libraries in Great Britain, 1845-1975, London, 1977.

Kennedy, James, W.A. Smith and A.F. Johnson, Dictionary of anonymous and pseudonymous English literature, 5 vols., London and Edinburgh, 1926.

Keohane, N.O., M.Z. Rosaldo and B.C. Gelpi (eds.), Feminist theory. A critique of ideology, Brighton, 1982.

Kevles, Daniel, 'The physics, mathematics and chemistry communities: a comparative analysis', in A. Oleson and J. Voss (eds.), The organisation of knowledge in modern America,1860-1920, London and Baltimore, 1979 , 139-72.

Kevles, Daniel, In the name of eugenics: genetics and the use of human heredity, New York, 1985.

Kingsford, R.J.L., The Publishers'Association, 1896-1946, Cambridge, 1970.

Kitteringham, G.,Studies in the popularisation of science in England, 1800-1930, University of Kent Ph.D. thesis, 1981.

Knight, David M., Natural science books in English, 1600-1900, London, 1972.

Knorr-Cetina, Karin D., The manufacture of knowledge. An essay on the constructivist and contextual nature of science, Oxford, 1981.

Knorr-Cetina, Karin D. and Michael Mulkay, Science observed. Perspectives on the social study of science, London, 1983.

Koestler, Arthur, The case of the midwife toad, London, 1971.

Kohler, E., Fron medical chemistry to biochemistry: the making of a biomedical discipline, Cambridge, 1982.

Kronick, David A., A history of scientific and technical periodicals. The origins and development of the scientific and technical press, 1665-1790, 2nd ed., Metuchen, 1976.

Kuhn, T.S., The structure of scientific revolutions, 2nd ed., Chicago, 1970.

Lankford, John, 'Amateurs versus professionals: the controversy over telescope size in late Victorian science', Isis, 72(1981), 11-28.

Lankford, John, 'Amateurs and astrophysics: a neglected aspect in the development of a scientific speciality', Social studies of science, 11 (1981), 275-303.

Latour, Bruno and Steve Woolgar, Laboratory life. The social construction of scientific facts, London and Beverly Hills, 1979.

Law, J. and R.J. Williams, 'Putting facts together. A study of scientific persuasion', Social studies of science, 12(1982), 535-58.

Lawrence, Christopher, 'Incommunicable knowledge: science, technology and the clinical art in Britain, 1850-1914', Journal of contemporary history, 20(1985), 503-20.

Layton, David, Science for the people. The origins of the school science curriculum in England, London, 1973.

Layton, David, Interpreters of science. A history of the Association for Science Education, London, 1984.

Lockyer, Mary T. and Winifred Lockyer, Life and work of Sir Norman Lockyer, London, 1928.

Lodge, Oliver, Ether and reality. A series of discourses on the many functions of the ether of space, London, 1925.

Low, A.M., Benefits of war, London, 1943.

McCollum, Elmer V., A history of nutrition. The sequence of ideas in nutrition investigations, Boston, 1957.

McGucken, William, Scientists, society and state. The social relations of science movement in Britain, 1931-47, Columbus, 1984.

MacLeod, Roy M., 'Printing under the golden lamp: Taylor and Francis Ltd. and work in progress on scientific periodical publishing', Victorian periodicals newsletter, No.5(1969), 11-12.

MacLeod, Roy M., 'Science in grub street', Nature, 224(1969), 423-7.

MacLeod, Roy M., 'Macmillan and the scientists', Nature, 224(1969), 428-30.

MacLeod, Roy M., 'Seeds of competition', Nature, 224(1969), 431-4.

MacLeod, Roy M., 'Macmillan and the Young Guard', Nature, 224(1969), 435-6.

MacLeod, Roy M., 'The new journal', Nature, 224(1969), 437-9.

MacLeod, Roy M., 'The first issue', Nature, 224(1969), 440.

MacLeod, Roy M., 'Securing the foundations', Nature, 224(1969), 441-4.

MacLeod, Roy M., 'Private army of contributors', Nature, 224(1969), 445-9.

MacLeod, Roy M., 'Faithful mirror to a profession', Nature, 224(1969), 450-2.

MacLeod, Roy M., 'Lockyer: editor, civil servant and man of science', Nature, 224(1969), 453-6.

MacLeod, Roy M., 'Into the twentieth century', Nature, 224(1969), 457-61.

MacLeod, Roy M., 'Resources of science in Victorian England: the endowment of science movement, 1868-1900', in P. Mathias (ed.), Science and society 1600-1900, Cambridge, 1972, 111-66.

MacLeod, Roy M. and Kay MacLeod, 'The contradictions of professionalism: scientists, trade unionism and the First World War', Social studies of science, 9(1979), 1-32.

MacLeod, Roy M., J.R. Friday and C. Gregor, The corresponding societies of the British Association for the Advancement of Science,1833-1929. A survey of historical records, archives and publications, London, 1975.

MacLeod, Roy M. and Peter Collins, The parliament of science. The British Association for the Advancement of Science, 1831-1981, Northwood, 1981.

Mann, P.H. and J.L. Burgoyne, Books and reading, London, 1969.

Marcet, Jane, Conversations on chemistry; in which the elements of that science are familiariyl explained and illustrated by experiments, 15th ed., 2 vols., London, 1846, (first published 1906).

Martindale, Don, American social structure. Historical antecedents and contemporary analysis, New York, 1960.

Mathias, Peter (ed.), Science and society,1600-1900, Cambridge, 1972.

Marwick, Arthur, Women at war, 1914-18, London, 1977.

Mayes, Paul (ed.), Periodicals administration in libraries, London, 1978.

Meadows, A.J., Early solar physics, London, 1970.

Meadows, A.J., Science and controversy. A biography of Sir Norman Lockyer, London, 1972.

Meadows, A.J., Communication in science, London, 1974.

Meadows, A.J. (ed.), Development of science publishing in Europe, Oxford and Amsterdam, 1980.

Meadows, A.J., 'Access to the results of scientific research: developments in Victorian Britain', in A.J. Meadows (ed.), Development of science publishing in Europe, Oxford and Amsterdam, 1980, 43-62.

Mendelsohn, Everett, 'The emergence of science as a profession in nineteenth-century Europe', in K. Hill (ed.), The management of scientists, Boston, 1964, 3-48.

Middleton, Nigel and Sophia Weitzmann, A place for everyone. A history of state education from the end of the eighteenth century to the 1970s, London, 1976.

Milgram, Stanley, Obedience to authority, London, 1974.

Millerson, Geoffrey, The qualifying associations. A study in professionalisation, London, 1964.

Missner, Marshall, 'Why Einstein became famous in America', Social studies of science, 15(1985), 267-91.

Mitchell, Peter Chalmers, My fill of days, London, 1937.

Montgomery, John, The twenties. An informal social history, London, 1957.

Moore, Tom Sidney and James,Charles Philip, The Chemical Society, 1841-1941. A historical review, London, 1947.

Morgan, Charles, The house of Macmillan (1843-1943), London, 1943.

Moseley, Russell, 'Tadpoles and frogs: some aspects of the professionalisation of British physics, 1870-1939', Social studies of science, 7(1977), 423-46.

Mould, Richard F., A history of x-rays and radium, London, 1980.

Mowat, Charles L., Britain between the wars, 1918-1940, London, 1955, reprinted 1964.

Murray, John, John Murray, founded 1768, London, n.d.

Myers, Greg, 'Nineteenth-century popularisations of thermodynamics and the rhetoric of social prophecy', Victorian studies, 29(1985), 35-66.

Neave, S.A., The history of the Entomological Society of London, 1833-1933, London, 1933.

Newman, Louise Michelle (ed.), Men's ideas/women's realities. Popular science, 1870-1915, New York and Oxford, 1985.

Nowell-Smith, Simon (ed.), Edwardian England, 1901-14, London, 1964.

Nowell-Smith, Simon (ed.), Letters to Macmillan, London, 1967.

O'Day, Alan (ed.), The Edwardian age: conflict and stability, 1900-1914, London, 1979.

Oleson, Alexandra and Sanborn C. Brown (eds.), The pursuit of knowledge in the early American republic: American scientific and learned societies from colonial times to the Civil War, London and Baltimore, 19/6.

Oleson, Alexandra and John Voss (eds.), The organisation of knowledge in modern America, 1860-1920, London and Baltimore, 1979.

Pannekoek, A., A history of astronomy, London, 1961.

Partington, J.R., A history of chemistry, vol.4, London, 1964.

Perlman, David, 'Science and the mass media', in G. Holton and W.A. Blanpied (eds.), Science and its public: the changing relationship, Boston studies in the philosophy of science, 33, Dordrecht and Boston, 1976, 245-60.

Plant, Marjorie, The English book trade. An economic history of the making and sale of books, London, 1939.

Popper, Karl R., Conjectures and refutations. The growth of scientific knowledge, 4th ed., London, 1972, reprinted 1981 .

Price, Derek J. de Solla, Little science, big science, Columbus, 1963.

Pyatt, Edward, The National Physical Laboratory. A history, Bristol, 1983.

Ravetz, Jerome R., 'Anti-establishment science in some British journals', in Helga Nowotny and Hilary Rose (eds.), Counter-movements in the sciences. The sociology of the alternataives to big science, Sociology of the sciences yearbook, 3, Dordrecht, 1979, 27-37.

Rayleigh, [Lord], The life of Sir J.J. Thomson, O.M., Cambridge, 1943.

Read, Donald, Edwardian England, 1901-15. Society and politics, London, 1972.

Reingold, Nathan, 'American indifference to basic research: a reappraisal', in G.H. Daniels (ed.), Nineteenth-century American science: a reappraisal, Evanston, 1972, 38-62.

Reingold, Nathan, 'Definitions and speculations. The professionalisation of science in America in the nineteenth century', in A. Oleson and S.C. Brown (eds.), The pursuit of knowledge in the early American republic: American scientific and learned societies from colonial times to the Civil War, London and Baltimore, 1976, 33-69.

Reingold, Nathan (ed.), The sciences in the American context: new perspectives, Washington, 1979.

Rosenberg, Charles, 'Toward an ecology of knowledge: on discipline, context and history', in A. Oleson and J. Voss (eds.), The organisation of knowledge in modern America, 1860-1920, London and Baltimore, 1979, 440-55.

Rosenberg, Charles, 'Rationalisation and reality in shaping American agricultural research, 1875-1914', In N. Reingold (ed.), The sciences in the American context: new perspectives, Washington, 1979, 143-63.

Rossiter, Margaret W., Women scientists in America. Struggles and strategies to 1940, London and Baltimore, 1982.

Rothberg, Marc, 'Organisation and control: professionals and amateurs in American astronomy, 1899-1918', Social studies of science, 11(1981), 305-25.

Rousseau, G.S. and Roy Porter, The ferment of knowledge. Studies in the historiography of eighteenth-century science, Cambridge, 1980.

Royal Society, Biographical memoirs of fellows of the Royal Society, 32 vols., London, 1955-86.

Royal Society, Obituary notices of fellows of the Royal Society, 4 vols., London, 1901-04; 9 vols., London, 1932-54.

Ruhe, Algot, Henri Bergson. An account of his life and philosophy, London, 1914.

Russell, Colin A., Noel G. Coley and Gerrylynn K. Roberts, Chemists by profession. The origins and rise of the Royal Institute of Chemistry, Milton Keynes, 1977.

Russell, Colin A., Science and social change, 1700-1900, London, 1983.

De Saussure, Ferdinand, Course in general linguistics, 2nd ed., London, 1981.

Shapin, Steven, 'Talking history: reflections on discourse analysis', Isis, 75(1984), 125-30.

Shapin, Steven, 'Pump and circumstance: Robert Boyle's literary technology', Social studies of science, 14(1984), 481-520.

Shapin, S. and A. Thackray, 'Prosopography as a research tool in history of science: the British scientific community, 1700-1900', History of science, 12(1974), 1-28.

Shattock, Joanne and Michael Wolff (eds.), The Victorian periodical press: samplings and soundings, Leicester, 1982.

Sheail, John, Nature in trust. The history of nature conservation in Britain, London, 1976.

Sheets-Pyenson, Susan, Low scientific culture in London and Paris, 1820-1875, University of Pennsylvania Ph.D. thesis, 1976.

Sheets-Pyenson, Susan, 'Popular science periodicals in Paris and London: the emergence of a low scientific culture, 1820-75', Annals of science, 42 (1985), 549-72.

Shenton, James (ed.), Free enterprise forever! Scientific american in the nineteenth century, New York, 1977.

Shils, Edward, 'The profession of science', Advancement of science, 24(1968), 469-80.

Shils, Edward, 'Faith, utility and the legitimacy of science', in G. Holton and W.A. Blanpied (eds.), Science and its public: the changing relationship, Boston studies in the philosophy of science, 33, Dordrecht and Boston, 1976, 1-15.

Shils, Edward, 'The order of learning in the United States: the ascendency of the university', in A. Oleson and J. Voss (eds.), The organisation of knowledge in modern America, 1860-1920, London and Baltimore, 1979, 19-47.

Shinn, Christine H., 'The beginnings of the University Grants Committee', History of education, 9(1980), 233-43.

Shinn, Terry and Richard Whitley (eds.), Expository science: forms and functions of popularisation, Sociology of the sciences yearbook, 9, Dordrecht, 1985.

Singleton, Gregory H., 'Popular culture or the culture of the populace?', Journal of popular culture, 11(1977-8), 254-66.

Smout, T.C., A century of the Scottish people, 1830-1950, London, 1986.

Snow, Philip, Stranger and brother. A portrait of C.P. Snow, London, 1982.

Social science citation index. An international multidisciplinary index to the literature of the social, behavioural and related sciences, Philadelphia, 1976-86.

Sokal, Michael M., 'The unpublished autobiography of James McKeen Cattell', American psychologist, 26(1971), 626-35.

Stead, W.T., Annual index to periodicals, 13 vols., London, 1890-1902.

Stearn, William T., The Natural History Museum at South Kensington. A history of the British Museum (Natural History), 1753-1980, London, 1981.

Stephen, Leslie and Sidney Lee (eds.), Dictionary of national biography, 21 vols., London, 1885-1900, reprinted 1960, and supplements.

Stewart, James (ed.), British union catalogue of periodicals, 4 vols., London, 1955-8, and supplements.

Stone, Lawrence, 'Literacy and education in England, 1640-1900', Past and present, no.42(1969), 69-139.

Swingewood, Alan, The myth of mass culture, London, 1977.

Taylor, A.J.P., English history, 1914-1945, Oxford, 1965.

Thackray, Arnold and E. Mendelsohn (eds.), Science and values: patterns of tradition and change, New York, 1974.

Thompson, Paul, The Edwardians. The remaking of British society, London and Bloomington, 1975.

Tobey, R.C., The American ideology of national science, 1919-1930, Pittsburgh, 1971.

Urbach, Peter, 'Francis Bacon as a precursor to Popper', British journal for the philosophy of science', 33(1982), 113-32.

Vartanian, Pershing, 'Popular culture studies: a problem in socio-cultural dynamics', Journal of popular culture, 11(1977-8), 281-9.

Walton, John K. and James Walvin (eds.), Leisure in Britain, 1780-1939, Manchester, 1983.

Weart, Spencer B., 'The physics business in America, 1919-1940: a statistical reconnaissance', in N. Reingold (ed.), The sciences in the American context: new perspectives, Washington, 1979, 295-358.

Webster, Charles (ed.), Biology, medicine and society, 1840-1940, Cambridge, 1981.

Werskey, P.G., 'Nature and politics between the wars', Nature, 224(1969), 462-72.

Werskey, P.G., The visible college, London, 1978.

Whalen, Matthew D. and Mary F. Tobin, 'Periodicals and the popularisation of science in America, 1860-1910', Journal of American culture, 3(1980), 195-203.

Whitley, Richard, 'Changes in the social and intellectual organisation of the sciences: professionalisation and the arithmetic ideal', in E. Mendelsohn, P. Weingart and R. Whitley (eds.), The social production of scientific knowledge, Sociology of the sciences yearbook, 1, Dordrecht, 1977, 143-69.

Whitley, Richard, 'Knowledge producers and knowledge acquirers. Popularisation as a relation between scientific fields and their publics', in T. Shinn and R. Whitley (eds.), Expository science: forms and functions of popularisation, Sociology of the sciences yearbook, 9, Dordrecht, 1985, 3-28.

Who was who. A companion to Who's who, 7 vols. and index, London, 1920-81.

Whorf, B.J., Language, thought and reality, Cambridge, Mass., 1956.

Wiebe, Robert H., The search for order, 1877-1920, New York, 1967.

Wiener, Philip P. (ed.), Dictionary of the history of ideas, 4 vols. and index, New York, 1973.

Willings press guide, 111th annual issue, East Grinstead, 1985.

Winter, J.M., The Great War and the British people, London, 1985.

Wolff, M., J. North and D. Deering (eds.), The Waterloo directory of Victorian periodicals, 1824-1900, Phase 1, Waterloo, Ont., 1977.

Yearley, S., 'Textual persuasion: the role of social accounting in the construction of scientific arguments', Philosophy of the social sciences, 11(1981), 409-35.

Yeo, Richard, 'Baconianism in nineteenth-century Britain', History of science, 23(1985), 251-98.

Young, James Harvey, The toadstool millionaires. A social history of patent medicines in America before federal regulation, Princeton, 1961.