SOME PROBLEMS IN THE PRESENTATION OF POPULAR SCIENCE

by

W.E.FLOOD M.A.

Lecturer in Education
University of Birmingham

Ph. D. 1949

PREVIEW

"It is no use improving the knowledge that scientists have about each other's work if we do not at the same time see that a real understanding of science becomes a part of the common life of our times."

J.D.Bernal,
The Social Function of Science.

This thesis concerns some of the problems which are encountered in trying to spread a knowledge of science, particularly by printed matter and lecture, to people who have had little or no formal training in science. It records the results of original investigations, the applications of these results, and suggestions based on experience in the field.

In Part I consideration is given to the need for spreading a knowledge of science to the "ordinary" man and to the existing ways in which this can be done. An examination is made of the difficulties to be overcome, and, from the many outstanding problems, certain ones selected for immediate research.

Part II records the results of an investigation made to determine the motives of people who voluntarily attend lectures in Popular Science. The investigation was made with the hope that a study of motives would suggest subjects, viewpoints, and approaches on which a more successful dissemination of popular science could be based. It is found that motives are very mixed but that, on the whole, people appreciate that a knowledge of science is necessary for an understanding of the present world.

In order to make a more direct assessment of people's particular interests in science, another investigation was devised. A new classification of popular science subjects was prepared and then a measure made of the degree of interest in these subjects. In Part III, in which the results are recorded, an examination is also made of the present distribution of output (in book and lecture) of these subjects, and suggestions made for improving the distribution.

A determination of popular subjects is not enough; an author (or lecturer) still has a choice of viewpoints and approaches. Six possible viewpoints are identified and studied in Part IV. It is found, as might be expected, that people are most interested in the practical applications of science, particularly how these applications affect them as individuals. Historical, biographical and social viewpoints seem to have little appeal to people who have some marked interest in science but a much greater appeal to those who are not manifestly interested.

One of the many factors leading to unintelligibility in popular science writings (and lectures) is the use of words which the reader cannot understand. Part V. therefore, concerns problems of vocabulary. An examination is made of vocabulary problems in science and of the difficulties of devising limited vocabularies. The writer has had insight into such problems through the preparation of Elementary Science Readers. These Readers are used in a study of essential words. But they do not cover, in width and depth, the whole range of Popular Science. The writer therefore envisaged the compilation of a dictionary of Popular Science and the evolution of a minimum essential vocabulary. Preliminary enquiries showed that Dr. West was also interested in the problem and the work was eventually done in collaboration. The resulting dictionary, it is hoped, will be an important contribution to spreading a popular knowledge of science. In this thesis, however, stress is given to the minimum (but adequate) vocabulary which was developed. This "Flood-West" vocabulary is critically examined, compared with other vocabularies, and used in the simplification of existing texts.

The techniques of preparing texts of Popular Science form a wide field for research. In the course of the investigations and experiments described in earlier Parts, and in the experience of writing texts for other purposes, certain elementary points of technique have emerged. They are recorded and discussed in Part VI.

Many problems remain uninvestigated. A list of problems which might form the bases of further researches is given at the end of the thesis.

. o O o .

ACKNOWLEDGMENTS

In carrying out the work described in this thesis, it has been my good fortune to be able to count as counsel and friend Dr. M.P.West. We met through the simultaneous but independent conception of the same aim - the compilation of a scientific dictionary, within a limited vocabulary, for the "ordinary" man. This work we subsequently undertook in collaboration.[1] But one cannot work with Dr. West without profiting, in a wider field, from his wisdom and experience. In the course of conversation and correspondence many ideas have arisen. Some of these I have developed into substantial sections of this work (though he may not necessarily agree with my interpretation of them); others have steered me clear of certain errors and misconceptions. He has been interested in all aspects of the work and I am indebted to him for his advice and encouragement.

I must also express my thanks to Professor F.J.Schonell, Head of the Education Department in the University of Birmingham. He performed the laborious but very valuable work of reading through the provisional script of each Part as it was prepared. He made a most useful criticism of Part IV (when in an early stage) and in many places suggested improvements in exposition and arrangement.

Mr R.W. Crossland (now of the Education Department in the University of Manchester) gave material assistance in the conduct of the enquiry described in Part II and helped in the preliminary tests of that in Part IV. My thanks are also due to directors, tutors, lecturers, principals, and teachers of many educational institutions who kindly allowed me to try tests with members of their classes or who distributed and collected questionnaires for me. Without their co-operation many of the investigations would have been impossible.

W.E. Flood

February 1949

1. The exact nature of this collaboration is explained in Part V. (Dr. West was sometime Research Professor in the Ontario College of Education, Toronto.)

CONTENTS

		Page
Part I.	General discussion of the problems.	1
Part II.	The motives of adults voluntarily attending lecture-courses in science.	42
Part III.	A study of people's interests in the various branches of science.	61
Part IV.	Popular viewpoints and approaches.	111
Part V.	Problems of vocabulary.	136
Part VI.	Some techniques in the writing of texts of popular science.	220
Some further problems for research.		241
Appendix.		245
1.	Detailed tables.	
2.	Bibliography.	

LIST OF TABLES

		Page
Part I.		
I.	Sources of interest in science.	16
II.	Degree of scientific reading by non-academic people.	24
III.	Variation of degree of reading with age.	26
Part II.		
IV.	Multiple voting (motive enquiry).	50
V.	Motives for study of science (from Table I of the Appendix).	53
VI.	Motives for study of science arranged by subject and sex.	56
Part III.		
VII.	Classification of popular science subjects.	69
VIII.	Interest ratings of Army group and its sub-groups.	78
IX.	Distribution of ABCDE markings.	79
X.	ABCDE markings of males.	82
XI.	ABCDE markings of females.	82
XII.	Gross distribution of ABCDE markings (male and female).	84
XIII.	Comparison of ABCDE markings of males and females.	85
XIV.	Numerical interest ratings of males.	91
XV.	Numerical interest ratings of females.	92
XVI.	Numerical interest ratings of whole lecture group.	93
XVII.	Variation of interests with age and the Interests of teachers.	97

		Page
XVIII.	Distribution of ABCDE markings of Army group.	99
XIX.	Army group. ABCDE markings and numerical means.	100
XX.	Distribution of subjects in popular science writings.	105
Part IV.		
XXI.	Points of view (by test I).	120
XXII.	Points of view arranged by sex and age; viewpoints of teachers (by test I).	121
XXIII.	Points of view of the Army group (by test I).	123
XXIV.	Viewpoints of Training College students (Test II).	127
XXV.	Association of B votes with A votes. (Non-science Training College students).	130
Part V.		
XXVI.	Number of technical words in school science (after Pressey).	149
XXVII.	Essential scientific words (LIST A).	181
XXVIII.	Semi-scientific words (LIST B).	182
XXIX.	Numerical comparison of the Basic and Flood-West vocabularies.	187
XXX.	Words of Basic with a range of meanings.	189
XXXI.	Composition of the Flood-West vocabulary in terms of the Basic vocabularies.	190
XXXII.	Flood-West words in the Basic General Science list.	191
XXXIII.	Flood-West words in the Basic Special Science lists.	191
XXXIV.	Words of the Basic lists not in the Flood-West vocabulary with indications of the Flood-West equivalents.	193

Page

XXXV. New Method words not in the Carnegie vocabulary. 212

XXXVI. Words in the Elementary Science Readers extra to those of the Flood-West and Carnegie vocabularies. 217

XXXVII. Words to be added to the vocabulary (based on the experiment with the Elementary Science Readers.) 219

TABLES IN THE APPENDIX

I. Analysis of motives of all students attending lecture courses in Natural Sciences. 246

II. Detailed analyses of A votes by subject and age. 247

III. ABCDE markings of males with results of chi-squared tests. 249

IV. ABCDE markings of females with results of chi-squared tests. 250

V. ABCDE markings of all students with results of chi-squared tests. 251

VI. Comparison of numerical(σ_0) tests and chi-squared tests of significant differences (MALES). 253

VII. Comparison of numerical(σ_0) tests and chi-squared tests of significant differences (FEMALES). 254

VIII. Comparison of numerical(σ_0) tests and chi-squared tests of significant differences (ALL STUDENTS). 255

IX. Results of the test of 66 apparently difficult words taken from Discovery. 256

X. The Flood-West scientific and technical vocabulary. 257

LIST OF TABLES (CONTD.)

		Page
XI.	Test of marginal words of the Flood-West vocabulary with Secondary Modern School pupils.	261
XII.	Examples of "dignity" words with simpler alternatives.	262
XIII.	"Wanted" words.	263
XIV.	Words of the Flood-West vocabulary taken by Ogden as international.	264
XV.	Words of the Basic science lists which are not in the Flood-West and New method vocabularies.	265
XVI.	Words of the Flood-West vocabulary which are not in the Basic lists or taken by Ogden as international.	266
XVII.	The Flood-West scientific and technical supplement to the Carnegie vocabulary.	268
XVIII.	Words used in the Elementary Science Readers extra to those of the Flood-West vocabulary.	271

PART I

GENERAL DISCUSSION OF THE PROBLEMS

PART I - General discussion of the problems.

		Page
Section 1.	The need for the propagation of scientific knowledge to the ordinary (non-academic) man.	3
Section 2.	The nature of the scientific background of the ordinary (non-academic) man.	10
Section 3.	The channels for the propagation of popular science.	14
Section 4.	The difficulties to be overcome.	29
Section 5.	The problems which have been investigated by the writer and are presented in this thesis.	39

1. THE NEED FOR THE PROPAGATION OF SCIENTIFIC KNOWLEDGE TO THE ORDINARY (NON-ACADEMIC) MAN.

It is necessary, in any examination of the problems concerning the propagation of scientific knowledge to the ordinary (non-academic) man, first to consider why such propagation is desirable. Why should the "man in the Street" wish or need to know anything about science ?.

We live in a scientific age; our environment is essentially scientific. We see the vault of the heavens, we are subject to the vagaries of the weather, we depend upon the biological and geological products of the Earth, we witness the rainbow, the earthquake, and the tides. On these natural manifestations of science Man has superimposed an ever-growing array of scientific contrivances. The train, the textile mill, the cinema, and the telephone are examples of such contrivances. Our two-fold environment, so largely scientific, determines what we eat, what we wear, what work we do, where we do it, how we spend our leisure. This environment determines the nature of our familiar life and, indeed, the very shape and structure of our modern society.

There exists a natural curiosity in the things about us. It is true that people take much for granted. They go to the cinema but seldom think of the techniques of photography and projection, they rush to work by means of train or car without thinking of the harnessing of power which has made their transport possible, they listen to the musical strains which emerge from their wireless sets but give little thought to the series of brilliant discoveries and inventions which makes the experience possible. Yes the presence of science in our daily affairs cannot fail to force a consciousness of science. As will be discussed more fully later, children have a great interest in science and there is no reason to suppose that this interest ceases with adulthood. It may lessen, however, if it is not satisfied. There are thousands of people, other than professional scientists, who maintain an interest, in some degree, in science. The interest may be specific and fairly deep as in the case of the amateur wireless constructor, or it may be a general sense of wonder and curiosity. Without provision of information and adequate instruction this interest is frustrated. Every encouragement should be given at all stages to that curiosity with which all people are endowed.

Further, it is axiomatic that an educated person should know something of the world around him. He should have some insight into, and understanding of, the beauties of nature. He should have some appreciation of manipulative and mental skill. He must know of the forces which determine the nature of his life and which shape the society of which he is a member. He must know the powers and limitations of these forces. He must distinguish the use of science from the misuse. A knowledge of science is as necessary to the make-up of an educated man as a knowledge of the Arts. An understanding of science is part of "culture."

At the risk of stating the obvious, it may be indicated that scientific culture does not demand specialised knowledge. X is no better than Y for knowing that a primrose is a dicotyledon with a sympetalous corolla and superior gynoecium. But he is better for having some understanding of Nature's miraculous processes in fashioning and perpetuating this flower, and some appreciation of the inter-dependence of living things. We do not expect Z to know the meaning of the letters T.C.P. on his bottle of mouth-gargle, but he is better for knowing something of the principles of bacteriology and for having some appreciation of the work of Pasteur and his followers. We do not expect everyone to understand the technicalities of atomic fission, but a man who knows nothing of its nature, powers and limitations cannot claim to be cultured. The days when culture was identified solely in terms of the classics and the arts are passed. Science is now a part of culture; it is essential to the education of a "normal" citizen.

But ignorance of science is more than lack of culture. It is harmful to the individual. In this highly scientific world, there is the danger that people may fall behind in awareness of the mechanisms which control their lives. They risk becoming the modern equivalents of savages who worship and fear that which they cannot understand. There are signs of this already. The re-kindling of interest in astrology, the wild beliefs in spiritualism, and the ready acceptance of improbable rumours and fantastic "explanations" are obvious indications. This gullibility of the public has been vividly portrayed by Bernard Shaw at the end of his play Geneva. As Sir Henry Dale has said,[1] "We are rapidly moving, have already moved far indeed, though without any general awareness, into an era in which the discoveries of science can no longer be regarded as something extraneous or additional, but have become an essential constituent of the common fabric of our daily life."

Not only is ignorance of science harmful to the individual; it is harmful to the community. The absence of a cultured and informed population means that the unconscious social influences which enter into all but the highly technical enterprises are not the matured, critical reflections of a responsible society, but the results of superstitions and prejudices. An ill-informed public applauds the unworthy if it is spectacular, it accepts the apparently attractive and rejects the less pleasing truth, it acquires a false perspective of real science and widens the gap between fact and a science of make-belief. The public is more gullible to the twisted arguments of a politician, more receptive to the crazy schemes of an eccentric administrator, less sympathetic to long-term and possibly expensive policies which would

---

1. The British Association Conference on "Science and the citizen; the public understanding of science." March 1943.

ultimately be for their betterment. "Over credulity, due to an essentially unscientific and easily biassed outlook regarding the dicta of science, places profound power in the hands of dictators and governments, enabling them to "put over" facts in the name of science which will be believed without enquiry by the general mass." (Bernard Lovell[1]). An ill-informed public, actuated by prejudices and assumptions of a pre-scientific age, leads to a distorted and eventually unsatisfactory social structure.

Finally it must be realised that scientific progress can only flourish in a sympathetic medium. "The absence of popular understanding, interest and criticism reinforces the already dangerous tendency to mental isolation" writes Bernal[2]. And in that isolation there can be neither fruitful progress nor social gain. An adequate scientific atmosphere can be secured by spreading more widely a knowledge of scientific ways and means. "It is no use improving the knowledge that scientists have about each other's work if we do not at the same time see that a real understanding of science becomes a part of the common life of our times." [3]

Two other supposed aims of science teaching are often put forward. First, there is the utilitarian value of science. It is obvious that any community must have its

---

1. Bernard Lovell. Science and Civilization p.111. (Thos. Nelson & Sons Ltd.) 1939

2. J.D.Bernal. The Social Function of Science. p.88 (Routledge & Sons).

3. ibid. p.304.

highly qualified experts and that an educational system which does not produce them is unsatisfactory. But what is essential to the whole (the community) is not necessarily essential to each of its parts (the individuals). Further, little reliance may be placed upon the supposed usefulness of scientific knowledge to the individual. Few people make great practical use of any scientific knowledge which they may have. After a course of elementary optics the ordinary man still goes to a professional optician if he suspects his spectacles are faulty; a knowledge of the mechanism of the telephone does not make a more efficient clerk. The utilitarian value of science, to the general mass, is small, and the plea for the propagation of scientific knowledge does not rest upon it.

Then it is said that science has a disciplinary value; that it disciplines the mind. It has been written: [1]"As an intellectual exercise it (science) disciplines the powers of the mind...It quickens and cultivates directly the faculty of observation. It teaches the learner to reason from facts which come under his own notice. By it the power of rapid and accurate generalisation is strengthened." It is not necessary here to discuss the grossly erroneous assumptions in psychology on which such statements are based. The disciplinary value of science is usually small and it forms no part of this argument.[2]

---

1. "Natural Science in Education." ("The Prime Minister's report") 1917. p.6. (H.M.S.O.).
2. It is surprising how psychological fallacies persist, in books, and in the minds of otherwise eminent men. See, for example, the claims for Biology teaching in School
p.262. Science Review No.104 p.77 and Flood's comment in No.105,

The plea for the propagation of scientific knowledge is based on its value to the individual as a part of culture and to the community as an essential ingredient for social welfare.

The need for the propagation of popular science, and its nature, have been the subjects of many enquiries and reports. A tabulation of the more important reports is given in the Bibliography to this Part. Two of them are of particular concern at this stage.

"Science Teaching in Adult Education". Committee report of the British Association, available as Reprint N.S.32. (1933). This report is hereinafter called the B.A.(1933) Report.

"Study of Science in Adult Classes" Report of the Executive Committee of the Workers Educational Association. (1932). This report is hereinafter called the W.E.A. (1932) Report.

In all such reports, and in all relevant conferences, the need for the propagation of science to the public is fully recognised, and consideration is given, in general terms, to aims, difficulties and means. "What is wanted," writes Sir Richard Gregory,[1] "is a humanising of science, a study of the action and reaction between scientific knowledge and social life, rather than explanations of facts and principles, whether presented as mere wonders or as possible aids to industry." The W.E.A.[2] expresses the

1. Natural Science in Education. B. of E. Report No. 8.
2. W.E.A. (1932) Report.

opinion that the primary function of science teaching in tutorial classes "is to make the student acquainted with the broad outlines of scientific principles exemplified in familiar phenomena and applied to the service of Man." These are expressions of aims.

The science which shall be taught must be neither academic nor vocational. It must satisfy the curiosity in scientific matters, it must provide a cultural understanding of the environment, it must supply that information which enables an individual, in matters of science, to become a sensible member of the community, it must produce a community which is science-conscious. Such science will be called, in this thesis, Popular Science.

---

2. THE NATURE OF THE SCIENTIFIC BACKGROUND OF THE ORDINARY (NON-ACADEMIC) MAN.

In attempting to present science to the public, consideration must be given to the general scientific level of the average man. Without such consideration little will be achieved.

Science was a comparatively late entrant into the educational system. Up to the middle of the 19th century all the great scientists were self-taught. The industrial revolution stressed the importance of science, and gradually science made its way into the universities and, still later, into the schools. But for some time science had a flavour of "radicalism". It appeared either as an extra subject or as a mean alternative for those "poorer minded" people who did not care for the rigour and supposed richness of the classics. One result of this was that science teaching was based on the same (unsuitable) principles which served for the "humane" studies. The present system, in fact, is a relic of the classical tradition. Only recently has science teaching fully relinquishe the bonds which enveloped it at birth, and evolved its own peculiar techniques.

Until the last few years, the educational system and the interpretation of science therein created some extraordinary gaps. Little science (other than Nature Study) was taught in the elementary schools. The large majority of people left such schools at the age of 14, never again to enter a formal educational institution. A little scienc was taught in the Senior and Central schools (for a minorit of people). The Technical Schools concerned themselves (and still do so very largely) more with vocational than cultural aims. The large majority of adults, therefore, has had little or no training in science. To the ordinary man, science is very largely a closed book.

A small privileged minority passed on to a secondary school and there received some instruction in "science." This science (until recently) was confined to very narrow grooves. For most boys it consisted of physics and chemistry; for most girls only of biology, or even just botany. While not refuting that physics and chemistry are basic subjects in a scientific education, and that biology is not without its cultural value, it is clear that such studies do not adequately represent science. Further, the treatment was essentially academic. In the belief that it is the duty of the secondary schools to provide the embryonic scientific expert, and what was good for them was good for all, the curricula were based on rigid examination requirements, with an eye ever open to university entrance. So the minority who passed through the secondary schools can hardly be said to have a wide background of science.

The narrowness of the secondary school curriculum has not escaped the attention of progressive teachers. In the last 12-15 years a new "subject" called General Science has emerged. It has been defined thus: [1]

"General Science is a course of scientific study and investigation which has its roots in the common experience of children and does not exclude any of the fundamental special sciences. It seeks to elucidate the general principles observable in nature, without emphasising the traditional divisions into specialised subjects until such time as this is warranted by the increasing complexity of the field of investigation, by the developing unity of the separate parts of the field, and by the intellectual progress of the pupils."

Here we have science for the future citizen. It seeks to embrace science as a whole, its viewpoint is more cultural than academic, it deals with common experiences. In fact, when interpreted at an appropriate level, it

---

1. "The Teaching of General Science". Science Masters' Association. John Murray, 1936.

approximates to the Popular Science which has been discussed. Not unnaturally, General Science (as a school subject) has had its critics.[1] It sacrifices depth to width, it may, or may not, be an adequate preparation for future university work, it demands an exceptionally qualified teacher for a proper presentation. This argument need not be taken up here. It is merely noted that there is a growing body of young adults who have had this type of scientific training.

The Education Act of 1944 made certain vital changes in the education of the "ordinary" man. With the raising of the school-leaving age and with compulsory secondary education, opportunities occur for a more liberal education. These opportunities are great in the Secondary Modern Schools (which cater for the great many who do not pass on to a Grammar or Technical School). At present, much of the teaching of science in these schools is scrappy and ill-organised. Some courses are ineffective dilutions of Grammar school courses, many schools have no proper laboratory facilities and/or little modern equipment, some teachers, frankly, are incompetent. Research, clear-thinking, and planning are needed. Although it is not the purpose of this thesis specifically to consider these problems, <u>some of the findings in the later parts of this work have useful application to Modern School Problems</u>. The Act also envisages the establishment of County

---

1. See, for example, School Science Review No. 70, p.180, and No.73, p.136.

Colleges for adolescents who have left full-time Schools. It may be hoped that therein endeavours will be made to provide the average man with an adequate scientific background.

What, then, is the present position ? Scarcely one person in ten over the age of forty has had any formal education in science. For the priveleged few who attended Secondary Schools the science was narrow and academic. The younger people probably know more than their parents but by no stretch of the imagination can it be said that they are well-grounded in science. It must be lamentably admitted that the bulk of the population is ignorant of science. There exists an enormous gap between the "man in the street" and the professional scientist. All efforts to fill this gap must necessarily be based on slender foundations.

3. THE CHANNELS FOR THE PROPAGATION OF POPULAR SCIENCE.

The basis for an increased understanding of science is obviously a reformed educational system. It is expected that the system foreshadowed by the 1944 Act will ultimately improve the scientific standard of the public. In particular, the Modern Schools and the County Colleges must play an important part. But, however good such schools may eventually become, they represent only the first stages of education. Further, at the present time, there are many people who will have missed what these schools are providing, and will provide. It is with post-school education that this thesis is primarily concerned. Many people, it is hoped, wish and will wish to continue (or begin) their scientific education. By what means can education in Popular Science be made available to them ?

For people who have left school, and who do not study science for technical or vocational purposes, there are four main channels for the propagation of Popular Science. These are: (1) classes and lectures, (2) printed matter, (books, magazines, newspapers), (3) radio talks and discussions, (4) cinematograph films. These media, of course, can also be the initial sources of interest in science, or the means by which an interest can be re-awakened. The writer has made some investigations to determine the relative importance of these media as sources of interest in science.

In the course of the "Motive investigation" described in Part II of this thesis, some examination was made of the sources of interest in science. 608 people, voluntarily attending science courses organised by university extra-mural departments throughout England and Wales, were asked to indicate on a given list of possible sources their own source(s) of interest. The results of this examination are summarised in Table I. The results are separately tabulated for the two sexes and each sex divided into two groups:

A. Those who had studied science at school,

B. Those who did not study science at school.

The scores are expressed as percentages of the total score in each sub-group.[1]

TABLE I

Sources of interest in Science (Percentages)

	No. of people	Source of Interest							
		Relatives, friends	School	Books, magazines	Lectures	Broadcasts	Films	Miscel-laneous	No statement
A. Science at School. F.	148	9.9	37.8	18.2	12.8	7.0	1.7	1.9	10.7
A. Science at School. M.	204	5.3	33.0	27.6	8.3	5.1	1.1	4.4	15.2
B. No Science at School. F.	94	13.1	2.1	21.3	21.3	12.3	2.3	1.1	26.5
B. No Science at School. M.	162	8.2	2.7	31.1	14.2	8.7	3.0	8.7	23.4

It is not surprising to find that the study of science at school was a great source of interest in the subject, but the unexpected revelation is the comparatively large part played by books and other printed matter. Probably school science was rather uninspiring its inadequacies have already been noted and, afterwards, books etc. put science in a more favourable light. It is significant that males owe more to books than females. The present interest, however, lies more with those who did not study science at school. A greater proportion gave no positive statement. These people probably found greater difficulty recalling or "pinning-down" the origin(s) of interest. The outstanding sources are books etc. and lectures. (It may be argued

1. This investigation, with the method of analysis, is fully described in Brit. Journ. Educ. Psych. Vol. XVIII, Part II, June 1948.

that lectures cannot form an origin. Why did the people go to the lectures ? As similar questions can be put in respect of books, broadcasts, films, and as further information is lacking, the results can only be taken as given.) Broadcasts and films played a very small part. It is realised that when these people were young little radio and film science was available. But certain facts are clear. Until school science is reformed and made more generally available, and the techniques of radio and film science are more fully developed, we must look to printed matter and lectures to stimulate interest in science.

An attempt must now be made to assess the values of the four main channels for the propagation of Popular Science at the present time.

LECTURES

Instructural lectures, either singly or in short or long courses, are provided by a number of organisations. There are three main agencies: the Extra-mural departments of universities, the Workers' Educational Association, and the Local Education Authorities. Working with these, or independently, are smaller associations and institutions. An examination of the range and quantity of various subjects provided by such bodies reveals an alarming failure to provide lectures on science. Although science was more prevalent in the early stages of the adult educational movement, there has since been a marked decline. The Board of Education Report (1927)[1] shows that the percentage of science courses arranged by the W.E.A. had fallen from 50% (Cambridge) and 42% (London) in 1882-87 to 14% and 4% respectively in 1921-26. The report further notes that "compared with the growth of interest in English Literature, Music, and the Drama since 1921, there has been no corresponding growth in the number of classes in Natural Science". From figures supplied by the university extra-mural departments[2] it can be shown that during the years 1939-40 to 1944-1945 the number of classes in science were about 5% of the total. In 1943 only 2.75% of the classes arranged by the W.E.A.[3] were in Biology and Physics and 1.22% in General Science (compared with International Relations 22.35%, Literature and Drama 12.72%, and Music 8.58%). In 1947 the figures for W.E.A.[4] classes were: General Science 3.2%, Biology and Physiology 2.6%. The B.A. (1933) Report gives similar discouraging figures in respect to other bodies. The possible reasons for this unsatisfactory position will be examined later, but the inescapable fact is that science lectures at present fail to reach more than a very small proportion of the population. Unless more lectures on Popular Science are provided,

---

1. "Natural Science in Adult Education." B. of E. Committee Paper No. 8.
2. Universities Extra-mural Consultative Committee Report on the war years 1939-40 to 1944-45.
3. W.E.A. Annual Report 1943.
4. W.E.A. Annual Report 1947.

and made sufficiently attractive to command much bigger audiences, lectures cannot be a powerful medium for the propagation of science to the public.

PRINTED MATTER

The printed word is probably the most important medium for the propagation of scientific knowledge. The professional scientist and the academic student rely on standard textbooks and reports and publications of learned bodies. Such works are not, in general, suitable for the ordinary public, and do not come within the range of this subject. For the ordinary man there has grown an abundance of popular scientific literature - books, magazines, etc. - equal almost in bulk to that of scientific literature itself. Although this literature exists it by no means follows that it adequately provides the dissemination of scientific knowledge which is required - in fact, one of the origins of the researches here recorded was the dissatisfaction with certain popular science magazines.

The science provided by the PRESS is far from satisfactory. Newspapers (and radio) play a very big part in informing the public about current affairs and in helping to form public opinion, yet the space (and time) given to science is inadequate to fulfil the real need. The press in Britain has never taken science seriously. Newspaper reports on scientific discoveries often take the form of sensational stories and are not infrequently inaccurate factually. What is to be made of the following headline in a newspaper ? "Heating by radio in the home." It is startling but utterly misleading. On further reading one discovers that the heating is to be by radio-frequency currents, and not, as is implied, by radio-transmission. And how many people understand what is meant by radio-frequency ? What is to be made of the caption to a picture of a power-station which quotes the output in kilowatts per hour ? Science is too often left to a feature-writer who has had no special scientific training, and the occasional expert who writes a "potted" article gives little attention to what the public can be expected to know or can readily understand. It should be as normal to employ a full-time member of staff, qualified in science, as it is to employ a sports editor. Some newspapers attempt to give instructions in science. A few utilise the services of writers who are endeavouring to present Popular Science in accordance with the aims here discussed, but many stress the sensational, give little attention to strict accuracy, and commit the crimes of the pedagogic tyro.[1] The Press, at present, does more harm than good in the cause of Popular Science.

MAGAZINES AND PERIODICALS provide another channel. There is a wide range of quality. Some (with an American flavour) do little more than purvey amazing stories. They have no great regard for accuracy or techniques of instruction. At the other extreme there are rather serious

---

1. "In houses the necessary draught is caused by the hot gases, which are lighter than air, rising up the chimney and leaving a space into which more air is drawn." - The Daily Telegraph (Children's section) 17th Jan.1948.

publications, such as Endeavour and Science Progress, which, for obvious reasons, make little appeal to the general public. Between these extremes, other well-intentioned publications have appeared. One of the best known is Discovery. Bernal writes:[1] "What we need is a good popular scientific illustrated weekly, though the new Discovery does something to remedy this lack." The first statement can be accepted but, as will be obvious from the examples in later Parts of this work, the second cannot. In spite of the formation of The Association of Scientific Writers, inadequate attention seems to have been given by editors of magazines to the <u>technique</u> of popular exposition. Some are not sure for whom they are writing - a general public or a scientifically educated public. A vocabulary examination[2] of Discovery, for instance, shows that alarming assumptions are made. Further, the scientific standard varies enormously from article to article or even within one article.

Finally, there exists a large quantity of POPULAR SCIENCE BOOKS. Their commercial success indicates that there is a great public demand for science in this form. Many of these books, unfortunately, are semi-sensational in style and are written by amateur scientists. Often they have very good pictures and diagrams (but sometimes some inaccurate ones), they stimulate interest in science (chiefly the "marvels" of it), they usually reveal little

---

1. The Social Function of Science p.93.

2. See Part V, Section 1.

understanding of teaching technique. It must be admitted that some good books, written by men of real ability, exist. "The World of Light" (Bragg) and "Engines" (Andrade) are examples. These, alas, do not set the tone. Popular science books have not been prepared with sufficient planning and foresight. There is an uneven spread of subject and little inter-linkage. There is scope for a connected series of works. Some publishers have realised this but their series may be criticised from other points of view. The Penguin series (Science News) is a real effort to fill a public want and its editors are becoming conscious of the necessary techniques of exposition. It consists, however, of a hotch-potch of unrelated articles. There is variety if assumption and overlap of explanation.[1] It is time research and commerce joined hands for the benefit of the public.

It is instructive here to note the findings in an unpublished investigation by the writer on the nature and degree of the scientific reading by ordinary people. In the course of the "motive investigation" (Part II) members of Extra-mural classes were also asked to indicate on an Often-Sometimes-Rarely-Never scale their degree of reading of various types of scientific literature, namely: Popular science books, Magazine and newspaper articles, Scientific fiction, Textbooks, (and also Science Broadcasts). By assigning marks of 3,2,1,0 to the four respective points of the scale, the degree of reading was expressed in

---

1. See, for example, the overlaps among the various articles of Science News 2.

numerical form. The results were separately evaluated for those who obviously had and those who had not a vocational interest in science,[1] for the two sexes, for those who had had elementary schooling (only) and for those who had had further (advanced) schooling. An examination was also made of age-variations (if any). As the maximum mark for each type of reading is 3n for n people (i.e. all in the group stating Often) the final marks could be expressed as percentages. Table II shows these results (omitting the age-differentiation). The results are also exhibited graphically (Graph I).

First a comparison can be made of the relative importance of the various types of reading for the group as a whole. The order is (1) magazines and newspapers (2) popular scientific books (3) textbooks (4) scientific fiction. (Broadcasts hold a high position - see later). Positions (3) and (4) are in accordance with expectations but the striking result is the importance of magazines and newspapers. This type of scientific literature has been strongly criticised and yet (for this batch of students at least) it is the most powerful medium for the dissemination of scientific knowledge. It is obvious that great attention must be given to the techniques of this medium.

---

1. The distinction was clear from the earlier part of the questionnaire.

TABLE II.

Degree of scientific reading by non-academic people. (percentages).

(a) Non-vocational people.

	Education	Number	Popular science books	Magazines Newspapers	Scientific fiction	Textbooks	Broadcasts
Females	Elem. Adv. All	59 138 197	39 51 47	61 72 69	41 45 43	33 38 36	67 71 70
Males	Elem. Adv. All	141 152 293	70 65 67	73 77 75	43 50 46	57 68 62	76 72 74
ALL	–	490	59	73	45	52	72

(b) Vocational people (too few to analyse by schooling)

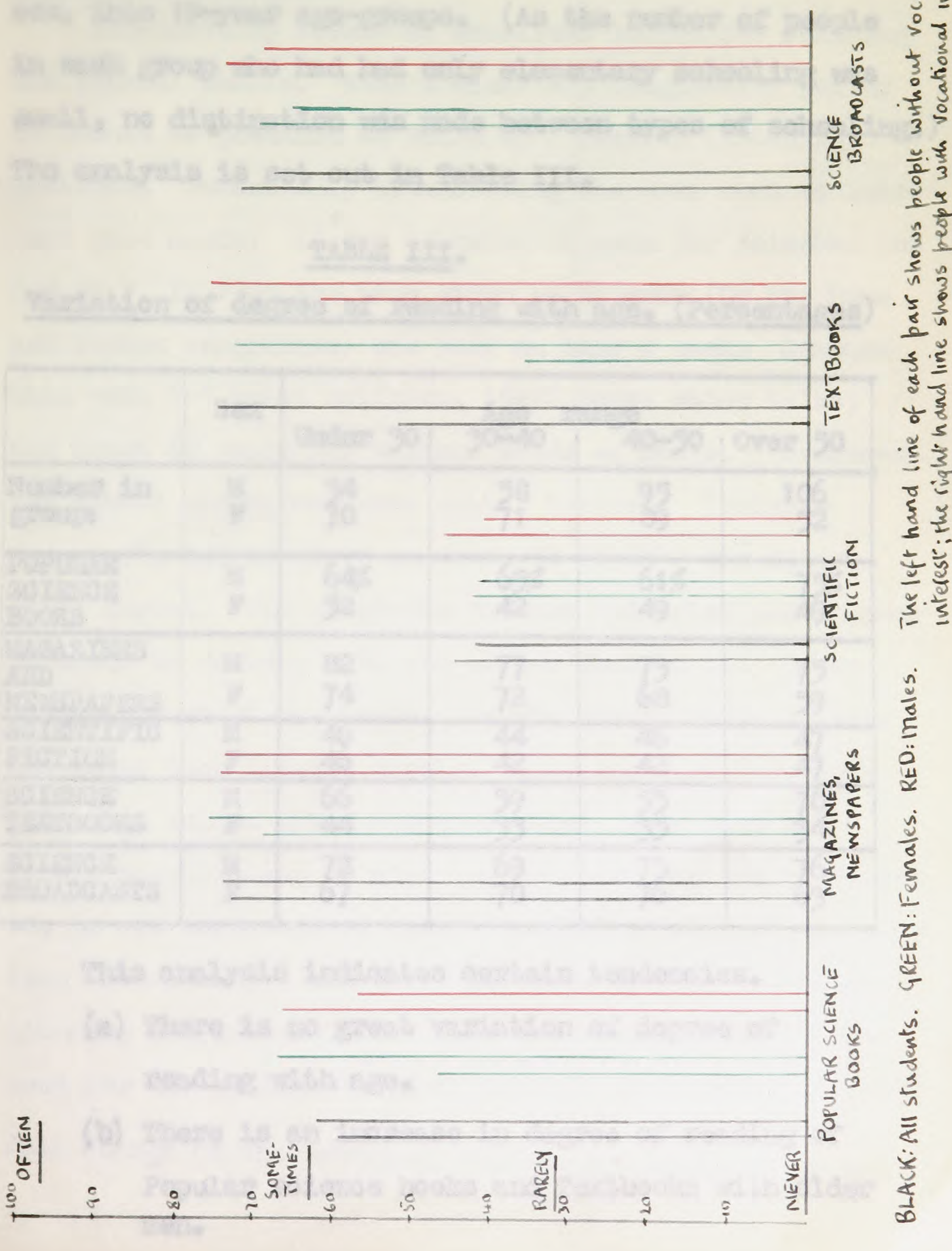
	Number	Popular science books	Magazines, newspapers	Scientific fiction	Textbooks	Broadcasts
Females	45	67	76	42	73	66
Males	79	57	73	41	76	70
ALL	124	61	74	42	75	68

Among the subsidiary results we note

(a) Males read more than females (non-vocational people).

(b) In practically every case, those who had more than elementary schooling read more than those who had not. (Perhaps the recent "secondary education for all" will remedy this deficiency.)

Graph I. Degree of scientific reading by non-academic people. (From table II)



(c) People with vocational interests read textbooks more often, which is in accordance with expectations.

The results also permitted some examination of possible variation of degree reading with age. The results of the non-vocational people were arranged, by sex, into 10-year age-groups. (As the number of people in each group who had had only elementary schooling was small, no distinction was made between types of schooling.) The analysis is set out in Table III.

TABLE III.

Variation of degree of reading with age. (Percentages)

	Sex	Age range Under 30	30-40	40-50	Over 50
Number in group:	M F	34 70	58 71	95 89	106 52
POPULAR SCIENCE BOOKS	M F	64% 52	65% 42	61% 49	75% 49
MAGAZINES AND NEWSPAPERS	M F	82 74	77 72	73 68	75 59
SCIENTIFIC FICTION	M F	46 46	44 42	46 42	47 47
SCIENCE TEXTBOOKS	M F	66 44	59 33	55 35	70 34
SCIENCE BROADCASTS	M F	72 67	69 70	75 76	76 63

This analysis indicates certain tendencies.

(a) There is no great variation of degree of reading with age.

(b) There is an increase in degree of reading of Popular science books and Textbooks with older men.

(c) Older females read less science in magazines and newspapers and listen less to science broadcasts.

The reasons for these variations have not been considered.

BROADCASTS ON SCIENCE

Broadcasting offers an excellent medium for reaching the general public. With a clear and imaginative policy it should be possible to build up a regular listening audience. Undoubtedly broadcasting has done much to introduce good music; it can likewise do much for science. But has it ? In 1944 the time given to science (On the Home and Forces programmes) was half an hour a week. Compare this with 6-7 hours religion, 10-12 hours other talks, and about 60 hours for various kinds of music. (Overseas and school programmes were rather better.) "Science Magazine", due to start on March 18 (1945), was delayed until August. The programme was then too brief and rushed. It ended in January 1946 and no one mourned it. Later "Science Survey" was begun. On the whole, radio science has never been treated justly. Some speakers have been good (but seldom given adequate time), many have had little appreciation of what the ordinary man can be expected, or not expected, to know - vocabulary assumptions have been astonishing - and there has been too little broad-planning and integration. Like the Press, there is the need for the employment of an authoritative person to take full charge of the problems, and for an extension of the space allotted to science. The listening public may be small at first (but, as already shown, there is good interest in radio-science) but that is no reason for not trying to do what, it is believed, is right and necessary. With the extension of television it should be possible actually to present the working of basic experiments (and to show the humanity of the men who perform them).

This thesis does not particularly consider broadcasting as means for spreading scientific knowledge, and the problems are therefore not more fully discussed.

SCIENTIFIC FILMS

The film is both a medium of exposition and an art-form. Film expositions, therefore, can be of great significance in interpreting science to the public. By the innate qualities of the film, such as the visual appeal, the composition in space and time, the blending of fact and background, the true place and importance of science can properly be presented. Many scientific film societies have grown up. But the film society is not enough; it reaches only a small proportion of the population. So many people regard the film merely as a means of amusement and it is only the relative few who seriously try to learn science that way. The film, at the present time, cannot be called a powerful medium for the propagation of popular science, although it may become so in the future. Again, this thesis is not directly concerned with the problems of this particular medium.

It is shown, therefore, that suitable media for the dissemination of popular science exist, and that the most important, at present, are the lecture and the printed word. These several media are adequate for the purpose if they are properly used. But, so far, they are imperfectly used. Problems of planning and integration, of methods and techniques, of stimulating and maintaining interest, of extending the use of the media have yet to be solved. This is essentially the justification of the pieces of research presented in this thesis.

4. THE DIFFICULTIES TO BE OVERCOME

If the sales of certain types of popular science books are ignored, it must be admitted that

(a) Popular science is not disseminated sufficiently,

(b) Popular science is not expounded effectively.

This suggests that there are serious obstacles. By examining these, the exact nature of specific problems will be seen.

Are people interested in science ?

Many lecturers and organisers of adult classes maintain that there is very little popular interest in science. Without interest there is little hope of making progress. It is asked "Are people interested in science ?"

Let us start with the school-child. The scientific interests of school-children have been the subjects of several investigations. Rallison[1] has examined the general interests of Senior School children. During the

1. Brit. Journ. Educ. Psych. Vol. IX Part II (June 1939).

course of a week, children in 40 school departments in a large town and 97 rural schools wrote down all the things they would like to know. (Their ages were 11+ to 13+). He found that

1,659 boys asked 18,049 questions on science and 4,931 on other subjects.

1,855 girls asked 9,371 questions on science and 12,333 on other subjects.

The difference between the sexes is irrelevant to the discussion. The significant point is that, on the average, the questions asked about science exceeded those asked in all other subjects by 60%. This does not indicate lack of interest in science.

Shakespeare[1] enquired into the relative popularity of school subjects in elementary schools. Science (represented by Nature Study) was given the positions of 8, 11,12,12, out of 17 subjects by the girls in four successive age-groups. Boys gave Science the positions of 4,5,4,2, out of 15 subjects. While appreciating that some of the appeal of school science may be due to the physical freedom and activity it permits, and that science only occupies a moderate position with girls, the results are far from suggesting antipathy to the subject.

Ball[2], in a similar enquiry to that of Rallison, found that out of 2,000 questions asked by junior school

1. Brit. Journ. Educ. Psych. Vol. VI Part III (June 1936).
2. School Science Review Nos. 67, 68.

children, 67% concerned science. Pritchard[1] has examined the relative popularity of Secondary school subjects. His results are worked out for 8 age-groups. It suffices here to give the average position of science subjects in the school curriculum. BOYS -10 subjects- Chemistry 1.5, Physics 7.1. GIRLS -11 subjects- Chemistry 5.1, Physics 8.2, Botany 6.4. It cannot be overlooked that girls find science of only moderate appeal, nor that Physics fails even to interest the boys. Pritchard found that some of the objections to Physics were:

it is less related to everyday life,

it demands too many calculations and formulae,

it uses less varied apparatus and is more monotonous.

All of these, be it noted, are not really objections to the subject but to the method of teaching.

A more recent investigation was undertaken by Houslop and Weeks.[2] They examined the relative popularity of subjects in a Secondary Grammar School. They found that of 20 subjects Chemistry was 2nd., Biology 3rd., Science (weighing and measuring) 5th. equal, and Physics 20th. (Gymnasium was 1st). Again it is found that Physics is of little appeal - due, probably to the content and manner of presentation - but even so the overall conclusion is that science is a popular subject.

---

1. Brit. Journ. Educ. Psych. Vol. V Part II (June 1935).

2. Houslop N.L. and Weeks E.J. The Interests of School-children. School Science Review. Nos. 100,110. (June, October 1948).

These several investigations do not indicate a lack of interest in science by school children, in fact, in some cases they indicate a definite, positive interest. The B.A. (1933) Report quotes the opinions of the leaders of a number of Adult Education Bodies. Two quotations will suffice here. "The limited interest shown by the public, even when a science course is provided, undoubtedly discourages local Committees responsible for the organisation of University Extension Courses from choosing the subject." (London Univ. Extra-mural Dept.) p.335. "Attempts to form classes for the study of scientific subjects has met with little or no response." (Durham and District.) p.335. The Report summarises (p.336) thus: "Our general impression is that the actual demand for science teaching is small in most districts, almost non-existent in some, but growing and becoming quite considerable in several." The intolerable position is reached that school children are interested in science, adults are not. Is it to be supposed that the interest suddenly vanishes with the leaving of school ?. This would be fantastic. In Hoy's enquiry[1] into the interests and motives for study among adults in evening classes he asked the question "Would you like to attend a class (lectures, talks, discussions) in science treated in a popular way as it affects your everyday life ?" Out of 344 replies 270 were in the affirmative. Some of the replies (including those of women) were very keen. It is suggested that <u>there is not a loss of</u>

---

1. Brit. Journ. Educ. Psych. Vol. III Part I (Feb.1933).

interest on attaining adulthood but a failure to keep the interest alive. It is an apparent, not a real, lack of interest. What are the causes ?. The writer suggests that the poor response to attempts to spread scientific knowledge is due to:

(1) failure by the administrative side of adult organisations to give science sufficient publicity and to make it attractive.

(2) apparent difficulty of the subject i.e. the supposition of the existence of an insurmountable "gap" between the ordinary man and the scientist.

(3) difficulties of providing adequate and suitable accommodation and equipment.

(4) lack of competent expositors.

(5) lack of any systematically determined technique.

These are the major obstacles to be overcome.

(1) Poor Publicity of Science

Publicity is outside the scope of this research and will therefore not be considered in detail. The following extracts from the writings of men of experience suffice to show that the problem is very real in the case of lecture-courses.

(a) W.E.A. (1932) Report

"the lack of interest may be more apparent than real owing to the fact that Courses in Natural Science have seldom appeared in the lists of possible subjects, with the consequence that any potential interest in such subjects has not been cultivated."

(b) Professor R.Peers (Nottingham University College) writes[1]

"The initiative in arranging classes is taken by one or two educated people who are interested in adult education, and if they, as frequently happens, have a purely literary outlook, science classes will not be chosen..... The reason for the comparative lack of development of science classes in the country generally is, I think, primarily the failure of those responsible to put the case to prospective students."

Again, science broadcasts are given at late or other unpopular hours, or relegated to the third programme.

(2) Difficulty of accommodation and equipment

This problem, again, is outside the scope of this research, but the problem is a very real one. It is fully discussed in the B.A. (1933) Report pp.339-340. In correspondence with tutors in Extra-mural departments the writer has received confirmatory evidence. It is debatable, however, to what extent practical equipment (other than visual aids) is necessary for the successful presentation of science to a popular adult audience.

(3) The problem of the gap

This is a very serious and very difficult problem. The stage is being approached when ordinary people tend to think of science as beyond them; they tend to be resigned

---

1. B.A. (1932) Report p.336-7

to regarding science as something very difficult, very abstruse, and, on occasion, very startling, comprehensible to the experts, inevitably incomprehensible to themselves. This problem can be split under two headings:

(a) the apparent remoteness of the subject

"the general public regards science courses as too technical and too specialised for them to understand."[1]

(b) the lack of elementary knowledge

"Scientists have a harder task than their Arts colleagues when they give a popular lecture. All educated people have a background of literature, history, and the arts, but many have had no scientific training. This will right itself in time...."[2]

Academic science is certainly remote. Formal courses of work on Physics and Chemistry, as such, fail to attract the general public. The lecturer or writer who meticulously follows the academic details of a subject, uses technical language, and has as his aim the presentation of Pure Science ("science for its own sake") will intensify the remoteness of the subject and certainly fail to appeal to the general public. On the other hand, it is reasonable to suggest that where the approach is along popular lines, related to the real issues of life, touching the everyday experiences of the student or the daily necessities of his community, any supposed remoteness will

---

1. Dr. Brierley (Reading) B.A.(1933) Report, p.338.

2. Sir Lawrence Bragg. "Lecturing to an unseen audience" The B.B.C. Quarterly. January 1948.

diminish or vanish. The problem is to find the right lines of approach, the right viewpoint, and the topics of greatest interest. These matters are the subjects of investigations described in later Parts of this thesis.

Lack of elementary knowledge is another aspect of the "gap". We have seen that the great majority of the public enters adult life with no or little previous training in science. The rapid growth and multiplicity of modern science has lifted current science (in its academic aspects) far above the educational standard of the ordinary man. The gap exists. Yet the writer presses the need for the dissemination of scientific knowledge. Can it be done ? The answer is that we can try. If we do not try, the gap will grow wider and eventually become insurmountable. The methods of bridging the gap are problems of technique.

(4) Lack of competent lecturers and writers

It is obvious, in view of the gap, that the dissemination of popular science can only be carried out by exponents of peculiar competence. The lecturer or writer must have a triple personality.

(a) He must be an expert in his subject (or his exposition will be faulty and unconvincing).
(b) He must understand the needs and abilities of his students and "filter" his material accordingly.
(c) He must be a teacher i.e. be conversant with the art of exposition.

Unfortunately the expert is not always an efficient teacher. The scientist in the university seldom has sufficient time (and sometimes little inclination) to study the art of exposition. His point of view, unless consciously modified, is inappropriate to the popular audience. Then there is also the feeling in the minds of many professional scientists that participation in popular science is a prostitution of their cause. The Secretary of the American Association for Adult Education writes:[1] "In the past the attitude of research staffs of our universities and scientific institutions.... has been to avoid adult teaching of scientific subjects wherever possible on the ground that such "popularisation" of necessity involved vulgarization and consequent loss of dignity to the research profession." It is not necessary here to criticise this attitude. The full-time teacher, on the other hand, possesses the necessary art but may lack expert knowledge, especially in recent developments.

So it cannot be hoped very often to find the triple combination of expert, filter, and teacher in one person. It follows that there is extreme difficulty in obtaining an adequate supply of suitable lecturers. The difficulty is discussed at some length in the B.A.(1933) Report, pp.341-4. The present writer can offer no immediate solution to the problem. Much can be done by first analysing and testing techniques, and then encouraging (or even training) would-be lecturers to use successful techniques. The problem is more easily solved in the case of the medium of written material. The triple combination

---

1. Quoted from the B.A.(1933) Report, p.337.

can be achieved by collaboration. Of two writers, each acquainted with the art of exposition, one can be the expert and one the filter. The business of the expert is to attempt to set down statements which are both accurate and clear; the business of the filter is to know nothing of the subject at the outset and to re-write the expert's statements as he interprets them. This process must continue until something is produced which is at once acceptable to the expert as correct and to the filter as intelligible.[1]

(5) Teaching techniques

It is not desirable here to outline the general principles of Teaching Method. There are tricks in the art of teaching. Generations of teachers have evolved the best ways of teaching this or that, have learned that this way is more successful than that, that this structure and sequence appeals but some other does not, that this leads to clear understanding and that to mental indigestion. Too often the popular exponent lacks this knowledge.

Many lecturers and authors fail to envisage the limitations of their audience and readers. What are these limitations ? They are limitations of knowledge, of fundamental principles, and of vocabulary. An expositor must inevitably make certain assumptions, but too often he sets his assumptions at too high a level. What body of facts may he legitimately assume ? Just what

---

1. This procedure was followed by Flood and West in the compilation of their Scientific Dictionary (see Part V). Who was expert and who was filter depended upon the nature of the subject.

vocabulary may he assume ? Can science be successfully presented within this vocabulary ? What is the educational background of his audience ? What do they want to know ? These are some of the questions which the successful expositor must be able to answer.

The techniques applicable to the exposition of popular science have not been fully determined; the answers to the above questions have not been found. These are problems for research. This thesis is a contribution to this field of research.

---

5. THE PROBLEMS WHICH HAVE BEEN INVESTIGATED BY THE WRITER AND ARE PRESENTED IN THIS THESIS

The major obstacles, briefly discussed in the previous section, indicate that many problems, in the sphere of popular science, have yet to be investigated. The writer has so far tackled some of these problems. He has limited his investigations to the spoken and printed word, and from within that range has selected certain problems.

The ability to read, or follow a lecture, intelligently is influenced, inter alia, by the degree of interest in the content of the book/lecture and by the nature of the outcome desired. However much one may wish to propagate scientific knowledge to the public, little progress will be made if the subject matter fails to interest (or fails to lead to interest), and if it fails to provide the reader/listener with what he wants to know. At this stage, what people want is more important than what they ought to have. Hence the first two problems are:

WHAT ARE THE MOTIVES OF NON-ACADEMIC PEOPLE WHO DESIRE TO LEARN MORE OF SCIENCE ?

IN WHAT PARTICULAR BRANCHES OR TOPICS ARE NON-ACADEMIC PEOPLE MOST INTERESTED ?

The results of investigations of these questions are presented in Parts II and III of this thesis.

Having established the motives and specific interests, the next problem is:

FROM WHAT POINT OF VIEW (i.e., ALONG WHAT LINE OF APPROACH) SHOULD THE SCIENCE BE PRESENTED ?

The results of investigations of this problem are given in Part IV.

A most important problem is that of vocabulary. What scientific vocabulary may an expositor assume ? What is the minimum vocabulary which is necessary for (a) the expression of scientific ideas, (b) fluent and "readable" exposition ? Hence the next investigations concern

PROBLEMS OF VOCABULARY.

The problem of vocabulary is important for English-speaking people, but is of even greater importance for people whose native language is not English. In this problem (as distinct from others) the writer has been able to consider the needs of the non-English reader. This aspect of the problem is considered, with other aspects, in Part V (vocabulary).

The TECHNIQUES OF WRITING POPULAR SCIENCE MATERIAL, both for use in this country and abroad, present a very big field for investigation. In the course of previous work herein recorded and in the light of other experience, the writer has been able to set down certain elementary points of technique. These are given in Part VI. This contribution does little more than touch the fringe of a great problem. Much more research is necessary. The writer hopes to be able to continue this research, both privately and with any interested M.A. students who may come under his direction.

PART II

THE MOTIVES OF ADULTS VOLUNTARILY ATTENDING POPULAR LECTURE-COURSES IN SCIENCE

PART II - The motives of adults voluntarily attending popular lecture-courses in science.

Page

Section 1. The nature and scope of the enquiry. 45

2. The conduct of the enquiry. 47

3. The analysis of the questionnaires. 50

4. General conclusions and applications. 58

NOTE

The investigation described in this Part of the thesis formed part of a wider investigation of Science in University Extra-mural courses. The whole investigation, which covered courses in both Natural Sciences and Psychology, included:

(a) origins of interest and degree of reading (described, for Natural Sciences only, in Part I of this thesis),

(b) motives for attendance (described, for Natural Sciences only, in this Part),

(c) satisfaction with the course (or otherwise), suggestions for improvement, willingness to attend further courses.

This whole enquiry was conceived, planned, and directed by the writer. He acknowledges the assistance given by Mr R.W.Crossland, then Staff Tutor in Science in the Extra-mural Department of the University of Birmingham. Mr Crossland assisted mainly by making trial tests with his own classes and by distributing the questionnaires among the Extra-mural bodies throughout the country. An account of (a) and (b) above, for both Natural Sciences and Psychology, was published in the British Journal of Educational Psychology, June 1948. In recognition of the assistance given, the writer added Mr Crossland's name to the title page.

1. THE NATURE AND SCOPE OF THE ENQUIRY

Although the aim is the ultimate creation of a scientifically educated community in which every individual has some knowledge of science, it is appropriate at this stage to direct attention more particularly to those adults who show some interest in science. These are the people who attend lecture-courses in science (e.g. those arranged by university extra-mural departments), read popular science books, listen to science broadcasts, and intentionally see scientific films. As a guide to studying the methods of presentation to such people it is useful first to investigate their motives for pursuing science. Their reasons help to indicate the viewpoints and approaches which will be most profitable.

Motives for studying science (other than vocational motives) have not been adequate investigated. Hoy[1] examined the interests and motives of adults attending evening classes in a large city. His investigations were not confined to science and were of a very general nature. The British Association[2] has expressed some opinions on the motives of adults who follow science courses of the kind under consideration. "The aims and motives of the students attending adult classes are less definite and more difficult to interpret. They are probably very mixed and change as

1. J.D.Hoy. An enquiry as to interests and motives for study among adult evening students. Brit. Journ. Educ. Psych. Feb. 1933.

2. B.A.(1933) Report.

their interest and knowledge increases." (p.347). It is evident that some objective determination of motives is required.

An examination of the motives of people who read popular science books is difficult and unreliable. An obvious course is the inclusion of a questionnaire in selected books borrowed from a public library. The mortality of the questionnaires would be high and, of great importance, there would be no assurance that the returned questionnaires would be representative of the reading public. It is possible that questionnaires would be returned mainly by eccentrics and others of abnormal motives. For this reason it was decided not to follow this course. An examination of the motives of adults attending lecture-courses is more reliable, for personal contact can be made (by the lecturer or tutor) with the students. The results so obtained will be limited to such kinds of students but the indications will probably be of wider application. This is the course which was adopted.

In the investigation, an attempt was made to determine the motives of adults voluntarily attending science lecture-courses, to determine the relative importance of the motives, and to examine any significant variation of motive with age, sex, and subject.

All extra-mural departments of all universities and university colleges in England and Wales were approached. All of these bodies responded and some effected an introduction to W.E.A. classes. The enquiry therefore fairly covered science courses throughout England and Wales. The diversity of age, schooling, and occupation showed that a very fair sample had been taken. Information was received from 55 classes. Unfortunately the enquiry was made in the early months of 1947 when severe weather restricted attendances. Perhaps this restriction had the advantage that the students who attended had clearly-cut motives. On the days when the questionnaires were distributed 652 students were present and 626 furnished information.

---

2. THE CONDUCT OF THE ENQUIRY

The necessary information was obtained by means of printed questionnaires. The preliminary questions asked for details of sex, age (in 10 year groups), occupation, and nature of schooling. A list of possible motives (letters (a) to (l)) was provided and a blank space provided for additional motives. This list was drawn up in the experience of trial tests with local extra-mural classes. It is set out in detail later. The order of motives was slightly mixed, chiefly to spread out the "improper" motives. The rubric ran as follows:

"Why do you attend this science course ?. To get knowledge, we presume, but why do you want the knowledge ?. Do you attend for other reasons as well ?. Mark these possible reasons as follows:

Put A against the chief reason (or reasons)

B against any reasons which might have some weight.

X against any reasons which, you are sure, have no weight.

You may add further reasons, if necessary, at (m)[1]. The criticism may be made that students should have been invited to state their motives without prompting, that it was unfair to suggest motives to them. Experience had shown that unprompted responses were very shallow. The list made the students think more carefully. They obviously thought beyond the range of the list, for the blank space was frequently used. In many cases the information recorded there could have been resolved into one more more of the suggested motives, but fresh motives were given in 19% of the questionnaires. This indicates that there was a good deal of independent thought. Two fresh motives (specified later) occurred sufficiently often for them to be tabulated separately.

For the purposes of tabulation and analysis the final list of motives was arranged under three headings (plus an additional one for miscellaneous motives). This grouping was not given on the questionnaire. It simplifies the presentation and interpretation of the results.

<u>List of Motives</u>

Vocational motives

(a) The knowledge will help me with my work.

(b) The knowledge will help me to pass an examination.

(c) The knowledge will help me to get a better job.

General desire for knowledge (Cultural motives)

(d) I feel ignorant and "out of it" when other people

---

1. On the questionnaire, (m), was the blank space.

talk about scientific matters and I cannot understand their conversation.

(e) I feel I want to know more than my friends.

*(f) I am interested in all branches of science.

*(g) I am interested in this particular branch of science.

(h) I feel I cannot understand the present world without knowing more science than I do.

(i) I want to know how scientists think, how their ways of thinking differ from those of literary men, lawyers, politicians, etc.

Social and Recreational motives

(j) I attend the classes to fill in an evening.

(k) The classes help me to see and mix with other people.

(l) My friend is interested in science and I want to share his (or her) interest.

(m) Science will help me with my hobby.

(n) I thought I would like to study science as a change from my work.

Miscellaneous

*(o) Miscellaneous motives.

* These motives were not given on the questionnaire.

Motive (f) appeared in various forms e.g. interest in nature generally, "science provides an interesting mental exercise". The miscellaneous motives were unimportant and often amusing. Typical motives were "To enlighten my children", "I always go to W.E.A. classes; this year we are doing biology."

3. THE ANALYSIS OF THE QUESTIONNAIRES

A preliminary survey of the questionnaires showed that multiple voting (i.e. the use of two or more A's or B's) was not infrequent and that few students bothered to use the sign X as instructed. It was decided to ignore the X's and to assume that any unmarked motives were inapplicable. The multiple voting complicated the method of assigning numerical values to the motives. The extent of multiple voting is shown in Table IV.

TABLE IV. Multiple Voting

	Number of A Votes.				Number of B Votes.				
	1	2	3	4 or more	0	1	2	3	4 or more
Females (242)	52%	25%	15%	8%	15%	17%	30%	18%	20%
Males (366)	46%	24%	16%	14%	15%	28%	23%	19%	15%

It was decided that the most satisfactory method of treating the multiple A votes was by assigning a mark of 1/n to each of n motives marked with an A. This overlooks the effect of the number of accompanying B votes. The absence of a B vote (15%) strengthens an A vote but its effect is small if the A vote is split. A single A vote with no B votes, however, is a very strong vote. It occurred in 22 cases out of 608 (3.2%). It was felt that the effect of this would be too small to warrant mathematical allowance for it, if indeed a satisfactory allowance could be devised. Hence a mark of 1/n was assigned to each of n A votes as already indicated. In the same way a mark of 1/n was assigned to each of n motives marked with a B.

It was impossible to draw a sharp line of demarcation between main motives (A) and subsidiary motives (B). It was apparent that some students found difficulty in making the distinction. In extreme cases, a student gave one A vote and several B votes (which was the writer's intention) or vice versa, but such extremes probably "balance up" in the averages. In view of the obvious difficulties of assessing the relative values of A and B votes, it was decided not to combine the A and B votes but to tabulate them separately.

The various courses were put into 5 groups: biology, geology, physical sciences[1], general science, social science. The title of a course was often sufficient to indicate the appropriate group; in doubtful cases the syllabus was consulted. Biology included both pure and applied branches but the viewpoint was that of a scientist. In social science the viewpoint was that of a sociologist i.e. how scientific (mainly biological) facts, theories, and development affect the activities, growth, and responsibilities of the individual and the community. General science covered all such titles as "Science in Everyday Life".

---

1. Mainly physics and chemistry. It includes one reply from a student in an astronomy class; the papers from the other 4 of this class were discarded as useless.

In the detailed analyses the results for each subject group were further divided into sex groups and age groups. Some of these sub-groups were small. (In all tables the numbers of students in the groups are shown.) The results of such sub-groups are therefore less reliable. They may indicate tendencies but important conclusions may not be based on them.

The results in each group (or sub-group) are expressed in numerical form in the following way. If the group contains N individuals, a total mark of N is available for all the A votes. The total of the actual marks (assigned as explained above) for each motive is expressed as a percentage of N. Similarly the B marks are expressed as percentages.

Differences were examined for significance as follows. The variance σ^2 of a percentage r was taken as r (100-r)/N where N is the total number in the group. The standard deviation σ_D of the difference of quantities with variances σ_1^2 and σ_2^2 is given by $\sigma_D^2 = \sigma_1^2 + \sigma_2^2$. If the actual difference was not less than three times the standard deviation of the difference it was taken as significant; if it was between two and three times it was taken as suggestive.

4. RESULTS AND DEDUCTIONS

Extra-mural departments and similar bodies are not primarily concerned with the provision for vocational or technical training, but rather with the serious presentation of scientific methods and results, both pure and applied. These two kinds of teaching inevitably overlap.

Hence, although it is not expected that students' motives will be strongly vocational, it may be found that some students attend the courses for vocational reasons.

First an examination was made of the motives for the whole range of science. The detailed analysis is given in Table I of the Appendix. A condensed analysis is given in Table V in which the motives are grouped under the four headings.

TABLE V.

Motives for study of Science (Condensed from Table I of the Appendix).

	Vote	Vocational	Cultural	Social	Miscellaneous
Females (242)	A	15.9%	48.1%	31.0%	5.0%
	B	10.7	43.7	44.1	1.5
Males (366)	A	21.2	45.6	32.3	0.9
	B	13.4	43.6	42.0	1.0
All (608)	A	19.1	46.6	31.8	2.5
	B	12.3	43.6	42.8	1.3

The heaviest vote is for cultural motives. The detailed Table shows that the outstanding single motive is (h) - to understand the present world. Students feel that a knowledge of science is needed for this purpose. If understanding the present world is a worthy motive (and few would deny that it is), this investigation indicates the direction in which popular science instruction should be orientated. Further, this positive assertion that knowledge of science is necessary for understanding the present world indicates that greater provision for the dissemination of popular science should be made. The fairly heavy vote for motive (i) is probably associated with that for (h). Social and recreational motives are fairly strong. The chief of these are (m) and (n) - science as a hobby and as a change from work. These results are encouraging for instructors. (From remarks on the questionnaires it was learned that the hobbies were gardening and bee-keeping, but it is suspected that in many cases science itself is the hobby.) The chief vocational motive is (a) - to help with daily work. The "improper" motives (e) and (j) not unnaturally received few votes. Among the B votes, besides the supporting votes for (h), (i), and (n), the heavy vote for (k) can be noted. This purely social motive is in accordance with expectations and is applicable to lectures on any subject.

This consideration of science as a whole reveals little difference between the sexes. The only significant difference in the A votes is for motive (m).

Table VI shows the motive percentages for each subject and sex. The striking feature is the pursuit of Social Sciences for cultural reasons, i.e. a general desire to understand the world and to know about science. Except for the female vote in General Science (which is based on small numbers), both the male and female votes for the cultural motives in Social Sciences are significantly or suggestively higher than those for the same motives in other subjects. Correspondingly, few people pursue Social Sciences for vocational reasons. Another marked feature is the pursuit of Geology for social and recreational reasons.

There are few sex differences. Males apparently have a greater vocational interest in geology and general science but small numbers prevent the forming of definite conclusions. Females pursue general science more for cultural reasons than males and find geology of even greater recreational interest.

The B votes, in general, support the A votes. As is expected, social and recreational motives stand high as subsidiary motives. The high male vocational motive in geology receives little B support. There was a striking sex difference in Physical sciences (based, unfortunately, on small numbers). The B votes strongly supported the male vocational motive but not the female vocational motive.

The full analysis of the A votes in all subject groups, arranged according to sex and age, is given in Table II of the Appendix. (Only in Biology and Social Sciences do numbers permit division into ten-year age-groups and even these groups are rather small. In other subjects the division is not so fine.) With small age-groups the figures only suggest possible trends. Attention is drawn to some of the many interesting features which the tabulation reveals. Certain B votes are quoted where they add useful information.

TABLE VI

Motives for study arranged by subject and sex

(The figures show percentages. In each subject and sex the upper line gives A votes and the lower line B votes.)

Subject	Sex	No.	Vocational	Cultural	Social	Misc.
BIOLOGY	F	103	21.3	39.5	35.3	3.9
			13.0	41.9	44.0	1.1
	M	146	19.8	43.8	35.8	0.6
			14.6	43.4	41.6	0.4
GEOLOGY	F	32	8.9	35.3	51.6	4.2
			12.3	32.4	50.7	4.6
	M	61	30.2	28.8	38.5	2.5
			8.9	41.6	47.1	2.4
PHYSICAL SCIENCES	F	14	35.7	44.7	19.6	-
			3.6	51.2	45.2	-
	M	32	30.6	40.8	28.6	-
			25.5	40.9	30.3	3.3
GENERAL SCIENCE	F	19	13.2	64.4	22.4	-
			14.8	52.5	32.7	-
	M	47	30.1	45.1	24.8	-
			16.9	40.3	42.3	0.5
SOCIAL SCIENCES	F	74	8.3	62.3	20.4	9.0
			7.0	46.6	44.6	1.8
	M	80	8.3	63.9	26.6	1.2
			7.4	49.4	43.2	-

BIOLOGY

The vocational motives, in both sexes, show a marked decline with age. The vote for motive (a) was strong for the under 30's and was supported, for this age-group, by a fairly strong B vote (F.15%, M.10%). In contrast, motive (h) - to understand the world - intensified with age. It received a heavy B vote. The associated motive (i) received a strong B vote (F. 15%, M. 12%). The strong recreational motives (m) and (n) can be noted. Males, particularly, find biology a help in their hobbies (possibly gardening) and both sexes find it a change from their work. Motive (d) - to remedy a feeling of ignorance - received B votes of 10% (F.) and 11% (m).

GEOLOGY

The greater vocational interest of males has already been noted. The subject seems to appeal most ~~for~~ in its social and recreational aspects. Motive (m) received a very high vote. It is probably, not that geology helps with a hobby, but that geology is itself the hobby. The vote for motive (h) was generally low compared with that in other subjects but, usually, the B vote was stronger than the A vote. Similarly motive (i) received a stronger B vote.

Physical sciences

Small numbers prevent the forming of reliable conclusions. Motives (a) and (h) predominate. Motive (d) received a fairly strong B vote (F. 22%, M. 10%).

General science

Numbers again were small. Motive (h) received the biggest vote. Motive (i) received a strong B vote (F. 31%, M. 17%). There was also strong B support for motive (n) (F. 19%, M. 15%).

Social science

As already noted, vocational motives are weak and seem to decline with age. Motives (h) and (i) were particularly strong. There was good B support for (i). The fairly strong "miscellaneous" motive of older females is interesting. It was made up chiefly of the general desire to become a better mother.

The purely social motive (k) - to see and mix with other people - received a strong B vote in all subjects except General science. The female vote was usually higher than the male. Except in geology, the motive intensified with age. The following figures indicate the strength (B vote) and extreme variation with age of this motive.

Biology:	F. 7-23%	M. 6-22%
Geology:	F.29-21%	M.26-7%
Physical sciences:	F.17%	M. 9%
General science:	F. 3-10%	M. 4-11%
Social sciences:	F.18-35%	M.16-27%

5. GENERAL CONCLUSIONS AND APPLICATIONS

Motives are certainly mixed and show odd variations with age. Except for the vocational motives of males in geology, there were no significant differences between the sexes. (In some cases, small numbers may have prevented other possible differences from becoming apparent.) As would be expected, vocational motives declined with age and a general "cultural" motive developed.

The most important motive is the general desire to understand the present world with the implication that a study of science is necessary for this purpose. This is important because it shows that people who have some interest in science have an appreciation of the cultural value of science. They recognise that science is not merely a utilitarian or technical subject but one essential to understanding modern life. If all people would recognise this the problem of producing a scientifically educated public would be less difficult.

It is interesting to find that many people find science (or at least lectures in science as given by Extra-mural bodies) of recreational appeal. Again it might be wished that more people would recognise that science can be a recreation and a hobby.

It appears that people who attend lecture-courses do so, in the main, from desirable motives; the major obstacle is that so few people attend such courses. Perhaps it is unreasonable to expect the bulk of the population to attend lectures in the evenings. The remedy, of course, is the better provision of science education in the schools. The schools can help in two ways; by presenting science as a cultural and recreational subject and by stimulating a greater interest in science so that children leaving school wish to learn more of it.

It may be wondered if this investigation gives any indication of the best subjects for developing a general cultural appreciation of science. (It appears that no particular steps need be taken in respect to sex or age.) The figures suggest that Social Sciences best provide a general scientific culture. Such a conclusion, however, is open to criticism. The figures show that this subject provides more for culture than for vocation - this is inherent in the nature of the subject - but other subjects, more markedly vocational, may nevertheless ultimately develop higher cultural values. Although Social Sciences have the greatest cultural appeal it does not follow that they adequately develop scientific culture.

PART III

A STUDY OF PEOPLE'S INTERESTS IN THE VARIOUS BRANCHES OF SCIENCE

PART III - A study of people's interests in the various branches of science.

		Page
Section 1.	The nature of the problem.	63
2.	The need for, and the construction of, a new classification of popular science subjects.	65
3.	The construction of a test of people's interests in popular science.	70
4.	The nature of the people tested, the conduct of the test, and the reliability of the sampling.	74
5.	Examination of the ABCDE markings.	79
6.	The translation of the results on to a numerical scale and the formation of orders of preference.	87
7.	Variations with age and the interests of teachers.	95
8.	The Army group.	97
9.	The application of the results.	101

A condensed account of the investigation herein described was published in ADULT EDUCATION, Vol. XXI, No. 2, (December 1948).

1. THE NATURE OF THE PROBLEM

The investigation described in Part II indicates the reasons why certain people wish to increase their knowledge of science, but science, even as popularly understood, covers a wide range of subjects. In attempting to determine the part that each subject can play in popular science education, it would be difficult to assess the relative values of the contributions of each subject. Even if such assessment were made, it does not follow that it would be a wise policy to give people what experts think is best for them. As popular science education is not yet highly developed it may be wiser to give people what they think they need. It has already been established that the motives of people who attend lecture-courses are, in the main, desirable ones, and, in any case, more will be achieved by proceeding along acceptable lines. The immediate problem, then, is the determination of people's interests in the various scientific subjects.

It is fully realised that people's interests may depend upon many factors and may also vary with time. Interest in a topic or subject depends, for example, upon ability in that subject, previous teaching and training, and environmental influences (e.g. friends, local facilities and stimuli). It can hardly be expected that a person will be deeply interested in a subject about which he knows nothing. In the case of popular science, however, a person is aware of subjects even if he is unaware of their names and has had no formal instruction in them, for popular science manifests itself in his every-day experiences. Thus it is possible for a person to take an interest in the flowers of the field or the stars of the sky without having had any instruction (or even enlightenment) in biology or astronomy. It is true, of course, that formal instruction may increase (or decrease) interest. It would be a useful but difficult research to attempt to determine the relation between the degree of interest in a given subject and the nature and amount of previous instruction in that subject. The first problem, however, in this almost unexplored field, is the gross examination of the degrees of interest in the various sciences.

The writer has not found record of any other research in this field of adult interests in science. Most previous researches in interests have concerned the range of inter-ests of individuals, often with the intention of indicating vocational or psychological tendencies.[1] The problem here is the assessment of each of a given range of inter-ests (namely various sciences) i.e. it is the interest, not the individual, which is under examination. Certain researches along these lines were noted in Part I but they were concerned only with the interests of school children.

A solution of the problem is very necessary. The proper dissemination of popular science can only take

---

1. For a general account of researches in interests see Fryer D. "The Measurement of Interests" (Henry Holt & Co., New York, 1931).

place when it is known what aspects of the great range of scientific knowledge best fulfil the aims and are also acceptable to the learner. Books are published, lecture-courses are arranged, broadcasts are given, but little attention seems to have been given to what the public wants or what it needs. Is the editor of a popular science magazine right in his distribution of articles in the various sciences ? Is an organising body of Adult Education right in stressing, for example, biology and psychology ? In this Part an attempt is made to answer such questions by research into the particular scientific interests of those ordinary people who, in some way, have shown a general scientific interest.

---

2. THE NEED FOR, AND THE CONSTRUCTION OF, A NEW CLASSIFICATION OF POPULAR SCIENCE SUBJECTS.

In order to investigate people's interests in different branches of science, to examine the present distribution (in books and lectures) of the various scientific subjects, and to indicate improvements, in this respect, within the range of popular science, an appropriate classification of these branches and subjects is needed. The obvious classification to which to turn is Dewey's Decimal Classification. The relevant parts of this classification are section 500 and most of section 600. The framework is set out below.

500 PURE SCIENCE	600 USEFUL ARTS. APPLIED SCIENCE
51- Mathematics	61- Medicine
52- Astronomy	62- Engineering

53- Physics	63- Agriculture, Agronomy
54- Chemistry (and Mineralogy)	64- Home Economics
55- Geology	65- Communication
56- Paleontology	66- Chemical technology
57- Biology (and Anthropology)	67- Manufactures
58- Botany	68- Mechanical trades
59- Zoology	69- Building

In addition to these, 15- Psychology, and parts of 38- Commerce and Communication, must be added. This list provides 22 subject headings. This classification is probably excellent for library purposes but it is not necessarily suitable for the present purpose. The popular science reader might well wish to make a distinction between Water power, Lighthouses, and Aeroplanes (all in 62-). We are led, therefore, to the decimal decomposition of the main headings, or, at least, of some of them. The decomposition of 53- (PHYSICS), for example, gives

530 General Physics
531 Mechanics
532 Liquids, Hydraulics, etc.
533 Gases. Pneumatics
534 Sound. Acoustics
535 Radiation. Light. Optics
536 Heat
537 Electricity
538 Magnetism
539 Molecular Physics

Now it is obvious that such sub-division leads to a lengthy list. If, for example, only 5 of the main headings are decomposed in this way, the original list of 22 becomes one of 67. In any large-scale investigation of people's interests, people cannot reasonably be expected to sub-divide and analyse their interests under 67 headings. For this reason alone, the Dewey classification is unsuitable for our purpose.

There is, however, another important objection to this classification for the present purpose. Consider, for example, the subdivision 536 (PHYSICS - Heat). On the shelves of a public library the writer has found, with the minimum of difficulty, books with the following titles:

(a) Combustion from Heracleitos to Lavoisier

(b) Theory of Heat

(c) Thermostats and Temperature-Regulating Instruments

(d) Industrial Applications of Infra-red.

Here is one subject but four types of interest - (a) History of science, (b) Textbook fundamentals, (c) Instruments and devices, (d) Industrial applications. Classification by subject is not necessarily the same as classification by interests. A person's scientific interests may be confined to one aspect e.g. history, or manufactures, and yet stretch across many conventional subjects. For the purposes of studying popular scientific interests, therefore, a new appropriately constructed classification is needed.

The writer constructed provisional classifications which seemed more appropriate. These were tested in two ways:

(1) Students in local Extra-mural classes were asked to indicate their interests in each of the "subjects" and to record any scientific interests for which there appeared to be no place.

(2) The writer examined book lists of popular science, allocating each book to its proper place in the classifications and noting any difficulties.

By such methods of trial and error a revised classification was gradually evolved. The classification given in Table VII was finally devised for the investigations to be described later in this Part. The interpretation of the items of the classification is explained in section 3.

A classification is made for a purpose and no classification is perfect. This classification is made for the purpose of testing and analysing people's interests in Popular Science. There are, of course, certain topics which might claim a place in two of the sections. Thus "Human fossils" might be placed under (13) or (17) - it depends upon the point of view. Likewise "The History of Blood Transfusion", primarily under (1), might, if treated in a certain way, be put under (10). Such cases can only be classified after a careful examination of the point of view and treatment. (Even Dewey's classification is open to this difficulty; a given book is not infrequently differently classified in different libraries.) Subsequent work, however, has revealed certain necessary modifications:

TABLE VII

Classification of Popular Science subjects (as used in the investigation).

(1) History of science.
(2) Scientific biography.
(3) Fundamentals of Physics and Chemistry.
(4) New discoveries and theories.
(5) New scientific devices.
(6) Applications of science to industry.
(7) Mechanical and electrical applications of science.
(8) Applications of science to everyday things.
(9) Civil engineering.
(10) Medicine, disease and health.
(11) Pure (non-useful) biology.
(12) Applied biology and agriculture.
(13) Ethnology and anthropology.
(14) Psychology.
(15) Aeronautics.
(16) Astronomy.
(17) Geology and Oceanography.
(18) Meteorology.
(19) Wireless.
(20) Propagation of scientific knowledge.
(21) Public control (direction) of science.
(22) Institutions, surveys, reports.
(23) Future advances.

(1) Section (5) needs to be split into (a) new laboratory devices, (b) new devices of outside application.

(2) A section should be provided for Scientific Method and Philosophy.

(3) A section might be desired for Laboratory Design and Equipment.

(4) A section is needed for science in warfare.

These modifications should be made to Table VII to give a final classification. The tests to be described were conducted in terms of the original classification.

---

3. THE CONSTRUCTION OF A TEST OF PEOPLE'S INTERESTS IN POPULAR SCIENCE.

In basing any form of test on the classification just discussed, it is necessary to design some popular interpretation of the various "subjects". Many ordinary people do not know what is meant by Ethnology (for example). What, exactly, does Civil Engineering include ? What distinction is to be drawn between new discoveries and new devices ? Accordingly a brief "definition" of each subject was devised. These "definitions" were not meant to be exact; they were meant to indicate the sort of science which each heading included. Thus, the definition of psychology might not be exact but it would serve its purpose if it brought into the mind of the ordinary person the nature of the subject. The definitions are set out below.

"Definitions"

1. History of science - Scientific knowledge and progress in the past. Stories of inventions (e.g. the dynamo) treated historically.
2. Scientific biography - The lives and work of famous scientists.
3. Fundamentals of physics and chemistry - Such matters as are usually found in school and university text-books.
4. New discoveries and theories - Latest discoveries and theories (at present not useful).
5. New scientific devices - New apparatus and methods. Ingenious devices e.g. burglar alarms, counting machines.
6. Applications of science to industry - Manufacturing processes. How substances (e.g. glass, dyes, rubber, plastics) are made or obtained.
7. Mechanical and electrical applications of science - Machines, engines, turbines, electric motors, etc.
8. Applications of science to everyday things - e.g. House lighting, water heaters, noise prevention in flats, etc.
9. Civil engineering - The building of, and working of, bridges, railroads, canals, sewers, roads, etc.
10. Medicine, disease, and health - Medicines, cures, and operations. Causes of disease; how to keep well.
11. Pure (non-useful) biology - Nature study. Natural history. Appearance, structure, lives of plants and

12. Applied biology and agriculture - Uses of plants and animals. Food, farming, the soil, etc.,
13. Ethnology and anthropology - Study of man. Different races of man. Pre-historic man.
14. Psychology - How the mind works. Defective minds. The testing of intelligence, ability, etc.
15. Aeronautics - Theory of flying. Types of aircraft. New models, new achievements.
16. Astronomy - Study of sun, moon, stars etc. Theories of the origin, nature, and fate of the universe.
17. Geology and oceanography - The rocks of the Earth. Fossil remains. Size, shape, and structure of the Earth (land and seas).
18. Meteorology - Cause of rain, fog, snow, winds, etc. Weather forecasting.
19. Wireless - How wireless works. New methods, new circuits. Television.
20. Propagation of scientific knowledge - Methods of teaching science.
21. Public control of science - Political, national, international use of science. Food control, health measures, government grants, etc.,
22. Institutions, surveys, reports - What institutions (e.g. universities) are doing. Exhibitions, public surveys and enquiries. Reports of meetings.
23. Future advances - Unsolved problems of science. What scientists are trying to do, what they hope to achieve.

The next step in designing the test is to decide how people's degree of interest shall be expressed. Remembering that the tests will be applied to ordinary people and that they will probably give the information by request and not by compulsion, it seems that a scale of five degrees is adequate. Ordinary people will not, or cannot, analyse their interests more finely. The following five degrees were selected:

(a) This interests me very much indeed.

(b) This is quite interesting.

(c) This is of moderate interest.

(d) This would not interest me much.

(e) This does not interest me at all.

This rating scale differs considerably from scales used by other investigators of interests. Most general interest tests are based on a like-indifferent-dislike scale, or, less often, on a five-point scale permitting two degrees of like and dislike. In the chosen scale no provision is made for dislikes but four positive degrees of like are given. It is not the intention here to investigate the dislikes of people who are not interested in science. Further, as the tests concern the subject, not (as usual) the individual, a fine scale of degrees is needed. It is assumed that the tests will be given to people of sufficient intelligence, at least when applied to science, to distinguish these degrees.

No guidance was given to the interpretation of these degrees. The writer has no evidence that such guidance as "eating strawberries = like very much" leads to increased reliability of interpretation. The test of reliable interpretation is: Do similar groups of people give virtually the same absolute results ? If so, it can be assumed that these groups interpreted the degrees correspondingly. The result of this criterion is described later.

The whole test-sheet was assembled in this form:

(1) Details of the marking scale with the instruction to mark each subject A,B,C,D,E, accordingly.

(2) The 23 "subjects" defined as above.

(3) Space for insertion of sex, occupation, and age (within the groups Under 20, 20-30, 30-40, 40-50, Over 50).

---

4. THE NATURE OF THE PEOPLE TESTED, THE CONDUCT OF THE TESTS, AND THE RELIABILITY OF THE SAMPLING.

The problems discussed in this thesis concern the presentation of popular science by book and lecture. A full enquiry should therefore cover both types of person.

Reader of books

Great difficulties prevent a proper investigation of the interests of this type of person. Obvious sources of information are libraries - both public and restricted e.g. (university Extra-mural) libraries. Enquiries revealed that libraries do not keep records of borrowings to the necessary fineness of detail. Birmingham Central Public Library, for example, does not record any more finely than the first figure of Dewey's classification. This is obviously useless for the present purpose. Further, such records, even if available, would be on the Dewey classification which has already been shown to be unsuitable. Another possibility would be to enclose a copy of the prepared test-sheet with every popular science book issued by a library. This is open to the objection described in Part II. There is no proof that the test-sheets returned are representative of the larger public, in fact, the method is condemned by the unreliability of the sampling. A better plan would be to issue the test-sheet with some well-known popular science periodical such as Discovery. The writer hopes that he may be able to do this when he has established some reputation in this field but at present such facilities are not available. He has therefore been forced to restrict the tests to the lecture audience. This limitation, of course, must be borne in mind when considering the results.

Lecture audience

Representative samples of people who are actively interested in science can easily be taken from those attending lectures and courses arranged by Extra-mural departments, the W.E.A., and similar bodies. The main difficulty is the obtaining of adequate numbers, for as noted elsewhere, classes are relatively few and attendance small. Eventually information was received from about 400 people attending such classes. This was achieved by

(a) postal contact with each of the 140 people whose names were on the science register of the Extra-mural department of the University of Birmingham.

(101 replies were received).

(b) personal contact with lecturers in local classes.

(c) postal contact with Directors and tutors of W.E.A. classes in various parts of the country.

A further 155 test-sheets (excluding spoilt ones) were received from an Army Education College. These, besides being interesting in themselves, were used for various check-tests, as described later. About 50 were also received from a Sixth-form class of a boys' Grammar School. It should be noted that in all cases there was sufficient personal contact and/or supervision for the returned test-sheets to be representative of the classes tested.

The test-sheets distributed under (c) above covered most geographical parts of the country. The courses were varied e.g. biology, astronomy, General Science - all science courses available were accepted. The extra-ordinary diversity of occupation, ranging from coal-miners to school teachers, from engine drivers to solicitors, indicated that a fair sample had been taken.

Some doubt might exist in respect to the reliability of small numbers. A sample is reliable if an equal one, drawn from the same source, gives almost identical results. In view of possible variation of interests with sex and age, numbers did not permit the formation of adequate similar groups and their comparison. But the Army group was homogeneous with respect to sex and almost so with respect to age (20-30) and served the purpose, inter alia, of affording some test of the reliability of small numbers.

First the interest-rating for each of the 23 subjects was evaluated for the group as a whole. (The method of doing this is described in section 6; the ratings may be considered as marks out of 10.) Then the group was divided at random into four sub-groups of 39, 40, 38, 38, and the interest-ratings evaluated for each of these. Table VIII gives the results. Realising that groups of 40 are small and that these men, though homogeneous in sex and age, are very mixed in schooling, civilian occupation, and general culture, the degree of correspondence between the sub-groups and whole group is remarkable. The coefficients of correlation between each of the sub-groups and the whole group are 0.94, 0.96, 0.98, and 0.90, respectively. (The last sub-group, by chance, contained all the Bandsmen who may have been a disturbing element.) It is improbable that groups of other people are so homogeneous but these results show that even groups as small as 40 can give fair indications of interest trends.

The Army sub-groups were also used to test the reliability of the interpretation of the scale. In each sub-group the overall mean of the 23 subjects was calculated. For the sub-groups A, B, C, D the overall means are 5.6, 5.8, 5.6, 5.2. The degree of agreement (even with the "disturbing" sub-group D) is good. It shows reliable interpretation of the degrees of the scale by the army men, and there is no reason to suppose that educated civilians are inferior.

TABLE VIII - Interest Ratings of Army group and its sub-groups.

	Subjects of Interest																						
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Whole group (155)	5.6	5.0	3.7	7.0	7.7	7.1	6.9	6.2	5.9	7.4	3.8	4.6	5.4	6.7	5.8	4.8	3.8	4.7	7.3	3.5	4.9	3.3	7.0
Group A (39)	6.0	5.7	4.8	7.0	7.7	7.2	6.2	7.2	5.3	7.5	3.3	4.4	4.9	6.9	6.2	4.6	3.1	5.1	7.2	3.5	5.0	3.4	7.4
Group B (40)	6.5	5.2	4.0	7.5	7.7	7.1	7.0	7.2	6.1	7.3	4.2	4.7	5.8	7.5	5.7	5.7	4.6	5.2	7.5	3.2	4.7	3.5	6.9
Group C (38)	5.0	5.4	3.1	7.3	8.2	6.3	7.5	7.0	6.0	7.1	3.5	4.8	5.5	6.7	5.9	4.3	3.5	4.4	7.5	3.6	4.7	3.5	7.3
Group D (38)	4.8	4.0	3.0	6.2	7.1	5.9	6.7	7.1	6.1	7.6	4.1	4.6	5.5	5.9	5.4	4.8	3.8	4.2	7.1	3.3	4.0	2.8	6.4

5. EXAMINATION OF THE ABCDE MARKINGS IN THE VARIOUS SUBJECTS.

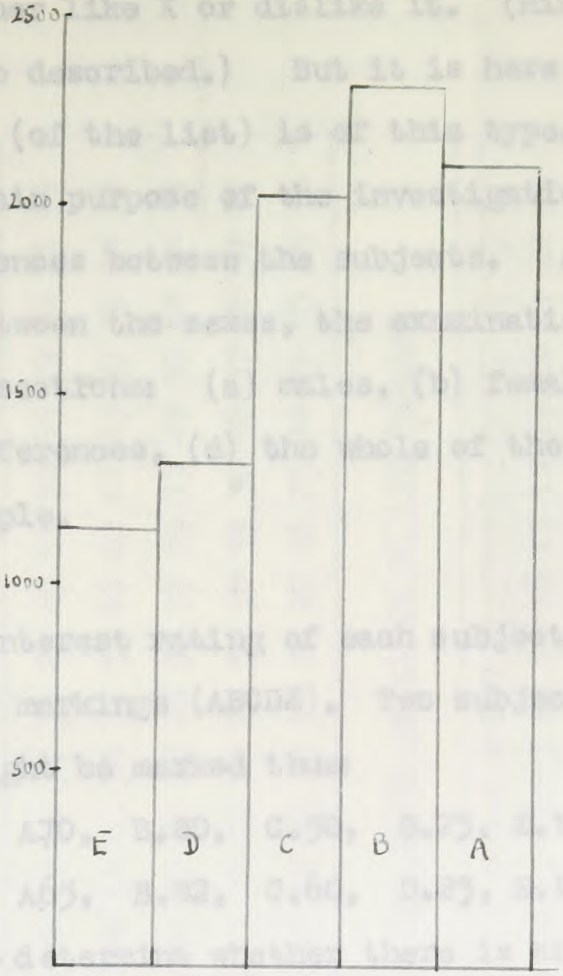
In order to obtain a comprehensive picture of the whole investigation it is necessary first to examine the distribution of the ABCDE markings. Counts were made to determine the total number of each mark recorded. (391 extra-mural and W.E.A. people marked 23 subjects.) The markings of the two sexes were separated. The results are shown in Table IX.

TABLE IX.

Distribution of ABCDE markings

	Males (241)	Females (150)	Total (391)
Number of A's	1266	865	2131
Number of B's	1438	898	2336
Number of C's	1332	714	2046
Number of D's	808	526	1334
Number of E's	699	447	1146

The differences between the sexes are discussed later. The distribution for the whole group (391) is shown in Graph 2. The distribution is far from normal; there is no reason why the distribution should be normal. The test group was specially selected as one having a positive interest in science. A bias towards the higher ratings, therefore, is expected.



Graph 2. Distribution of ABCDE markings

If, next, the distribution of the ABCDE markings for any one subject is examined, either for the sexes separately or for the whole group (the details are given in subsequent tables), it is found that in no case is there any evidence for a U-shaped distribution. The maximum is either at one of the ends or somewhere between. This is an important finding. It might have been expected that some subject either greatly appeals (to some) or completely fails to appeal (to others). It is commonly said that people either like X or dislike it. (History of science often is so described.) But it is here established that no subject (of the list) is of this type.

The main purpose of the investigation is to examine the differences between the subjects. Anticipating differences between the sexes, the examination is divided into these sub-sections: (a) males, (b) females, (c) male-female differences, (d) the whole of the extra-mural and W.E.A. people.

(a) Males

The interest rating of each subject is described in terms five markings (ABCDE). Two subjects X and Y, for example, might be marked thus:

X. A70, B.80, C.50, D.25, E.16.

Y. A65, B.82, C.60, D.23, E.11.

We wish to determine whether there is any significant difference between these ratings. This is most satisfactorily done by chi-squared tests. We can determine the probability that the differences are due to chance. If the probability is less than 0.05 the difference may well be of importance; if it is less than 0.01 the difference can safely be taken as significant.

With 23 subjects there are 253 pairs of subjects, each forming a 5x2 classification. The probabilities were evaluated for all of these 253 pairs. Table X shows the actual markings of the males.

The probabilities that the differences are due to

TABLE X. - The ABCDE markings of 241 Males

	SUBJECT																						
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
A	33	30	29	94	61	86	45	55	34	86	70	69	57	76	21	89	61	32	53	29	36	21	99
B	68	56	63	76	62	83	60	78	57	80	58	65	54	71	32	67	62	81	49	47	49	34	86
C	81	75	55	49	74	50	80	74	63	46	55	55	55	49	55	33	53	75	49	39	64	64	39
D	37	47	51	15	27	14	34	24	54	13	30	28	42	26	52	30	39	30	46	55	46	57	11
E	22	33	43	7	17	8	22	10	33	16	28	24	33	19	81	22	26	23	44	71	45	65	6

TABLE XI. - The ABCDE markings of 150 Females

	SUBJECT																						
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
A	17	20	14	47	23	42	1	48	4	96	88	59	63	86	5	50	43	33	12	24	29	9	52
B	45	60	28	48	51	62	14	47	25	34	34	42	44	31	11	47	42	58	32	31	40	29	43
C	42	44	31	24	40	26	48	31	32	11	17	29	21	21	24	26	33	38	37	26	38	42	33
D	27	22	30	20	21	14	41	19	47	4	8	16	11	8	41	13	21	17	33	29	26	38	20
E	19	4	47	11	15	6	46	5	42	5	3	4	11	4	69	14	11	4	36	40	17	32	2

chance are shown in detail in Table III of the Appendix.

It must be noted that this analysis does not place the subjects in an order of merit. Inspection, however, indicates the cause of difference. Thus subjects 22 and 23 clearly differ because 23 has a preponderance of A and B markings while 22 has a preponderance of D and E markings. Subject 23 clearly ranks higher than subject 22. But subjects 1 and 19, in which it is impossible by inspection to assign an order, differ because of the distribution. Subject 1 has a marked maximum in the B-C region while subject 19 has a fairly even distribution of markings.

It is not necessary at this stage to comment on the results individually; the tabulation adequately reveals the information. In section 6 of this Part an attempt is made to assign an order of interest and there to comment on the findings.

(b) Females

The subject differences for females can be examined in a similar way. Again there are 253 pairs of subjects giving 253 5x2 chi-squared classifications. These were calculated. The actual ABCDE markings are given in Table XI, and the results of the chi-squared calculations in Table IV of the Appendix.

(c) Male-Female differences.

Cursory inspection of the preceding tables shows that sex differences exist. These are now examined in detail. Table XII, compares the total distributions of the markings. To facilitate comparison the distributions are reduced to

TABLE XII.

Gross Distribution of ABCDE markings(male/female)

	Female		Male	
	markings	%	markings	%
A	865	25.2	1266	22.9
B	898	26.0	1438	25.9
C	714	20.7	1332	24.0
D	526	15.2	808	14.6
E	447	12.9	699	12.6

There is no significant difference between these markings. This, however, indicates an overall similarity between the sexes; it does not indicate a lack of difference between interest in various subjects.

An examination of the difference (if any) between the male interest in any subject and the female interest in that subject can be made by a chi-squared test. The significance of the difference of the male and female markings can be determined for each of the 23 subjects. The results of this analysis are shown in Table XIII. (Probabilities less than 0.05 are suggestive of a real difference, probabilities less than 0.01 indicate a significant difference.) In most cases inspection clearly indicates whether the overall interest rating in each subject is higher for males or females.[1]

1. In the actual calculation of the value of chi-squared it was clear which terms carried most weight. This assisted in determining the order.

TABLE XIII - Comparison of ABCDE markings of males and females

(P is the probability that the difference is due to chance. Probabilities less than 0.01 are written as 0.01)

		SUBJECT																						
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
MALES (241)	A	33	30	29	94	61	86	45	55	34	86	70	69	57	76	21	89	61	32	53	29	36	21	99
	B	68	56	63	76	62	83	60	78	57	80	58	65	54	71	32	67	62	81	49	47	49	34	86
	C	81	75	55	49	74	50	80	74	63	46	55	55	55	49	55	33	53	75	49	39	64	64	39
	D	37	47	51	15	27	14	34	24	54	13	30	28	42	26	52	30	39	30	46	55	46	57	11
	E	22	33	43	7	17	8	22	10	33	16	28	24	33	19	81	22	26	23	44	71	46	65	6
FEMALES (150)	A	17	20	14	47	23	42	1	48	4	96	88	59	63	86	5	50	43	33	12	24	29	9	52
	B	45	60	28	48	51	62	14	47	25	34	34	42	44	31	11	47	42	58	32	31	40	29	43
	C	42	44	31	24	40	26	48	31	32	11	17	29	21	21	24	26	33	38	37	26	38	42	33
	D	27	22	30	20	21	14	41	19	47	4	8	16	11	8	41	13	21	17	33	29	26	38	20
	E	19	4	47	11	15	6	46	5	42	5	3	4	11	4	69	14	11	4	36	40	17	32	2
Males significantly higher	P	-	-	.014	-	-	-	.01	-	.01	-	-	-	-	-	.01	-	-	-	.01	-	-	-	.01
Females sig.hr.	P	-	.01	-	-	-	-	-	-	-	.01	.01	.038	.01	.01	-	-	-	.014	-	-	-	-	-

The subjects in which there are significant differences can be conveniently summarised thus:

Male interest higher	Female interest higher
3. Fundamentals	2. Biography
7. Mechanical applications	10. Medicine
9. Civil engineering	11. Pure biology
15. Aeronautics	12. Applied biology
19. Wireless	13. Ethnology
23. Future advances	14. Psychology
	18. Meteorology

These results are much as might be expected but this investigation confirms, by testing, what one has previously only suspected. The difference in Meteorology, however, is surprising and inexplicable.

The practical application of these results is obvious. Given an audience which is wholly (or mostly) male or female, some subjects will be of peculiar interest, some will not.

(d) <u>The whole group of extra-mural and W.E.A. people</u>

In view of the proved sex differences it might be argued that results for a mixed group are valueless. This is not so for the following reasons:

(1) a book is not usually written for one sex only; it will be read, if it is interesting, by members of both sexes. The above results merely indicate that a book on a particular subject is more likely to be read by one sex or the other.

(2) A lecture audience is seldom unisexual. For reasons already stated, the 391 people tested are representative of the whole spread of extra-mural and W.E.A. audiences. The combined result is applicable to the general make-up of such classes.

As before, the significance of differences between the subjects can be tested by chi-squared calculations. Again there are 253 5x2 classifications. The probabilities for these were evaluated. The results are shown in Table V. of the Appendix. Comment is deferred until the interest ratings have been given numerical values.

6. THE TRANSLATION OF THE RESULTS ON TO A NUMERICAL SCALE, AND THE FORMATION OF ORDERS OF PREFERENCE.

,The interest ratings have not been fully investigated until they have been expressed in a numerical form. Further, numerical values are needed in order to assess the appropriateness (or otherwise) of the science education which is already being given, and to make suggestions for improvements.

So far no assumptions have been made about the numerical interpretations of the ABCDE markings except that, in judging the possible causes of differences, an A mark has been vaguely taken to be higher than a B mark, and so on. In devising a numerical scale there is an immediate difficulty. There is no reason for assuming that the points A,B,C,D,E represent unit differences of interest. But neither is there any reason to assume that they do not. In the absence of any specific guide we can only arbitrarily fix a numerical scale and then attempt to justify its reasonableness (not its accuracy). Any results so obtained must be regarded as reasonable approximations.

As already noted, few investigators have worked with scales involving several positive degrees of interest. Brainard[1] used a scale of seven degrees (ranging from very unpleasant to very enjoyable) and assessed them at 1,2,... ..7. Cox[2] used a seven-point scale ranging from -3 to +3. Notice the assumption of unit differences of interest. It seems appropriate here to use a linear scale (i.e. unit differences). Actually the markings ABCDE represent class-intervals. If, then, it is desired to establish a scale ranging from 0 to 10, these class-intervals should be rated at the midpoints of 0-2, 2-4, 4-6, 6-8, 8-10. This, however, would be misleading to the casual reader. Thus if every of N persons marked a subject with an A, the score for that subject would be 9N and the mean 9, i.e. an "all-out" vote for a subject would result in a mark of only 90%. The result would be more readily intelligible if this "all-out" vote received a mark of 100%. Similarly an "all-out" E vote should receive a mark of 0%. Accordingly a marking scale was chosen thus: A = 10, B = $7\frac{1}{2}$, C = 5, D = $2\frac{1}{2}$, E = 0. (These values were chosen in preference to 4,3,2,1,0 because "marks out of ten" are more intelligible to the ordinary reader.)

---

1. Brianard, P.P. Interest Tests in Vocational Guidance. Voc. Gui. Mag. 1928. (Quoted from Fryer.)

2. Cox, C.M. The Early Mental Traits of Three Hundred Geniuses. Vol. II. Genetic Studies of Genius. (Stanford Univ. Press 1926). (Quoted from Fryer.)

By using this scale, a numerical mean (indicating the central tendency) is evaluated for each subject for males, females, and the whole group. The variation (dispersion) within the subject is evaluated as the standard deviation σ and the reliability (or rather the unreliability) as $\sigma/\sqrt{N}$ where N is the total number within the group. In comparing one mean with another, the standard error of the difference is evaluated; if the actual difference is not less than three times standard error of the difference it is taken as significant, if it is between two and three times it is suggestive. Significant differences obtained in this way are compared with those obtained by chi-squared calculations. If any absurd discrepancies are revealed the numerical treatment is unreliable.

Tables VI, VII, VIII of the Appendix show the details of these comparisons. The findings are as follows:

(1) There are a few subjects which σ-calculations show to be significantly different and yet chi-squared calculations show the probability (of chance) to exceed 0.01. <u>But in each of these cases the probability does not exceed 0.05.</u> Hence the numerical method does not falsely indicate significant differences.

(2) The σ-calculations show as NOT significantly different some subjects which, by chi-squared calculations, are significantly different. This is explainable. Subjects with similar central tendencies may have differing distributions.

It is shown therefore that the numerical method does not lead to absurdities, in fact its indications are remarkably good. Hence a fair amount of reliance can be given to the numerical results which are discussed in the subsequent paragraphs of this Part.

Tables XIV, XV, XVI, show the numerical results for males, females, and the whole lecture-group. The subjects are set out in order of interest ratings. As an aid to quick understanding, an indication is given of the approximate difference (for each Table) which is significant. (This difference varies slightly for any pair of subjects because the dispersions vary.) The dispersions must not be interpreted as indications of unreliability. The means (central tendencies) are reliable to the figure $\sigma/\sqrt{N}$; the dispersions serve to show the spread of the central tendency.

First an examination is made of the mean of the subject means. The results are:

Male 5.8 $\pm$ 1.1 Females 5.9 $\pm$ 1.7

Whole lecture group 5.8 $\pm$ 1.3

These means of means indicate the interest in science as a whole. It is immediately apparent that there is no difference between the "overall" interests of males and females (of this lecture group). The dispersions of the means of the means, however, show a marked divergence. The dispersion is higher for females, indicating greater variation from one subject to another. Females, it is discovered, are more extreme in their likes and indifferences. Compare,

TABLE XIV. - Numerical interest ratings of MALES

Order	Subject number	Subject	Interest rating	Dispersion
1	23	Future advances	7.7	2.5
2	4	New discoveries etc.	7.4	2.7
3=	6	Industrial applications	7.2	2.7
	10	Medicine, disease etc.	7.2	2.9
5	16	Astronomy	6.7	3.2
6	14	Psychology	6.6	3.2
7	8	Everyday applications	6.5	2.9
8=	5	New devices	6.3	2.9
	12	Applied biology	6.3	3.2
10	11	Pure biology	6.2	3.5
11	17	Geology	6.0	3.3
12=	18	Meteorology	5.7	2.8
	7	Mechanical applications	5.7	3.0
14	13	Ethnology, anthropology	5.6	3.4
15	1	History of science	5.5	2.9
16	19	Wireless	5.2	3.5
17=	9	Civil engineering	5.0	3.1
	2	Scientific biography	5.0	3.1
19=	3	Fundamentals	4.8	3.2
	21	Public control	4.8	3.3
21	20	Propagation of science	4.0	3.5
22	22	Institutions, surveys, etc.	3.8	3.2
23	15	Aeronautics	3.5	3.2

Based on 241 replies. Differences greater than 0.8 - 0.9 are significant.

TABLE XV. - Numerical interest ratings of FEMALES

Order	Subject number	Subject	Interest rating	Dispersion
1	10	Medicine, disease etc.	8.5	2.5
2	11	Pure biology	8.3	2.5
3	14	Psychology	8.1	2.6
4=	12	Applied biology	7.3	2.8
	13	Ethnology, anthropology	7.3	3.1
6=	6	Industrial applications	7.0	2.7
	23	Future advances	7.0	2.8
8	8	Everyday applications	6.9	2.8
9	16	Astronomy	6.8	3.2
10	4	New discoveries etc.	6.7	3.1
11	18	Meteorology	6.6	2.6
12	17	Geology	6.4	3.1
13	2	Scientific biography	6.2	2.4
14	5	New devices	5.8	2.9
15	21	Public control	5.6	3.2
16	1	History of science	5.2	3.0
17	20	Propagation of science	4.5	3.7
18	19	Wireless	4.2	3.3
19	22	Institutions, surveys, etc.	4.1	3.0
20	3	Fundamentals	3.9	3.4
21	9	Civil engineering	3.4	2.8
22	7	Mechanical applications	3.0	2.5
23	15	Aeronautics	2.4	2.7

Based on 150 replies. Differences greater than 1.0 - 1.1 are significant.

Graphical representation of Interest ratings.

RED: Male. GREEN: Female.

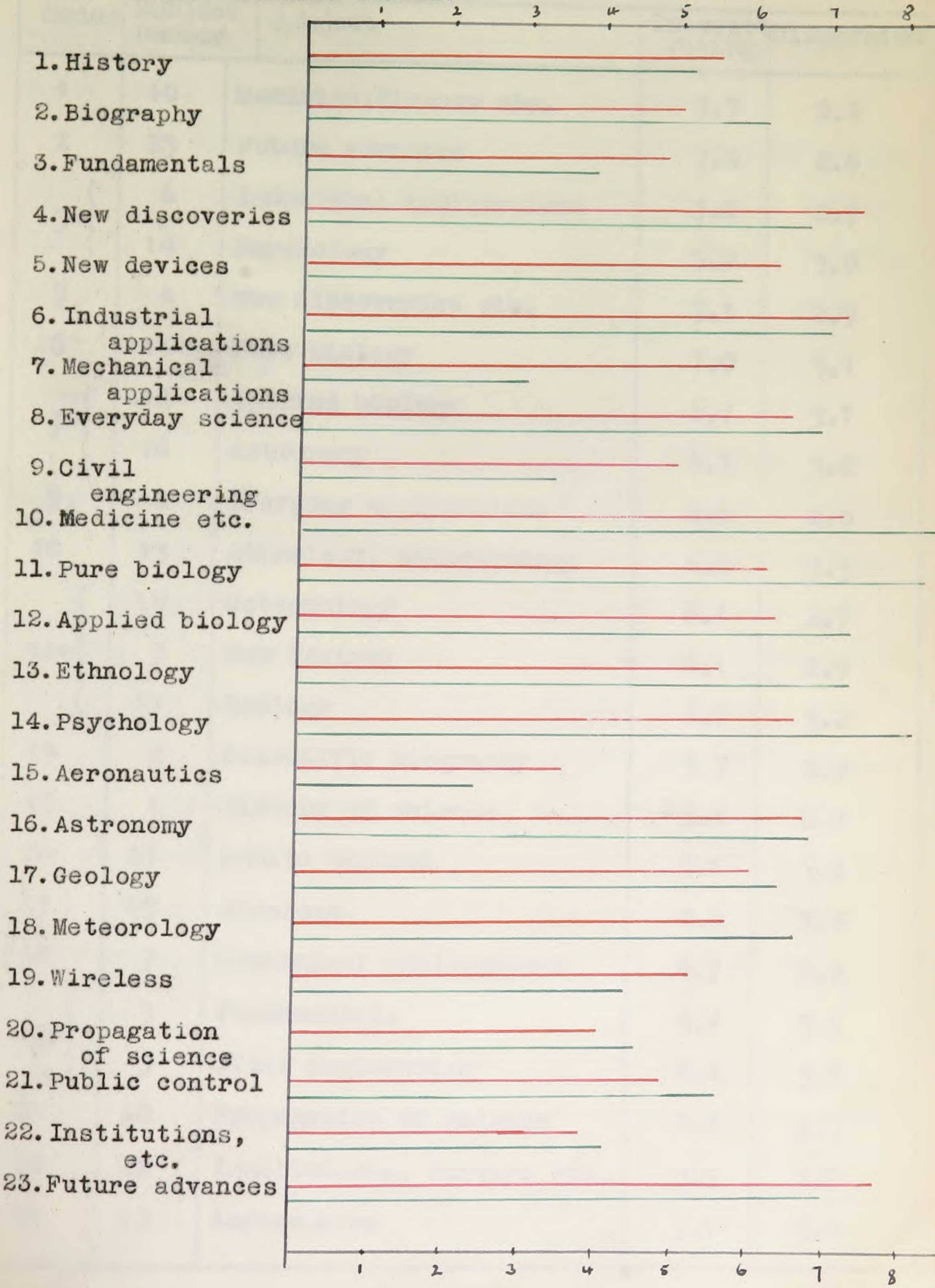


TABLE XVI. - Numerical interest ratings of whole lecture-group

Order	Subject number	Subject	Interest rating	Dispersion
1	10	Medicine, disease etc.	7.7	2.8
2	23	Future advances	7.4	2.6
3=	6	Industrial applications	7.2	2.7
	14	Psychology	7.2	3.0
5	4	New discoveries etc.	7.1	2.9
6	11	Pure biology	7.0	3.1
7=	12	Applied biology	6.7	3.1
	16	Astronomy	6.7	3.2
9	8	Everyday applications	6.6	2.8
10	13	Ethnology, anthropology	6.2	3.3
11=	18	Meteorology	6.1	2.7
	5	New devices	6.1	2.9
	17	Geology	6.1	3.2
14	2	Scientific biography	5.5	2.9
15	1	History of science	5.4	2.9
16	21	Public control	5.1	3.2
17	19	Wireless	4.8	3.4
18	7	Mechanical applications	4.7	2.8
19=	3	Fundamentals	4.4	3.3
	9	Civil engineering	4.4	3.0
21	20	Propagation of science	4.2	3.5
22	22	Institutions, surveys etc.	3.9	3.1
23	15	Aeronautics	3.1	3.0

Based on 391 replies. Differences greater than 0.6 are significant.

for example, the highest and lowest ratings of each sex:

Male 7.7, 3.5 Female 8.5, 2.4.

There may well be a psychological reason for this difference; here the deduction is merely recorded.

It is not necessary to comment in great detail on the subject orders; Tables XIV, XV, XVI summarise the information. Certain features may be noted. Medicine, Health, and Disease have a great popular appeal. Biology comes high, particularly for the females, and Future Advances comes high, particularly for males. Psychology holds a high position. It is noted, perhaps with surprise, that wireless, civil engineering and aeronautics have relatively little appeal. The position of aeronautics is revealing. It is unquestionably of little appeal both to males and females. Yet during the War it was a popular subject.[1] It may also be noted that Public Control of Science and the Affairs of Public Bodies and Institutions have little appeal. (The ordinary man is not yet fully conscious of the repercussions of science on communal and social life.) That Fundamentals, savouring (perhaps wrongly) of school and scholarship, should have little appeal is not surprising.

It is important to note that all the suggested subjects received some, though variable, measure of support.

---

1. A librarian has indicated to the writer his personal detection of the same violent swing of appeal of this subject.

People who are interested in science (e.g. this lecture group) are interested, to some degree, in all subjects of science.

7. VARIATIONS WITH AGE AND THE INTERESTS OF TEACHERS

Interests certainly vary with circumstances and opportunities, but it is possible that they also vary with age. An attempt is made to investigate age-variation (if any). It seemed useful too to investigate the interests of teachers, for teachers have a direct bearing on the general process of scientific education. The whole lecture group was divided, by sex, into sub-groups according to age and the teachers (male and female separately) put into other sub-groups. These sub-groups varied in size from 25 to 49.[1] Any results based on such small numbers must be regarded with caution but it has already been known that groups of 38-40 are not completely unreliable.

The results are set out in Table XVII. (M is the mean of the 23 interest ratings and σ its standard deviation.) The overall means M for each of the sub-groups are approximately constant, indicating that there is no appreciable change of intensity of interest in science generally with age. The deviations (or dispersions) are variable. As already noted, females show a higher dispersion, indicating more violent degrees of interest. A striking result is low dispersion of the young students.

1. The male student group (23) was supplemented by adding in the results from 46 boys in a sixth form of a Grammar School.

This indicates less violent likes and dislikes - a result not unexpected in young people. The high dispersion of the female 20-40 group may be of significance. Possibly the extremes of likes and dislikes is related to some psychological factor in the make-up of females of these ages.

There are few (if any) marked variations of interest with age. Some of the variations may be due to real causes but numbers do not permit rigid conclusions. In particular, the following can be noted.

<u>Males</u>

General rise of interest in 10 and 11 (biology), 14 (astronomy), 17 (geology).

<u>Females</u>

General rise of interest in 9 (Everday applications), and 17 (geology).

General fall of interest in 19 (Wireless).

The marked extremes in the 20-40 age-group: high interest in 14 (psychology), low interest in 3 (fundamentals) and 15 (aeronautics).

It is useful to note that subjects not often taught at school - geology, biology (males), astronomy (males) - are found to be of interest upon acquaintance. The fall of female interest in wireless, aeronautics, and fundamentals (absence of vocational interest) is not unexpected.

The writer was particularly keen to examine any marked peculiarities of teachers. Of the numbers available,

Table XVII - Variation of Interest with age and the Interests of Teachers

	No.	Subject. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	M	σ
MALES Students																										
under 20.	69[1]	6.0	5.0	5.2	7.7	7.2	6.8	6.4	6.3	6.0	6.1	4.8	4.4	4.3	5.5	5.2	5.9	4.4	5.4	6.0	4.0	4.5	4.4	7.4	5.6	1.00
20 - 30	40	4.8	3.8	4.9	7.8	6.3	7.5	5.9	6.1	4.8	6.5	4.4	4.9	5.4	6.4	4.0	7.6	5.2	5.5	6.2	2.9	4.7	3.2	8.1	5.5	1.4
30 - 40	50	6.0	5.0	4.9	7.3	6.2	7.9	6.9	7.4	5.9	7.3	6.5	6.8	5.5	6.9	3.7	5.9	5.8	5.7	5.7	3.6	5.2	4.4	7.8	6.0	1.2
40 - 50	45	5.1	5.3	4.9	7.4	5.8	7.0	5.2	5.7	4.0	7.8	7.2	6.8	5.7	7.3	2.7	6.8	6.2	5.2	4.4	4.0	5.2	4.3	8.1	5.8	1.4
over 50	49	5.5	5.4	4.6	6.4	5.9	7.4	5.2	6.9	5.9	7.4	6.5	6.6	6.4	6.5	3.6	7.8	7.1	7.0	5.2	4.1	4.8	3.3	7.4	5.9	1.2
Male Teachers	34	6.1	5.6	4.5	8.5	6.8	7.0	4.7	6.3	3.7	6.9	6.7	7.4	5.6	6.7	2.6	6.3	6.2	5.1	4.1	6.2	4.1	3.5	7.4	5.7	1.5
FEMALES Students																										
under 20	25	5.1	5.8	4.4	6.9	5.5	6.1	3.2	5.9	3.4	8.7	8.6	7.8	7.8	8.7	3.2	6.6	5.4	6.8	5.5	5.0	5.1	3.4	6.3	5.9	1.7
20 - 40	34	5.2	6.2	2.6	5.9	6.4	7.3	2.4	7.6	3.2	8.7	7.8	6.6	7.0	9.2	2.2	6.3	6.2	6.5	4.2	2.8	5.4	2.9	6.5	5.6	2.1
over 40	38	5.5	6.0	4.1	6.2	5.4	7.0	2.7	7.3	3.8	8.0	8.9	7.0	7.2	7.7	2.1	7.9	7.3	6.9	3.9	3.6	5.5	4.4	7.3	5.9	1.8
Female Teachers	53	5.1	6.4	4.3	7.4	5.8	7.3	3.6	6.7	3.2	8.7	7.9	7.7	7.2	7.4	2.3	6.3	6.4	6.5	3.7	6.0	6.1	4.3	7.6	6.0	1.7

I. 23 students from lecture courses, 46 from sixth form of Grammar School.

some were known to be science teachers; probably many were.[1] Few "teacher peculiarities" are apparent. Males seem to have a slightly greater interest in the history of science, a more pronounced interest in new discoveries and theories, and (naturally) an interest in the propagation of scientific knowledge. Females also show a marked interest in the propagation of scientific knowledge, and rather more interest (than other females) in Public Control and Future Advances.

The general conclusion of this section is that, apart from small trends as noted, interest in particular subjects does not vary markedly with age.

8. THE ARMY GROUP

Unusual facilities were available for administering the test to men in an army education college. The test was restricted to better classes of men i.e. illiterates and men of low intellectual grades were excluded. This group differs from the lecture group in two ways:

(a) Completion of the test-sheet was compulsory (though a few men spoiled their test-sheets).

(b) The men were not necessarily interested in science at all.

The latter point is important. The test-sheet was not designed for people who had no, or negative, interest in science. In this respect the results are unreliable but the results are not without value.

1. It should be noted that these teachers attended lecture-courses; no attempt was made to assemble a group directly.

An examination was first made of the frequency distributions of the ABCDE markings. These are set out, with those for the lecture group for comparison, in Table XVII. In the army group, D and E were used slightly more frequently as might be expected. It is probable that the E's include marks which would have been put in the positive dislike category if such were available. Of greater

TABLE XVIII

Distribution of ABCDE markings of Army group

	Army group		Lecture group	
	Total number	Percentage of whole	Total number	Percentage of whole
A	853	23.9	2131	23.7
B	859	24.1	2336	26.0
C	730	20.5	2046	22.8
D	551	15.5	1334	14.8
E	572	16.0	1146	12.7
	3565	100.0	8993	100.0

importance is the high frequency of A and B markings. Possibly they arose from a desire to please the officers but it is not unreasonable to think that they indicate a general interest in science. This result supports the contention in Part I that a positive interest in science exists in the ordinary man.

Table XIX shows the full data with the numerical deductions. It can be compared with Table XIV (Males in

TABLE XIX.

ARMY GROUP. ABCDE markings and numerical means

	SUBJECT 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
A	26	24	10	51	70	42	60	50	31	65	20	24	34	57	48	36	19	12	66	12	20	16	60
B	45	36	31	50	42	60	36	55	49	46	20	27	38	36	31	25	25	44	40	25	37	17	44
C	41	42	32	34	30	30	29	36	35	25	28	40	30	34	25	30	27	42	27	26	41	25	21
D	27	26	33	13	10	14	21	8	24	13	41	32	26	14	25	22	28	29	17	36	30	42	20
E	16	27	49	7	3	9	9	6	16	6	46	32	27	14	26	42	56	28	5	56	27	55	10
Mean	5.6	5.0	3.7	7.0	7.7	7.1	6.9	6.2	5.9	7.4	3.8	4.6	5.4	6.7	5.8	4.8	3.8	4.7	7.3	3.5	4.9	3.3	7.0
σ	3.0	3.0	3.1	2.8	2.6	2.6	3.1	3.2	3.1	2.8	2.9	3.3	3.5	3.2	3.7	3.8	3.6	3.0	2.8	3.3	3.6	3.3	3.1

the lecture group). The most striking feature is the similarity. In about 14 of the subjects there is little difference in the interest ratings. This indicates

(a) The intensity of interest of the ordinary man (as represented by the army man) differs little from that of the man who exerts himself to attend lecture courses.

(b) The relative likes (among the various subjects) are similar.

On the whole the army dispersions are slightly higher but not invariably so. Dispersions are markedly smaller (i.e. less variation) for subjects 11, and 19, and markedly higher for subjects 15, 16, and 23.

The army interest is higher in 7 (Mechanical applications), 15 (aeronautics) and 19 (wireless). This is in accordance with expectations. The army interest is lower in 3 (fundamentals), 11 and 12 (pure and applied biology), 16 (astronomy), 17 (geology), and 18 (meteorology). The lower interest in fundamentals and in the "aesthetic" subjects (11, 16, 17, 18) is not unexpected. These men have probably not had the opportunity to discover the cultural values of these latter subjects. It is surprising, however, to find a low interest in applied biology (possibly associated too narrowly with pure biology) and in meteorology.

---

9. APPLICATIONS OF THE RESULTS

The results of this enquiry can be applied in two ways:

(a) To judge the appropriateness of the scientific education (by book and lecture) which has recently been disseminated.

(b) To suggest desirable improvements in this respect.

It is fully realised that the results are based on the opinions of those people who voluntarily attend lecture courses and that there are many more people who profess an interest in science but do not attend such courses. (The writer feels that the results are certainly representative of the lecture course people.) But two points must be appreciated:

(i) There is no reason to believe that other people are markedly different from those who attend lectures.

(ii) Except for obvious vocational interests, the Army results (i.e. results of a group not selected on scientific grounds) do not differ markedly from those of the lecture course people.

It appears, therefore, that it is not unreasonable to apply the results to the wider public but, of course, the findings must not be taken too rigidly.

Bearing in mind that people have an interest (of some degree) in all the subjects, a yard-stick can be constructed by expressing the interest rating of each subject as a percentage of the sum of the interest ratings. This could be done for each sex, for an imaginary body composed of equal numbers of each sex, or for a body with the same composition as the lecture group. As lectures or books are seldom provided for one sex only, a yard-stick for a mixed group seems more useful. The male-female distribution of the lecture group may be representative of the wider public (it is not known) but its yard-stick would not differ much from that of a group of equal numbers. The findings, in any case, are only approximate. Accordingly the lecture group yard-stick (being real and not artificially compounded) is used in the following investigations. This yard-stick is shown in the second column of Table XX.

Discovery

This is a monthly magazine of science purporting to bring scientific progress to the ordinary intelligent man. The writer has examined the issues of five years (1943 - 1947 inclusive). Each article was assigned to its place in the classification, and its extent (inclusive of pictures and diagrams) recorded in pages and tenths. Six articles (one on scientific warfare) were excluded as being outside true science, and indefinite paragraphs of the editorials were excluded. In four cases an article was split as being equally classifiable under two headings. In all, the text of nearly 1500 pages was classified. The amounts for each subject were then expressed as percentages of the whole. The results are shown in part of Table XX.

On the score of pure numbers, Discovery gives too much space to New Devices, Applied Biology, Public Control, and the work of Institutions etc., and too little space to Everyday Applications, Psychology, and Future Advances.[1]

1. The coefficient of correlation is 0.13.

Much depends upon the policy of the proprietors (Discovery is a commercial proposition) but even so the space appears to be ill-distributed. A reader cannot help noticing the undue stress on Public Control of science. It may be desirable for the community that its members should have wider knowledge of the communal repercussions of science, and educationists may hope eventually to develop social consciousness, but, as matters are, people are not greatly interested in this kind of knowledge.

In examining these results certain other points must, in fairness, be appreciated. The quantity of interesting information available is not the same in all subjects. One cannot write so spaciously on Future Advances as (for example) on Industrial Applications. Further, Discovery may think that Future Advances is covered by Institute Reports. Then, some of the New Devices may soon lose their novelty and become Everyday Applications. Discovery itself regrets the paucity of Everyday Science information: "Science has not paid sufficient attention to ameliorating the conditions of everyday life" [1] and if science has done little, a magazine cannot but record little.

No excuse can be found for the very small attention to psychology - unless indeed Discovery refuses to call it a science.

Science News

This is a Penguin series which appears at approximately three monthly intervals. At the time of writing, [2]

1. Discovery, March 1946.
2. June 1948.

TABLE XX - Distribution of subjects in Popular Science publications

Subject number	Rating %	DISCOVERY Pages	DISCOVERY %	SCIENCE NEWS Pages	SCIENCE NEWS %	Nat'l Book League List	Cumulative List
1	4.0	71.2	4.8	42.8	4.9	5	11
2	4.1	59.4	4.0	-	-	6	6
3	3.3	65.1	4.3	57.4	6.5	28	13
4	5.3	60.2	4.0	137.6	15.6	2	8
5	4.6	152.1	10.1	47.9	5.5	-	5
6	5.4	92.2	6.2	26.9	3.1	1	2
7	3.5	50.4	3.4	6.0	0.7	-	12
8	4.9	8.2	0.6	41.0	4.7	5	1
9	3.3	13.7	0.9	0.7	0.1	-	-
10	5.8	84.8	5.7	205.7	23.4	2	18
11	5.3	132.9	8.9	17.0	1.9	44	(81)
12	5.0	154.8	10.3	101.0	11.5	-	(66)
13	4.6	10.4	0.7	1.1	0.1	13	11
14	5.4	10.2	0.7	39.3	4.5	-	13
15	2.3	29.3	2.0	2.5	0.3	-	15
16	5.0	56.5	3.8	16.7	1.9	10	7
17	4.6	49.6	3.3	94.6	10.8	12	4
18	4.6	21.9	1.5	33.5	3.8	7	2
19	3.6	15.5	1.0	4.3	0.5	-	4
20	3.1	49.2	3.3	-	-	-	-
21	3.8	156.0	10.4	-	-	-	10
22	2.9	128.0	8.5	-	-	-	-
23	5.6	23.2	1.6	1.7	0.2	1	-
		1494.8	100.0	877.7	100.0	136	289

seven issues have been made. Issue 2 was completely devoted to Atomic Energy. The writer has analysed the other issues. Analysis was difficult because some articles were long and touched upon many subjects. An article on Photography, for example, touched upon surveying, archaeology, ecology, forestry, geology, physics, metallography, and other subjects. It was necessary therefore to split the articles under the various headings of the classification in proportion to the amount of space given to each topic. The group of pictures in each issue was ignored. The results of the analysis are given in Table XX.

This publication apparently deliberately omits reference to Public Control, Institute Proceedings, and Biography. In this respect it is the opposite of Discovery. Although these topics are of relatively small appeal, it seems unwise to omit them completely. Science News is also deficient in civil engineering, pure biology, anthropology, and astronomy. Conversely, it gives undue space to new devices, medicine, applied biology, and geology. The first of these is explicable in terms of its aim and title; the next two are admittedly popular subjects. There seems to be an unreasonable stress on geology. The writer does complain of the space given to fundamentals. It is believed that a popular presentation of fundamentals (which this publication tries to give) is not unacceptable to the reader.

In view of the allocation of one whole issue (No. 2)

---

to Atomic Energy, certain subjects (Nos. 3,4,5,21) were unduly stressed. In order to be fair, this issue was omitted from the analysis. The justification for the issue was the great topical interest at that time. The issue suffered, however, from consisting of a series of separate articles, with unnecessary overlap of exposition.

Popular Science books

Analysis of popular science books is difficult. The writer made some rough attempt to gauge the present position in the following ways.

Examination was made of List No. 107 of the National Book League (books of popular science.)[1] Judging by the given broad classification (anthropology, general science, astronomy, physics, chemistry, geology and meteorology, biology, botany, zoology, - mathematics was ignored) and by the book titles, each book was assigned to a place in the classification of this research. Obviously one book might have covered several topics and titles can be misleading; the results are therefore only rough. (Several books apparently on scientific philosophy were ignored.) The numbers of books are shown in Table XX; it was considered unreasonable to express them as percentages. Some of the books assigned to subject (3) might have been classified under (8).

Examination was also made of Whitaker's Cumulative Book List for 1947. This lists all books published during the year. Extreme difficulty was experienced in trying to

---

1. This was compiled in 1938. It was the latest one available in 1947.

identify books on popular science (merely by the titles) and in finding any demarcation between Applied Biology and Gardening, between Applied Biology and Pets, and between Pure Biology and Ramblers' guides. The results (Table XX. shows number of books) are therefore very rough. In view of the difficulties it was considered unprofitable to examine the lists of other years.

It is unwise to draw conclusions from these very rough analyses. It appears however that undue stress is given to Pure Biology. It is interesting to note that book publishers (not magazine publishers) realise the appeal of ethnology and anthropology.

Lecture Courses

Analysis of lecture courses given by Extra-mural and W.E.A. bodies is also difficult because, in published data, all science is classified under biology, physical science, and psychology. It has already been noted (Part I) that biology often exceeds the physical sciences. The W.E.A. (1932) Report states "Biology is by far the most attractive of scientific studies to members of Tutorial Classes." In spite of the reasons there put forward, the present writer suggests (in view of the results of this investigation) that inadequate unbiassed evidence was available to the writer of the report.

Information obtained in the course of the Motive investigation (Part II) is applicable here. The writer made contact with every science class arranged by Extra-mural bodies which was available. The classes are therefore fairly representative of the range of Extra-mural courses. The classes were distributed as follows: fundamentals 4, industrial applications 1, everyday applications 6, medicine and health 3, pure biology 13, applied biology 17, ethnology 1, astronomy 2, geology 8, total 55. The writer also made contact with 15 classes of psychology but these did not represent the whole number available. The stress on biology is obvious. Omissions include New devices and discoveries, (possibly covered by isolated lectures), engineering (possibly considered vocational), and, perhaps wisely, aeronautics.

Why are there so many classes in biology ? Admittedly biology has a high interest rating but the results do not suggest that it should figure more often than all the other sciences combined. Possibly biology is the subject most easily understood by people who have had little formal training in science. The physical sciences require a deeper knowledge of fundamentals. Again the problem of the gap is encountered. It appears that certain sciences are omitted because they are difficult and yet these subjects are vital to the development of a scientifically educated public. The organisers of adult science classes appear to be too limited in outlook, - and the gap is not surmounted by ignoring it.

The results of this investigation have a prognostic value. It is shown which subjects are of greatest appeal. Preferred subjects may not be the best, immediately, for the realisation of the aims set out in Part I. but with popular knowledge of science being at so low an ebb the correct approach at present is through those subjects which will be well received. This investigation helps to increase an understanding of immediate needs and means.

PART IV

POPULAR VIEWPOINTS AND APPROACHES

PART IV - Popular viewpoints and approaches

		Page
Section 1.	The nature of the problem.	113
2.	Test-sheet I and the conduct of the first test.	116
3.	Results and deductions of test I.	118
4.	Discussion of the results of test I.	123
5.	The conduct, results, and deductions of the second test.	125
6.	Discussion and conclusions.	131

1. THE NATURE OF THE PROBLEM

The investigation described in Part III indicated subjects (or branches of science) which have a high interest rating. The success of a book, article, or lecture, however, depends, not only on the subject, but also on the way the subject is treated. A scientific topic can usually be presented from several points of view. Consider, for example, the topic Blood Transfusion. This will have a high interest rating. It can be presented as a matter of pure medicine and surgery, or in terms of its direct effect on the individual. It can be treated historically (as in Science News 3) with or without biographical details. It can be presented as arising from, or satisfying, a social need; it can be given as an imperfect solution of present problems with some indication of possible and desirable advances. It is not suggested that a given topic should be presented rigidly from one viewpoint only, or even that it could be, but in the preparation of a lecture or written article, the leading viewpoint must be clearly fixed, for it forms the elementary scaffolding round which the whole structure is built.

The need for understanding the point of view of the pupil is obvious to any competent teacher. The teacher's knowledge of his class enables him to select the most successful approach. In the presentation of popular science to the adult it is likewise necessary to know the viewpoint of the learner, but it is less easy to find out what that viewpoint is. Not infrequently an inexpert lecturer or author, in trying to adapt his specialised knowledge to the requirements of the ordinary adult, fails to treat the subject from the viewpoint which brings understanding and success (or even to define any viewpoint at all).

Educationists, of course, have appreciated the need for working from the right point of view. To remove the inhibiting effects of the "gap", "lecturers and tutors need to approach their task in a very different manner from that adopted for the ordinary student of the university or technical college." (B.A. (1933) Report p.339). Later (p.343) it is written "They (the tutors) must be capable, too, of appreciating the questions and the point of view of their students." Such statements indicate a problem but do not suggest solutions. In the "Suggestions and Recommendations" (p.355) certain positive statements are made. ".... the approach must be from the popular everyday applications of scientific method on practical occasions and common experience, to a discovery of principles, and from such discoveries, in detail, to the formulation of a systematic body of knowledge." This prescription (still rather vague) may or may not be successful; no indication is given of any evidence or experience on which the statement is based.

On page 346 of the Report there is a revealing statement. Mr S. Myers of the Deptford Men's Institute writes: "At the L.C.C. Men's Institutes we adopt a special approach. We have found it not only sound but essential to proceed from the immediate interests of the students, and to build round them a progressive educational course." There is nothing "special" about this approach; every teacher is aware of the need to start from immediate interests. The mere fact that the statement is reproduced in the Report shows that, in adult education, viewpoints and approaches have received inadequate attention.

It is necessary to determine the viewpoint of the "ordinary" man. From what angle does he view science ? Along what lines should a topic be developed if it is to command and satisfy popular interest ? Is any one viewpoint applicable to a large mixed group ? The writer has not found record of any previous researches in this field. An initial difficulty is the identification and definition of viewpoints. A study of popular science articles (e.g. in Discovery and Science News) and lectures revealed six possible ways in which a given subject might be treated.

(1) As a matter of pure science.

(2) The practical applications of the subject as they affect the individual.

(3) Historical treatment.

(4) Biographical and/or dramatic treatment.

(5) The social importance of the subject e.g. how the subject arose from, or satisfies (or modifies) a social need.

(6) The limitations of our present knowledge and use of the subject with indications of desired advances.

It is not suggested that every topic can be treated in each of these ways. (Examples of those which can be so treated are Plastics, X-rays, and Blood Transfusion.) Neither is it suggested that these are the only possible viewpoints.

The writer decided to work on these six viewpoints as an exploratory study.

---

2. TEST-SHEET I AND THE CONDUCT OF THE FIRST TEST

In designing a test of popular reaction to these six viewpoints considerable difficulty was encountered in framing definitions of the viewpoints which were clear and intelligible to the persons undergoing the test. Preliminary trials of possible test-sheets were made with members of local Extra-mural classes and with various other adults interested in the study. A test-sheet was evolved for an initial large-scale investigation. It is called Test-sheet I and is given below.

Test-sheet I

A scientific topic can usually be presented, in a popular written article or popular lecture, from several points of view. The letter X represents a scientific topic. It may be Magnesium, Atoms, Fertilizers, Psycho-analysis, etc. We suggest six points of view. We refer here to the MAIN viewpoint of the article or lecture (e.g. a very brief historical introduction would not be excluded from an article which is treated, IN THE MAIN, from one of the viewpoints 1, 2, 4, 5, 6).

(1) Pure Science ("Knowledge for its own sake")

My subject in this article is X. You may have met X in the form of ... or when dealing with ... but we are not here concerned with applications or uses. I shall have to answer the question: what is the special interest of X to the pure scientist ?

(2) Applications of Science ("How does it affect me ?")

You may not have noticed it, but X comes into your daily life in many ways. If it were not for X you would ... you could not ... Let us see what X really is, what is the science underlying its work, and how it affects you.

(3) Historical ("The story of science")

X was known to the Egyptians in 3000 B.C. The Ancient Greeks ... The Romans ... In more recent times ... In 1710 ... In 1835 ... Turning to the present century ...

(4) Biographical ("The drama of science")

The subject X had its real beginning with Mr Y. He was born in ...., the son of a .... After leaving school he... In 1743 while still a student he ... Encouraged by this he tried ... It was in 1752 that he made his great discovery. When he tried ... he found that .... Later ....

(5) Environmental ("Science satisfies a need")

In 1856 there was a tremendous demand for ... This was due to the following causes .... Various attempts were made to cope with this demand e.g.... These were not entirely satisfactory because ... Mr. Z tried ... This led to ... and to X.

(6) "The challenge of a problem"

In order to do ... we need XX. We have not found this yet. First we got x... Then X ... X will do ... but not ... Research is proceeding along the following lines ... We may get XX if ...

The marking instructions were as follows.

Mark A against the point of view which appeals to you most.

Mark B against the point or points of view which would have some appeal.

Mark O against the points of view which do not appeal to you.

Space was provided for details of sex, age (by 10-year groups), and occupation.

The test was carried out with approximately the same people who were tested in Part III. The group therefore consisted of science students in Extra-mural and W.E.A. classes throughout the country. The Army group was also tested. In many cases the test-sheets of Part III and this Part were completed at the same occasion. A few classes, however, received only one or other of the test-sheets; the total numbers are therefore similar but not identical.

---

3. RESULTS AND DEDUCTIONS OF TEST I

A preliminary examination of the completed test-sheets showed that the test was rather difficult, for spoilt sheets amounted to about 5%. It was also found that

(1) very few people used the mark O; apparently they left disliked viewpoints unmarked,

(2) some people marked more than one viewpoint with an A.

In view of (1) it was decided to ignore any O marks and to treat all viewpoints without an A or B as disliked.

The incidence of splitting of A votes was as follows:

Lecture group. Males 52.7%, females 39.6%.

Army group. 33.6%.

These results in themselves are interesting. Females, apparently, are more precise (or certain) in their preferences than males. (This seems to tally with their more marked likes and dislikes in Part III.) The army men may have been taught to carry out instructions precisely. The problem is how to rate the split votes. In the absence of further guidance, it was decided to assign a mark of 1/n to each of n viewpoints marked with an A. Then if N people completed the test, there were N marks available. The final mark for each viewpoint was expressed as a percentage of the total (N) marks. The B votes were treated separately in a similar way. There is no reliable way of combining A votes and B votes. The army group was kept quite separate from the lecture group.

In anticipation of possible sex differences the results for the two sexes were first kept separately. A record was also kept of the number of people whose occupations were obviously connected with science. (There were too few to form a separate group.) The results for the two sexes, and for the combined lecture group are given in Table XXI.

The "A" scores for this test-group may be summarised as follows:

Of greatest appeal - Practical application to the individual (2).

TABLE XXI

Viewpoints (male and female) by Test I

In each group the top line shows the A votes and the bottom line the B votes (both as percentages)

	Number	Number occupational	Viewpoints 1	2	3	4	5	6
Males	241	41	22.6 16.0	35.6 17.6	7.4 13.8	5.7 15.6	8.0 21.4	20.7 15.6
Females	139	1	20.2 11.4	34.4 16.9	5.3 18.2	11.3 22.4	9.1 20.0	19.7 11.1
Whole group	380	42	21.8 14.2	35.1 17.4	6.6 15.4	7.8 18.1	8.3 20.9	20.4 14.0

Of medium appeal - Pure science (1), Future problems (6).
Of small appeal - Historical (3), biographical (4), and social (5) viewpoints.

The "B" scores are more even. The highest male B score is for viewpoint (5) and the highest female B score for viewpoint (4). Chi-squared tests were made to determine if the B scores differed significantly from a chance (16.7%) distribution. The male score is certainly not significantly different from a chance score and so the higher vote for (5) may not be important. The probability of the female score differing by chance from an even distribution is 0.11 i.e. the distribution, though not certainly different, is possibly so.

The appears to be little difference between the sexes. A chi-squared test of the male/female A scores showed that the probability of correspondence is 0.6. The chief factor of difference is viewpoint (4). The higher female interest in biography was also revealed in Part III.

The whole group was then divided according to sex and age, and (for reasons which appear presently) separate groups made of male and female teachers. The A scores of these sub-groups are given in Table XXII.

TABLE XXII.

Viewpoints (by test I) by sex and age, and the viewpoints of teachers. (Percentages).

	Number	No. occupat-ional	Viewpoints 1	2	3	4	5	6
Males								
students	70[1]	-	21.6	28.8	9.0	7.3	13.6	19.7
20-30	55	18	30.6	31.2	4.2	2.7	6.9	24.4
30-40	51	12	15.0	39.0	8.5	4.6	5.5	27.4
40-50	40	8	22.9	40.8	6.3	6.3	8.3	15.4
over 50	33	3	25.7	33.8	6.1	8.1	6.1	20.2
Females								
students	22	-	6.0	34.1	3.0	23.5	16.7	16.7
20-40	32	1	13.5	44.8	3.6	14.6	10.0	13.5
over 40	31	-	25.8	46.8	6.5	-	9.1	11.8
Teachers								
male	38	-	18.8	38.2	11.9	8.3	9.7	13.1
female	54	-	26.9	21.3	6.5	10.8	5.5	29.0

1. 24 in lecture group, 46 from a Grammar School added.

The sub-groups are rather small. Accordingly chi-squared tests were made to determine whether, for each group, the distributions differed significantly from the chance distribution of 16.7% for each viewpoint. Except for the very small group of female students it was found that the probability of correspondence with the even distribution was less than 0.05 and, in most cases, less than 0.01. It appears therefore that the distributions are significant. Far less reliance can be placed upon the variations from one group to another. Certain apparent trends, however, can be noted. In both males and females there appears to be gradual rise with age in the appeal of viewpoint (2) - application to the individual. The female interest in biography seems to diminish with age and to be accompanied by a growing interest in pure science. The heavy vote by the 20-30 male group for viewpoint (1) is probably due to the high proportion of people vocationally interested in science. Except for these trends, variations with age are irregular and (probably) unreliable.

The viewpoints of teachers are bound to affect the nature of their teaching, and teachers (of various kinds) may be authors and lecturers. It is necessary therefore to examine the viewpoints of teachers. Are their viewpoints significantly different from those of the other people tested ? Chi-squared tests show that the viewpoints of the teachers are not significantly different. Female teachers seem to have rather more interest in future advances and less interest in practical applications, but the differences are not statistically reliable; further, these particular teachers are not necessarily representative of teachers as a whole.

The army group apparently found the test difficult to understand for about 20% of the returned test-sheets were spoiled and valueless. The results of the remaining test-sheets are set out in Table XXIII.

TABLE XXIII

Viewpoints of Army group (Test I)

Total number 128. Scores in percentages.

	Viewpoints 1	2	3	4	5	6
A vote	10.5	38.0	12.3	10.9	13.8	14.5
B vote	12.3	18.0	14.3	21.8	21.3	12.3

The A scores differ significantly from a chance distribution of 16.7% for each viewpoint only because of the big vote for viewpoint (2). The B scores do not differ significantly from a chance distribution. It appears that, except for a definite preference for viewpoint (2), these men were not sufficiently discriminating to cope with the test. The results are of little value.

---

4. DISCUSSION OF THE RESULTS OF TEST I

The results and deductions set out in section 3 refer to the use of test-sheet I and to people who voluntarily attend lecture-courses in science.

The outstanding indication is that, in the propagation of popular science, the approach should be through the practical applications of science, particularly as they affect the individual. This conclusion is not unexpected. The recommendation given in the B.A. Report (quoted earlier) is substantially sound (providing that the stress is on science rather than scientific method and that emphasis is given to the impact of science on the individual).

It is possibly surprising that Pure science and Future advances received so much support. (It has already been found that Future advances has a high interest rating.)

It is probable that many of the people who attend science lecture-courses have had some training in science (e.g. at school) and are keen to develop and extend their knowledge. The small support for the historical, biographical and social viewpoints is likewise surprising. In order to investigate this more closely, an examination was made of the incidence of unsplit A votes. For each viewpoint, the score of unsplit A votes was expressed as a percentage of the total score. The results, for males and females respectively, are: viewpoint (1) 50%, 57% (2) 63%, 68% (3) 33%, 28% (4) 35%, 70% (5) 21%, 47% (6) 16%, 60%. These figures show that the vote for the historical and social approaches, though small, consisted largely of "bits" of split A votes (and likewise the male vote for 4, 5, and 6 i.e. the historical and social appeals, though swamped by the appeal of other viewpoints, were wider spread than appeared initially.

The results obviously depend, not only on the people tested, but on the nature of the test-sheet. A strong supporter of the historical approach might suggest that the test-sheet was biassed. It is true that the definition of the historical treatment was terse but the writer believes that it correctly conveyed the nature of the approach. Viewpoint (1) was no more attractively presented but it received strong support. The provisional conclusion is that, for the people tested (i.e. those who have some definite interest in science), the historical and social approaches are of considerably less appeal than the other approaches named.

5. THE CONDUCT, RESULTS, AND DEDUCTIONS OF THE SECOND TEST.

The results of the first test indicate the need for examining the viewpoints of people who have not revealed any particular interest in science. It was clear from the earlier experience that any test of a similar nature could only be carried out with people of some fair degree of education. (The Army men were unable to cope satisfactorily with the test.) Further, it is desirable, (if possible) to make the nature of the test clearer and to re-word the definitions of the historical, and social viewpoints. Hence a second test-sheet was designed. This is called Test-sheet II.

In this test-sheet an introductory paragraph was given, in terms of the subject "Plastics", to show how a topic could be treated in various ways. It was hoped that the specific example would make the nature of the test clearer. Viewpoints (1), (2), and (6) were left unchanged; viewpoints (3), (4), and (5) were re-written as follows.

3. Historical ("The Story of science")

A presentation of the history of X, tracing the development of the subject, and of our knowledge of it, from early times or its beginning to the present day.

4. Biographical.

A presentation based on the men who contributed most to the development of the subject, enlivened by details of their lives, circumstances, successes, etc. (N.B. The BBC is able further to develop this approach by dramatisation.)

5. Social impacts of science.

A presentation which shows how X arose from a social requirement, how it met (fully or partially) a social need, how it affects the life of the community in some marked way.

The test was administered to about 400 students in Emergency Training Colleges. These students form a group of intelligent people, homogeneous with respect to age and recent eduction, but representing a good cross-section of the more able young people of the country. Details of sex were not available but it was known that the sexes were about equal. Except for a small group (see later), these students were not receiving instruction in science and were not manifestly interested in science at all.

From the whole group it was possible to form a small group (41) of people known to be studying science at the colleges. (It is believed these are all males.) But these people, who are training to become Primary and Modern School teachers, do not study science very deeply. In the remainder of this section they are called the "scientists". The results for these scientists and for the remaining non-scientists are kept separate.

First an examination was made of the proportion of non-scientists who gave each viewpoint <u>some</u> support (i.e. an A vote or a whole or part B vote). The results, in percentages of the total number (351), are as follows: viewpoint (1) 30%, (2) 90%, (3) 88%, (4) 78%, (5) 90%, (6) 47%. The relative small appeal of viewpoints (1) and (6) is discussed later. The immediate conclusion is that if science is presented to a group of non-scientific (but otherwise educated) people from a practical, historical, biographical, or social viewpoint, over three-quarters of the group will find the viewpoint of some appeal.

The results were then scored, for the scientists and non-scientists separately, as in test I, i.e. the A and B votes were kept separate, an n-fold split vote was divided among the n viewpoints marked[1], and the scores expressed as percentages of the total score. The results are set out in Table XXIV.

TABLE XXIV

Viewpoints of Training College Students (Test II)

		Viewpoints					
		1	2	3	4	5	6
Scientists (41)	A	12	40	5	14	21	8
	B	12	14	22	18	19	15
Non-scientists (351)	A	3.4	30.0	22.2	14.2	25.9	4.3
	B	7.1	19.4	20.0	20.8	21.9	10.8

These results must be compared with those for the Extra-mural and W.E.A. lecture-groups (Table XXI). First, examination is made of the small group of "scientists" of the Training College group. It is seen that the practical approach (2) again receives the greatest support but the social viewpoint (5) jumps to second place. There is a slight rise in the biographical appeal (4). These rises

1. The number of split A votes was less than 3% of the total.

are at the expense of pure science (1) and future advances (6). The A vote for the historical approach remains low. Turning to the non-scientists, it is seen that the practical approach receives the greatest (but diminished) support, pure science and future advances are of little appeal, and there is a marked rise in the appeal of the historical approach.

The contrast with the lecture group is significant. What is the meaning of these different results ? The writer believes that the difference is due to an essential difference between types of people in the groups. The people who voluntarily attend lecture courses in their spare time, though not professional scientists, have a marked interest in science, backed, probably, by earlier training in science. Some, perhaps, attend the lectures in order to refresh their knowledge and to "keep up to date". It is not surprising to find that these people are particularly interested in pure science and in future advances. It is found that a historical approach does not appeal to such people. The small (but valuable) group of Training College "scientists" consists of people who have some interest in science, but, probably, have had only a shallow academic training. They are rather less interested than the first group in pure science and future advances, and rather more interested in practical applications and social impacts. They too do not feel a historical approach to be of major appeal but the relatively high B vote shows that this approach is not altogether disliked. The bulk of the Training College group consists of people who show little or no interest in science. Probably they have had little or no training in science. To them, pure science and future advances are of little appeal (and probably unintelligible); practical applications, though still of major interest, receive slightly diminished support. Now the historical approach leaps into prominence, accompanied by an increased interest in social repercussions.

This explanation of the differences is rational. The writer believes it to be the true explanation. The significance of the results, in the diffusion of popular science, is discussed in the next section.

The data was also examined to see if there is any association between A votes and B votes i.e. if a given A vote tends to be accompanied by a certain B vote. Table XXV shows the results of this detailed analysis. It gives, for each viewpoint marked with an A, the percentage distribution of the B votes (counting split votes as fractional) which accompanied it. For purposes of comparison, the distribution of the B votes for the group as a whole is also shown.

A person giving an A vote to a certain viewpoint is debarred from giving a B vote to the same viewpoint. It is expected therefore that the percentage figures for the remaining viewpoints will be slightly higher than those for the group as a whole. Examination is made to see if any figures are considerably higher (or lower). The actual number of people giving an A vote to viewpoints (1) and (6)

TABLE XXV

Association of B votes with A votes. (Non-science Training College Students)

The table shows the distribution (as percentages) of the B scores accompanying each A viewpoint.

A	No.	Viewpoint B 1	2	3	4	5	6
1	12	-	31	19	6	19	25
2	105	8	-	27	23	31	11
3	78	8	24	-	27	30	11
4	50	6	26	30	-	32	6
5	91	6	31	24	23	-	16
6	15	12	29	21	27	11	-
All	351	7	19	20	21	22	11

are small and the results for these viewpoints are not reliable.

The indications can be summarised thus:

A vote for pure science - accompanied by B votes for practical applications and future advances, with a marked indifference to biography.

A vote for practical applications accompanied by a B vote for social impacts.

A vote for history accompanied by a slightly increased B vote for biography and social impacts.

A vote for biography accompanied by B votes for history and social impacts.

A vote for social impacts accompanied by B votes for practical applications.

A vote for future advances accompanied by B votes for pure science and practical applications, with a marked indifference to social impacts.

Most of these results are in accordance with expectations and add little to the solution of the problems. One result only is surprising - that people mainly interested in future advances are not interested in social impacts - but this result, being based on small numbers, is unreliable.

Finally, an attempt was made to combine the A and B scores of the non-scientists in order to get some overall evaluation of viewpoints. Combined scores were evaluated on the assumption that an A vote is worth three B votes. (There is no justification for this, or any other, proportion.) The results are as follows: viewpoint (1) 4%, (2) 27%, (3) 22%, (4) 16%, (5) 25%, (6) 6%.

---

(6) DISCUSSIONS AND CONCLUSIONS

The writer feels that, in this complex problem of viewpoints and approaches, his investigations and results are little more than exploratory. Six viewpoints have been identified and examined; there may be others which are of importance and are sufficiently distinct for investigation. Further, a more extensive and intensive investigation of the six viewpoints is desirable. It would be useful to examine the viewpoints of readers of popular science books and periodicals and to investigate (by other methods) the approaches likely to be successful with people of limited education. But the provisional conclusions so far made are of sufficient value to be placed on record.

The approach of greatest appeal has been found to be that through the practical applications of the subject to the individual. The average man asks the question "What use is that to me ?" This may indicate a self-centred attitude and a limited view of the values of science, but it also indicates the need for starting from the immediate experiences and contacts of the individual. This approach is obvious to any competent author or lecturer. It is suggested in the B.A. Report (already quoted). Yet it is surprising how many authors and lecturers select other approaches. In Science News VI, for example, there is an article entitled Making Penicillin. In accordance with the findings of this Part, a good approach would have been to indicate the growing need for penicillin production (for more and more individuals are requiring it) and hence the need for improved production methods. The actual article begins "There are three historic occasions in the story of penicillin" and ends with production figures.[1]

A significant factor in the investigations has been the historical approach. Popular science books and lectures are not infrequently based on a historical structure (see Making Penicillin). Holmyard, Hogben, and (latterly) Sherwood Taylor are typical authors with a historical outlook. Is such an approach justified ? The investigations

---

1. The historical treatment cannot be justified by the findings of the investigations. The writer possesses a letter from the editor stating that the readers are mainly people who have some fair knowledge in one or more fields of science.

show that people who have some marked interest in science and have had some scientific training much prefer other approaches. But for people at present not manifestly interested in science, or without scientific training, the historical approach has a marked appeal. It seems that this approach has a great value in stimulating an interest in science and in revealing the cultural values of science, but that people who already appreciate science do not care for this approach.

In the B.A. Report (p.255) it is written "While the historical approach to scientific problems provides ... the most direct approach for adult audiences, the prevalent neglect of the history of discovery among professional teachers of science is an important reason why teachers competent to teach science to adults are so rare." The writer considers this to be a dangerous statement. It has been shown that the historical approach is not justified for all types of adult students. Further, it has been shown that another approach (practical applications) is of wider and greater appeal.

It is necessary to point out that a given approach, although of great appeal, may not permit a successful teaching sequence. Practical applications may form a suitable starting-point, and a desirable ending-point, but it may well be necessary, in the development of the subject, temporarily to set them aside and to proceed along more academic lines. In a similar way, a historical development may not be a good teaching development. Historical and biographical details of Faraday's experiments on electro-magnetic induction, for example, may arouse interest, but the order of his discoveries is not the best teaching sequence.

The investigations show that, except for those with some definite interest in, and understanding of, science, approaches should seldom be from the viewpoint of the pure scientist. Probably the rarity of good teachers of popular science for adult students is due to neglect of this principle.

It was noted in Part I that the educated member of the community needs to understand the social impacts of science. Science shapes social conditions; its direction depends upon social conditions. Hogben, for example, has attempted to link science with social change in certain of his books (Science for the Citizen, Mathematics for the Million). The investigations show that people with a deep interest in science (based, probably, on an academic training) are not greatly interested in treatment from a social point of view. People who know less of science are more interested in social effects. It is possible that the social effects of science are not emphasised in the schools. "School courses may, in time, be affected profoundly by these newer ideals, but so far the effect has not been great. Children seem somewhat less responsive and interested than adults in this way of handling science."[1] The difficulty may be that

---

1. The Teaching of Science in Secondary Schools. Incorporated Association of Assistant Masters and Science Masters Association. (Murray) p.130.

social impacts do not provide a good teaching sequence of science; but that is not a valid reason for allowing a child to leave school, or an adult to persist, with the idea that science is confined to the laboratory or workshop.

PART V.

PROBLEMS OF VOCABULARY

PRELIMINARY NOTE

In this Part of the thesis an account is given of experiments and investigations to determine a minimum but adequate vocabulary for the exposition of popular science. The writer wishes to acknowledge the advice and encouragement given, in many of the sections, by Dr. M.P. West, sometime Research Fellow in the Ontario College of Education, Toronto.

The compilation of the Scientific and Technical Dictionary (described in section 4) was a joint research in which each author made approximately equal contributions. (The advantages of collaboration in such a work are set out later.) The Flood-West vocabulary which developed from the dictionary experiment is therefore also a joint product. But Flood, particularly, took charge of the vocabulary as soon as it began to take shape. He maintained the vocabulary lists, made the final vocabulary check of the scripts, and graded the words. He effected the consolidation of the Flood-West vocabulary with the Carnegie vocabulary. (West, particularly, took charge of the illustrations.)

The earlier sections (1-3) are based on Flood's independent reading and studies. The later sections (6-7), in which the Flood-West vocabulary is critically examined, also represent independent work. The opinions expressed in these earlier and later sections are not necessarily those of West. In section 9 some account is given of another experiment conducted solely by Flood.

The Flood-West vocabulary is to be published as a supplement to the Carnegie Report on Vocabulary Selection (Revised edition) 1949.

Accessory material

The Scientific and Technical Dictionary, from the compilation of which the Flood-West vocabulary evolved, is in the course of publication by Messrs Longmans, Green & Co. Ltd. A specimen extract (in typescript) is submitted with this thesis.

The Elementary Science Readers, which formed the basis of the vocabulary experiment described in section 9, are also in the process of publication by Messrs Longmans, Green & Co.Ltd., A copy of one of them ("The Air around Us") is submitted with this thesis.

PART V - Problems of Vocabulary

		Page
Section 1.	The need for vocabulary control in popular science.	140
2.	The work of other investigators of science vocabularies.	147
3.	The problems of constructing limited vocabularies.	151
4.	The compilation of the dictionary.	165
5.	The Flood-West vocabulary.	178
6.	Comparison of the Flood-West vocabulary with the science vocabularies of Basic English.	185
7.	Test of the Flood-West vocabulary for continuous texts.	200
8.	Consolidation of the Flood-West vocabulary with the Carnegie vocabulary.	211
9.	Analysis of the vocabulary of the Elementary Science Readers.	213

1. THE NEED FOR VOCABULARY CONTROL IN POPULAR SCIENCE

The reasons for difficulty of comprehension of reading material have formed the subject of many researches and dissertations. An exhaustive study has been made, for example, by Gray and Leary,[1] with special reference to the difficulties of adults of limited reading ability. Cullough, Strong and Traxter[2] have discussed at length the problems of improvement of reading ability. Difficulty of comprehension obviously depends upon many factors. It depends, for example, upon the reader's interest and motive for reading. It depends upon the nature of the concepts. A book by Einstein on the Special Theory of Relativity might well be incomprehensible to an ordinary reader, even if written in monosyllables. Such factors lie with the reader. But difficulty of comprehension also depends upon factors which are within the author's control These factors include style of exposition, rate at which new concepts are introduced, amount and nature of illustrative examples, and the structural elements of the text. Gray and Leary examined the effect of structural elements in detail and were able to evolve a formula, based on the numbers of certain structural elements (e.g. different words, difficult words, sentence length, etc.) by which the difficulty of a text could be estimated. Simpler

---

1. Gray S.G. and Leary B.E. What Makes a Book Readable. University of Chicago Press. (1935).

2. Cullough C.M., Strong R.M., and Traxter A.E. Problems in the Improvement of Reading. McGraw Hill Book Co. Inc. (1946).

formulae have later been devised by others.[1] Cullough, Strong and Traxter tabulated the reasons for comprehension difficulty. It is significant that all such formulae and tabulations include the number of "difficult" words, or other exceptional words, that is, vocabulary is an important factor in reading difficulty.

Vocabulary is certainly a significant factor in the intelligibility of popular science writings. The chief cause of unintelligibility, other than the nature of the concepts involved, is the use of words which the reader cannot understand. The following passages are taken from a well-known popular science periodical ("Discovery").

(a) "The pressures, temperatures, and humidities registered during the flight were recorded at the ground station by the variations in the frequency of the radio-transmission, the frequency being varied by changing the inductance." (Sept. 1946, p.266).

(b) "As the density of the air is inversely proportional to its absolute temperature, a component - the thermal wind - can be obtained from the isothermal chart, which will give the upper wind when compounded vectorially with the sea-level geostrophic wind." (Sept. 1946, p.267).

---

1. For example: Dale, E. and Chall J.S. A Formula for predicting Readability. Educational Research Bulletin XXVII. College of Education, Ohio State University, (1948).

It is no wild assumption to suggest that these passages are unintelligible to the ordinary man.

To substantiate this criticism of Discovery the writer selected 66 apparently difficult words from four consecutive issues of Discovery, (June - September 1946). (These words are of no particular importance here and are given in Table IX of the Appendix.) He tested about 80 schoolboys who were studying science for School Certificate and Higher School Certificate examinations. He found that 41 of the words were unknown to half the test-group and that 8 words were unknown to 95% of the group. The detailed results are given in the Table. Yet the articles were written, presumably, for people who have had little or no academic training in science. An advertisement reads:[1] "Its articles are written by eminent scientists and technologists, but in language that non-specialists can understand. Discovery should be in every school library."

Writers of popular science articles are becoming conscious of the problems of vocabulary. Footnote "explanations" of occasional words are given and glossaries are provided in certain well-known series (Penguin Science News and New Biology). The words for footnote explanation are apparently haphazardly chosen and sometimes the explanation does little to clarify. There is a tendency to define X (the obscure) by Y (something no less obscure) without going on to complete the clarification by explaining Y.

---

1. See, for example, School Science Review No. 99 p.xxvi.

Thus, in Discovery (June 1946 p.163) we read "In 1943 the average monthly production of penicillin in Britain was 300 mega units (a mega unit is one million International units)." But what is an International unit ? On page 212 of the same volume there is a footnote explanation of "invert sugar", but the explanation assumes knowledge of rotation of the plane of polarisation of polarised light.

Likewise the selection of words for glossary explanation appears to have been done with little (if any) objective consideration. Thus in New Biology 5 the glossary includes cell, habitat, red blood cells, shoulder girdle, vertebrate. A reader of such a book is unlikely to be stumped by these. Within the articles the present writer has found, with very little trouble, the following words used without explanation: artifact, heterotrophically, histological, mucilaginous, multiseriate. Vocabulary control in popular science has not been tackled seriously.

Causes of unintelligible vocabulary in popular science

A scientist uses unintelligible words in popular science writings for several reasons.

(1) He is so accustomed to using these words that he cannot break the habit, just as a sailor cannot help calling the back of a ship the stern. He does not enquire whether the word is really necessary to his exposition.

(2) He feels a sense of shock and loss of dignity in using the popular rather than the scientific word. He also tends to assume a "dignified" style in order, presumably, to emphasise the importance and dignity of the subject.

The ideal style, regardless of dignity or impudence, is at once the clearest and most exact. Thus a writer wishes to say that modern biologists talking about evolution use "generation" as a time-unit in preference to years. He writes (Discovery, Aug. 1946, p.242)

> "In the eyes of the vast majority of biologists the time-factor was finally ousted from the arena of evolution by the concept of the generation, which in addition to its original meaning of a step in the pedigree covered by one individual from its birth to the birth of its offspring, acquired a chronological significance."

(3) The third reason is vocabulary "creep". The intervals between words on a word-frequency list are progressively smaller. A writer therefore tends to enlarge his working vocabulary by a series of assumptions each on a decreasing scale. "If the reader knows A surely he knows B, and if B why not C, and if C...."

(4) The writer does not keep before him a constant and unvarying type of reader. He tends to assume difficult words, especially towards the middle and end of an article, having gone out of his way earlier to explain easier words. He strains at the gnat but swallows the camel. In a publication consisting of several articles written by different authors the variation of assumption is often very marked. One writer, for example, assumes the word "ion"; another writer, later in the

book, explains it (Discovery, June 1946, pp.167,169).

(5) The expert sometimes forgets that he may use a certain word with a restricted or special meaning whereas the ordinary man may use the word (and understand the word) in a wider, less specific sense. Pressure, mass, work, paraffin are examples of such words. "One reason", writes Haldane,[1] "why other people find it hard to understand science, and why scientists are apt to lose their tempers with other people, is that scientists either use ordinary words with a special meaning, or invent words of their own which ordinary people do not understand."

The methods of vocabulary control in popular science writings

In any popular science writings there must be some fundamental assumption of vocabulary just as there must be some fundamental assumption of knowledge. But there must be some limit to that assumption. A writer, having defined his readers (English, American, Overseas, etc.) must work within a standard vocabulary of words which may be assumed. If he wishes to use "outside" words he may do so but he must introduce the words deliberately and with explanation.[2] The editor of a series of books or periodicals should provide all contributing authors with a standard vocabulary.

---

1. Haldane, J.B.S. "What 'hot' means" from A Banned Broadcast and other essays (Chatto and Windus) p.127.
2. No vocabulary can predict with certainty the names of everyday things which will or will not be known by a certain group of reader, e.g. the names of foods. The writer, knowing his readers, may add such words to the vocabulary.

It might also be desirable to publish the vocabulary with the book or periodical, together with the statement: These words are assumed; if you do not know them you will find a simple explanation in the Introductory Handbook to this series.

How shall this standard vocabulary be determined ? Two problems arise.

(1) What is the scientific vocabulary of the expected reader of the book, periodical, etc., ?

(2) What is the minimum vocabulary needed for an adequate, readable exposition of the subject ?

The scientific vocabulary of the average reader of a popular science work is difficult to determine. Variety of education, occupation, environment, and interests has resulted in a wide range of vocabulary attainment. The present writer is unaware of any attempts to test the scientific vocabulary of adults who, though not professional scientists, are interested in science. It should not be difficult for the editor of a book-series or periodical to assess the average vocabulary of his readers by inserting a test-sheet in every copy of a particular issue. (This method is not available to a private research worker.) It is easier to assess the vocabulary of people who attend popular science lectures. The writer has noted it as a further research problem.

Of at least equal importance is the determination of the minimum vocabulary which is necessary for the exposition of popular science. This is the problem to which the present writer has given particular attention. The results of his investigations and findings are presented in this Part of the thesis. If the minimum vocabulary is found to exceed the vocabulary which can be assumed, the additional words must be "taught". If the extra words are few they can be taught in the course of the exposition i.e. treated as "outside" words, but, if they are many, special vocabulary-building books must be prepared.

In carrying out the work of finding the minimum vocabulary, the writer did not confine his attentions to the English reader. There are millions of Africans, Indians, Chinese, etc. whose languages contain little or no scientific vocabulary. They must read their science in another language and English is a suitable language for the purpose. Let the complete vocabulary of all types of words needed for popular science writings be determined. The foreigner must learn them all; the Englishman will already know the "ordinary" words of the list. The necessary scientific vocabulary for the Englishman can be obtained by eliminating from the total list those words which he is sure to know.

2. THE WORK OF OTHER INVESTIGATORS OF SCIENCE VOCABULARIES

The task of constructing a limited vocabulary for popular science has not been simplified by the work of other investigators. The writer is unaware of any such vocabularies other than Ogden's Basic English vocabularies. Several researches, however, have been made into the vocabularies which are at present in use, particularly in textbooks. These researches indicate the enormous range of scientific terms in general use. Thus Ogden[1] reports the sifting of technical vocabularies of every sort resulting in the analysis of 50,000 terms most commonly used in the sciences. Even in school subjects a very large number of technical terms is involved. Pressey[2] has listed about 7,000 words considered important to an understanding of school science. Powers[3] has produced a list of 1828 "uncommon" words in physics extra to those in Thorndike's 10,000 word-frequency list. Curtis has also produced lengthy lists (see later). Some detailed consideration of the work of Pressey and of Curtis is desirable at this stage.

Pressey[2] examined the technical vocabularies of 19 subjects in school textbooks. She exhaustively examined school textbooks until her lists of technical words appeared to be complete. She then invited 796 teachers to indicate the words which are essential to an understanding of the subjects. For the 19 subjects over 14,000 words were so found of which about half were in science subjects. Table XXVI shows the distribution of these words among the various subjects. (Note that certain sciences, e.g.

---

1. C.K. Ogden. The Basic Vocabulary; a statistical analysis. Kegan Paul, Trench, Trubner & Co.Ltd. (1930). p.18.
2. L.C.Pressey. The determination of the technical vocabulary of the school subjects. School and Society. Vol. XX (1924). The special vocabularies of the Public School subjects. Public School Publishing Co. Bloomington, Illinois. (1926).
3. S.R.Powers. A vocabulary of scientific terms for High School pupils. Teachers College Record. XXVIII (Nov.1926).

TABLE XXVI.

Number of technical words in school sciences
(After Pressey)

	Essential words	Accessory words	Total
Common to all sciences	191	24	215
Biology	675	718	1393
Chemistry	765	532	1297
General science	916	648	1564
Physics	709	331	1040
Physiology	293	573	866
			6375

astronomy, geology, which are not regularly taught in schools, are omitted.) Pressey's lists are open to some criticism. The criterion of importance was the combined opinion of teachers. Individual judgments are unreliable if the terms of reference are vague. Further, the lists are supposed to present the technical (and therefore difficult) words of the subjects, but they contain many words which are so common in ordinary speech that they cannot be regarded as technical or difficult. The physics list, for example, contains the words bend, cloud, hook.

The lists prove to be of little value in constructing a limited vocabulary for science. No attempts were made to discover if words could be eliminated as redundant. Thus both melt and fusion, and both stratum and layer, are included. Other pairs of words e.g. antiseptic and disinfectant are essentially from the same head-word. And, strangely, there are certain obvious omissions. Thus deposit (general science) and bud (biology) are missing. This investigation therefore does little more than indicate the magnitude of the problem; it does not help in constructing a limited vocabulary.

Curtis[1] has more recently carried out similar investigations. He sought words which were essential, but could be taught in high school courses. He produced 629 terms for general science, 825 for biology, and 543 for chemistry. In collaboration with Schneck[2] he produced over 1600 terms for physics, reduced them to 998, and finally published lists of the 250 most important and the 250 next important. Examination of these lists shows that, in many cases, importance was attached to the concept rather than to the term. Thus the first list includes absolute unit and absolute zero, Archimedes' principle, accelerated motion, and so on. Further it is difficult to agree with some of his allocations of importance. It is strange that lens, pump, radio, solution (to mention only a few) should appear in the second (and not the first) list. There are also inconsistencies. Thus magnetic flux appears in the first list but field of force in the second. How one can teach and use the first term without previously using the second is not stated. This investigation, therefore, like Pressey's, is not helpful in the present task.

---

1. F.D. Curtis. Investigations of the vocabularies in textbooks of science for secondary schools. Ginn & Co. Boston. (1938).

2. J.W.Schneck and F.D.Curtis. The important scientific term in High School physics. The School Review Vol.50, 1942. University of Chicago.

Finally, Ogden[1] has prepared lists of scientific words for the presentation of science. These "Basic" lists, of course, are limited. As shown at length later, his vocabularies were prepared for purposes different from those of the researches here described. They were not consulted during the construction of the vocabularies which follow. Comparisons were made by Flood afterwards. (See Section 6).

It is shown therefore that the construction of a limited vocabulary for the exposition of popular science must be made ab initio. This is the task which Flood, and Flood in collaboration with West, undertook.

---

3. THE PROBLEMS OF CONSTRUCTING LIMITED VOCABULARIES

Although the individual words of a language are far from constituting all the effective units of that language (for a unit may be a particular assembly of words), all who are concerned with problems of vocabularies and simplifications must first study words. A limited vocabulary primarily consists of a limited number of words; but, as is developed later, it should also consist of a limited number of meanings. It is usual to state the size of a vocabulary in terms of the number of words. This immediately raises the question: What is one word ?

---

1. Basic English Applied (Science). C.K.Ogden. Kegan Paul, Trench, Trubner & Co. Ltd., 1931.
   Basic for Science. C.K. Ogden. As above. (1942).

What is a word ?

Palmer[1] has given some analysis of different types of words (or of "linguistic symbols"). The classification can be applied to words needed for the exposition of popular science.

(1) Monologs, Pliologs, Miologs

> A monolog is a single word non-cognate, non-derived, used in a single form, readily translatable into a native language, e.g. bubble, bury, chisel.
> A pliolog is something more than one word.
> A miolog is something less than one word.

Consider the word OUTLINE. Is this a word ? Yes. So "out" is one word, "line" is another, and "outline" a third. (And"line-out" (football) is a fourth.) If all four words are included in a vocabulary, should they be counted as four words ? Ogden would argue that if "out" is known and "line" is known, then "outline" is known. Many would not agree with this, but would agree that the difficulty of learning "outline" is less than that for a whole new word when the component parts are known.

Consider the words CRYSTALLIZE, RECRYSTALLIZE. Are these two words ? They are not equivalent to two words in difficulty of learning. The prefix "re-" is probably known in other connections. If "re-" is known, words like recrystallize, regelation, reaction, re-combination do not constitute wholly additional words to crystallize, gelation,

---

1. H.E.Palmer. The Grading and Simplifying of Literary Material. The Institute for Research in English Teaching. Tokyo.

action, combination. "Re-" is something less than a word, crystallize in a word, recrystallize in something more than a word. It would appear that each separate word-form should not be counted in a limited vocabulary. An alternative is to count only "head" words.

(2) -gons and -gemes

A monologon is any independent word.
A monologeme is a group or family of words consisting of a head-word together with its derivatives.

Thus, pure, impure, purity, impurity, purify, purifies, purified, purification are monologons.

The group of words based on the head-word "pure" is a monologeme.

It may appear at first sight that the unit in a limited vocabulary should be the monologeme, but difficulties are encountered. Consider these examples.

IMPURE. If the reader knows "pure" and "im/in-", impure is inferable. There would be no need to count impure as an extra word.

VAPOUR, EVAPORATION. Here there is a change of one letter. It might need pointing out but would involve little learning burden. Together, the words constitute only slightly more than one word.

HEREDITARY, INHERITANCE. These are a little harder. The connection needs pointing out but there would be little learning burden.

It would not be unreasonable to count such word-groups as singles. Now consider these examples.

VOLT, METER. These are (two) single words.

VOLTMETER. This can be regarded as a derivative of "volt". As such, its meaning needs pointing out but it is not equivalent to a wholly new word. But "voltmeter" is also a derivative of "meter". As such, its meaning is not inferable, and would probably not be readily learned if its meaning is pointed out. It counts as a new word. The word might be recognised as member of one monologeme but not as member of another.

SPECTROMETER. This word is a derivative of both "spectrum" and "meter". Its meaning is certainly not inferable if "meter" is known; it is doubtful if its meaning would be inferred from a knowledge of "spectrum". Although a derivative of two Head-words, it properly should be listed as a new word.

The monologeme, therefore, is not an infallible unit in vocabulary construction.

3. Proper Names

Although ordinary nouns can be listed, a difficulty arises with proper nouns. In science one encounters, for example, names of chemicals, of plants and animals, of types of rocks. A list of these would exceed any normal sized dictionary. The obvious solution is to place such names outside the sphere of vocabulary limitation and to use them as the need arises.[1] But even this decision

1. Proper nouns are discussed in more detail in Part VI, section 2.

creates problems. Consider the names aluminium, chalk, tin, lime, frog, worm, grape, rice. Are these names of chemicals, animals, plants, or are they ordinary English words. ? It is difficult to draw a rigid line.

4. Homonyms

These are words which happen to have the same spelling but have entirely different meanings. Examples are:

bark (of tree)	file (tool)
bark (of dog)	file (row)
arc (curve)	light (not dark)
arc (electric spark)	light (not heavy)

Such words should obviously be listed separately just as if the spellings were different.

5. Quasi-homonyms

These are words which are theoretically semantic varieties of the same word but now differ so much in meaning that they are effectively homonyms. Examples are:

cell (biology)	develop (= grow)	bar (of river)
cell (electric)	develop (photo)	bar (of iron)
solution (liquid)	fuse (melt)	
solution (of a problem)	fuse (join as in biology)	
condense (turn to liquid)		
condense (electric condenser)		
condense (chemical coalescence of molecules)		

Such words create great difficulties in the constructing of limited vocabularies.

6. Semantic varieties

One word may have two or more related but slightly different meanings. Thus "keep" can mean not give back, continue to be, and not go bad. Such different meanings are semantic varieties or usages. Highly scientific words usually have precise meanings and semantic varieties are rare. But less specialised words used in science writings may give rise to semantic varieties. Thus Philbrick[1] points out that "is made of", "is composed of", and "consists of" have various meanings and that these are sources of trouble in introductory courses. Haldane[2] draws attention to the confusion arising from the use of the word "heat" for a sensation and for a form of energy which causes it (and likewise the confusion between "hot" water and "hot" mustard.) Even in popular science writings for English people care must be taken to avoid ambiguous semantic variations.

The problems created by semantic varieties are much more acute when preparing texts for readers whose native language is not English. Then attention must be given to the meanings and usages of "ordinary" English words. When it is appreciated that some common words have many semantic varieties (84 have been tabulated for the word "keep") it is seen that the task of constructing a vocabulary is very complex.

In addition to the problems brought to light by this examination of types of words, a further problem arises in science vocabularies. Some words of ordinary speech have been given special or restricted meanings in science.

---

1. Philbrick F.A. Chemical Semantics. School Science Review, Feb. 1943 (Vol.XXIV, No. 93).

2. Haldane J.B.S. "What "Hot" Means" from A Banned Broadcast and other essays. (Chatto and Windus).

Examples of such words are

bond	field	power
charge	induce	pressure
compound	mass	salt
elastic	paraffin	strain
energy	pole	work

If a given vocabulary includes such a word, may it be used in both its ordinary and its scientific meanings ? If it is intended that the word should be available in both senses, should it be separately listed in each sense and counted as two words ?

Some solutions of the problems

These problems are much less difficult when it is realised that the merit of a limited vocabulary does not lie solely in the mere number of its words. A vocabulary of say 1000 words which tacitly includes exceptional derivatives and meanings is inferior to one of say 1500 words in which all exceptional derivatives and meanings are stated and counted separately. Some constructors incorrectly assume that there is virtue in the mere number of words. The guiding principle should be the burden of learning. If a derivative or meaning constitutes a learning difficulty then it should be counted as a further word. It may not be easy accurately to determine the learning difficulty of every proposed word. But does it matter ? An honest constructor will list all words and meanings which might reasonably be sources of difficulty. His list may be longer than those of others but the reader (who is the important person) knows exactly what is expected of him.

With this consideration in mind, answers to some of the problems discussed above can be formulated.

(1) With hyphenated and compound words the real test is this. Would the meaning be clear if the compound were translated literally into another language ? Consider the example "outline". Literal translations are dehors ligne (French) and extra-linea (Latin). These translations do not adequately convey the meaning of the original word "outline". The word should therefore be listed additionally to "out" and "line". The justification for this test is that the reader must translate every new word into known words (into English words by an Englishman and into native words by a foreigner).

The word "head" provides another example. Whereas "head" was encounted over 100 times in a million running words, "headline" was met only 20 times, "headway" only 5 times, and "headwater" only once in a counter of $2\frac{1}{2}$ million running words.[1] "Headache" is probably a legitimate compound, headline and headway are doubtful, and headwater is definitely an illegitimate "stretch" of vocabulary.

(2) There must exist some proportion between the remoteness of the derivatives and the size of the vocabulary. With a small vocabulary only "near" derivatives should be assumed. When there is a slight

---

1. These figures are from the Lorge-Thorndike Semantic Count. Teachers' College, University of Columbia.

alteration in the spelling (e.g. vapour - evaporate, heredity - inherit) but, the connection having been pointed out, there is no real learning difficulty, the words should be tabulated but not counted. If there is learning difficulty (e.g. spectrometer) the word should count as a new word. Obviously the constructor must here use his judgment.

(3) It is difficult to distinguish between certain scientific names and "household" words. West's definition list for the New Method dictionary includes such words as copper, chalk, iron, lime. These four words are placed by Thorndike[1] with respect to frequency as follows:

chalk	1st half of 5th thousand
copper	2nd half of 2nd thousand
iron	2nd half of 1st thousand
lime	2nd half of 3rd thousand

They are obviously words of ordinary speech. "Aluminium" occurs in the 10th thousand (Thorndike). Is this an ordinary word ? One can say that a word which occurs in the first 10,000 (or 20,000 or 30,000) should not be considered a mere name but an ordinary word. There is no justification, however, for drawing the line at any particular level.

(4) Homonyms should be listed separately.

---

1. E.L. Thorndike. The Teacher's Word Book. Teachers' College, Columbia University.

(5) In the case of quasi-homonyms and of words with many semantic variations, the precise meanings permitted in the vocabulary should be stated. It is optional whether the separate meanings should be counted: the value of a vocabulary does not lie in the mere number of its words.

(6) The writer believes that when words are used with special scientific meanings, such meanings should be listed and counted separately. Thus he would include mass (= lump) and mass (= inertia), and salt (= condiment) and salt (= product of an acid and a base), as separate words. It is dishonest to do otherwise.

The criterion of word frequency

In selecting words for limited vocabulary one naturally thinks (inter alia) of word frequencies. Thorndike,[1] Horn,[2] Faucett and Maki,[3] and others have investigated the frequencies of use of ordinary English words. The writer is unaware of any attempt to investigate the frequency of use of scientific words. The investigations of Pressey and others, however, are little different from frequency studies. It is necessary to note that word-frequency

---

1. E.L.Thorndike. The Teacher's Word Book.
   E.L. Thorndike and I. Lorge. The Teacher's Word Book of 30,000 words. (Teachers' College, Columbia University.)

2. E. Horn. A Basic Writing Vocabulary. College of Education, University of Iowa.

3. L.Faucett and Itsu Maki. A Study of English word-values statistically determined from the latest extensive word counts. Matsumura Sanshodo, Tokyo.

cannot be the leading criterion in selecting words for a limited vocabulary. Frequency of use is not the same as necessity. A survey of modern suburban kitchens might reveal that a mincer is of frequent occurrence but in selecting articles for a "Robinson Crusoe" expedition one would exclude a mincer. The work can be done, perhaps less effectively but adequately, by another instrument which is also useful in other ways. The word "butter" is put by Thorndike in the second 500 words but it is of limited usefulness. The word "extra" is of much greater usefulness and applicability but occurs in the 4th thousand. There are some common words which can be dispensed with altogether in a limited vocabulary (e.g. slumber and type both of which occur in the 5th 500) but there are other words of less frequency which are necessary even in a small vocabulary (e.g. spiral, 10th thousand). There are many words which a science expert uses very frequently but which need form no part of a limited vocabulary; they can be easily explained in situ when required or can easily be avoided. Such words are coefficient (e.g. of expansion), contact, and proteinaceous.

Further, it must not be assumed that the frequency of use of a word by a writer is a necessary indication of the understanding of the word. Thus Thorndike puts "flaunt" in the 8th thousand and "radio" in the 10th thousand but the latter word is surely better known.

The criteria of word selection

The selection of a word depends upon its value, not its frequency of use. The "bargain" to the learner may be represented by (value of word)/(cost of learning). The actual value of a word depends upon several factors.

(1) A word is of high value if it is frequently NEEDED. A science vocabulary must include, for example, the words atom, cell, electrolysis, protein.

(2) A word must be included if it is of moderate necessity but cannot easily be replaced by other words. Examples are: neutron, electric condenser, violet (not purple).

(3) A word of wide connotation and applicability is of higher value than one of limited meaning. Thus, "hydrocarbon" is a more valuable word than "methane".

(4) A selected word should be free from a tendency to duplicate a word already in the vocabulary. Thus "approximate" is unnecessary if the vocabulary includes "near/ly."

(5) A word is valuable if it is of use in making clear the meanings of other words. Thus by means of a few "key" words like anvil, bearing, cast, chisel, crank, hammer, lever, nut and bolt, saw, many machine-shop practices can be described.

(6) A rarer word is often more valuable than a more common word because it is more explicit e.g. vomit (not spit).

(7) A rarer word may be preferred if its simpler alternative is liable to be confused with another word (or

meaning) in the vocabulary. Thus "seizure" is preferred to "fit" because the latter word is used in other senses.

(8) The value of a word is increased if it is consonant with normal speech. Thus "ampere" is really a totally unnecessary word. It can always be replaced by "coulomb per second", which phrase gives an even better understanding of current. Further "coulomb" has other applications. But "ampere" is so commonly used that its avoidance would not be consonant with normal speech.

(9) It may be desirable to include a word purely for style. The writer calls these words "dignity" words. They are discussed at length later in this work.

<u>The methods of constructing limited vocabularies</u>

In constructing a limited vocabulary two points are of fundamental importance.

(a) A limited vocabulary is designed for a specific purpose. Thus a vocabulary for everyday speech may be quite inadequate for telling fairy tales, a vocabulary for commerce may be quite inadequate for science.

(b) Vocabularies must not be designed subjectively. The test of the value of a vocabulary is what it can (and cannot) do; it must therefore be constructed by the process of writing.

In attempting to evolve a minimum but adequate vocabulary for the exposition of popular science, the writer has made two extensive investigations.

(1) He envisaged the writing of a scientific and technical dictionary within the least necessary vocabulary. The dictionary was to explain, as to a person of no special training in a science, all in science that could be explained to such a person. As a result of this writing, a minimum scientific vocabulary would emerge. The vocabulary was to evolve, therefore, from an attempt to explain all that it was necessary to explain in science. In preliminary enquiries in this field, this writer discovered that Dr. M.P.West had also conceived a similar plan. Eventually it was agreed that the work should be done in collaboration. The collaboration had several advantages.

(a) The task was so immense that division of labour was sensible.

(b) With a dual authorship errors are less likely to occur, omissions and commissions are more likely to be detected, the final quality is higher.

(c) The combination approximated to the expert-filter-teacher author which was discussed in Part I. For this purpose one acted as expert and one as filter (the roles varied according to the nature of the subject) and both were familiar with the techniques of teaching.

As an outcome of this work, the Flood-West vocabulary emerged. This work is described and discussed in sections 4-8 which follow.

(2) The writer has been engaged in the preparation of a series of elementary science books for use mainly in West Africa (and other colonies.) The books are written with great attention to vocabulary control. Although they are being prepared for commercial purposes, the writer has used them to make a careful study of vocabulary problems. This work is supplementary to the dictionary work with West. It has the advantage that it tests a writing, not a defining, vocabulary. The outcome of this work was the re-discovery of many of the words of the Flood-West vocabulary, plus certain words which seemed necessary, or at least desirable, in continuous texts. This work is described in section 9 which follows.

The vocabularies which are constructed in these ways contain all types of words necessary for the exposition of popular science. As already noted, the vocabulary for English readers can be formed by eliminating the words of ordinary speech which are sure to be known.

---

4. THE COMPILATION OF THE DICTIONARY

Preliminary considerations

A dictionary can have one or both of two functions. Its purpose may be Explanation, Limitation, or both. The criterion of adequacy of an entry is

(a) in an explaining dictionary: Is the entry intelligible ?

(b) in a limiting dictionary: Is the entry precise

In an explaining dictionary the aim is to render intelligible words which are unknown (and this may involve rendering intelligible ideas which are unknown). Explanation can be effected by identifying the word within the reader's experience. Thus COAL can be explained as "the black stuff we burn on the fire". The material is identified. When the reader has no experience or reference point i.e. the word or idea is outside his experience, description and explanation must proceed until the idea is built up. This would be necessary, for example, with the word ENTROPY. This latter procedure can be called encyclopaedic writing. In the limiting dictionary the aim is to delimit the meaning of the word. It may be for a legal purpose e.g. in order to provide an authentic answer to a question in a court of law "Is this stuff coal ?". It may be for the purpose of scientific definition e.g. A DYNE is that force which when acting on a mass of one gramme produces an acceleration of one centimetre per second per second".

The inefficiency of many dictionaries is due to confusion of purpose. Usually there is wavering between the two functions, and, not infrequently, the compiler leans towards Limitation because he is more afraid of his critics than of his public. A technically incorrect or inadequate definition is likely to produce severe criticism from his professional colleagues but the reader of an unintelligible definition is likely only to blame his stupidity. Hence it is always safer for the lexicographer to be meticulously correct even at the cost of intelligibility, rather than intelligible at the cost of strict accuracy.

It is this confusion of purpose, with a strong leaning towards Limitation, which produces the well-known absurdities in dictionaries. Absurdities arise from attempting to define obviously known words or from stressing accuracy at the cost of intelligibility. Thus in Chambers Technical Dictionary these entries occur:

BELL - A sound-emitting metal device, operated by striking.

POD - A dry fruit formed from a single carpel, having a single loculus containing one (rarely) to several seeds, and usually opening at maturity by splitting along both ventral and dorsal sutures.

These are delimiting definitions. They do not explain unknown words in terms of known words. The original words, in fact, are probably included within the fundamental explaining vocabulary. A reader is unlikely to refer to the dictionary for an explanation of such words. (Chambers eventually gives an example of a pod.)

Sometimes a lexicographer tries to please both the reader and the critic by giving both explanations and limitations. He often puts the latter first. Thus a reader who is confronted by the word KERATIN first reads in Chambers:

KERATIN - An insoluble scleroprotein formed by the transformation of the eleidin granules in the superficial cells of the stratum granulosum of the vertebrate integument.

The critic is satisfied; the reader is irritated. It is not until later that the reader finds, if he reads so far, that keratin is the stuff hair and finger nails are made of. What is the purpose of the dictionary ?

A scientific dictionary for the reader of popular science obviously needs to be an explaining dictionary. The reader wants to interpret a VOLT in terms of his flash-lamp battery, not in terms of joules and coulombs. The lexicographer must be prepared to endure the criticism of the expert. Further, as has been noted on several previous occasions, he must be a combination of expert, filter and teacher. A joint authorship is clearly necessary. Flood and West attempted to provide this combination. The dictionary which they compiled is essentially an explaining dictionary (though this did not preclude occasional delimitation.)

An explanation may be either identifying or encyclopaedic. An encyclopaedia explaines and describes things both inside and outside the readers experience. This results in long articles and, eventually, to the grouping of entries. Grouping is absurd in a dictionary. If it is wise to put every kind of bacterium under "bacteriology", why not put bacteriology, with other groups, under "medicine" ? People do not read a dictionary (and seldom an encyclopaedia.) They just want to know the meaning of a particular word. The compilation of a dictionary is harder than that of an encyclopaedia. Each entry is a separate creation and, as such, should be as far as possible independent of others.

Independence of entries causes difficulties, especially if there is also control of vocabulary. The inter-dependence of ideas almost forces the compiler to make use of cross references. Cross references annoy the user. Many dictionaries abound in them. Suppose a reader seeks the meaning of the word GAUSS. He consults Chambers dictionary. He finds:

GAUSS - The c.g.s. electromagnetic unit of flux density; it is equal to one line (or maxwell) per square centimetre.

The significant words of the "explanation" seem to be "flux density."

FLUX DENSITY - The quantity of flux passing through unit area.

Turning to "flux" he finds:

FLUX - See electric ---, magnetic ---.

The entry under magnetic flux begins

MAGNETIC FLUX - The surface integral of the magnetic field intensity normal to the surface...

Then the eye notices the following entry:

MAGNETIC FLUX DENSITY - The normal magnetic flux per unit area. Symbol B. Measured in lines per square cm. or gauss, it being postulated that each fictitious unit north pole emanates 4π lines so that the mechanical force on the said pole, when placed in a field of unit flux density, is one dyne. See intensity of field.

The reader may or may not understand unit north pole. If he does not, he still does know what "gauss" means. And he is unlikely to follow the last instruction to see intensity of field. The series of entries may be accurate but, even with the annoying cross references, fails to explain.

For economy of exposition, one cross reference is pardonable and, perhaps, desirable in certain cases. The entry to which reference is made, of course, should give an adequate and clear explanation.

When a dictionary is written by a team of uncoordinated specialists, there is the danger of one-sided explanations of words with more than one application. Thus Chambers includes "perimeter" as a medical instrument but not as the length of the boundary of a plane figure. Likewise, "farinaceous" is given with respect to botany, and "farina" with respect to textiles, but the application of the adjective to food is omitted. The expert+filter is a better instrument for the compilation of an explaining dictionary of popular science than a team of experts.

The length of an entry is an important matter for consideration. The explanations in many dictionaries are usually short. Much of the reader's knowledge may be hazy; he relies on the dictionary to "unhaze". An entry must be adequately explained or not at all. To say that "Calculus" in a branch of mathematics probably tells the reader no more than he already knew. To say that a heptode is a 7-electrode valve might fulfil the reader's requirements but possibly the reader wishes to know more. A compromise must be effected between being encyclopaedic and being useless. Now one can explain almost anything if one takes sufficient space. The length of an entry is determined, not by the importance of the entry, but by the difficulty of explanation. The question is: Does the importance of the entry justify the space needed to explain it ? If the answer is yes, the entry goes in, at the length necessary for proper understanding; if the relative importance does not justify a lengthy (but necessary) explanation, the entry should be omitted. Concepts such as CALCULUS, ENTROPY, RELATIVITY, VALENCY, require considerable space for adequate explanation but their importance justifies the space.

The rules of composition of the Flood-West dictionary

In consideration of the points just discussed, and of the purpose of the dictionary, (namely, for the reader of popular science), Flood-West devised the following rules of composition.

(1) Words should not be included which are (a) adequately explained in an ordinary dictionary, (b) only used by an expert in speaking to an expert.

(2) No word may be omitted because explanation is difficult but only because the explanation would take more space than is justified by its importance.

(3) Every explanation must be clear to a person who knows little or nothing about the subject, and must be made with not more than one cross reference to any other explanation. (References to additional information may be given at the end.)

(4) Every explanation must be of such length as is necessary to give an adequate idea of the meaning; sometimes a page or more may be necessary. (But the book is not an encyclopaedia; it deals with words, not subjects.)

(5) Special attention must be given to word-elements (roots, prefixes, suffixes etc.) so that the reader is enabled to break up and interpret new scientific terms for himself.

The whole is to be written within a minimum vocabulary, which vocabulary is devised by the experiment of writing the dictionary.

Some of these rules are severe. The most difficult one is (3). It is not easy, for example, to explain PENTODE with cross reference only to one of triode, grid, screen-grid, secondary emission, anode etc. In rare cases it was necessary to state "First see... (triode)". A more profitable way of dealing with such difficulties was by "double definition". Thus in defining A the writers were compelled to introduce word B. B was then defined on the spot either by parenthetical explanation or by footnote to the entry. (It is clear that a word introduced many times in this way becomes a "wanted" word and may ultimately be included as an essential defining word.) This rule of not more than one cross reference applied, of course, to vocabulary as well as to concepts.

Great importance was attached to rule (5). With a knowledge of "meccano" elements the reader is helped in interpreting new words. The many Latin names, especially in biology, would be more intelligible if translated. In the Penguin New Biology 5, for example, the following names (and others) occur: Chamaesiphonales, Microcystia, Pleurocapsales. With a knowledge of elements the reader is better able to understand these names, in fact, the author of the article might well have effected translations.

<u>The actual compilation of the dictionary and the evolution of the Flood-West vocabulary</u>

The immense task of compiling the text of the dictionary occupied about two years. Each letter of the alphabet was examined and revised at least six times. In general one author made a preliminary draft of the letter (leaving out entries which the other could obviously cope with more easily) and sent it to the other for first examination. The other added new words which had been overlooked and revised the tentative explanations. The letter then passed backwards and forwards between the authors until both were satisfied. Frequently particular entries needed many revisions. These were the difficult but very important concepts such as calculus, entropy, phase rule, relativity. In these cases the interplay between expert and filter was very effective. In general, West acted as the filter for words of the physical sciences and mathematics, and Flood as the filter for words of medicine and applied sciences. No entry was passed until the expert was satisfied that the explanation was accurate and the filter that it was intelligible.

As sources of words standard scientific dictionaries such as those of Chambers, Uvarov, Beadnell, Van Nostrand, were consulted. Flood also examined the indexes of standard textbooks on aeronautics, astronomy, botany, chemistry, all branches of physics, wireless, all branches of mathematics, geology, general biology, and other words on the physical and technical sciences. West also consulted standard works on engineering, medicine, building, plastics, textiles, ships. Reference was made to other standard works, (e.g. Encyclopaeida Britannica) and experts were consulted when needed. The total number of entries is estimated to be 10,000.

In the course of the compilation many useful techniques of exposition were discovered or evolved. These are discussed in Part VI. The use of picture or diagram was found to be most desirable and great use was made of it. West evolved a system of picture-writing of the molecular structure of organic compounds.

The writing of the dictionary had two main purposes: the provision of a dictionary useful to the ordinary man, and, of greater concern in this thesis, the discovery of the minimum vocabulary necessary for the exposition of popular science.

It was necessary to take some existing vocabulary as the starting point. The authors started with the defining vocabulary of West's New Method Dictionary.[1] (This dictionary defines about 24,000 items of ordinary (non-scientific) English by the use of a defining vocabulary of 1490 words.[2] It was written primarily for the foreigner whose native language is not English.) They then proceeded to write the dictionary, explaining scientific and technical words, using this same vocabulary and bringing in additional words as their necessity became established.

It was found that several types of words were needed.

(1) Frequently needed highly scientific words, e.g. Electrolysis, Electric Condenser, Hydrocarbon, Spore.

(2) Semi-scientific words e.g. Soluble, Elastic, Temperature.

(3) Words needed for the explanation of a group of things e.g. Daisy for explanations involving the Compositae family, Yeast for explanations involving enzymes.

---

1. Published by Messrs Longmans, Green & Co.Ltd.,

2. This vocabulary is set out in "How to use the New Method Dictionary" (Longmans, Green & Co.Ltd.) and discussed in "Definition Vocabulary", M.P.West, Bulletin No. 4 of the Department of Educational Research, University of Toronto.

(4) Words needed only fairly often but for which there is no easy substitute e.g. Universe, Violet (colour).

(5) Ordinary defining and construction words (known to an Englishman).

(6) Words sure to be known without which the explanations would look silly e.g. Beer, Cube. (Such words were actually avoidable).

(7) Words avoidable as definers but useful as part of a general technical vocabulary e.g. Anvil, File (tool).

(8) Words avoidable as definers but desirable for style. These "dignity" words are discussed later (Section 5).

In the process of writing, many words almost automatically forced themselves into the vocabulary. These were ordinary English words (such as damp, deck, decorate, detail, dot, double, etc.) and the very frequently needed scientific words (such as atom, battery, cell, compound, conductor, electron, etc.) Other words were used in the process of writing and noted. At first they were "wanted" words; when their frequency of use became apparent they were accepted into the defining vocabulary. Words were only accepted after careful consideration by both authors. Throughout the writing strict economy of vocabulary was exercised.

When the scripts were completed it was necessary to re-examine them for errors of vocabulary control. Flood undertook the major responsibility for this re-examination. A note was made of all words which had been used in the scripts but which had not been listed in the vocabulary. Some of these words were added to the vocabulary without hesitation (they had been overlooked). Other words were accepted after consideration; some were rejected and the scripts amended. Examples of such discovered words are of interest.

SORE had been used in the explanations of gall, glanders, moellen, scarlatina, sprue, streptococci, syphilis. As the word is also a common ("sure-to-be-known") word, it was accepted.

STAIN had been used in the explanations of basophil, eosinphil, Nissl, oxalates, specific stain, and, as STAINLESS, of austenite, chromium. As the word is a common one in ordinary speech and there is no easy alternative to stainless, it was accepted.

PHYSICAL had been used in the explanations of astrophysics, conservation of matter, fixation, entropy (Nernst), hysteria, metallurgy, neurosis. It is noticed that the word is used in two senses: pertaining to natural properties and processes and to the body.

In view of this confusion the word was rejected.

At the completion of this examination there remained a list of words which were avoidable but desirable. Some of these were accepted (e.g. collar, heel, modern, raw, soak, thorn); it would have been childish to omit them. Others (e.g. canvas, diagonal, nostril, slanting) were rejected; they were recorded as "wanted" words.

As a result of this study the Flood-West vocabulary was evolved. It contains 479 words extra to those of the New Method vocabulary. It is discussed in the next section.

5. THE FLOOD-WEST VOCABULARY

The final Flood-West vocabulary, consisting of 479 words, is set out in Table X of the Appendix. Attention is drawn to certain features. Some words have been restricted in meaning (e.g. "cure a disease, not bacon), scientific extensions of ordinary words are tabulated additionally (e.g. "develop" a photograph), and words used in two rather different senses are tabulated separately (e.g. "cell" of a living body and of an electric battery). This vocabulary is additional to the New Method vocabulary of 1490 words. The dictionary is therefore written within a vocabulary of 1969 words. This consolidated vocabulary is not quite the absolute minimum for the exposition of popular science. It would have been possible to manage with about 30 words less but it was decided to retain certain "dignity" words for reasons discussed presently.

The consolidated vocabulary is of little interest to authors of texts for English readers. Even some words of the Flood-West list, being ordinary words, are sure to be known by English readers, and need not appear in a standard popular science vocabulary. For this reason (and others) it is desirable to classify and grade the words of the list.

The words of the Flood-West list are very mixed. Some are obviously highly scientific, some can be called semi-scientific, others are ordinary English words. Many can be classified by inspection. In order to obtain some light on marginal words Flood carried out a test with school-children.

First he set aside words which were obviously highly scientific (e.g. hydrocarbon, neutron) and those which were obviously words of ordinary usage (e.g. carpet, ceiling). This left a list of about 100 marginal words. Some (perhaps many) of these words, would be known to a person who had had training in science at a secondary Grammar School. But the "ordinary" man is more likely to be a product of the Secondary Modern School. Persons so educated may have had a little training in science (though probably more science will be taught in these schools in the future) and this science will not have been highly specialised. Flood therefore decided to test his marginal list with children in the better classes of the final year at these schools.

The test was not conducted elaborately. Its purpose was not the determination of the children's vocabulary but the gaining of some light on the words of the list. Accordingly personal contact was made with the classes, the purpose of the test explained to the children, and the children urged to mark honestly which words they knew and which they did not. They were asked to write a brief note of explanation of any words whose meanings were in doubt. Although this method is bound to result in a margin of error, the writer feels, from his experience of conducting the tests, that the results are honest indications of the children's understanding of the words. The tests served the purpose of helping in the grading of the words. The actual words so tested and the numerical results are given in Table XI of the Appendix. (The tests indicated several other possible researches e.g. a rigid test of the vocabulary of the children, variations of vocabulary with sex, etc.)

Flood-West decided that 60 words of their vocabulary are difficult to anyone who has not had training in science. Of these 22 were separated as being specially difficult. The list of 60 words is called LIST A. It is given in Table XXVII. It represents the minimum vocabulary of scientific words which must be known. This list, with the explanations, should appear in the glossary to a book, or some indication given that these words must be looked up in a dictionary before starting to read the book.

A second list of 125 semi-scientific words was prepared. This is called LIST B; It is given in Table XXVIII. These are words which would probably be known by an educated Englishman but which might not be known by a foreigner of small reading vocabulary or by an Englishman of limited education, especially on the scientific and practical sides. Examples of such words are absorb, bearing (of a machine), circumference. Words of lists A and B were defined in the dictionary so that anyone who stumbles on one of them can look it up. These words might also be included in a

TABLE XXVII

Essential scientific words (LIST A)

Words of special difficulty are printed in CAPITALS

alkali /ne
ALTERNATING CURRENT
AMPERE
BENZENE RING
BOND (chemical
cavity (of the body)
cell (biology)
cell (electricity)
circuit
compound (chemical)
CONDENSER (electrical)
conductor
ELECTROLYSIS
ELECTRON
element (chemical)
equation
ferment (to, a-)
field (magnetic)
fossil
FREQUENCY (electrical)
generate (electricity)
gland (of body)
graph
HYDROCARBON
INDUCE (electricity)
ION
insulator
larva
MASS (scientific use)
membrane
mica
MOLECULE
NEGATIVE (electrical)
NEUTRON
NUCLEUS
orbit
organism
oxidise
parasite
pole (electrical, magnetic)
POSITIVE (electrical)
PROTEIN
quinine
radioactive
radium
resin
resistance (electrical)
SALT (chemical)
seizure (fit)
soluble, solution
SPECTRUM
SPORE
storage battery
tissues (of living body)
valve (machine, radio)
VOLT

Measures

centigrade
fahrenheit
gramme
metre, centi-, milli-

Total 60

TABLE XXVIII

Semi-scientific words (LIST B)

absorb
aerial
alloy
analyse
(antiseptic)
artery
atmosphere
atom
bacteria
barometer
battery
bearing (of machine)
bolt (nut)
bulb
cartridge
cast (iron etc.)
celluloid
charge (to charge a battery, positive charge)
circumference
coil
compress
cone
contract (v)
crank
cube, -ic
cylinder (shape, engine)
decimal
degree
dense
develop (photo.)
diameter
(disinfectant)
dissolve
eclipse
elastic
emotion
energy
equator
evaporate
expand
fertilize (seeds)
fertilize(r) (chemical)
friction
fungus, -i

gear (wheel)
glaze
gourd
gravity
(hereditary)
horizon, -tal
image
impulse
infect -ious
inflame /mation
inherit
inject
intelligence (-test)
jute
laboratory
lathe
lens
lever
lined, lining
loom
magnet
magnify
maize
malaria
manure
mine, mineral
mould (shape)
negative (photo.)
neutral
nut (bolt)
offspring
operation (surgical)
ore
parallel
particle
petroleum
piston
planet
plastics
pollen
pressure
prism
propeller
proportion
pulley
pulse
pupil (of eye)

radiate
radius
react
reflect
revolve
right-angle
rivet
scale (measure)
sensitive, /ory
septic, anti-
sieve
smallpox
source
spiral
squared, -root
surgery
switch
telescope
television
temperature
thermometer
transparent
unit
universe
urine
vacuum
vapour
vary
vein
vibrate
vitamin
volcano
volume
vomit
wedge
X rays
yeast

---

glossary or Introduction to any book for a foreigner or a young reader.

It is stressed that no such classification of words can be rigid. The classification was made in order to examine the composition of the Flood-West vocabulary and to effect some distinction between lists for Englishmen and lists for foreigners.

The rest of the added vocabulary (294 words) consists of "ordinary" words. These are almost certainly known by English readers and many are probably known by foreign readers. Some of these words, being the names of common things, are sure to be known by the foreigner, in fact, some are usually accepted as international. Examples of international words are alcohol, beer, camera, chocolate, telegraph.

The added vocabulary, as already noted, contains some "dignity" words. These could all have been avoided in writing a dictionary in the smallest possible vocabulary for foreigners only; they could have been replaced by simpler words or phrases. Table XII of the Appendix gives examples of such words. They should not be excluded from the lists for several reasons.

(1) The exclusion would lead to lack of clarity in the explanations. Too large a vocabulary is an obstacle to understanding but so also is one which is too small.

(2) The exclusion of these words would have a further and equally unfavourable result; it would make the

explanations sound childish or "queer". A childish prattling explanation is liable to be mistrusted.

(3) The Flood-West vocabulary was devised not merely for the purpose of the dictionary. Consideration must be given to others who may want to use the vocabulary: writers, teachers, and the learners themselves. It is very difficult for teachers to do without these words (the words tend to slip in unconsciously) and learners, even more than their teachers, do not want to sound childish.

In compiling the dictionary Flood-West made a list of "wanted" words. These were not used in the actual dictionary but were only avoided with difficulty. These "wanted" words are apt to slip in as errors of vocabulary control. Some are technical (List A) words, many are List B words, some are dignity words. They are set out in Table XIII of the Appendix. The list A words are:

catalyst	organic (chemistry)
electrode	secrete
mammal	stimulus
	structure

As it is hoped that this work may be useful to teachers and writers outside the narrow circle of those practised in vocabulary control, most of these wanted words should be included in a writing vocabulary.

6. COMPARISON OF THE FLOOD-WEST VOCABULARY WITH THE SCIENCE VOCABULARIES OF BASIC ENGLISH

The only other vocabulary (known to the writer) constructed for writing in science is that of Basic English (C.K. Ogden). The general vocabulary of Basic English consists of 850 words.[1] These, Ogden claims are sufficient for ordinary communication in idiomatic English, and do the work of 20,000 words. For the purposes of science, provision is made of an additional general science vocabulary of 100 words and of further lists of 50 words for each of the particular sciences. Thus the total vocabulary for any one science consists of 850 + 100 + 50 = 1,000 words. With the appropriate 1,000 list, Ogden claims that any scientific congress or periodical can achieve internationalism.

It is not the purpose here to examine the general (850) vocabulary. Expositions of its nature and advantages have been made by Ogden,[2] Richards,[3] and others. West[4] has made an adverse criticism. In function, the general vocabulary corresponds to the New Method (1490) list. The additional Basic science lists are, in some measure, comparable with

---

1. This is really an understatement. In addition to the 850 words, measurements, numerals, currency, calendar, and "international" terms in English form, with certain onomatopoetic words, are permitted.

2. Basic English. C.K.Ogden. Kegan Paul,Trench, Trubner & Co.Ltd.,

3. Basic English and its uses. I.A.Richards. Kegan Paul, Trench, Trubner & Co.Ltd.,

4. A critical examination of Basic English. M.P.West, E. Swenson and others. Bulletin No. 2 of The Department of Educational Research, Ontario College of Education,

the Flood-West vocabulary. The present study is based on the General Science list and the special lists for Physics+chemistry, Mathematics+mechanics, Biology, and Geology.[1]

Before embarking on detailed comparisons and criticism it is necessary to appreciate the purpose of Basic English. It "is primarily designed for the purposes of international commerce, science; congresses, travel, radio, talking pictures, etc. where the need for an auxiliary medium of communication is greatest, particularly in the East."[2] It exists therefore for the purposes of communication between people who are cognisant with the nature of the material under discussion. It does not necessarily permit simplification of concepts. An article on an abstruse subject in science is not necessarily more intelligible to the layman because it is written in Basic English. This reveals a sharp divergence between the Basic vocabularies and the Flood-West vocabulary. They are not designed for the same purposes. Although comparisons between the two vocabularies is profitable it is impossible to determine which is the "better" or more useful.

Immediately any attempt is made to compare the sizes of the two vocabularies two difficulties arise.

---

1. Basic for science. C.K.Ogden. Kegal Paul, Trench, Trubner and Co.Ltd., (1942).

2. The Basic Vocabulary; a statistical analysis. C.K.Ogden. Kegan Paul, Trench, Trubner & Co.Ltd., (p.7)

(1) The Basic special lists do not yet cover all the sciences (pure and applied).

(2) The Basic vocabulary may be considerably extended by the use of "international" words.

Ignoring, for the moment, these difficulties, the sizes of the vocabularies are compared in Table XXIX.

TABLE XXIX.

Numerical comparison of Basic and Flood-West vocabularies

BASIC		FLOOD-WEST	
General vocabulary	850	New Method vocabulary	1490
General science vocabulary + 4 special vocabularies	300	Flood-West science vocabulary	479
Total	1150	Total	1969

This apparently indicates that the Basic vocabularies are economical and that the Flood-West vocabulary is extravagant. This unfavourable comparison vanishes when the two difficulties stated above are considered. The Basic lists do not yet cover (other than by accidental overlaps) such subjects as aeronautics, building, medicine, engineering practice, meteorology, and psychology. These, and other subjects, are covered by the Flood-West vocabulary. Of even greater significance is acceptance in Basic of "international" terms. In "Basic for Science" 600 such terms are listed. Many of these are specialised terms and cover concepts beyond the range of the Flood-West vocabulary, but, when consideration is given to their inclusion, the

Basic vocabulary is seen to be less economical than appeared initially.

A further false reduction of the Basic lists is made by permitting one word to cover two (ore more) rather different meanings. In most cases the different meanings are related i.e. the word, in each sense, is fundamentally the same, but the ordinary (as distinct from the expert) reader might well not understand all the usages of the word. The word "capacity" provides an illustration. A reader might understand it to mean "volume (held by a vessel)" but not understand capacity for heat or electricity. Basic permits the use of the word in a range of meanings and counts it as only one word. Table XXX shows such words in the Basic Science vocabularies.

In the Flood-West vocabulary no words are accepted as international (though some are sure to be known by readers both in this country and abroad). A word known internationally, by experts, is not necessarily known to the general reader of popular science. Thus the following words taken from Ogden's list of letter A are unlikely to be known by the general reader: aberration, achromatic, allantois, amnion, asymptote, atavism, aureole, autogenous, axon. The general reader would need to consult a dictionary.

In constructing a detailed comparison of the Flood-West vocabulary and the Basic vocabularies attention must be given to the peculiar structure of Basic English. In Basic English nouns predominate and there is a minimum of

TABLE XXX.

Words of Basic with range of meanings

WORD	RANGE OF MEANINGS
alternate	1.Applied to leaf arrangement on plant stem 2.Extended to alternating current
arc	1.Part of a circle 2.Electric spark
axis	1.Line about which object may turn 2.Line of reference 3.Main plant stem
capacity	1.Volume which can be held 2.Thermal and electric capacity
cell	1.Unit of living body 2.Electric cell
compound	1.Thing made of different parts 2.Substance made up of elements 3.Flower,animal, etc. made of simpler individuals.
cross	1.Lines at an angle 2.Mixed parentage
density	1.Weight per unit volume 2.Amount of electricity (etc.) held on unit area or in unit volume
fusion	1.Melting 2.Joining of parts (biology)
generation	1.Production of e.g. heat, electricity 2.Production of offspring 3.Stage in family tree 4.Period in family history
gill	1.Of fish 2.Of the reproductive part of Agaricae
plug	1.Pad closing hole 2.Electric connector
projection	1.Piece sticking up or through 2.Geometric projection 3.Optical projection (e.g. by lantern)
solution	1.Substance dissolved in a liquid 2.Working out or getting answer to a problem

verbs. A word must be considered common to the two vocabularies if the same root is present. Thus "reproduce" in the Flood-West vocabulary is comparable with "reproduction" in the Basic vocabulary. An analysis of the Flood-West vocabulary in terms of the Basic vocabularies is given in Table XXXI.

TABLE XXXI.

Composition of the Flood-West vocabulary in terms of the Basic vocabulary

Words of the Flood-West vocabulary	
(a) in the general (850) Basic vocabulary	70
(b) in the Basic General Science vocabulary	31
(c) in the 4 Special Science vocabularies	49
(d) accepted in Basic as international	111
(e) not in the Basic lists	218
TOTAL:	479

That words of the Flood-West vocabulary should occur in the general Basic vocabulary arises from the differences between the New Method vocabulary and the Basic vocabulary. The words are non-scientific. Examples are: base, camera, comb, cork, detail, drain, exist, fork, linen, rod. Similarly, some (50) words of the Basic science lists are included in the New Method list. Examples are: age, cave, desert, exact, ground, length, mix, rock, shell, surface, wild. None is really a scientific word. These overflows into the General Basic and New Method lists need not be discussed. The other types of words must be examined, especially those which are in one or other of the vocabularies but not in both.

Table XXXII shows the words of the Flood-West vocabulary which are in the Basic General Science list. Table XXXIII shows the words of the Flood-West vocabulary which are in the 4 Basic Special Science lists.

TABLE XXXII

F-W words in the Basic General Science list

absorb	evaporate	resistance
area	experiment	screen
ash	friction	sensitive
bubble	generate	similar
cell (biol.)	groove	soluble, solution
cell (elect.)	hinge	spark
compound	layer	tide
deposit	nucleus	transparent
disturb	origin -al	tube
equation	pressure	valve
	reproduce	

(A few other words were in the original (1931) list but removed from the later (1942) list.)

TABLE XXXIII

F-W words in the Basic Special lists

(a) Physics+chemistry list

charge (elect.)	furnace	pendulum
circuit	image	radiate
coil	insulate	switch
combine	lens	vapour
conductor	oxidise	wedge
dense	particle	

Table Continued:

Table XXXIII Continued

(b) Mathematics+mechanics list		
circumference	multiply	triangle
diameter	piston	vary
fraction	pulley	volume
lever	total	
(c) Biology list		
bark (of tree)	gland	lung
bud	inherit	petal
cavity (of body)	jaw	pollen
ferment	juice	skull
fertilize	kidney	stain
fibre	liver	suck (er)
		tissue
(d) Geology list		
clay	ore	

A further 111 words of the Flood-West vocabulary are accepted by Ogden as international. These are listed in Table XIV of the Appendix.

It is now necessary to examine words which Ogden includes in the Basic lists but which are not in the Flood-West vocabulary. Analysis shows that these words are of two kinds:

(1) Useful general words which Flood-West managed to avoid (possibly at the cost of other words) but which Ogden preferred to the exclusion of other words.

(2) Specialists' words, essential to fluent communication between experts, but outside the necessary vocabulary of the popular science reader. (Care must be taken to

note that some of these words e.g. cast, dip, flow, strike (from the geology list) are specifically intended for use in restricted scientific senses.)

All the words of the first group can be avoided (by synonym or periphrasis) by the use of the Flood-West vocabulary. A few have already been noted as "wanted" words. Table XXXIV sets out the words of this group i.e. non-specialist words, with indications of the equivalents in the Flood-West vocabulary.

TABLE XXXIV.

Non-specialist words of the Basic lists not in the Flood-West vocabulary with indications of the Flood-West equivalents

The particular Basic lists are indicated as follows:
G - general, PC - physics+chemistry,
M - mathematics + mechanics, B - biology, Ge - geology

Words marked * have already been noted as Wanted words

	Basic	Flood-West equivalent and comments
Ge	accessory	extra, helping, not a main part
G	adjacent	lying near, next, joining
G	alternate	first...then....and so on
G	application	v. to use, put, cause to... (A useful word) n. use
M	approximation	n. near-truth, ...is nearly true adv. nearly
M	arbitrary	This word can be avoided by sentence reconstruction and by use of such words as choose, not by rule, as we like
G	arc	(1) piece (bit) of curve (2) electric spark, electric flame
G	axis	axle, turning line, centre line
PC	buoyancy	power of floating

Table XXXIV. Continued

	Basic	Flood-West equivalents and comments
G	capacity	volume, holding power (A specialist's word in thermal and electrical usages)
G	case	example, position, etc.
B	claw*	horny foot (A useful word)
PC	clip	spring-fastener, tap
PC	collision	hitting, coming (running, hitting) together
G	column	post, tower, upright row
M	constant	fixed number, ..which does not change (vary)
PC	corrosion	rusting, becoming stained, wearing away
G	decrease	get (become) less (smaller)
G	deficiency	lack of, not enough
PC	dilution*	n. weakness, weak strength v. to make weaker, to add water
G	discharge	n. loss of charge, losing of charge v. to lose charge
PC	dissipation	scattering, wasting, spreading
B	domesticating	becoming home-like
G	elimination	getting rid of, pushing out (away), losing
G	environment	surroundings, conditions
Ge	erosion	wearing away (by....)
B	fin	A useful word in biological words and only to be avoided if of infrequent occurrence.
Ge	flood	great amount of water, overflow of water
G	focus	coming together (to a point, the same place), bringing together

Table XXXIV. Continued

Basic		Flood-West equivalent and comments
Ge	fracture	break, crack
PC	funnel *	A difficult word to avoid in PC writings. If required it is best introduced via a diagram
G	fusion	(1) melting (physics) (2) joining, running together (biology)
B	germinating	growing, beginning to grow
B	gill	See fin. Alternative is breathing-organ. (Its application to Agaricae is a specialist's use)
Ge	gravel	coarse sand, sand and stones
B	hoof	See fin. foot (context adds to meaning)
B	host	... on (in) which it lives
G	impurity	The word "pure" is in the New Method vocabulary. This derivative needs parenthetical explanation on its first occurrence. Lack of purity. The material causing lack of purity
G	individual	single person, separate person (unit)
G	interpretation	understanding, meaning, explanation, making clear the sense of
M	intersection	crossing, cutting, place (point) of...
G	investigation	enquiry, examination, search for
PC	lag	slow coming about, time of waiting, to fall behind (Application to alternating electric quantities is a specialist's use)
G	link	join, ring (of chain), bond (chemical)
M	magnitude	size, strength
B	mature	grown up, developed, fully grown
G	mean	average, middle

Table XXXIV. Continued

	Basic	Flood-West equivalent and comments
PC	medium	material (thing) in which... is done (travels, happens, etc.)
M	oblique	at an angle, not upright, not at right-angles
PC	plug	pad of..., cork v. to close with (a pad etc)
M	probability	"probable" is in the New Method list. This derivative is permissible if not given a quantitative sense.
M	projectile	thing thrown (shot), bullet
M	ratio	A difficult word to avoid. Relation between..., X is... times bigger than Y, in the proportion of,
M	rectangle	possibly a specialist's word. Four sided figure (this, of course, is not accurate)
G	reference	in relation to, by comparison with
PC	repulsion	driving away
PC	residue	remains, material left (behind)
PC	reversible	can work both ways (forwards and backwards)
M	reinforcement	acting together, adding more forces, strengthening
G	rigidity	stiffness, firmness
G	rot	decay
G	rotation	turning round, revolution, spinning
PC	saturated	...can hold (dissolve etc.) no more, as full as possible
B	scale	(As a measure, in the F-W vocabulary.) A useful word in biology. Thin flat plates, leaf-like parts.

Table XXXIV. Continued

	Basic	Flood-West equivalent and comments
G	seal	close tightly, shut out the air
G	section *	part cut off, as if cut off (through)
PC	solvent	usually avoidable by periphásis or by use of "the liquid" in the proper context
G	specialization	becoming used or developed for special purposes
G	specimen	example, thing (part, unit) kept as an example
PC	stable	steady, not easily changed or broken
B	stalk	stem
G	stimulus *	...which excites, drives on, impulse
G	substitution	putting in place of, replacing
G	successive	following, ...and each coming after
M	sum	total, problem
PC	suspension	holding up. In its chemical sense "held in suspension" is replaceable by "floating about in"
G	thrust	force, push
PC	tongs	A strange inclusion in the Basic vocabulary. Seldom would it be necessary in popular science to refer so specifically to this instrument of manipulation
G	transmission	sending, carrying,

The following mathematical words will probably be known to a reader of popular science. They are all avoidable by (a) periphrasis, (b) specific reference to the quantity concerned.

denominator, divisor, numerator, product, quotient, subtraction

The second group of words included in the Basic lists but not in the Flood-West vocabulary consists of specialists' words. Most of them would need explanation in a text of popular science if, indeed, they need be used at all. They are given in Table XV of the Appendix.

Finally an examination must be made of the words which are included in the Flood-West vocabulary but which are not included in the Basic lists. They are given in Table XVI of the Appendix. Analysis shows that these words are of various kinds.

(1) Words for which Ogden uses alternative equivalents. Examples: average (mean), revolve, spin (rotate), flesh (meat).
(2) Words which Ogden apparently omits as "luxury" alternatives to simpler words. Examples: damp, moist (= wet, rather wet), purple (= red-blue).
(3) Words which Ogden "smuggles" in as (illegitimate) extensions of simpler words. Examples: mass, develop (photo.), salt.
(4) Words which Ogden accepts with two or more meanings. Example: nut.
(5) Words arising from the peculiar structure of Basic. Thus Basic includes 'solution' but not 'dissolve'.
(6) Names of plants, animals etc. Examples: ape, bat, coconut, crab, fern, snail.
(7) Words applicable to subjects for which, so far, Basic lists have not been provided. Examples: chisel, lathe, rivet, weave.

(8) Words whose absence from Basic is difficult to understand. The writer has examined all the standard books by Ogden which are available to him but has not been able to find these words. They appear to be of such common occurrence and utility that their absence is not understandable. Omitting those in subjects for which Basic vocabularies have not yet been provided, these words are as follows.

aerial	dye	rust
alloy	fertilizer	scrape
ankle	gramophone	sew
beetle	magnify	sore
bolt	mend	spit
cast	mirror	starch
chew	mould	tar
cure	ordinary	tough
	passage	wind, to
		yeast

Ogden, of course, aimed at a minimum vocabulary; Flood-West aimed at readable and adequate vocabulary. A vocabulary which is too small is as great a source of difficulty as one which is too big. This has already been elaborated in the discussion of "dignity" words.

The comparison of the vocabularies is valuable but it is profitless to attempt to assess which is the better. Basic employs a smaller vocabulary and covers subjects in a more specialised way; the Flood-West vocabulary is bigger but allows a more readable style (and therefore easier exposition), includes words which are sure to be known by readers of popular science, and covers a wider range of subjects. The Flood-West vocabulary is honest in separately listing specialised meanings and derivatives and does not accept internationally known words. Within the field of popular science the Flood-West vocabulary is in no way inferior to Basic and, in several ways, is better. It also has the further advantage that it can be used as the nucleus of a vocabulary of popular science for English people.

7. TEST OF THE FLOOD-WEST VOCABULARY FOR CONTINUOUS TEXTS

The Flood-West vocabulary was evolved by the experiment of writing a dictionary. It was designed to be adequate for the explanation of all scientific terms likely to be met by readers of popular science. But a vocabulary adequate for definition is not necessarily adequate for continuous exposition. Flood's work with the Elementary Science Readers (section 9) affords a good test of vocabulary for continuous texts but it is desirable to examine the powers of the Flood-West vocabulary alone. The techniques of simplification are discussed in Part VI; in this Part attention is given chiefly to problems of vocabulary. Flood experimented with the vocabulary-simplification of various passages taken from existing texts. Three of these (two short and one long) simplifications, as for a foreign reader, are given with the originals in the following pages. It is seen that the Flood-West vocabulary is adequate for the purpose.

Extract A (Plant disease) was selected because it contains many difficult scientific words. In the main, simplification could only be effected by explanatory footnotes.

Extract B (Photography and Geology) was selected because it contains many difficult "non-scientific" words. Sentence re-construction was also necessary.

Extract C (Anti-vitamins) was selected because it touches upon two popular sciences: chemistry and biology. Otherwise the passage was selected at random from the Penguin Science News. The extract consists of the first 1000 running words.

Extract A. Original from "Physiology of disease resistance in plants." ("Nature" March 20 1948 Vol. 161).

"Cuticular resistance is the only means of defence of some plants against specific parasites (wound parasites). Frequently the cuticular barrier is circumvented by invasion through stomata or other natural opening (for example, the stigmas of flowers) where the cuticle is poorly developed. [1] Once inside the plant, parasites of the facultative type [2]disorganise the host tissue and live on the dead remains. The chief substance

---

Words outside the Flood-West vocabulary are underlined.

1. Awkward collocation caused by omission of verb.
2. All words ending in -ise are spelt -ize in the Flood-West vocabulary.

concerned in this process is [3]pectinase enzyme. Resistance [4]may take the form of retardation or inhibition of growth of the invader or interference with its offensive mechanism. Thus acidity of cell-sap, or presence of [3]tannins, oils, glucosides etc., may prevent growth of a potential parasite. A similar effect is obtained when the metabolism of the [5]latter [4]leads to the formation of substances ('staling substances') which [6]by and by inhibit growth; [7]hence the formation of leisons of limited size."

Words outside the Flood-West vocabulary are underlined.

3. Names of substances are permissible. Tannins and glucosides, being class-names could be explained in desired.
4. Possibly an awkward collocation.
5. Former and latter are needless sources of difficulty to a foreigner.
6. Needless collocation.
7. Difficulty increased by omission of verb.

Simplification of Extract A.

Resistance by the [1]cuticle is the only means of defence of some plants against certain parasites (those which get in through wounds). Frequently the parasites pass the cuticle by going through the natural openings in it (such

---

1. cuticle = wax-like outer part of the skin.

as the [2]stomata or the [3]stigmas of flowers) where the cuticle is not well developed. A facultative parasite is one which can live as a free-growing plant or as a parasite. When facultative parasites are inside the plant on which they live, they disorganize the tissues and live on the dead remains. The chief substance concerned in this process is the [4]enzyme pectinase. Resistance may be caused by the slowing down or stopping the growth of the incoming parasite or by interfering with its means of attack. Thus acidity of cell-liquid, or presence of tannins, oils, glucosides, etc., may prevent the growth of a possible parasite. A similar effect is obtained when the chemical processes in the possible parasite form substances ([5]"staling substances") which later prevent growth. As a result the areas attacked by the parasites are limited in size.

---

2. stoma = small hole in surface of leaf for breathing etc. (Plural: stomata.)

3. stigma = top part of female organ of a flower on which the pollen comes.

4. enzyme = substance produced by a living cell which causes chemical processes to take place but which is not itself used up in the processes.

5. stale = not fresh.

Note that "facultative" is explained in the text. This is a frightening word and is not merely a vocabulary

Extract B. From "Modern Applications of Photography" - Science News VII p.85

This passage is difficult, especially for a foreigner, because of the abundance of uncommon (but not highly scientific) words.

"Changes in vegetation over a period of time are often associated with important topographic processes, and as the surveys spread to such vegetation types as sphagnum bog and submerged seaweed beds, they impinge on the interests of geologists, for they yield indirect data on such problems as the silting of estuaries, coast erosion and other factors controlling the development of scenery."

Notes:

1. Difficulty is further increased by the complex sentence structure.
2. "Survey" would have been explained earlier in the article; it is left unchanged in the following simplification. It could be replaced, if necessary, by "examination" or "study".
3. Names of sciences e.g. geology are usually accepted as international but even so explanation may be necessary.
4. Beds, indirect, and scenery are not used in their primary senses.

Simplification of Extract B.

Changes in the kinds of plant-life over a period of time are often related to important changes in the nature of the land. The surveys interest [1]geologists, for they also cover such kinds of plants as sphagnum bog (moss growing on low-lying west land) and underwater areas of sea-plants. Thus they provide information, in a roundabout way, on such problems as the filling in of river-mouths with sand and mud, the wearing away of the coast, and other things which control the nature and appearance of the land.

---

1. Scientists who study the rocks and nature of the Earth.

Extract C consists of the first 1000 running words of an article on Anti-vitamins taken from Penguine Science News No. 7. No attempt has been made to simplify the concepts; the simplification is in respect to vocabulary and, occasionally, to sentence structure. The word "enzyme" was explained in the glossary, hence the footnote explanation in the simplified version is not counted in comparing the lengths of the two versions. Explanations have been provided, by footnote or within the text, of the following words: compete, inhibition, antibody, pancreas, carbohydrate, cane-sugar, malt-sugar, biochemist. Even with these additions the length of the simplified version is only 1043 words.

Extract C. Original from Penguin Science News No.7 pp.56-60

Anti-vitamins, by Professor John Yudkin

Many substances are now known which antagonise the action of certain of the vitamins. Such substances may, in an animal, produce the signs of vitamin deficiency, even though the diet contains what is normally an adequate amount of the vitamin. In so far, therefore, as these "anti-vitamins" may occur in natural foodstuffs, they are clearly of importance in the field of practical dietetics. But a closer study of them, and of the history of their discovery, shows that they have a far wider theoretical and practical interest. An understanding of them is, for example, necessary for those who are concerned in the present intensive research for new drugs for the treatment of human disease.

Most of the anti-vitamins belong to the group of "metabolic analogues" or competitive inhibitors. To understand how this type of substance functions we shall have to go back a long way through quite unexpected paths. We might begin with Erlich, who, nearly 50 years ago, developed his "side-chain" theory to account for the phenomenon of specific immunity.

When a person develops an immunity to a bacterial infection like typhoid fever, his blood becomes capable of reacting with the typhoid bacteria, and making them "agglutinate" or clump together. What has happened is that, during the infection, the typhoid bacteria (the antigen) made the infected patient produce in his own blood a specific antibody so that whenever the blood comes again into contact with typhoid bacteria the antibody reacts with the bacteria, which then agglutinate and so are rendered harmless.

According to Erlich's theory, the reaction between the antibody developed in the blood and the antigen of the bacteria occurs by a union between the two; the fact that antigens for different bacteria combine with different and very specific antibodies in the host is supposed to be due to the two substances being of such a structure that the one just fits into the other. No other antibody will combine with this antigen because no other will have a structure which fits the appropriate group or "side-chain" of the antigen.

Specificity of Enzymes

A similar idea was developed by biochemists to explain how it is that enzymes, like antibodies, are very "fussy" about the exact constitution of the substance (subtrate) with which they react. For example, the pancreas makes several enzymes, which digest proteins, carbohydrates and fats. But the enzyme which digests proteins will not digest fats or carbohydrates. More than this, an enzyme which will act on one sort of carbohydrate will not attack another. One enzyme will act on cane sugar, but not on malt sugar; although they are similar sugars, there are certain chemical differences between them which make only one able to attach itself to the enzyme. The simile which is commonly used to explain this extraordinary specificity of enzyme action is that of the "lock and key". The atoms and bonds which go to make up a chemical substance confer upon it a characteristic structure just as the grooves and notches confer a characteristic structure to a key. And just as the key will only fit a lock for which it is made, so a chemical substance will only fit its appropriate enzyme. Unless it fits, the enzyme cannot act upon it.

Enzyme inhibition

With this sort of picture in mind, many workers have been carrying out investigations on the mechanism of enzyme reaction. Oneof the most active laboratories in this field is at Cambridge, where Dr Stephenson and her colleagues have been studying the enzymes of bacteria for more than 20 years. In one of these studies, it was found by Dr Quastel that certain substances interfered with the action of an enzyme upon its own specific substrate. The action which he was studying was the oxidation of succinic acid by the enzyme oxidase, and the substance which interfered was malonic acid. One curious thing about the interference was that the degree of interference did not depend so much on the absolute amount of malonic acid that was present, as on the relative amounts of malonic to succinic acid. When malonic acid was added to the active enzyme, the rate of oxidation of succinic acid was reduced, but it was considerably restored if more succinic acid was added and again inhibited if more malonic acid was added.

It seemed as if there was a competition between these two substances. Because of their similar structure, either could apparently combined with the enzyme, although only the succinic acid could be acted upon. Since there was only a limited amount of enzyme, the combination of malonic acid with the enzyme meant that there was less of the enzyme available to combine with the succinic acid. One can picture the molecules jostling each other for places on the enzyme. And one can see how it is that the amount of oxidation which occurs depends on the relative amounts of the two competing types of molecules.

Sulpha Drugs

A similar explanation was advanced by Dr Woods, who had also been a pupil of Dr Stephenson, to account for the action of the sulphonamide type of drug on bacteria. Bacteria may, like animals, require particular nutrients - vitamins - for their growth, and one of these, required by several species of bacteria, is a substance called para-aminobenzoic acid. Dr Woods was struck by the chemical resemblance of several of the sulpha drugs to this substance, and suggested that these drugs act by competitive inhibition. That is, they get in the way of the vitamin whereever it is in the bacteria that it carries out its function. This theory, that the sulpha drugs act as anti-vitamins for certain species of bacteria, is supported by the fact that bacteria prevented from growing by the addition to their culture medium of one of the sulpha drugs, are able to grow again if para-aminobenzoic acid is added.

Vitamins and their competitors

Since that time, a number of substances have been found which act as anti-vitamins in animals. Many of them are...

Simplification of Extract C

ANTI-VITAMINS

Many substances are known which work against the action of cetain of the vitamins. Such substances, if in an animal, may cause signs of lack of vitamins even though the food which is eaten contains an amount of vitamins which is usually enough. As these "anti-vitamins", as they are called, may be present in natural foods they are clearly important in the study of food-preparation. But a closer study of them, and of the history of their discovery, shows that they are of far wider interest, both in theory and in use. For example, all those who are now keenly looking for new drugs for curing human diseases must understand them.

Most of the anti-vitamins belong to the group of "competitive inhibitors". (This name is explained later.) We shall have to go back a long way, along unexpected paths, to understand how this kind of substance works. We might begin with Erlich who, nearly 50 years ago, put forward

---

Note. It is easier to explain the name "competitive inhibitor" after the characteristic mechanism has been discussed. The name "metabblic analogue" does not appear again in the article and is omitted as unnecessary.

his "side-chain" theory to explain the strange facts of freedom from attack from certain diseases.

When a person develops a freedom from attack by bacteria (e.g. typhoid fever bacteria) which have infected him, his blood becomes able to react with the bacteria and make them "agglutinate"(stick together in masses). This is what happens. When the infection takes place, the typhoid bacteria (called the antigen) make the infected person produce a certain antibody* in his blood. Whenever the blood meets typhoid bacteria again the antibody reacts with the bacteria which then agglutinate and so become harmless.

According to Erlich's theory, the reaction is a joining of the antibody made in the blood with the antigen of the bacteria. The antigens of certain bacteria (e.g. typhoid) combine only with their own special antibody in the blood and with no other antibody. The two substances (Antigen and Antibody) are built up in such a way that one just fits onto the other. No other antibody will combine with a certain antigen because no other is built in the way which fits the special group or "side-chain" of the antigen.

Enzymes** are "particular."

A similar idea was put forward by biochemists, who study the chemical substances in living things, to explain why enzymes, like anti-bodies, are very "particular" about the composition of the substance (called the substrate) with which they react. For example, the pancrease (an organ behind the lower part of the stomach) makes several enzymes which attack proteins, carbohydrates (e.g. sugar, starch) and fats. But the enzyme which attacks proteins does not attack carbohydrates or fats. Further, an enzyme which acts on one kind of carbohydrate does not attack another. One enzyme acts on cane-sugar (from the sugar-plant) but not on malt-sugar (made from grain). Although they are similar kinds of sugar, there are certain chemical differences which made only one sugar able to join itself to the enzyme. We commonly explain this particular "choice" of an enzyme by comparing the two substances with a lock and key. The atoms and bonds which make up a chemical substance

---

* antibody - substance formed in the blood to fight against a disease.

** enzyme - substance (protein) produced by living cells which cause chemical changes to take place although present only in small amounts.

Note - The use of "will" to mean "is in the habit of" is objectionable. When translated into the future tense of another language it does not make sense. In lines 29-33 of this page the present tense is substituted.

give it a particular shape just as the grooves and cuts in a key give it a particular shape. And just as the key will only fits a lock for which it is made, so a chemical substance will only fits its own special enzyme. If it does not fit, the enzyme cannot act on it.

Enzyme inhibition

With this kind of picture in the mind, many workers have been carrying out enquiries on the methods of enzyme reactions. One of the most active laboratories in this work is at Cambridge where Dr. Stephenson and her helpers have been studying the enzymes of bacteria for more than 20 years. In one of the studies Dr. Quastel found that certain substances interfered with the action of an enzyme upon its own particular substrate. The action which he was studying was the oxidation of succinic acid by the enzyme called succinic oxidase, and the substance which interfered was malonic acid. One strange thing was that the amount of interference did not depend on the actual amount of malonic acid which was present; it depended rather on the relation between the amounts of malonic acid and succinic acid. When the malonic acid was added to the acting enzyme the rate of oxidation was made slower but the rate became quicker again when more succinic acid was added.

It seemed that the two substances struggled against each other. Because of their similar shapes, either (it seemed) could combine with the enzyme, although only the succinic acid could be caused to oxidise. As there was only a certain amount of the enzyme, the joining of the malonic acid with the enzyme caused there to be less enzyme for use by the succinic acid. We can picture the molecules struggling with each other to join the enzyme. And we can see why the amount of oxidation which takes place depends upon the relation between the amounts of the two kinds of "struggling" molecules. This action is called Competitive Inhibition; the two substances compete (struggle) against each other and so inhibit (prevent) the action.

Sulpha drugs

Dr. Woods, who had also been studying under Dr. Stephenson, put forward a similar explanation of the action of the sulphonamide drugs. Bacteria may, like animals, need certain special substances (vitamins) for their growth, and one of these, needed by several kinds of bacteria, is a substance called para-aminobenzoic acid. Dr. Woods noticed the similar chemical shape of several of the sulpha drugs and this substance. He put forward the idea that these drugs act by "competitive inhibition", that is, the vitamin and the sulpha drug compete inside the bacteria. This theory, that sulpha drugs act as anti-vitamins for certain kinds of bacteria, is helped by the fact that bacteria are prevented from growing if sulpha drugs are added to the food-material on which the bacteria are living but they are able to grow again if para-aminobenzoic acid is added.

Vitamins and their competing substances

Since that time, a number of substances have been found which act as anti-vitamins in animals. Many of them are......

---

8. CONSOLIDATION OF THE FLOOD-WEST VOCABULARY WITH THE CARNEGIE VOCABULARY

The Flood-West vocabulary with the New Method vocabulary provides a complete vocabulary for the exposition of popular science. The New Method vocabulary, from which the consolidated vocabulary originates, is not the only limited vocabulary of ordinary English which has been devised. Palmer, Faucett, and others have studied vocabulary problems and produced other lists. None of these lists, including the New Method list, has been universally accepted. In order to co-ordinate the work of West (in Bengal), Palmer (in Tokyo) and Faucett (in China), and to make use of the word-frequency researches of Thorndike, the Carnegie Corporation convened a conference of these workers and others.[1] This and later conferences resulted in plans for continuance of studies and the compilation of a provisional limited vocabulary.[2] This "Carnegie vocabulary" therefore,

---

1. Conferences were held in October 1934 (New York) and June 1935 (London). Committees met at additional times.

2. Interim Report on Vocabulary Selection. (P.S. King & Son Ltd., London). A revised edition will be published in 1949.

is free from any individual whims, and forms, as nearly as possible, an impersonal "universal" limited vocabulary. If the Flood-West vocabulary is to attain "universality" it must be harnessed, not to the New Method vocabulary, but to the Carnegie vocabulary.

In effecting this linkage of the Flood-West vocabulary with the Carnegie vocabulary, it is necessary to determine which words of (a) the New Method list, (b) the Flood-West list are already included. The remainder constitute the list to be added. Flood effected the linkage. The Carnegie list contains approximately 2,000 words. Fifty of the words in the New Method list are not included. Of these, 20 appear not to be applicable to popular science; the remaining 30 words must be added. Table XXXV shows these 50 words.

TABLE XXXV. New Method words not in the Carnegie vocabulary

(a) words to be added to Carnegie		
acid	garment	nerve
ant	hen	obtain
bee	horn	pillar
boot	jelly	pole (= staff)
bowel	lamb	port
breast	lime	range
candle	magic	rose, a
cease	microscope	spear
cigarette	mist	trousers
compass	muscle	vegetable
(b) Words considered unnecessary for science		
adjective	fulfil	participle
bear (n.)	grief	prince
bible	keen	silly
desert, to	knight	slang
fairy	lion	swift
fortress	nasty	tense
fox	palace	(of verb)

Of the Flood-West vocabulary, 158 words are already in the Carnegie list, i.e. the Carnegie Conference considered these words of general utility. Thus there are 321 words to be added. Further, the Carnegie list includes "mine" but not "mineral" and "resist" but not "resistance" (needed in electricity). By also adding in the 51 "wanted" words (Table XIII of the Appendix) a final list of 404 words is obtained. This list converts the Carnegie vocabulary into a vocabulary for popular science. It is set out in Table XVII of the Appendix. It is to be published in the revised edition of the Carnegie Report in 1949. It represents the final outcome (in respect to vocabulary) of the dictionary experiment.

9. ANALYSIS OF THE VOCABULARY OF THE ELEMENTARY SCIENCE READERS

The Elementary Science Readers originated from an attempt to provide a series of readable but informative books on the elementary principles of physics and chemistry for people in West and East Africa. After six had been written, it was decided to make certain modifications so as to render them suitable also for English children in Secondary Modern Schools. Ultimately, English and African editions will be available.

At present[1] the scripts of six books have been completed. They deal with:

---

1. December 1948.

1. The Earth - Shape, size, day and night, seasons, rocks, soil, geological evolution.
2. The Air - Physical properties and applications, weather, chemical composition, combustion, aviation.
3. Light - The elementary principles, including colour, optical instruments, invisible radiations, photo-electric cell.
4. Machines and Engines - Simple mechanical contrivances, hydraulic contrivances, pneumatic machines, wind-, water-, steam-, oil-, electric- power.
5. Minerals, Extraction of useful materials - Building materials, coal, oil, the common metals, jewels.
6. Electricity - The standard elementary principles.

Books on Heat and on Properties and Structure of Matter are to follow.

The vocabulary was analysed after the texts had been prepared for the African readers. A few slight changes are being made for the English editions. As the native languages of people in West Africa are not English, the texts were written with deliberate vocabulary economy. They therefore provide an experiment in the vocabulary necessary for the exposition of elementary science. The experiment contrasts with the dictionary experiment in that (1) the texts are continuous, (2) the texts are informal and "readable".

The writer started with a vocabulary drawn up by H.A.Harman.[1] This vocabulary was based on the Carnegie list, West's New Method list, Palmer's "zones", and other sources. It was drawn up subjectively. The writer was one of the first to try this vocabulary and his findings are recognised as tests of it. As this vocabulary was only tentative, the writer was allowed to use other words at his discretion, in accordance with his requirements, so that, in effect, the provided vocabulary was only a guide to a vocabulary experiment.

The six books represent about 200,000 words. (Diagrams and pictures were also used.) Within the range of subject matter covered, this seems adequate for study. It is important to note that no attempt was made to reduce the vocabulary to a minimum. "Dignity" words and verbal illustrations were used whenever it seemed desirable. A few words of "local" colour (e.g. yam) were excluded from the analysis.

The first investigation was a comparison between the vocabulary which was used and the Flood-West vocabulary. As anticipated, many words of the Flood-West list were re-discovered. (It was not expected that all would be re-discovered because the Readers did not cover the whole range of science and were of an elementary standard.) In view of the elementary nature of the Readers, some of these

---

1. Late Assistant Director of Education in the Gold Coast, now of Messrs Longmans, Green & Co.Ltd.,

words, especially any in Lists A, were explained, or made inferable, when first used. It was found that 346 words of the Flood-West vocabulary had been used. This number included 35 words in List A. (It is already apparent that subsequent books will reveal the necessity of other words in list A, e.g. atom, ion, nucleus, and molecule in the proposed book on the structure of materials.) In view of the magnitude and thoroughness of the dictionary experiment, the discovery of the need of these 346 words is of little significance. The words are therefore not here tabulated.

Of greater importance are the words which the writer used but which are not in the Flood-West vocabulary. The list of these words (81) is given in Table XVIII of the Appendix. Many of the words are immediately recognised as words of general utility i.e. they are not scientific words. Examination showed that 60 of them are in the Carnegie vocabulary. As the outcome of the dictionary experiment was finally expressed (for reasons given) as an addition to the Carnegie vocabulary, it is necessary, in this experiment, only to examine the words which are extra to both the Flood-West and the Carnegie vocabularies.

In compiling this list of extra words, care was taken to ensure that, if the word is included in the Carnegie list, it is included with the desired meaning. The word "apply", for example, is in the Carnegie list but restricted in meaning to "apply for a position". The meaning "apply a force" is excluded. After the list of extra words had been drawn up, consideration was given to the need and/or desirability of using each word. The results of this examination are given in Table XXXVI.

Table XXXVI. Words used in the Elementary Science Readers extra to those of the Flood-West and Carnegie vocabularies.

Word	Comments
apparatus	"Instrument" is not an exact equivalent; a chemist would not call his assembly of glass-ware an instrument. The word seems to be essential.
apply	A very convenient word e.g. to apply a force, electric pressure, etc.
assume	A useful dignity word. Sure to be known by an English reader.
awkward	A useful dignity word. Sure to be known by an English reader.
bay	Essential in geographic texts, really outside a vocabulary for science.
blotting-paper	Useful as a familiar example of a porous material. Almost sure to be known by all types of readers.
cape	As for bay.
crane	An essential word (It is childish and awkward to evade it.)
hoe	Unnecessary. (Used only once.)
however (= but)	The use of this word to mean "but" is very common and is liable to be used unconsciously by writers inexperienced in vocabulary control. Its use is unobjectionable for English readers. The foreigner learns the word to mean "in whatever (way)". For him it is better to start a sentence with But even though purists object to this practice.
instruction	Avoidable but very useful. (Sure to be known by an English reader.)

Table XXXVI Continued:

Word	Comments
jar	Most limited vocabularies (e.g. New Method, Carnegie) are deficient in the names of containers. A jar is a homely example of a small container in this country but not so well known overseas.
kite	Considerable use was made of this word in a chapter on aeroplanes. It is probably well-known and can be introduced via a picture.
knob	A very useful word for a small projection e.g. the contacts of an electric bulb. Considered essential.
oven	Neither "fire" nor "furnace" give quite the right meaning. This word (or "stove") seems essential.
pedal	An essential word, familiar through the bicycle.
spices	Unnecessary; used only once.
tiny	Avoidable (the alternative is "very small"). The writer found this word very liable to creep in as an error of vocabulary control.
trip, to	Used only once. Avoidable by "fall over".
truck	A very desirable word. "Cart" is childish and often an unsatisfactory alternative. The word is sure to be known (via the railway) by all types of readers.
tunnel	A very useful word when dealing with railways, quarrying, mining, etc. The writer considers it essential.
This list excludes names of animals (e.g. giraffe), names of chemicals (e.g. nickel), etc.	

It appears, therefore, that as the result of the study of 200,000 words of continuous text, only eight additional words (apparatus, apply, crane, knob, oven, pedal, truck, tunnel) have been proved to be necessary. It is impossible to know when saturation has been reached but it is unlikely that many more words will be found. None of these words are list A words but apparatus, apply, crane, pedal might prove to be list B words.

In the course of writing a note was kept of words which were actually explained but which seemed to be desirable in any working vocabulary. After re-consideration, it is recommended that concave, convex, direct current should be added to the vocabulary. Four other words were noted as desirable but not essential i.e. "wanted" words. These are focus, fuel, spray (v.), and tank (= container). The final outcome of the experiment with the Readers is therefore the addition of eleven words, with four more "wanted" words, to the vocabulary determined by the dictionary experiment. These additional words are recorded in Table XXXVII.

Table XXVII. Words to be added to the vocabulary (based on the experiment with the Elementary Science Readers.

apparatus	direct current	pedal
apply	*focus	*spray, to
concave	*fuel	*tank (= container)
convex	knob	truck
crane	oven	tunnel

* "wanted" but not essential.

PART VI.

SOME TECHNIQUES IN THE WRITING OF TEXTS OF POPULAR SCIENCE

PART VI. - Some techniques in the writing of texts of popular science.

		Page
Section 1.	General comments	222
2.	Some methods of vocabulary control	224
3.	Some particular points of technique	234

1. GENERAL COMMENTS

A text of popular science can be prepared in three ways:

(a) by original composition

(b) by re-writing (simplifying) material already existing

(c) by translation from a text in another language.

Most texts are prepared by original composition. Just as the words and music of a song should be conceived together, so too a text should be written for a particular type of reader. A popular adaptation of a difficult text is seldom successful. Translation from another language should never be necessary in popular science.

Re-writing and simplification of existing texts, however, is a possible, and even desirable way of making certain English texts available to readers whose native language is not English. The original text may have been designed for an "ordinary" English reader, and its general style and exposition may be admirable, but certain elements of difficulty (e.g. vocabulary, sentence construction) may make it unsuitable to the foreign reader. A number of successful popular science books (e.g. those by Andrade, Bragg, and Huxley) are worthy of re-writing and great opportunities exist for the re-writing of several of the popular science periodicals (e.g. Science News). Extract C in Part V section 7 indicates the type of re-writing which is necessary.

Some authors have the peculiar gift of writing readable, stimulating, and informative texts. Is this a kind of magic art or is it due to a conscious employment of successful techniques ? In many cases the author is probably unconscious of the secrets of his success. But this does not prevent other would-be authors from learning successful techniques. At present the techniques of writing popular science for the "ordinary" man have not been fully analysed. The provision of a complete guide to successful writing is impossible. Much research has yet to be done. The present writer has scarcely touched the fringe of the problem.

The art of exposition is essentially the art of teaching. It has already been stressed that the author should be a combination of expert, filter, and teacher. Ability to teach is the result of experience, study, and ~~one~~s personal make-up. But it is not necessary in this thesis to discuss the general principles of teaching method.

Considerable space has been given in this work to vocabulary and phraseology. It is well realised that even if attention is given to such elements, and to the general principles of exposition, a~~s~~ text may still be difficult. Difficulty of comprehension obviously depends also upon the nature of the concepts expounded. This lies partly outside the control of the author. Yet an author must not too readily assume that a topic is too difficult to explain to an ordinary reader. Several times in the course of the dictionary experiment a topic appeared to be beyond explanation to an ordinary reader (hyperbolic functions is an example) but it was found that a reasonable measure of explanation could be achieved by the repeated operation of the expert-filter technique. Attention was drawn in Part I to the gap between the scientist and the ordinary man. If the gap is not bridged it may become a chasm. Difficulty of explanation is a challenge to the author.

2. SOME METHODS OF VOCABULARY CONTROL

In Part V the need for vocabulary control was established and minimum adequate vocabularies worked out. It is now assumed that an author is attempting to write within some limited vocabulary. Are there any special techniques in using limited vocabularies ?.

The vocabularies may be limited with respect to scientific terms only. Such a vocabulary might be used in preparing texts for English readers. Limitation of "ordinary" words is unnecessary (providing the style is not needlessly pompous or involved). For foreign readers the vocabulary must also be limited with respect to "ordinary" words. (The Flood-West and New Method lists constitue such a vocabulary.) Consideration is first given to the limitation of scientific terms. Most of the techniques which are described are obviously applicable also to the limitation of ordinary words. But limitation of ordinary words is a greater problem and requires some further comment.

Some sources of error in the control of scientific terms

Experience of writing within limited vocabularies has revealed to the present writer two very common sources of error.

(1) There are some words which as commonly used lie within most elementary vocabularies and which are sure to be known by the reader, but which are used in science with special or restricted meanings. Examples are work, power, mass, pressure, energy, paraffin, strain. The first three words (and also press) occur in the New Method 1490 list. But the scientific usage of these words may well lie outside the permitted vocabulary. Unless the scientific usage of the word is specifically included in the vocabulary the word must not be so used. Much difficulty is caused by an unwary author who overlooks that his special scientific use of an ordinary word may not be known to the reader. The suggestion is here made that in popular science writings a word used in a scientific sense should be rendered distinct from the word used in an ordinary sense. This could be done, for example, by giving the word a capital letter or by adding the symbol (S) when used in a scientific sense. Thus

power = strength, ability

Power or power(S) = rate of doing work.

(2) Some words are used in science with two related meanings but only one may be known to the reader or be permitted by the limited vocabulary. Consider, for example,

the word "condense" and its derivatives "condensation", "condenser." Condense (= change from vapour into a liquid) may be known and/or permitted by the vocabulary. Condenser (= vessel in which a vapour condenses) and condensation (= process of turning into a liquid) are permissible derivatives. But the unwary author may use "condenser" in its electrical sense and "condensation" as applied to coalescence of organic molecules. Ogden allows such usages (see Part V, Table XXX) but the writer suggests that such practices confuse the reader and constitute a source of difficulty. Words of this kind are quasi-homonyms; although the various usages are essentially one, etymologically, they are effectively different words. An author must be sure that his usage of a word is consistent with the usage stated or implied in the given vocabulary.

Methods of introducing "outside" words

In the development of his subject an author must introduce words which are outside his permitted vocabulary. Thus in one of the Elementary Science Readers ("The Wonders of Light") Flood introduced the words: arc, concave, convex, crescent, filament, lightning, opaque, penumbra, periscope, refract, retina, searchlight, stearin, submarine, tallow, tank (= box), umbra. Many other harder words which were within the vocabulary (e.g. bulb, reflect, lens, image) were also explained. An author, of course, must be sure that the outside word is really needed and that he is not using it from force of habit or from a sense of dignity.

Outside words can be introduced in a variety of ways.

(1) The book or periodical can be provided with a glossary in which any outside words used in the book are explained. This has already been done in certain popular science books but it appears that the words for inclusion in the glossary have been chosen haphazardly. Glossaries at present often explain relatively easy words and omit relatively hard ones. Thus the glossary of New Biology V includes cell, habitat, red blood cells, shoulder girdle, vertebrate. Within the articles, the following words are used without explanation: artifact, histological, mucilaginous, multiseriate, heterotrophically, and others of equal obscurity. But the provision of a glossary, even if it is properly constructed, is only satisfactory if the number of outside words is small.

(2) The word can be explained in a footnote. This procedure would be tedious if the number of words so treated were large.

(3) The word can be explained in brackets immediately after its use, e.g. "vitreous (glass-like) material"
"the waterproof cuticle (skin)"
This procedure is limited to words for which the explanation can be brief. Generally a near synonym will be given.

The practice of linking synonyms by the word "or" in an attempt to effect an explanation unobtrusively is objectionable. Phrases of the following type are not uncommon:

"the amplification or strengthening of the current"

"using 1 oz. of albumin or egg-white"

The word "or" means an alternative, that is, opposite. If the reader does not know the meaning of amplification, he argues thus. "or" means "opposite". The opposite of strengthening is weakening. So amplification means weakening. A better procedure is to use "that is".

(4) The word can be inferable by faking the sentence so that the meaning of the word is apparent without a formal explanation having been given, e.g.

"a protein diet, e.g. one containing plenty of meat and cheese,....."

(5) The word can be deliberately explained, if necessary at some length, as an essential part of the text. This is clearly necessary when the word is a "key" word in the particular book or article. Thus in an article on Weather Forecasting it may be necessary to "teach" the words cyclone, isobar, cold-front, etc. Such formal explanations should come before the word is used. The reader should not be allowed to crash into a difficult word and then to lose the thread of the argument in a digression introduced to explain it.

<u>The use of proper names</u>

Proper names e.g. names of chemicals, plants, rocks etc. are, in general, outside vocabulary control and may be used without qualification. Thus the name Iridium for a metal is no more difficult than the name Smith for a character in a book. Specific "low-level" words cannot be avoided. There is no synonym for calcium, glycol, or geranium. Sometimes reference to a familiar experience helps to identify the thing named e.g. "calcium (the metal in lime)......."

"glycol, as used for an anti-freeze in cars,....." Latin names, especially in Botany and Zoology, should wherever possible, be translated. A translation adds interest and helps to make the word stick in the memory; it also helps to build up a vocabulary of roots, prefixes, and suffixes which is useful on other occasions. There is sometimes a gain in clarity if the class or nature of the named thing is given, e.g.

..... by means of the enzyme diastase

..... the hydrocarbon xylene

..... the juice of the tree Pistacia

Care must be taken when using a name not to assume knowledge of the nature or properties of the thing. This danger occurs more frequently with class - or "higher level" names e.g. ketone, coniferae, coelenterates, silicates. Such names are often used (wrongly) with an assumption of knowledge of the characteristics of the class. The characteristics should be explained, if necessary, or made inferable by the naming of a familiar example of the class. This latter device is very useful. Examples are:

... carbohydrates (like sugar and starch)....

... Agaricales (which includes the common mushroom)....

A word of intermediate level can often be avoided by the combination of a high level word with low level word(s) e.g.

carnivore = flesh-eating animal

compositae = daisy-like flowers

No vocabulary can predict with certainty the names of everyday things which will or will not be known. The writer, having defined his readers, can add such names to his vocabulary as he thinks will be known. Thus Flood, in the African editions of his Readers, used the name "kerosene" without qualification, because kerosene is a familiar commodity in West Africa and is known by that name.

Vocabulary control of "ordinary" words

When the writing vocabulary is limited with respect to "ordinary" words, as in the preparation of texts for foreign readers, the task of the author is more complex. It must be noted, however, that the fixing of a rigid boundary to a vocabulary is neither necessary nor wise. Just as an author should not use too freely words which approach the outer limit of a vocabulary, so too he should not exclude too rigidly words which lie just beyond it. He cannot assume that the reader knows precisely the words of the vocabulary - neither more nor less. If the general education and study of the reader have brought him to the level of the vocabulary, he probably knows, and certainly will not be disturbed by, a few extra words. (This is not necessarily applicable to scientific words.) Facility of writing within limited vocabularies comes with the experience of writing. The Elementary Science Readers show that a smooth, readable style can be achieved even within a vocabulary of less than 2,000 words.

The process of writing the text may be actual translation from an existing text, but original composition is little different from translation. The author effectively translates from his normal language into a simplified language. In both cases the problem of using "outside" words arises. Some of the methods for introducing outside scientific words are applicable but, in general, the outside "ordinary" word should be avoided rather than introduced. The word can be dealt with in two ways:

(a) The phrase or sentence in which the word occurs can be deleted. It is possible that the word was used purely for style or that the reference is merely an unimportant interpolation. The deletion may be made without loss to the text.

(b) The word can be avoided by replacement or substitution. This may be by the use of a near synonym or by periphrasis.

Replacement by near synonym is only possible in a small proportion of cases. In some instances simplification may be effected without significant change of meaning by replacing a low-level word by a higher-level word. Thus it may be possible to replace bacon by meat, sparrow by bird, and so on. Another device is the replacement of the name of an article by the Trade name of a particular make of that article e.g. Thermos for vacuum flask. This is only possible, of course, when the author knows that, for his particular readers, the trade name is better known than the general name.

Replacement by periphrasis can be effected in a variety of ways. Each author will devise his own techniques for each particular circumstance. It must be noted that when a phrase or chiché has been constructed for a particular linguistic symbol, it may not be applicable to all occurrences of that symbol. Much depends upon the context. If it is found that a word needs frequently to be replaced by periphrasis, it becomes a "wanted" word. It should be "taught" at its first occurrence and then used as a word of the vocabulary. A "taught" word should be introduced several times soon after its introduction in order to increase familiarity.

Care must be taken to substitute the names of local equivalents of common things. Thus "yam" may be preferable to "potato", "hoe" to "spade", and "orange" to "apple". In a like way, metaphors and similes must be replaced by their local equivalents. It is clearly necessary for the author to be acquainted with the local conditions.

It must be noted that vocabulary control is insufficient if this means the rejection of words outside the vocabulary but the use of words within the vocabulary <u>in all their senses and combinations.</u> As Palmer[1] has pointed

1. Palmer H.E. The Grading and Simplifying of Literary Material.

out, regard must be paid to the "principle of lexicological proportion." The inclusion of a word in the vocabulary is no justification for using it in all its senses and collocations. It is very necessary to observe some proportion between the radius of the vocabulary and (a) the degree of regularity of the derivatives of the words in it, (b) the semantic varieties of the words, (c) the non-normal collocations of the words. The "test of translation" (into the native, or other, language), mentioned in Part V section 3, is of value in considerations of (b) and (c).

Finally it is recognised that vocabulary is not the only source of difficulty for readers of limited ability in the language. Reference has already been made to the work of Gray and Leary.[1] They made a detailed study of the factors of intelligibility in general (non-scientific) reading matter. They estimated (by means of reading tests) the difficulty of selected passages and then found the degree of correlation between the difficulty score and the presence of various factors which might be a cause of difficulty. From 44 structural elements which bore some relationship to difficulty they selected 8 of particular significance: number of different hard words, number of easy words, percentage of monosyllables, number of first, second, and third-person pronouns, average sentence length in words, percentage of different words, number of

1. Gray W.S. and Leary B.E. *What Makes a Book Readable.*

prepositional phrases, number of simple sentences. They found that of these, all but the 2nd. 3rd. and 4th. are elements of difficulty. To these the writer would add the presence of figures of speech and the absence of paragraph headings.

3. SOME PARTICULAR POINTS OF TECHNIQUE

In the course of the compilation of the dictionary (with West) and the writing of the Elementary Science Readers, certain particular points of technique emerged. The list of these, which is now presented, is not meant to be exhaustive; neither does it provide the Open Sesame to successful popular science writing. But these techniques, fashioned in the light of experience, appear to be of sufficient value to merit record. Some of the points may seem rather elementary yet it is surprising how often popular science writers overlook them. These techniques are obviously of great importance in the preparation of texts for foreign readers. As, however, the English reader needs a clear style, in order that he may give his full attention to the subject-matter, they are not inapplicable to the writing of texts for him.

(1) A long awkward sentence is better split into two or more shorter sentences. (See, for example, Extract B in Part V section 7). An appearance of jerkiness and obvious simplification may be avoided substituting semi-colons for full-stops. The active is usually

clearer than the passive. The use of the future tense to mean "is in the habit of" is objectionable, especially for young readers and readers whose native language is not English. It is objectionable (and unnecessary) to write "the enzyme will attack starch"; the present tense is adequate and not misleading. So also the use of "would" to mean "is probably" is objectionable (e.g. This would be Pyrites, I suppose").

(2) The use of verbal illustrations is an elementary practice of teaching procedure. It is worth pointing out, however, that scientific units should be interpreted in terms of common experience. Thus "volt" should be interpreted in terms of a flash lamp or car battery, "foot-candle" in terms of the normal requirement for reading, and so on. Some attempt should be made to help an understanding of the very big and the very small by comparison with known magnitudes. Some magnitudes, however, lie beyond the threshold of understanding e.g. astronomical and atomic magnitudes. It is extremely doubtful if verbal (or pictorial) illustrations can help in such cases.[1]

(3) A very common cause of unintelligibility is lack of examples. A concrete example not only makes the generalisation easier to understand, it adds greatly to interest. In medicine it is the case-histories

---

1. For some discussion of this, see Adams J. Exposition and Illustration in Teaching. (Macmillan). Chapter XII.

which give reality to the general discussion; so also in mathematics a process may suddenly become intelligible to the learner when he is told of one of its practical uses. Yet there is in some writers and lecturers a curious inhibition against giving practical examples, as if they are afraid to come down to earth - afraid that their learned generalisation made concrete might lose some of its impressiveness (as indeed it often does).

(4) Some things cannot be explained in words; they are essentially visual. Thus it is almost impossible to explain what a spiral is (other than by mathematical expression) without recourse to drawing or action. Obviously diagrams and/or pictures must be given. The paucity of diagrams in popular science writings may be explained by the fact that many writers have an exaggerated idea of the cost of making line-blocks.

If space allows, the parts of a diagram should be indicated by name rather than by symbol. When symbols are used they should be chosen so that they suggest the name. Thus S should be chosen for Switch, B for Battery, and so on. (Difficulties arise, of course, when two parts begin with the same letter; double letter arrangements, e.g. By for battery, should be used.) A line in a diagram can conveniently be designated by using the first and last letters of its name. Thus a normal can be labelled by N at one end and L at the other, a mirror can be labelled M..R, and so on.

Pictures and diagrams should be purely factual. A whimsical style is usually offensive to an adult reader and engenders distrust of the soundness of the work.

(5) Reading material is essentially visual. No one reads a dictionary aloud, few people read books of popular science aloud. (This Part of the thesis deals solely with written material.) Practices which may be objectionable in speech may be permissible or even desirable in written material.

In general, there should be no need to use "the former" and "the latter". The mathematician does not say "x plus y squared is equal to the former squared plus twice the product of the former and the latter plus the latter squared". He re-uses his original terms x and y. So too in reading material, repetitions of words (which might be objectionable when reading aloud or speaking) are often conducive to clarity.

In a similar way, the use of "this substance" or "this plant" etc. should be kept to a minimum. It is clearer to repeat the name of the substance, plant, etc.

Pronouns are a common cause of misunderstanding. The main function of a pronoun seems to be euphony; in eye-language and in writing whose chief object is clarity, the repetition of the noun is often desirable.

Abbreviations which might be objectionable in the spoken word are sometimes used with advantage in the written word. A neat example occurs in "The Wonders of Light" (Flood). In order to avoid the use of the word "normal" (in its geometric sense) the writer introduced the term "right-angle line". After pointing out the abbreviation, the term "RA line" was used subsequently. The abbreviation led to greater speed of reading and so of understanding of the passages. In the dictionary (which no one reads aloud) greater use was made of abbreviations. When a key word was repeated in any entry, e.g. the word enzyme, it was designated by its first and last letters e.g. e.e .

(6) Negative explanations can be of value. Examples are: "using a mineral oil (obtained from rocks, not from plants)......" "We do not obtain aluminium by smelting its ore with carbon but by...."
The quotation of the negative reinforces the accompanying positive.

(7) The importance of explaining etymological elements has already been noted. It is of great value in vocabulary building. In the dictionary experiment the idea was followed by grouping together all words based on the same root, e.g. lign-, ligneous, lignin, lignite were explained (in a group) before ligne.

(8) The author must be careful not to irritate the reader. Irritation is certainly caused by a failure to explain what the reader cannot be expected to know; it is also

caused by explaining what that reader can well be expected to know. (But the reader is flattered if an explanation is given of something he happens to know.)

Finally, one point must be emphasised and one question asked. Too much stress can be put on "laying a sound foundation". The value of a sound foundation is not denied but its laying must not discourage the reader (or hearer). It must be remembered that most people learn popular science (by book or lecture) voluntarily. One cannot expect them to drink deeply until they have at least tasted the Pierian Spring - not merely lapped at its muddy edge. One defect of the traditional Grammar School physics course is that it consists largely of foundations; the average pupil who leaves school at 16 enjoys little or none of the superstructure and loses interest in the subject. Too often a reader of popular science is discouraged by the apparently aimless labour of laying a foundation. "I don't seem able to get on with this because I don't know what it is all about or where it is leading". This is not a plea for running before walking or for flashy "wonders" of science, but a popular science text must reach further than the foundations. If a "nucleus of understanding" is established knowledge can spread outwards.

The query is this: Is there any one best possible explanation of a difficult point or subject ? In the course of the dictionary Flood and West met many awkward topics (e.g. calculus, entropy, relativity). Writing, filtering, and re-writing resulted in many versions of explanation, some along different approaches, some in detail, some more general, and so on. The final (accepted) version was deemed to be the best. Suppose unlimited time and money were spent in writing, filtering, testing, re-writing. Would it be possible-to evolve a perfect, unsurpassable explanation of one of these difficult topics ? Or does it depend upon the characteristics of the pupil and of the teacher ?. If it were possible to evolve some optimal explanation (i.e. better than all others) how many millions of school hours might be saved throughout the world and with them pounds of public money. One wonders what was the cost to the British Empire of the inadequate explanations in the old arithmetic books - and old-fashioned Euclid. A study of techniques is a valuable undertaking.

SOME FURTHER PROBLEMS FOR RESEARCH

SOME FURTHER PROBLEMS FOR RESEARCH

In the course of the studies described in the previous pages, and in other considerations of the propagation of science to the ordinary man, many problems have emerged. A list of those problems which might form the bases of further research are given below.

Interests, Viewpoints etc.

(a) What fraction of the adult population (i) reads popular science books, (ii) attends popular science lectures, (iii) listens to popular science broadcasts ?.

(b) To what extent, and in what way, is interest in popular science related to (i) schooling or previous training in science, (ii) occupation ?

(c) Why are many adults apparently not interested in science?

(d) To what extent is interest related to (i) ability in science e.g. when at school, (ii) general interest in reading ?

(e) To what extent does school-science provide science for citizenship ? In what ways could school-science be modified towards this end ?

(f) What fraction of people, having begun to read a standard popular science book (e.g. Science for the Citizen) have failed to finish reading it.? Why did they not finish it ?

(g) Do people prefer a long book, a short book, or a series of short articles on popular science ?

(h) To what extent is interest influenced by the general style and format of the book ? What are the significant factors of style and format ?.

(i) An extended study of viewpoints (Part IV).

(j) A critical examination of newspaper-science as regards (i) accuracy, (ii) interest, (iii) assumed standard of knowledge, (iv) constancy of standard.

(k) A similar examination of broadcast-science.

(l) An examination of the particular interests of readers of popular science books and periodicals.

Comprehension

(a) What are the chief causes of difficulty in standard popular science books such as Science for the Citizen ?

(b) Is difficulty of comprehension related to preconceived impressions of difficulty ?

(c) To what extent do (i) familiarity with the subject, (ii) interest in the subject, affect comprehension ?

(d) On what factors (within the text itself) does difficulty of comprehension depend ?
How much weight can be given to non-scientific vocabulary and to structural elements in determining the difficulty of popular science book for an English reader ?

(e) Are people frightened by mathematical expressions ? To what extent do arithmetical examples add to, or detract from, comprehension ?

(f) To what extent do (i) scientific names (e.g. names of chemicals), (ii) chemical formulae add to, or detract from, comprehension ?

(g) To what extent (if any) do frequent paragraph headings aid comprehension ?

(h) A study of different versions of the same topic to determine if an optimal exposition is possible.

(i) A study of different verbal illustrations (or analogies) in the explanation of a particular topic.

(j) A study of possible methods of aiding comprehension of magnitudes which are outside daily experiences.

Vocabulary

(a) What is the average scientific vocabulary of
  (i) readers of popular science books and periodicals,
  (ii) the ordinary person who does not, at present, read popular science books,
  (iii) the pupil on leaving a secondary Modern School ?

(b) Do the average vocabularies of (a) vary significantly with (i) sex, (ii) locality ?

(c) What is the vocabulary burden of an average popular science book ?

(d) How far can scientific terms and names be understood through a knowledge of roots, suffixes, prefixes, etc.?

(e) A more extended study of the grading of the Flood-West vocabulary.

Use of Visual Material

(a) What is the value in a book of
 (i) general pictures, e.g. views of factory lay-out, of farms, of country to be developed for minerals, etc.
 (ii) specific pictures e.g. of a particular apparatus, machine, biological organism, etc. ?

(b) To what extent do people understand diagrams ? A study of the techniques of making diagrams.

(c) To what extent do people understand charts and graphs for showing magnitudes, variations, etc. A study of the types of charts and graphs which are most effective.

APPENDIX

1. Detailed Tables.

2. Bibliography.

TABLE I.

TABLE I.

Students

Question

Females (242)
Males (366)
All Students (608)

TABLE I. Analysis of motives (A and B votes) of all students attending lecture-courses in Natural Sciences.

Students present: 652 in 55 classes

Questionnaires returned: 626

Questionnaires discarded as useless: 18

Useful questionnaires: Female 242, Male 366.

		Vocational				General desire for					Knowledge		Social and Recreational						Misc.
		a	b	c	Total	d	e	f	g	h	i	Total	j	k	l	m	n	Total	o
Females (242)	A	14.2	1.3	0.4	15.9	8.6	0.2	4.1	3.0	22.6	9.6	48.1	1.3	4.3	2.7	6.2	16.5	31.0	5.0
	B	6.9	1.1	2.7	10.7	9.9	1.6	0.6	-	15.2	16.4	43.7	3.3	18.5	4.5	5.0	12.8	44.1	1.5
Males (366)	A	15.1	3.5	2.6	21.2	4.0	0.3	5.5	2.2	24.5	9.1	45.6	1.1	3.0	2.0	13.9	12.3	32.3	0.9
	B	5.9	3.3	4.2	13.4	8.9	3.1	0.8	0.7	13.2	16.9	43.6	3.3	15.0	3.0	8.5	12.2	42.0	1.0
All Students (608)	A	14.8	2.6	1.7	19.1	5.8	0.3	4.9	2.5	23.8	9.3	46.6	1.2	3.5	2.3	10.8	14.0	31.8	2.5
	B	6.3	2.4	3.6	12.3	9.3	2.5	0.7	0.4	14.0	16.7	43.6	3.3	16.4	3.6	7.1	12.4	42.8	1.3

TABLE II

TABLE II. Detailed analyses of A motives by subject and age. (Percentages)

(1) Biology

	No.	Vocational				Desire for knowledge							Social and Recreational						Misc.
		a	b	c	Total	d	e	f	g	h	i	Total	j	k	l	m	n	Total	o
Females under 30	32	28.1	7.8	2.7	38.6	9.4	-	0.5	-	10.5	1.6	22.0	-	3.7	1.1	8.5	19.9	33.2	6.2
30 - 40	33	15.4	-	-	15.4	13.7	1.5	6.1	3.0	18.4	4.1	46.8	-	3.5	4.1	4.8	22.4	34.8	3.0
over 40*	38	10.8	0.9	-	11.7	6.0	-	2.6	-	23.6	15.2	47.4	0.9	7.0	5.9	6.9	17.6	38.3	2.6
All females	103	17.7	2.8	0.8	21.3	9.5	0.5	3.2	1.0	17.9	7.4	39.5	0.3	4.9	3.8	6.7	19.6	35.3	3.9
Males under 30	20	34.6	6.2	2.9	43.7	-	-	1.7	-	16.7	5.8	24.2	-	-	-	19.6	12.5	32.1	-
30 - 40	37	16.7	5.4	4.5	26.6	5.9	0.5	6.3	9.5	16.7	6.4	45.3	-	1.9	0.5	15.3	10.4	28.1	-
40 - 50	46	6.3	-	6.2	12.5	8.8	-	7.6	2.2	16.5	11.7	46.8	-	1.9	1.3	20.0	15.7	38.9	1.8
over 50	43	3.9	6.6	-	10.5	1.8	-	6.0	-	27.0	13.8	48.6	0.8	3.6	1.1	22.3	13.1	40.9	-
All males	146	12.1	4.2	3.5	19.8	4.8	0.1	6.0	3.1	19.6	10.2	43.8	0.2	2.1	0.9	19.5	13.1	35.8	0.6
All students	249	14.4	3.6	2.4	20.4	6.8	0.3	4.8	2.2	18.9	9.0	42.0	0.2	3.2	2.1	14.2	16.0	35.7	1.9

(2) Geology

	No.	a	b	c	Total	d	e	f	g	h	i	Total	j	k	l	m	n	Total	o
Females under 40	18	8.3	-	-	8.3	-	-	2.8	8.3	15.7	1.9	28.7	1.9	3.7	2.8	22.2	27.8	58.4	4.6
over 40	14	9.5	-	-	9.5	-	-	21.4	14.3	5.3	3.0	44.0	2.4	3.0	3.0	22.6	11.9	42.9	3.6
All females	32	8.9	-	-	8.9	-	-	10.9	10.9	11.2	2.3	35.3	2.1	3.4	2.9	22.4	20.8	51.6	4.2
Males under 40	29	32.0	4.4	1.1	37.5	1.1	-	6.7	2.8	9.1	-	19.7	2.1	0.9	7.1	23.2	9.5	42.8	-
over 40	32	19.7	3.4	-	23.1	0.9	0.3	-	7.8	24.4	3.6	37.0	1.7	4.7	2.4	18.2	8.5	35.5	4.4
All males	61	25.8	3.9	0.5	30.2	1.0	0.2	3.3	5.5	16.9	1.9	28.8	1.9	3.0	4.4	20.4	8.8	38.5	2.5
All students	93	20.0	2.5	0.4	22.9	0.7	0.1	5.9	7.3	15.0	2.0	31.0	2.0	3.1	4.0	21.1	12.9	43.1	3.0

(3) Physical sciences

	No.	a	b	c	Total	d	e	f	g	h	i	Total	j	k	l	m	n	Total	o
Females	14	35.7	-	-	35.7	11.3	-	1.4	-	27.0	5.0	44.7	-	7.4	1.8	-	10.4	19.6	-
Males	32	23.5	4.2	2.9	30.6	2.1	1.1	6.3	1.0	22.1	8.2	40.8	3.1	1.0	1.9	7.1	15.5	28.6	-
All students	46	27.3	2.9	2.0	32.2	4.9	0.8	4.8	0.7	23.7	7.2	42.1	2.1	2.9	1.9	4.9	13.9	25.7	-

Table Continued:

* Includes 6 over 50.

TABLE II (Contd)

TABLE II - Continued

(4) General science

	No.	Vocational				Desire for knowledge							Social and Recreational						Misc.
		a	b	c	Total	d	e	f	g	h	i	Total	j	k	l	m	n	Total	o
Females under 40	10	15.0	-	-	15.0	-	-	15.0	-	28.3	10.0	53.3	3.4	8.3	5.0	-	15.0	31.7	-
over 40	9	11.1	-	-	11.1	22.2	-	5.6	-	35.6	13.3	76.7	-	2.2	2.2	-	7.8	12.2	-
All females	19	13.2	-	-	13.2	10.5	-	10.5	-	31.8	11.6	64.4	1.7	5.4	3.7	-	11.6	22.4	-
Males under 40	22	28.8	12.9	10.6	42.3	0.9	0.9	3.8	-	15.3	3.8	24.7	-	2.4	-	6.8	13.8	23.0	-
over 40	25	10.7	-	-	10.7	3.0	-	8.7	-	39.0	12.0	62.7	2.3	7.3	4.0	7.0	6.0	26.6	-
All males	47	19.1	6.0	5.0	30.1	2.0	0.5	6.5	-	28.0	8.1	45.1	1.2	5.0	2.1	6.9	9.6	24.8	-
All students	66	17.4	4.3	3.5	25.2	4.4	0.3	7.6	-	29.0	9.3	50.6	1.4	5.2	2.6	4.9	10.1	24.2	-

(5) Social science

	No.	a	b	c	Total	d	e	f	g	h	i	Total	j	k	l	m	n	Total	o
Females under 30	14	16.7	1.2	1.2	19.1	7.1	-	7.1	-	21.4	25.0	60.6	3.6	3.6	2.4	-	10.7	20.3	-
30 - 40	22	11.4	-	-	11.4	10.6	-	-	5.7	29.9	17.8	64.0	-	4.5	2.3	1.1	14.4	22.3	2.3
40 - 50	22	4.5	-	-	4.5	15.2	-	-	4.5	25.0	11.4	56.1	-	3.0	-	1.5	16.7	21.2	18.2
over 50	16	-	-	-	-	5.2	-	-	3.1	49.0	12.5	69.8	7.8	1.6	-	1.6	5.7	16.7	13.5
All females	74	7.9	0.2	0.2	8.3	10.1	-	1.4	3.7	31.0	16.1	62.3	2.4	3.3	1.1	1.1	12.5	20.4	9.0
Males under 30	8	-	3.1	3.1	6.2	3.1	-	-	-	34.4	34.4	71.9	6.3	8.3	-	5.2	2.1	21.9	-
30-40	15	25.0	-	3.3	28.3	5.5	-	-	-	37.2	6.7	49.4	-	1.7	-	-	13.9	15.6	6.7
40-50	28	3.4	-	-	3.4	9.5	-	4.0	-	41.4	13.7	68.6	1.0	2.8	2.8	9.2	12.2	28.0	-
over 50	29	2.7	-	0.4	3.1	5.7	1.0	10.7	-	36.1	11.1	64.6	-	5.1	4.0	4.4	18.8	32.3	-
All males	80	6.9	0.3	1.1	8.3	6.9	0.3	5.2	-	38.0	13.5	63.9	1.0	4.0	2.4	5.3	13.9	26.6	1.2
All students	154	7.4	0.3	0.6	8.3	8.4	0.2	3.3	1.8	34.7	14.8	63.2	1.7	3.6	1.7	3.3	13.2	23.5	5.0

TABLE III

TABLE III. ABCDE markings of males (241). (See Part III.)

	SUBJECTS																						
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
A	33	30	29	94	61	86	45	55	34	86	70	69	57	76	21	89	61	32	53	29	36	21	99
B	68	56	63	76	62	83	60	78	57	80	58	65	54	71	32	67	62	81	49	47	49	34	86
C	81	75	55	49	74	50	80	74	63	46	55	55	55	49	55	33	53	75	49	39	64	64	39
D	37	47	51	15	27	14	34	24	54	13	30	28	42	26	52	30	39	30	46	55	46	57	11
E	22	33	43	7	17	8	22	10	33	16	28	24	33	19	81	22	26	23	44	71	46	65	6

Chi-squared tests of significances of differences

The table shows the probability that the difference between any pair of subjects is due to chance.
* denotes that the probability is 1/100 or less.
Where the probability lies between 1/100 and 1/20 it is shown as parts per thousand.
The space is left blank where the probability exceeds 1/20.

1																							
2	-																						
3	*	-																					
4	*	*	*																				
5	26	*	*	*																			
6	*	*	*	-	*																		
7	-	-	*	*	-	*																	
8	*	*	*	*	-	*	45																
9	-	-	-	*	*	*	39	*															
10	*	*	*	-	*	-	*	*	*														
11	*	*	*	*	-	*	27	*	*	*													
12	*	*	*	*	-	*	14	20	*	23	-												
13	*	18	17	*	18	*	-	*	-	*	-	-											
14	*	*	*	33	-	47	*	20	*	-	-	-	11										
15	*	*	*	*	*	*	*	*	*	*	*	*	*	*									
16	*	*	*	*	*	*	*	*	*	27	50	-	*	-	*								
17	*	*	*	*	-	*	50	*	16	*	-	-	-	-	*	20							
18	-	38	*	*	13	*	-	18	*	*	*	*	*	*	*	*	*						
19	*	*	12	*	*	*	*	*	-	*	39	*	-	*	*	*	-	*					
20	*	*	16	*	*	*	*	*	*	*	*	*	*	*	-	*	*	*	*				
21	*	-	-	*	*	*	*	*	-	*	*	*	-	*	*	*	*	*	-	11			
22	*	*	*	*	*	*	*	*	*	*	*	*	*	*	-	*	*	*	*	47	26		
23	*	*	*	-	*	-	*	*	*	-	*	*	*	*	*	*	*	*	*	*	*	1	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23

TABLE IV

TABLE IV. ABCDE markings of females (150). See Part III.)

	SUBJECTS																						
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
A	27	20	14	47	23	42	1	48	4	96	88	59	63	86	5	50	43	33	12	24	29	9	52
B	45	60	28	48	51	62	14	47	25	34	34	42	44	31	11	47	42	58	32	31	40	29	43
C	42	44	31	24	40	26	48	31	32	11	17	29	21	21	24	26	33	38	37	26	38	42	33
D	27	22	30	20	21	14	41	19	47	4	8	16	11	8	41	13	21	17	33	29	26	38	20
E	19	4	47	11	15	6	46	5	42	5	3	4	11	4	69	14	11	4	36	40	17	32	2

Chi-squared tests of significances of differences

The table shows the probability that the difference between any ~~part~~ pair of subjects is due to chance.
* denotes that the probability is 1/100 or less.
Where the probability lies between 1/100 and 1/20 it is shown as parts per thousand.
The space is left blank where the probability exceeds 1/20.

1																							
2	13																						
3	*	*																					
4	*	*	*																				
5	–	–	*	*																			
6	*	*	*	–	*																		
7	*	*	*	*	*	*																	
8	*	*	*	–	*	–	*																
9	*	*	47	*	*	*	–	*															
10	*	*	*	*	*	*	*	*	*														
11	*	*	*	*	*	*	*	*	*	–													
12	*	*	*	–	*	–	*	–	*	*	16												
13	*	*	*	–	*	33	*	–	*	*	31	–											
14	*	*	*	*	*	*	*	*	*	–	–	50	48										
15	*	*	*	*	*	*	*	*	*	*	*	*	*	*									
16	*	*	*	–	*	–	*	–	*	*	*	–	–	*	*								
17	*	*	*	–	–	–	*	–	*	*	*	–	50	*	*	–							
18	*	–	*	50	–	–	*	–	*	*	*	26	*	*	*	12	–						
19	50	*	–	*	*	*	*	*	–	*	*	*	*	*	*	*	*	*					
20	*	*	–	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	–				
21	–	16	*	39	–	*	*	*	*	*	*	*	*	*	*	11	–	*	*	*			
22	27	*	–	*	*	*	*	*	–	*	*	*	*	*	*	*	*	*	–	29	*		
23	*	*	*	–	*	–	*	–	*	*	*	–	13	*	*	24	–	–	*	*	*	*	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23

TABLE V

TABLE V. ABCDE markings of all students (391). (See Part III.)

	SUBJECTS																						
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
A	50	50	43	141	84	128	46	103	38	182	158	128	120	162	26	139	104	65	65	53	65	30	151
B	113	116	91	124	113	145	74	125	82	114	92	107	98	102	43	114	104	139	81	78	89	63	129
C	123	119	86	73	114	76	128	105	95	57	72	84	76	70	79	59	86	113	86	65	102	106	72
D	64	69	81	35	48	28	75	43	101	17	38	44	53	34	93	43	60	47	79	84	72	95	31
E	41	37	90	18	32	14	68	15	75	21	31	28	44	23	150	36	37	27	80	111	63	97	8

Chi-squared tests of significances of differences

The table shows the probability that the difference between any pair of subjects is due to chance.
* denotes that the probability is 1/100 or less.
Where the probability lies between 1/100 and 1/20 it is shown as parts per thousand.
The space is left blank where the probability exceeds 1/20.

1																							
2	—																						
3	*	*																					
4	*	*	*																				
5	15	18	*	*																			
6	*	*	*	—	*																		
7	*	*	*	*	*	*																	
8	*	*	*	17	38	18	*																
9	*	*	—	*	*	*	40	*															
10	*	*	*	*	*	*	*	*	*														
11	*	*	*	50	*	*	*	*	*	*													
12	*	*	*	—	*	*	*	36	*	*	—												
13	*	*	*	*	*	*	*	*	*	*	38	—											
14	*	*	*	—	*	*	*	*	*	—	—	—	*										
15	*	*	*	*	*	*	*	*	*	*	*	*	*	*									
16	*	*	*	—	*	*	*	*	*	*	—	—	*	—	*								
17	*	*	*	*	—	*	*	*	*	*	*	—	—	*	*	*							
18	18	43	*	*	—	*	*	*	*	*	*	*	*	*	*	*	*						
19	*	*	—	*	*	*	11	*	37	*	*	*	*	*	*	*	*	*					
20	*	*	—	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	50				
21	39	*	26	*	*	*	—	*	*	*	*	*	*	*	*	*	*	*	—	*			
22	*	*	45	*	*	*	*	*	—	*	*	*	*	*	*	*	*	*	*	*	*		
23	*	*	*	—	*	—	*	*	*	*	*	*	*	33	*	*	*	*	*	*	*	*	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23

Explanation of Tables VI.VII, VIII.

In these Tables (given on the following pages) comparisons are made between the significant differences of the ABCDE markings (see Part III) as estimated (i) by use of the numerical scale and standard deviations (ii) by chi-squared tests.

Column (a) gives the number of the subject (in order of the interest score on the numerical scale).

Column (b) gives the interest score on the numerical scale.

Column (c) shows, for each subject, the range of subjects within which none differs significantly from that subject. For all subjects outside the range, the actual difference is at least 3 times the standard deviation (σ_D) of the difference. For subjects shown in brackets the difference lies between 2 and 3 times the standard deviation.

Column (d) shows subjects inside the range for which the probability (by chi-squared tests) exceeds 1/100, but, from Tables III,IV,V, it is seen that in noneof these cases does the probability exceed 1/20. Hence the use of the numerical scale and σ_D tests does not indicate as significantly different subjects which chi-squared tests show not to be significantly different.

Column (e) shows subjects inside the range which, by chi-squared tests, are significantly different. The differences arise from differing distributions (not from differing central tendencies). The numerical scale does not reveal such differences.

Table VI. Comparison of numerical(σ_o) tests and chi-squared tests of significant differences. (MALES).

For an explanation of this Table see p. 252.

(a)	(b)	(c)	(d)	(e)
23	7.7	4-10	-	-
4	7.4	23-10(16)	14	16
6	7.2	23-8	-	16,8
10	7.2	23-8	12	8
16	6.7	(4)6-17	-	4,6,8,5
14	6.6	6-17(18)	4,13	18
8	6.5	6-17(18,7)	-	6,10,16,11,17
5	6.3	16-13	1	16
12	6.3	16-13(1)	10	18,1
11	6.2	16-1	19	8,18,1
17	6.0	16-1(19)	9	8,18,1
18	5.7	(14,8)5-2	-	14,12,11,17,13,19,9
7	5.7	(8)5-2	-	19
13	5.6	5-2(3,21)	14	18,1
1	5.5	(12)11-21	5	12,11,17,13,19,3,21
19	5.2	(17)18-21	11	18,7,1,2
9	5.0	18-21	17	18
2	5.0	18-21	-	19
3	4.8	(13)1-21(20)	-	1
21	4.8	(13)1-21(20)	22	1
20	4.0	(3,21)22,15	-	-
22	3.8	20-15	21	-
15	3.5	20,22	-	-

Table VII. Comparison of numerical (σ_0) tests and chi-squared tests of significant differences. (FEMALES).

For an explanation of this Table see p. 252.

(a)	(b)	(c)	(d)	(e)
10	8.5	11-14	-	-
11	8.3	10-14	12,13	-
14	8.1	10,11(12,13)	-	-
12	7.3	(14)13-17	11	-
13	7.3	(14-12)17	11	18
6	7.0	12-2	-	2
23	7.0	12-2	-	2
8	6.9	12-2	-	2
16	6.8	12-2(5)	21	2,5
4	6.7	12-5	21	2,5
18	6.6	12-5	-	13
17	6.4	12-21	-	2
2	6.2	6-21	1	6-4,17
5	5.8	(16)4-1	-	16,4
21	5.6	17-1	16,4	-
1	5.2	5-19	2,22,	20
20	4.5	1-3	-	1
19	4.2	1-9	-	-
22	4.1	20-9	1	-
3	3.9	20-7	-	7
9	3.4	19-7	-	-
7	3.0	3-15	-	3,15
15	2.4	7	-	7

Table VIII. Comparison of numerical(σ_0) tests and chi-squared tests of significant differences. (ALL STUDENTS).

For an explanation of this table see p. 252.

(a)	(b)	(c)	(d)	(e)
10	7.7	23(6,14)	-	23,6
23	7.4	10-11	-	10,11
6	7.2	(10)23-11(12,16)	8	10,11-16 ,14
14	7.2	(10)23-11(12-8)	-	6,8
4	7.1	23-16(8)	-	-
11	7.0	23-16(8)	13	23,6,8
12	6.7	(6,14)4-8(13-17)	-	6,18,5
16	6.7	(6,14)4-8(13-17)	-	6,8-17
8	6.6	(14-11)12-13(18-17)	6	14,11,16,13,18,17
13	6.2	(12,16)8-17	11	16,8,18,5
18	6.1	(12-8)13-17	1,2	12-13,17
5	6.1	(12-8)13-17(2)	1	12,16,13
17	6.1	(12-8)13-5(2)	-	16,8,18,2
2	5.5	(5,17)1,21	18	17,21
1	5.4	2,21(19)	18,5	19
21	5.1	2-7	3	2
19	4.8	(1)21-9(20)	-	1
7	4.7	21-9(20)	-	3,20
3	4.4	19-20(22)	21	7
9	4.4	19-20(22)	-	20
20	4.2	(19,17)3-22	-	7,9,22
22	3.9	(3,9)20	-	20
15	3.1	-	-	-

TABLE IX. Results of the test of 66 apparently difficult words taken from Discovery. (Part V. Section I)

Word	Unknown by	Word	Unknown by
ethnographer	100%	monochromatic	63%
agronomist	100	pupation	62
synoptic chart	98	cracked hydrocarbon	62
phylogenetic line	98	isotope	60
filarial	96	inductance	60
mycologist	95	vulcanisation	58
geostrophic	95	gamma rays	50
cretinic degeneration	95	die-casting	50
echelon	90	erg	48
anthropology	90	neutron	48
vectorially	90	refractory substance	48
taxonomist	88	Wheatstone bridge	47
nutrient liquid	85	cathode ray tube	47
A.F. oscillator	85	toxic	45
interpolation	83	theodolite	43
geophysicist	83	atomic number	40
geneticist	83	micro-ammeter	40
stellar	81	hygrometer	38
thermodynamics	80	isothermal chart	33
radio-altimeter	80	aneroid	30
calcined	78	deoxidiser	30
carrier wave	78	synthesise	28
thermo-junction	75	refractive index	23
orientation	73	kilowatt-hour	20
polarising media	73	electrolyse	15
thermal efficiency	70	spore	12
co-planar	70	absolute temperature	8
pathological	68	humidity	8
positron	68	bromine	7
cyclotron	67	dehydration	5
fungicidal	67	isobars	5
angstrom unit	67	calorie	0
mutation	65		
astrophysics	65		

. . . .

TABLE X. THE FLOOD-WEST SCIENTIFIC AND TECHNICAL VOCABULARY

Words marked * are scientific extensions of "ordinary" words in the New method list. Other words with qualification in brackets are limited to the usage so designated.

absorb
accurate
advertise, -ment
aerial
affect
agriculture
alcohol
alkali /ne
alloy
alternating current
aluminium
ampere
analyse
anchor
ankle
(antiseptic)
anvil
ape
area
artery
artificial
ash
atmosphere
atom
attract
automatic
average
axle

bacteria
balance
balloon
bark (of tree)
barometer
base, -d
bat (animal)
battery
bearing (of machine)
bedbug
beer
beetle
belt
benzene ring
bleed

bolt (nut)
bond (chemical)
bounce
brake
breed, to
bubble
bud
bulb
bullet
bundle
bury
butterfly

cabbage
calf
camera
cardboard
carpet
cartridge
carve
cast (iron etc)
cavity (of the body)
ceiling
cell (biology)
cell (electricity)
celluloid
cement
centigrade
(centimetre)
channel
charcoal
*charge (to... a battery, electric..)
check
chemistry,/ical
chew
chisel
chocolate
cinema
circuit
circumference
clay
climate
coarse

coconut
coil
coke
collar
comb
combine
compare
complex, complicated
composed of
compound (chemical)
compress
condenser (electrical)
conductor (heat, elect)
cone
conscious
consists of
contract (v.)
cord (string, spinal)
cork
cough
crab
crank
cream
crystal
cube /ic
cupboard
cure (disease)
current
cushion
cylinder (shape, engine)

daisy
damp
decimal
deck
decorate
degree
dense
deposit

TABLE X. Continued

design
detail
develop (grow)
develop (photo.)
diagram
diameter
diamond
digest
(disinfectant)
dissolve
disturb
ditch
dot
double
drain, -age
*dress (wound)
drill (tool)
drug
due to
dye

echo
eclipse
efficient
elastic
electrolysis
electron
element
(chemical)
emotion
energy
equation
equator
evaporate
excess
exchange
exist
expand
experiment
extra
extract
factory
(manufacture)
fahrenheit
fan
ferment (to, a)
fern
fertilize (seeds)
fertilize (r)
(chemical)
fibre
*field (magnet)
file (tool)

film cinema-
flavour
flea
flesh
fork
fossil
fraction
frequent
frequency
(electrical)
friction
frog
fungus,/i
furnace

gear
generate,/or
(electricity)
gland (of body)
glaze
glue
gourd
gradual
grain of
gramophone
gramme
grape
graph
gravity
grease
grind
groove
gum

habit
heal
heel
(hereditary)
hinge
honey
horizon -tal
hydrocarbon

image
imitate
impulse
include
induce
(electricity)
infectious, dis-,t
inflame/mation
inherit
inject

insulate
intelligence
...-test
interfere
interval
ion
irritate

jaw
jet
juice
jute

kidney

laboratory
ladder
larva
lathe
lavatory
layer
lemon
lens
lever
lie (v.)
lily
limit
lined, lining
linen
liver
lizard
loom
loop
lungs

magnet
magnify
maize
malaria
(manufacture)
manure
*mass (scientific)
mast
mathematics, /cal
membrane
mend
mental
metre
centi-
milli-
method
mica
mine, mineral
mirror

TABLE X. Continued

model	plaster (building)	right-angle
modern	plastics	ripe
moist -ure	plough	rivet
molecule	*pole (battery, magnet)	rod
mosquito		rudder
moss	polish	rust
moth	pollen	
motion	position	*salt (chemical use)
mould (shape)	positive (elect.)	saw(n,v.)
multiply (2 x 2, become more numerous)		scale (measure)
	potato	scent
	pottery	scissors
mustard	poultry	scrape
negative (elect.)	pressure	scratch
negative (photo.)	prism	screen
neutral	problem	seizure
neutron	process	sensation
normal	-proof	sensitive
nucleus	propeller	sensory
*nut (bolt)	proportion	septic, anti-
	protein	series
oar	pulley	sew
offspring	pulp	sex
onion	pulse (impulse, blood)	shallow
operation (surgical)		sieve
orbit	pump	similar
ordinary	pupil (of eye)	skull
ore	purple	slit, slot
organ (of body)		smallpox
organism	quinine	snail
organize		soak
origin -al	radiate	soda-water
oval	radioactive	soluble, solution
oxidise	radium	soot
(oxygen)	radius	sore
	rare	source
pad	rate	spark
palm-tree	raw	spectrum
parallel	ray	spider
parasite	react	spin
partial	reflect	spine
particle	remove	spinal cord
passage	replace by	spiral
peg	represent	spit
pendulum	reproduce	split
percentage	resin	spoke (wheel)
period	resist,	sponge /y
petal	resistance (elect)	spore
petrol -eum	revolve	squared
pink	rib	square root
piston	rice	stage (time)
plane (tool)	rid, get...of	stain
planet	rifle	standard

TABLE X. Continued

starch	transparent
state (say)	triangle
statement	tribe
steel	trumpet
steer	tube
sting	tuft
stockings	type (printer's)
storage battery	tyre
straw	
strip (n)	unit
substance	universe
suck	urine
surgery /ical	
surroundings	vacuum
sweat	valve (machine,radio)
switch	vapour
system	varnish
	vary
tap (v.)	vein
tap (instrument)	vibrate
tar	vinegar
telegram /ph	violet
telescope	vitamin
television	volcano
temperature	volt
tend -ency	volume
test	vomit
thermometer	
theory	weave
thorn	wedge
tide	weed
-tight	whale
tile	wheat
tip (end)	wind (v.)
tissue (of living body)	worm
tobacco	wrinkle
toe	
tool	X rays
torch (electrical)	
total	yeast
tough	

TABLE XI. Test of marginal words of the Flood-West vocabulary with Secondary Modern School pupils.

Total number of pupils tested - 374 (mixed, boys and girls).
Ages of pupils - Mainly 14, a few 15.

The figures show the percentage of pupils who did not know the words.

absorb	21	expand	2	organism	40
aerial	9	evaporate	7	parallel	7
alloy	36	fahrenheit	29	parasite	57
alternating current	48	ferment	66	petroleum	16
analyse	36	fertilize (flower)	19	piston	21
antiseptic	6	fertilizer	7	planet	11
artery	20	fossil	49	plastics	4
atom	10	friction	40	pole (mag.)	48
bacteria	26	fungus	32	pollen	3
bearings (machine)	28	gear (wheel)	25	positive (elect.)	57
cast	27	generator	38	protein	43
cavity (body)	50	gland	19	quinine	44
cell (plant)	25	glaze	24	radius	14
cell (elect.)	53	graph	31	resin	57
celluloid	17	gramme	48	resistance (elect.)	51
centigrade	35	image	7	right-angle	4
charge (elect.)	28	infectious	20	rivet	18
circuit (elect.)	41	inflammation	19	seizure	70
circumference	16	inherit	29	soluble	67
compound (chem.)	53	inject	4	square root	18
conductor (elect.)	38	insulator	45	storage battery	47
contract	6	jute	65	television	2
crystal	9	lathe	29	thermometer	4
cylinder	10	lens	12	tissues (body)	40
develop (photo.)	5	loom	19	transparent	6
diameter	7	maize	9	universe	23
dissolve	3	malaria	15	vacuum	11
eclipse	27	magnetic field	53	valve of machine	29
element (chem.)	68	membrane	53	valve radio	5
equation	56	metre	19	vein	10
equator	2	mica	77	vitamin	15
		mould (shape)	25	volume	3
		negative (photo.)	7	volcano	9
		neutral	26	vomit	41
		orbit	82	yeast	4
		ore	24		

. . . .

TABLE XII. Examples of "Dignity Words" with simpler alternatives

composed of	-	made of, made up of
consists of	-	is made of, is made up of
deposit	-	comes down out of
including	-	and.......also
method	-	way
obtained from	-	got from, got out of
period	-	time, age
position	-	place
replaced by	-	put in place of
represents	-	stands for, shows
revolve	-	turn round, go round
similar	-	rather like, of much the same kind
substance	-	stuff, material
system	-	set of, group of, way of
theory	-	idea
vary	-	change, become bigger or smaller

. . . .

TABLE XII. "Wanted" words. (Words frequently needed but not included in the final Flood-West vocabulary.

*These words would probably be included in List A.

abdomen
avoid
boundary
brittle
canvas
carrot
*catalyst
claw
concentrated
convenient
corresponds to
cross-section
diagonal
dilute
dose
*electrode
equivalent
filter
flax
formula
funnel
gap
germ
globe
knit
lick
*mammal
nostril
oppose
*organic (chemistry)
pear
permanent
pivot
plane (surface)
plum
sack -ing
sausage
*secrete
section
skeleton
slanting
sole (of shoe)
soup
sow (seeds)
stern (ship)
*stimulus
*structure
tank (war)
temporary
yard (ship)
yolk

Note

Anode and Cathode are frequently needed but can be avoided by "positive electrode" and "negative electrode".

Enzyme is a wanted word but can be avoided by reference to a biological catalyst.

. . . .

TABLE XIV. Words of the Flood-West vocabulary taken by Ogden as international

*Words of general utility (not confined to science)
**Words of less general utility for use in their appropriate contexts.
+Words sub judice (1946).

+alcohol
alkali /ne
alternating current
*aluminium
+ampere
analysis
anchor
antiseptic
artery
+at~~o~~mosphere
+atom
bacteria
barometer
battery
*beer
benzene
celluloid
cement
*chemistry
*chocolate
coke
composition
+condenser
cone
contraction
crystal
cube
cylinder
decimal
diagram
diamond
eclipse
elasticity
electrolysis
+electron
+element
+energy

equator
extraction
+film
fossil
frequency
fungus
+graph
gravitation
gum
horizon
hydrocarbon
imitation (biol.)
induce (elect.)
infectious
inject (geol.med.)
interval (maths.)
ion
+laboratory
larva
+magnet
**malaria
*mathematics
membrane
method
metric
mica
mineral
model
molecule
negative (elect.)
negative (photo.)
neutral
neutron
orbit
organ (of body)
organism
parasite

period
petroleum
planet
plastic
pole (elect.)
positive
prism
problem
proportion
protein
pulse
pupil
**quinine
radioactive
**radium
radius
reflect
series
+spectrum
spinal cord
spiral
spore
*telegram
telescope
television
temperature
+thermometer
*tobacco
+universe
urine
vacuum
vein
vibrate
vitamin
volcano
**volt
X rays

. . . .

TABLE XV. Words of the Basic science lists which are not in the Flood-West and New Method vocabularies.

Note. Certain words are listed below because the scientific use of the word is not within the Flood-West and New Method vocabularies (e.g. unknown, flow).

General science	Physics+chemistry	Geology
component	adsorption	birefringence
latitude	beaker	cast
longitude	conservation	cleavage
projection	flask	contour
shear	fume	dip
strain	grating	drift
stress	porcelain	dyke
	reagent	eruption
Maths.+Mechanics	*receiver	extinction
	reflux	fan (delta)
acceleration	valency	fault
amplitude	vortex	flint
congruent		flow
cusp	**Biology**	foliation
damping		fracture
infinity	abdomen	glacier
integer	appendage	igneous
intersection	cartilage	inclusion
inverse	degenerate	intercept
locus	duct	interpenetration
momentum	metabolism	intrusion
multiple	sac	outcrop
node	secretion	outlier
prime	sepal	overlap
reciprocal	slide (micro.)	scarp
recurring	stamen	schist
reinforcement	thorax	sedimentary
resolution	vascular	shale
term	vestigial	sill
unknown		slate
velocity		strike
		texture
		twin
		unconformity

*"receive" is in the New Method list; "receiver" (as applicable to radio) is probability inferable.

. . . .

TABLE XVI. Words of the Flood-West vocabulary which are not in the Basic lists or taken by Ogden as international.

accurate
advertise
aerial
affect
agriculture
alloy
ankle
anvil
ape
artificial
average
axle
balloon
bat (animal)
bearing (of machine)
bedbug
beetle
belt
bolt (nut)
bond (chemical)
bounce
breed
bullet
bundle
bury
butterfly
cabbage
calf
carpet
cartridge
carve
cast (iron etc.)
ceiling
centigrade
channel
charcoal
cheek
chew
chisel
climate
coarse
coconut
compress
consist
crab
crank
cream
cupboard
cure
daisy
damp
deck
decorate
develop (photo.)
dissolve
ditch
dot
double
dress (wound)
drill (tool)
drug
due to
dye
echo
*efficient
emotion
excess
exchange
extra
factory
fahrenheit
fan
fern
fertilizer
field (magnetic)
file (tool)
flavour
flea
flesh
frog
gear
glaze
glue
gourd
gradual
grain of
gramophone
grape
grease
*grind
habit
heel
honey
include
inflame
intelligence
interfere
irritate
jet
jute
ladder
lathe
lie, to
lily
lined, lining
lizard
loom
loop
magnify
maize
manure
mass (scien.)
mast
mend
mental
mirror
*modern
moisture
mosquito
moss
moth
mould (shape)
mustard
nut (bolt)
oar
offspring
onion
ordinary
oval
pad
palm-tree
partial
passage
peg
percentage
pink
plaster
pottery
poultry
propeller
-proof
pulp
purple
rare
raw
remove
replace by
resin
revolve

the 1931 Basic General Science list.

TABLE XVI. Continued

rib	steer
rid	sting
rifle	straw
right-angle	strip (n.)
ripe	surgery
rivet	surroundings
rudder	sweat
rust	tap (instrument)
salt (chem.)	tap, to
saw (n.v.)	*tar
scent	thorn
scrape	-tight
*scratch	tile
seizure	tip (end)
septic	tool
sew	torch
shallow	tough
sieve	tribe
slit, slot	trumpet
smallpox	tuft
snail	type (printer's)
soak	tyre
soda-water	varnish
soot	vinegar
sore	vomit
source	weave
spin	weed
spit	whale
split	wheat
spoke (wheel)	wind, to
squared, -root	wrinkle
standard	yeast
*starch	

. . . .

TABLE XVII. The Flood-West scientific and technical supplement to the Carnegie vocabulary.

The more difficult scientific terms are printed in CAPITALS. Words marked with a * were not used in the dictionary experiment but were avoided only with difficulty. They should appear in a science vocabulary.

absorb
abdomen*
accurate
acid
aerial
affect
alcohol
ALKALI /NE
alloy
ALTERNATING CURRENT
aluminium
AMPERE
analyse
anchor
ankle
ant
(antiseptic)
anvil
ape
area
artery
atmosphere
atom
automatic
avoid*
axle

bacteria
balloon
bark (of tree)
barometer
bat (animal)
battery
bearing (of machine)
bedbug
bee
beer
beetle
BENZENE RING
bleed, to
bolt (nut)
BOND (chemical)
boot
bounce
boundary*
bowel

brake
breast
breed, to
brittle*
bubble
bud
bulb
bullet
butterfly

cabbage
calf
candle
canvas*
carpet
carrot*
cartridge
carve
cast (iron etc)
CATALYST*
CAVITY (of body)
cease
ceiling
CELL (biology)
CELL (electrical)
celluloid
cement
CENTIGRADE
(centimetre)
channel
charcoal
charge (electric.., to...a battery)
cheek
chemistry (ical
chew
chisel
chocolate
cigarette
cinema
CIRCUIT
circumference
claw*
climate
coconut
coil
coke

compass
COMPOUND (chemical)
compress
CONDENSER (electrical)
CONDUCTOR (electricity,heat)
concentrated*
cone
consists of
contract, to
convenient*
cord (string,spinal)
corresponds to*
crab
crank
cross-section*
crystal
cube /ic
cylinder(shape engine)

daisy
decimal
deck
decorate
dense
deposit
design
develop (photo.)
diagonal*
diagram
diameter
digest
dilute*
(disinfectant)
dissolve
dose*
drain /age
dress (a wound)
drill (tool)
drug
dye

echo
eclipse
ELECTRODE*
ELECTROLYSIS
ELECTRON

TABLE XVII Continued

ELEMENT (chemical)	heel	magic
emotion	hen	magnet
energy	(hereditary)	magnify
EQUATION	hinge	maize
equator	honey	malaria
equivalent*	horn	MAMMAL*
evaporate	HYDROCARBON	manure
expand		MASS (scientific use)
extract	image	
	impulse	mast
FAHRENHEIT	INDUCE(electricity)	mathematics /ical
FERMENT, TO, A	infectious	MEMBRANE
fern	disinfectant	mental
fertilize (seeds)	inflame /mation	METRE
fertilize (r) (chemical)	inherit	CENTI-
	hereditary	MILLI-
fibre	inject	method
FIELD (magnetic)	INSULATOR	MICA
file (tool)	intelligence	microscope
filter*	i. test	mineral
flax*	interval	mirror
flea	ION	mist
formula*	irritate	moist /ure
FOSSIL		MOLECULE
fraction	jelly	mosquito
FREQUENCY (electrical)	jet	moss
	jute	moth
friction		mould (shape)
frog	kidney	muscle
fungus /i	knit*	mustard
funnel*		NEGATIVE (electrical)
furnace	laboratory	
	lamb	negative (photo.)
gap*	LARVA	nerve
garment	lathe	neutral
gear	lavatory	NEUTRON
GENERATE /OR (electricity)	layer	normal
	lemon	nostril*
germ*	lens	NUCLEUS
GLAND (of body)	lever	nut (bolt)
glaze	lick*	
globe*	lily	obtain
glue	lime	offspring
gourd	lined, lining	onion
gramophone	linen	oppose*
GRAMME	liver	ORBIT
grape	lizard	ore
GRAPH	loom	ORGANIC (chemistry)*
gravity	loop	ORGANISM
groove		oval
gum		

TABLE XVII Continued

OXIDISE (oxygen)

palm-tree
parallel
PARASITE
partial
particle
pear*
peg
pendulum
period
permanent*
petal
petrol (eum
pillar
piston
pivot*
plane (surface)*
plane (tool)
planet
plastics
plum*
pole (=staff)
POLE (electric, magnetic)
pollen
port
POSITIVE(electrical)
potato
pottery
poultry
prism
process
-proof
propeller
proportion
PROTEIN
pulley
pulp
pulse (impulse, blood)
pupil (of eye)

QUININE

radiate
RADIOACTIVE
RADIUM
radius
range
react
remove

RESIN
RESISTANCE (electrical)
revolve
rib
rifle
rivet
rose, a
rudder

sack /ing*
SALT (chemical use)
sausage*
SECRETE*
section*
SEIZURE
sensation
sensitive /ory
septic
antiseptic
series
sex
sieve
similar
skeleton*
skull
slanting*
slit, slot
smallpox
snail
soak
soda-water
sole (of shoe)*
SOLUBLE, SOLUTION
soot
soup*
source
sow (seeds)*
spark
spear
SPECTRUM
spider
spine, spinal cord
spiral
spoke (of wheel)
sponge /y
SPORE
squared, square root
starch
stern (ship)*
STIMULUS*
STORAGE BATTERY

structure*
surgery /ical
switch

tank (war)*
tap (instrument)
tar
telescope
television
temporary*
thermometer
theory
-tight
tile
tip (end)
TISSUE (of living body)
torch(electrical)
transparent
trousers
triangle
trumpet
tuft
tyre

urine

vacuum
VALVE (machine, radio)
vapour
varnish
vary
vegetable
vein
vibrate
vinegar
violet
vitamin
volcano
VOLT
volume
vomit

wedge
whale
wrinkle

X rays

yard (of ship)*
yeast
yolk*

TABLE XVIII. Words used in the Elementary Science Readers extra to those of the Flood-West vocabulary.

Words marked * are not in the Carnegie vocabulary.

advantage	gap	pile (= heap)
almost	hardship	pool
*apparatus	*hoe	prize
*apply	*however	puzzle
*assume	(= but)	rescue
avoid	immediate	rot
*awkward	indeed	sample
*bay	information	scarce
*blotting	*instruction	seldom
-paper	invent	spade
bucket	*jar	*spices
*cape	*kite	spill
coin	*knob	spoil
column	lean (= slope)	stir
convenient	lid	suggest
*crane	lump	temple
crime	mention	*tiny
crush	merchant	toy
dip	mere /ly	treasure
discuss	moderate	*trip, to
distinguish	noon	*truck
district	occasionally	*tunnel
dive	oppose	upset
drag	*oven	violent
dull	overcome	voyage
familiar	pale	wipe
flood	parcel	wrap
fun	*pedal	

. . . .

BIBLIOGRAPHY

The following books, articles, and papers (consulted during the present work) contain information and/or opinions relevant to the problems under discussion.

Parts I - IV

General

Bernal J.D. The Social Function of Science. (Routledge).
Association of Scientific Workers. Science and the Nation. (Pelican).
Lovell B. Science and Civilization (Thos. Nelson).
Nokes H.C. Science in Education. (Macdonald).
Crowther J.G. The Social Relations of Science. (Macmillan).
Bennett J.L. The Diffusion of Science. (John Hopkins Press, Baltimore).
Hill D.W. The Impact and Value of Science (Hutchinsons).

From the School Science Review

Bryant C.L. Science and the Spens Report. Vol.XXI, No.82. Dec. 1939.
Soddy F. Science for Rulers. Vol. XXV, No. 95. Nov. 1943.
Woods S.R. Science and Education. Vol. XXV. No. 96. Feb. 1944.
Steels H. The Educated Man, Science and the Teacher. Vol.XXV, No. 97. June 1944.
Cullen W. Science and the Schools. Vol. XXVI. No.99. Feb. 1945.
Crowther J.G. The Social Relations of Science. Vol.XXVI, No. 100, June 1945.
Bernal J.D. Science Teaching in General Education. Vol. XXVII, No.102. Mar. 1946.
Whitmore B.G. Science Teachers and Society. Vol. XXVIII, No.104. Oct.1946.
Astbury W.T. Science in Relation to the Community. Vol. XXIX. No.109. June 1948.

Other reports and articles

British Association. Popularisation of science through public lectures. Committee report. 1916.
British Association. Science teaching in adult education. Committee report. 1933. Available as Reprint N.S.32.
Board of Education. Natural science in adult education. Paper No. 8 of the Adult Education Committee.
British Institute of Adult Education. Science and adult education. Sixth annual conference, 1927.

Workers Educational Association. Study of science in adult classes. Report of the Executive committe, 1932.
Clifford M.H. Taking science to the adult. Discovery. Sept. and Oct. 1946.
Crossland R.W. Science in adult education. Further Education. Vol. 2, No. 3. Dec. 1948.
George T.N. The teaching of science to adults. Annual conference of the Scottish Branch of the British Institute of Adult Education, Oct. 1948 (Reported in Adult Education, Vol. XXI. No. 2. Dec. 1948)

Resumés of the following proceedings were also consulted.

British Association Conference 1943. Science and the Citizen; the public understanding of science.
British Association. Report presented to the Scientific Conference of the Royal Empire Society, 1946.
Institute of Chemistry. Conference of the London and S.E. counties section. 1945. The Publicity of science.

Aims of science teaching

Certain sections of the books and reports listed above, also:

Cawthorne H.H. Science in Education. (Oxford Univ.Press)
Phillips M.E. and Cox L.E. The Teaching of Biology. (Chaps.1-6). (University of London Press)
Sumner W.L. The Teaching of Science (Chap.1) (Basil Blackwell).
Science Masters Association. The Teaching of General Science. (Chap.4). (John Murray)
Joint Committee of the Incorporated Association of Assistant Masters and the Science Masters Association. The Teaching of Science in Secondary Schools (Chap.2) (John Murray).

History of science teaching

Turner D.M. History of Science Teaching in England. (Chapman and Hall)
Fyfe W.H. Science in Secondary Education. School Science Review. Vol. XVI, No. 63. Mar. 1935.
Board of Education Reports:
Natural science in education (The "Prime Minister's" report) 1918.
The education of the adolescent (The "Hadow" report) 1932.
Curriculum and Examinations in Secondary Schools (The "Norwood" report) 1941.

General science

Science Masters Association. The teaching of General Science. Parts I and II. (John Murray)
British Association. General science in schools. Reprint No. 33.

Comments and criticisms appear in the following issues of School Science Review (Vol. and No.):
II 5, IV 13, IV 14, V 19, VII 26, XIII 52, XIV 56, XV 60, XVI 61, XVII 66, XVII 68, XVIII 70, XVIII 71, XVIII 72, XXVII 103, XXIX 107.

Interest in science

Rallison R. The scientific interests of senior school children. British Journal of Educational Psychology. Vol. IX part II. (June 1939).
Pritchard R.A. The relative popularity of secondary school subjects. Brit. Journ. Education Psychology. Vol. V parts II and III. (June, November 1935).
Shakespeare J.J. An enquiry into the relative popularity of school subjects in elementary schools. Brit. Journ. Educational Psychology Vol. VI part II (June 1936).
Ball H.R.V. Children's interests and experience in relation to science. School Science Review. Vol.XXVII Nos. 67, 68. (March, June 1936).
Houslop N.L. and Weeks E.J. The interests of school children. School Science Review. Vol. XXIX. No. 109, XXX No. 110. (June, October 1948).
Hoy J.D. An enquiry as to interests and motives for study among evening class students. Brit. Journ. Educational Psychology Vol. III part I. (Feb.1933).
Flood W.E. and Crossland R.W. The origins of interest and motives for study of natural sciences and psychology among adults in voluntary courses. Brit. Journ. Educ. Psychology. Vol. XVIII part II. (June 1948).

Statistics of classes provided by Extra-mural departments of universities and by the Workers Educational Association may be obtained from annual reports.

Subsidiary references

Brown J. Teaching science in schools (Univ.London Press).
Westaway F.W. Science teaching. (Blackie).
Westaway F.W. Scientific Method (Blackie.)
Haldane J.B.S. A banned broadcast and other essays. (Chatto and Windus).
Lauwerys J.A. Education and Biology (Sands).
Hall Sir D. and others. The Frustration of Science. (Allen and Unwin).
Russell B. The Scientific Outlook. (Allen and Unwin).
Crowther J.G. Science and Life. (Gollancz).

Nunn Sir P. Article on science in The New Teaching (Edited by Sir John Adams). (Hodder and Stoughton).

Bragg L. Lecturing to an unseen audience. The B.B.C. Quarterly. Jan. 1948.

Fryer D. The measurement of interests. (Henry Holt, New York).

Parts V - VI

Reading and intelligibility

Gray S.G. and Leary B.E. What makes a book readable. (Univ. Chicago Press) 1935.

Cullough C.M., Strong R.M., Traxter A.E. Problems in the improvement of reading. (McGraw Hill Book Co. Inc.) 1946.

Dale E. and Chall J.S. A formula for predicting readability. Educational Research Bulletin XXVII. College of Education. Ohio State University. 1948.

Flesch R. A new readability yardstick. Journ. of Applied Psychology, June 1948. (American Psych. Association).

Science vocabularies

Powers S.R. The vocabulary of scientific terms for High School Pupils. Teachers College Record XXVIII. Nov. 1926.

Pressey L.C. The determination of the technical vocabulary of the school subjects. School and Society. Vol.XX. 1924.

Pressey L.C. The special vocabularies of the public school subjects. Public School Publishing Co. Bloomington, Illinois. 1926?.

Curtis F.D. Investigations of the vocabularies in text-books of science for secondary schools. Ginn & Co. Boston. 1938.

Schneck J.W. and Curtis F.D. The important scientific terms in high school physics. The School Review Vol. 50. (Univ. of Chicago) 1942.

Word frequency

Thordike E.L. The Teacher's Word Book. Teachers College. University of Columbia.

Thorndike E.L. and Lorge I. The Teacher's Word. Book of 30,000 words. Teachers College, Univ. of Columbia.

Horn E. A Basic writing vocabulary. College of Education, University of Iowa.

Faucett L. and Hsu Maki. A study of English word values statistically determined from the latest extensive word-counts. Matsumura Sanshodo, Tokyo.

Fielstra C. and Curtis F.D. A comparison of the Thorndike word lists. Journal of Educational Psychology Vol.XXX No. 6. Sept. 1939. (Warwick and York Inc.Baltimore).

Swenson E. and West M.P. On the counting of new words in textbooks for teaching foreign langauges. Bulletin No. 1 of the Department Educational Research, Ontario College of Education, University of Toronto.

Vocabulary problems, limited vocabularies

West M.P. The New Method Dictionary. Longmans, Green & Co. Ltd.
West M.P. How to use the New Method dictionary. Longmans, Green & Co.Ltd.,
West M.P. Definition Vocabulary. Bulletin No. 4 of the Department of Educational Research, Ontario College of Education, University of Toronto.
Interim Report on Vocabulary Selection (Committee of the Carnegie Corporation) P.S. King & Son Ltd. 1936. (A new edition is in the course of preparation and should be published in 1949. It includes the Thorndike-Lorge semantic count. The writer has had access to the provisional typescripts.)
Morris I. Principles of vocabulary control. English Language Teaching. Vol. 1. Nos. 6, 7, Vol. 2. Nos 2,3, (May, June, Oct. Nov. 1947).
English Language Teaching editorials. Vol. 1 No 3, Vol. 1 No. 4.
Lockhart L.W. Word Economy (Kegan Paul) 1931.
Palmer H.E. The grading and simplifying of literary material. The Institute for Research in English Teaching. Tokyo. 1932.
Philbrick F.A. Chemical Semantics. School Science Review. Vol. XXIV. No. 93. Feb. 1943.
Haldane J.B.S. What "hot" means. What "hard" means. A banned broadcast and other essays. (Chatto and Windus)

Basic English.

Ogden C.K. Basic English. Kegan Paul.
Ogden C.K. The Basic words. Kegan Paul 1932.
Ogden C.K. The Basic vocabulary; a statistical analysis. Kegan Paul. 1930.
Ogden C.K. Basic English Applied (science).Kegan Paul 1931.
Ogden C.K. Basic for Science. Kegan Paul. 1942.
Richards I.A. Basic English and its uses. Kegan Paul.
West M.P. Swenson E., and others. A critical examination of Basic English. Bulletin No. 2 of the Department of Educational Research. Ontario College of Education, University of Toronto.

Subsidiary references

Haldane J.B.S. How to write a popular science article. A banned broadcast and other essays. Chatto & Windus.
Science News 4. Editorial. Penguin.
Ogden C.K. and Richards I.A. The Meaning of Meaning. Kegan Paul.

Bodmer F. The Loom of Language. Allen and Unwin.
Jacob H. On the Choice of a Common Language. Pitman.
(Contains a big section on Basic English.)
West M.P. Bilingualism. Government of India Occasional Report 13. 1926.
West M.P. On learning to speak a foreign language. Longmans, Green & Co.,
Palmer H.E. The scientific study and teaching of languages. Harrap.

For use in conjunction with the thesis.

APPENDIX TO

SOME PROBLEMS IN THE PRESENTATION OF POPULAR SCIENCE

by

W.E.FLOOD M.A.,Ph.D. University of Birmingham.

Since the completion of the original thesis early in 1949 I have continued to study the problems of vocabulary discussed in Parts V and VI. Experience of writing within the limited vocabulary (the "Flood-West" vocabulary of the thesis) has suggested a small number of desirable revisions. I have also been able to test more fully some other limited vocabularies, particularly those of Basic English, and more accurately to compare them with my own. A revised and extended account of the problem of vocabulary is to be published as a monograph by the Institute of Education, University of Birmingham. Meanwhile I have prepared this Appendix to accompany the original thesis; it records the more important of the revisions. The opportunity is also taken to correct a few minor errors.

The work of other investigators of science vocabularies

p.149. Delete: Other pairs of words e.g. antiseptic and disinfectant are essentially from the same head-word.

Substitute: Derivatives were not treated systematically. Thus atom and atomic are given as separate words but attract is not given in addition to attraction.

p.150. (Schneck and Curtis).

For magnetic flux put transformer
For field of force put alternating current.

Delete lens.

The work of Powers[1] and, more recently, of Cole[2] deserves careful study.

Powers followed Pressey with two major researches on the vocabularies of the sciences at High School level. In his first work he analysed textbooks of general science, chemistry, and biology and produced lists showing the number and frequency of use of uncommon words. In his second work he examined more texts, periodicals and articles to determine "a list of the 'uncommon' words found to be most important on the basis of range and frequency of usage in science texts and in other reading material about scientific subjects". He defined an uncommon word as one outside the 10,000 words most frequently used in general reading matter (as listed by Thorndike). From rather more than two million running words of text he extracted about 14,000 uncommon words. Many of these were compound words. By the elimination of all those compounds whose meanings he considered to be inferable, he reduced the total list to 7948 words. He then defined as an important word~~s~~ one whose frequency from all sources was as much as 10, or one which appeared in at least three of his five kinds of material. In this way he produced his final list of 1828 words.

The list reveals many peculiarities. It includes a number of mere names (e.g. acetanilide, alizarin) and also some proper names (e.g. Galileo, Antares). A number of derivatives are listed separately (e.g. adulterant/ adulterate/adulteration, biologic/biologist/biology). The academic nature of some of the sources is reflected in such words as angiosperm, antheridium, archegonium. The definition of an uncommon word as one not among the 10,000 most frequently used words in general reading material may be defended but such a definition does not necessarily identify an important scientific term even though scientific material was analysed. I cannot agree that applicable, appreciable, armistice, attainable (for example) are important scientific terms.

More recently Cole has attempted to organise the results of the many investigations into a coherent pattern and to produce a summary in the form of usable word-lists. The number of terms presented for each of the sciences are as follows: biology 693, chemistry 520 (+ a further list of 121 for organic chemistry), general science 261, hygiene 318, physics 530. The total number of different terms in the group of science subjects is stated to be 1,423. Many of the defects of the earlier Pressey lists (e.g. redundancy, irregular treatment of derivatives) have been removed. Interesting features are:

(a) Each word is accompanied by an index showing its frequency of occurrence in general reading matter. The indices of common words which are used in science in special senses (e.g. charge, pole, root) are specially marked.* It is significant that 355 words of the chemistry, physics and biology lists do not occur among the 20,000 most common words.

(b) Chemical symbols and chemical prefixes and suffixes are included.

(c) Abbreviations are included (e.g. B.T.U., E.M.F.).

(d) The lists includes many mere names (e.g. of chemicals).

(e) Compound words and scientific collocations are given, e.g. angle of reflection, directly proportional, lines of force, melting point. From the point of view of vocabulary the meanings of many of these compounds and collocations are inferable.

The general level of the lists represents the maximum which a good pupil might know after studying the sciences for about six years at an English Secondary Grammar school.

It is apparent from such surveys that earlier investigations of the vocabularies of the science subjects do not provide a suitable vocabulary for the exposition of Popular Science. The word-lists were largely based on textbooks and therefore include many words of an academic nature. (Cole's lists for example include conjugate foci and hypercotyl.) The potential reader of P.S. in unlikely to know many of these words and, in view of the difficulty of understanding the concepts they denote, is unlikely quickly to learn them. The problem of vocabulary in P.S.

---

*There are, however, some unmarked words (e.g. frequency, accommodation, strain, stress) which are used in science in more specialised senses than in general speaking and writing.

is not solved by the provision of a word-list consisting of a thousand or more terms drawn from science textbooks.

The unsuitability of the earlier word-lists for the purpose of P.S. is due, not only to the nature of the sources from which the words were selected, but also to the criteria by which the words were selected. The chief criteria have been frequency of occurrence in existing texts and importance (of the concept denoted by the word).

Although frequency can be a useful guide for the selection of words for a limited vocabulary its value must not be over-rated. Frequency of occurrence in existing texts may indicate the words which must be taught so that such texts can be read, and may suggest the order in which the words should be taught, but it does not indicate which words are essential for conveying the ideas presented in the text. Necessity of use is a far more important criterion than frequency of occurrence.

Cole emphasises that "a list of essential words in a subject is substantially a list of the outstanding elementary ideas which must be mastered for the understanding of subject matter". The words were chosen, not for their importance as words, but for the importance of the concepts they denote. It is true that a student must learn the concepts denoted by the words in order to understand the fundamentals of the subject and to be able to proceed to more advanced studies; he must also know the words in order to read the textbooks now in use. But these consid-[illegible] not apply to the reader of Popular Science.

Although it must be assumed that the reader has a few of the elementary concepts, the main purpose of the book is to teach concepts. The writing vocabulary for the exposition of P.S. should not be a list of essential scientific words (ideas) <u>in</u> the subject but a list of words by the use of which the essential ideas can be explained.

The vocabulary lists produced by other workers, though interesting and useful in many ways, do not directly help in the compilation of a limited vocabulary for P.S.

References.

1. Powers S.R. The vocabularies of High School science text books. Teachers College Record, XXVI. 1925.
   A vocabulary of scientific terms for High School students. Teachers College Record, XXVIII. 1926.

2. Cole L. The teacher's handbook of technical vocabulary. Public School Publishing Co. 1940.

In addition to references quoted in the thesis, see also:

Baird D.O. A vocabulary study of biology notebooks of fifty representative secondary schools in New York State. Journal of Educational Psychology, XXII. 1931.

Edwards A.S. A mathematics vocabulary test and some results of an examination of university freshmen. Journal of Educational Psychology, XXVII. 1936.

Frank J.C. The nomenclature of High School chemistry. Journal of Chemical Education, VI. 1929.

Kitzmiller A.B. Certain vocabulary problems in High School chemistry. Science Education, XV. 1930.

Patty W.W., Painter W.I. A technique for measuring the vocabulary burden of textbooks. Journal of Educational Research, XXIV. 1931.

Pressey L.C. and Elam M.K., ---- and Pressey E.L., Zook R.C. ----- and Narragon F.R. Articles on the vocabularies of mathematics. School Science and Mathematics, XXXII. Elementary School Journal, XXXIII

Remmers H.H. and Grant A. The vocabulary load of certain secondary school mathematics textbooks. Journal of Educ. Research, XVIII. 1928.

Stevenson E.N. An investigation of the vocabulary problem in college biology. Journal of Educational Psychology, XXVIII. 1937.

The Flood-West Popular Science vocabulary (supplemental to the New Method vocabulary).

Continued experience of writing within this vocabulary has shown the desirability of slightly extending the vocabulary as printed in the thesis. Very few of the additions are scientific words; most are words which could be avoided but which are so well known by readers that it is silly to avoid them.

The list now comprises 505 words with 73 'wanted' words. All relevant numbers in the thesis should therefore be suitably amended.

The additional ~~tx~~ words are given below; they should be added to Table X at the back of the thesis.

bead	hydrogen	pint
bleach	invent	shell (of gun)
bruise	ivory	signal
carbon	oblong	slanting
crane	opium	submarine
decrease	ounce	toad
electrode	oxygen	ton
fir	per	trunk (tree)
gallon	pilot	yolk

The word evaporate should be put in brackets and added as a derivative of vapour; slot should be ~~dxltx~~ deleted. Frequency should be extended to include waves, inherit to include hereditary, type to include typewriter, and soda-water should be split to include both soda and soda-water. Violet should be limited to colour.

The following additions should be made to Table XII ('wanted words') :

apparatus	focus	pod
argument	fuel	prize
button	knob	proton
chin	oven	razor
china	owl	spoil
coin	ox	spray
crime	paddle (oar)	truck
direct current	pedal	tunnel
drawer		wrap

Electrode, slanting, and yolk should be deleted; cross-section should be put in brackets as a derivative of section.

List A (p.181) should include Electrode. (The following 'wanted' words may be considered as list A words: catalyst, direct current, mammal, organic (chemistry), proton, secrete, stimulus.) The list on p.184 should be deleted.

List B (p.182) should include:

alcohol	coke	opium
alloy	hydrogen	oxygen
bleach	oblong	shell (gun)
carbon		yolk

The following should be deleted: bulb, emotion, volume, intelligence. Evaporate should be put in brackets as a derivative of vapour. (The following 'wanted' words may be considered list B words:

abdomen	equivalent	pivot
concentrated	filter	plane (surface)
(cross-section)	focus	section
diagonal	formula	structure
dilute	funnel	yard (ship)

Certain revisions are necessary to Table XVII at the end of thesis (Supplement to Carnegie). The following words should be deleted: avoid, boundary, convenient, gap, oppose, permanent, soup, sow. Evaporate and cross-section should be put in brackets as derivatives. The * (=wanted word) should be deleted from electrode, slanting, yolk. The following should be added:

apparatus*	hydrogen	pedal*
bleach	ivory	pilot
bruise	knob*	pod*
carbon	multiply	proton*
chin*	(=become more	shell (gun)
china*	numerous)	spray*
crane	oblong	submarine
direct current	opium	toad
fir	oven*	truck*
focus*	owl*	tunnel*
fuel*	oxygen	
	paddle*	

The total addition to the Carnegie vocabulary then becomes 426 words. Relevant numbers in the thesis should be amended.

It has been explained that the Flood-West vocabulary is not a list of essential scientific terms but a list of words by which the ideas denoted by such terms can be explained. It is instructive therefore to examine the frequency of the listed words in general reading matter; this will indicate whether the word is likely to be known by the general reader. Thus 'thorn', really a specific word of biology, is within the 4,000 most common words; it is sure to be known by the reader. Electrolysis is not within the 20,000 most common words; it is unlikely to be known by the non-scientific reader. Further, if a listed word has a very low frequency, and it appears not to be a scientific word, it presence in the list must be seriously questioned.

Frequencies were examined by means of the Thorndike-Lorge list of 30,000 words. Words with special scientific meanings (e.g. pole of a magnet) were excluded from the analysis. As homonyms and quasi-homonyms are in not distinguished in the Thorndike-Lorge list (e.g. spoke, state, wind) it was not possible to determine the frequency of ~~24~~ 34 words. (Ten of these words are in list B.) The distribution of the words of the vocabulary in the various frequency ranges is given in the Table on the next page.

Of the 11 words with frequencies of less than 1 per million, 9 occur in list A. The 2 exceptions are septic and bedbug. Septic was assigned to list B because its derivative 'antiseptic' is better known. Bedbug was excluded from list A and from list B. This word, really a specific of medicine, is seldom needed and its meaning is inferable from the more common words 'bed' and 'bug'. Of the other 41 words with frequencies of less than 4 per million all but 7 occur in list A or list B. These 7 are: cinema, gramophone, lavatory, pedal, pod, slanting, soot. I suggest that all of these words are better known than the frequency indicates.

Words with frequencies between 4 and 15 per million represent the second 5,000 words in order of commonness. Most of the remaining words of list A and B occur in this range. Two words of list A have higher frequencies: solution, resist. Solution stays in list A because the much-needed derivative 'soluble' is far less common and experience has shown that it is not well-known. Resist stays in list A because it gives rise to the scientific term 'electrical resistance'.

Frequency of occurrence of the words of the Flood-West in general reading matter.

Frequencies are expressed as the average number of occurrences in 1 million words. The table shows the number of vocabulary words within each range.

Frequency range	Thousand (approx)	Number of words in range		
		Vocab.	Wanted	Total
over 99	1st	14	-	14
50-99	2nd	55	7	62
30-49	3rd	70	13	83
19-29	4th	76	14	90
14-18	5th	49	5	54
10-13	6th	46	6	52
8-9	7th	~~24~~ 34	5	39
6-7	8th	30	5	35
5	9th	19	1	20
4	10th	8	1	9
3	11th	13	2	15
2	to	12	3	15
1	20th	11	-	11
Less than 1	-	9	2	11
Ordinary words with special meanings in science.		25	2	27
Homonyms, etc		34	7	41
		505	73	578

The science vocabularies of Basic English

Since the writing of the thesis I have been able further to study the possibilities of Basic English. In Basic a xigix single word-unit is allowed to covera range of meanings (e.g. 'current' covers 'electric current' and current events'); compounds are supposed to be inferable (e.g. 'offspring' is allowed because 'off' and 'spring' are listed). I do not agree with this "short count" method of listing a vocabulary but I find, of course, that Basic is more elastic than I thought. Some words (e.g. offspring) which I thought not to be available in Basic are, in fact, available. Hence all numbers and lists in the 'Basic' section of the thesis (and relevant Tables at the back) are inaccurate

Before revising the numbers and lists, it is worthwhile to note that Ogden suggests that Basic may solve the problem of vocabulary in Popular Science. In "Basic for Science" sample passages are given to show that Basic can be used for popular exposition. In some of these passages only the 850 words of the general list and the 50 general international words are assumed. In others, some of the commoner international words are assumed and in one the General Science list is also assumed. Other words are explained when they are first used. These passages are remarkably good but careful examination shows that the vocabulary is not quite big enough. Thus candle, film, mouse, tide are among the words explained in the texts; explanation of such words might well be irritating to the English reader. Explanation is given of certain elementary scientific words, e.g. lens, heredity, temperature, element, - words of such general utility in Popular Science that they should form part of the working vocabulary. On the other hand, a number of international terms (e.g. atom, molecule, energy, planet, microscope, mineral, magnetic, formula) are assumed. No indication is given of which words may or may not be assumed, i.e. the working vocabulary has no fixed boundary. I do not think that the Basic system provides a self-contained, adequate vocabulary for Popular Science; it was not designed for that purpose.

As is explained in the thesis, exact numerical comparisons cannot be made. The figures (given below) for the comparison of the total (consolidated) Flood-West list and the Basic list are as near as I can make them.

Examination is first made of the words which are included in the Basic science lists but which are not available in the Flood-West list. The 300 Basic words are numerically distributed as follows.

General science list (100)	
Words in New Method list	30
Words in FW supplemental list	31
Other words	39
Special sciences lists (200)	
Words in New Method list	24
Words in FW supplemental list	49
Other words	127

The 166 words not available in the Flood-West system are of five kinds.

(1) Words which, at the level of P.S., can be avoided by the use of other words which are available. (For some there is a synonym; others can be avoided by periphrasis.)

These 55 words are -

adjacent
alternate
application
approximation
arbitrary
arc
axis (1)
buoyancy
capacity
case (=example, condition)
collision
constant
corrosion
deficiency
discharge (2)
dissipation
domesticating
elimination
erosion
fume
fusion
germinating
host
individual
interpretation
investigation
lag
link
magnitude
mature
mean (average)
medium (n.)
oblique
plug
projectile
rectangle
reference
repulsion
residue
reversible
rigidity
rotation
saturated
seal (enclosure)
solvent (3)
specialization
specimen
stable
stalk
substitution
successive
suspension
thrust
tongs
transmission

(1) a possible extension of Axle.
(2) a possible extension of Charge
(3) a distant derivative of dissolve (and soluble), but easily avoided.

(2) Words which are needed in Popular Science and are irreplaceable but are needed only on rare occasions. There are four such words: flint, gravel, porcelain, slate.

(3) Mathematical terms which a reader would probably know from his school studies. There are 10 such words:

denominator
divisor
multiple
numerator
product
quotient
ratio
subtraction
sum
term

(4) Words which are too technical for use in Popular Science without explanation. (It should be noted that some apparently common words, e.g. dip, strike, are included in this list; they are used in Basic in highly scientific senses.) 74 such words are listed. The symbols G (=geology), P(=physics) and M (=mathematics) indicate that the words are used only

1 senses in these subjects.

acceleration
accessory (G)
adsorption
amplitude
appendage
beaker
birefringence
cartilage
cast (G)
cleavage
clip
component
congruent
conservation
contour
cusp
damping (M)
dip (G)
drift (G)
duct
dyke
eruption
extinction (G)
fan (G)
fault (G)
flask
foliation
grating
inclusion (G)
infinity
integer
intercept
interpenetration
intersection
intrusion (G)
inverse
locus
metabolism
momentum
node
outcrop (G)
outlier
overlap (G)
prime (M)
probability (M)
projection
reagent
reciprocal
recurring
reflux
reinforcement
resolution (M)
sac
scarp
schist
sedimentary (1)
sepal
shale
shear
sill (G)
slide (microscope)
stamen
strain
stress
strike (G)
texture
thorax
trap (P)
twin
unconformity
valency
vascular
vestigial
vortex

(1) Layer (rocks) is a convenient alternative in elementary texts.

(5) The remaining 23 words are as follows.

*abdomen
*claw
column (=row)
degenerate
*dilution
environment
fin
flood
*focus
fracture
*funnel
gill
glacier
hoof
igneous
latitude
longitude
rot
scale (leaf, fish)
*section
*secretion
*stimulus
velocity

These words can be avoided but they are useful. Eight of them (marked *) have already been noted as 'wanted'. All might be added to a Popular Science list.

Examination is now made of the words which are included in the Flood-West lists but not in the Basic lists. The 505 words of the FW list are numerically distributed as follows.

Words in the general (850) list	81
Words in the General Science list	31
Words in the Special Sciences lists	49
Words taken as international*	117
Words not available in Basic	227

*This includes both general and scientific international words, metric measures, and names (e.g. of chemicals).

It is only necessary here to consider the words of lists A and B which are not available in Basic. The following words arise from list A.

bond - This term is covered in Basic by Link (general science) and Valency (physics+chemistry).

negative - In "Basic for Science" Positive is listed as international but Negative is listed only as international with reference to photography. Private correspondence has elucidated that Negative must also be considered international in its electrical sense; it was omitted from the published lists in error.

resin - This term was originally selected by Flood-West in order to effect explanations of Plastics. As Plastics is now almost a household word such explanations are hardly necessary. The term was retained because it is needed in pharmacology and in connection with paints and lacquers.

seizure - This may be considered a 'dignity' word. It was selected because its obvious alternative, Fit, has another, more common meaning.

storage battery - The Basic equivalent is Accumulator (international). The latter term is probably preferable for the English reader. For overseas readers storage battery presents less learning burden; store is a common word and battery is already in the FW vocabulary.

Field (magnetic), mass (scientific use), and salt (chemical use) are available in Basic as extensions in meaning of the familiar words. Soluble is a very useful word but does not appear in Basic.

There are 39 words of list B which are not available in Basic.

(a) Words of applied science for which Basic does not deliberately provide:

bearing (of machine), bolt, cast (metal etc), crank, cartridge, gear (wheel), glaze, lathe, loom, manure, mould (shape), propeller, rivet. (*pivot, *yard).

Of these, it is suggested that Cast and Mould are of general utility.

(b) Words which might be accepted as names:

gourd, jute, maize, malaria, opium, smallpox, yeast.

(c) Dignity words: magnify, revolve, vomit. (Magnify can be avoided by the use of "make bigger" but the substitution of "strong glass" for "magnifying glass" (as in "Basic for Science" p.67) is not really satisfactory.

(d) Words which are needed fairly often and are recommended for inclusion in any further Basic lists:

aerial	dissolve (2)	sieve
alloy	fertilizer	source
bleach	inflame	surgery
compress)1)	oblong (3)	yolk
develop (photography)	septic (4)	

(1)Compression is accepted as international in engineering.
(2)Dissolve, being a verb, is not consistent with the Basic system.
(3)Rectangle is the Basic alternative
(4)Antiseptic is accepted as international.

Tables XIV, XV, XVI at the back of thesis should be disregarded.

Corrections to pp.201-205

p.201. Amend the middle of Extract A to read -

"....by invasion through stomata or other natural opening, or by way of parts (for example, the stigmas of flowers) where the cuticle is poorly developed."

p.202. "Inhibit" should be underlined.

p.202. Amend the middle of the simplification to read -

"....by going through stomata[2] or other natural openings, or through parts (for example, the stigmas[3] of flowers) where the cuticle is not well developed."

p.204. Extract B. Although "vegetation" is not an inferable derivative of "vegetable", it might be conceded that "indirect" and "scenery" are inferable derivatives of "direct" and "scene". The last line of the simplification (p.205) might be rendered thus: ....which control the development of the appearance of the land.

p.219

It will be noted that many of the words of Table XXVII have now been taken into the vocabulary or added as 'wanted' words.

References

Of the many works consulted since the writing of the thesis, the following should be specially noted.

Bongers H. The history and principles of vocabulary control. Wocopi, Woerden (Holland).

Crammer J.L. The popularisation of science through cheap books. UNESCO/NS/69. 1949.

Kapp R.O. The presentation of technical information. Constable and Co. 1948.

Mohr J. A study of popular books on the physical sciences. (Degree thesis, New York 1942).

Trenaman J. Intelligibility of Educational Broadcasts. Nature, Vol.166, No.4228. (Nov.1950).

Education Department,
University of Birmingham,
Edmund Street,
Birmingham 3.

W.E.Flood

10th July 1950.

A sample of

A SCIENTIFIC AND TECHNICAL DICTIONARY

by

W. E. FLOOD M. A.

and

M. P. WEST D. Phil.

showing

A to ACRYLIC RESINS, and

ENTROPY to EYE-PIECE.

NOTE

In this sample,

(1) pronunciation signs are omitted (In the published work pronunciation is given in the international phonetic script)

(2) the sign ☐ in the margin indicates that a diagram or line-drawing is provided in the published work.

In the preliminaries of the published work explanation is given, inter alia, of the following:

(1) the sign ↓ means "see" or "q.v.".

(2) needless repetitions of words are avoided occasionally by using only the first and last letters, e.g. "s.e" for "substance".

It is estimated that the whole work includes about 10,000 entries.

A - chemical sign for † Argon.

a' - at the, e.g. a'baft - at the back of the ship; a'beam - at side; a'board - on (in) the ship.

a-/, an-/ - not, without, e.g. acephalic - without a head, amorphous - without form or shape, not in crystal form.

A.C. - † alternating current.

a.c. - ante cibum, (medicine to be taken) before food.

A.C.E. - automatic computing machine, like †A.S.C.C. but using cards (not paper) and working by a simpler system.

A.P. - †arithmetic progression.

A.U. - † Angstrom unit.

A.S.C.C. - automatic sequence controlled calculator; an instrument using valves (like radio valves) to do large calculations, the c.ns to be done are cut as holes in a long strip of paper.

A.S.D.I.C. - †asdic.

A.W. - † atomic weight.

abdomen - (1) the part of the body below the lungs; it contains the organs with which food is digested and the organs of reproduction. (2) the third part of an insect body - head, thorax, abdomen.

abductor - muscle which moves a limb outwards from the body.

aberration - wandering away. (1)used of light when a lens does not bring all the light (e.g. of different colours) to the same point (=chromatic aberration) or where the lens is not correctly curved and so bends part of the picture out of shape (=spherical aberration). (2) When a man on the Earth is looking at a star he does not see the star where it really is; the star-light takes some time to reach him, and the Earth is moving, so he see the star where it was. The difference between the seeming and the real place is the a.n.

abomasum - the fourth stomach of a grass-eating animal, e.g. a cow; in it the main work of digestion is done.

abortion - producing young before the proper time and not completely formed. *Contagious abortion - disease of cows caused by the organism Brucella abortus; it causes loss of the young animal in the 6th or 7th month. (*passed on, by touch, from one animal to another).

abrasive - substance used for rubbing away or polishing, e.g. sandstone, emery, carborundum.

abreaction - process, in the curing of mental disorder, in which the sufferer calls back to mind and faces some unpleasant memory which he is trying to forget.

abscess - an area of the body infected with bacteria; a collection of septic matter (bacteria and dead blood-cells) e.g. under the skin.

abscissa - The exact position of any point P can be described in map-making or mathematics by its distance from two lines at right angles; NP is called the abscissa (the cut off part) and MP the ordinate. abscission layer - the place where the stem of a fruit (e.g. an apple) or leaf breaks off from the branch.

absolute - perfect, pure.

absolute alcohol - pure a.l with no (or very little) water in it.

absolute magnitude - "Magnitude" (=bigness) here means the amount of light of (the brightness of) a star. The apparent magnitude is the comparative brightness as seen from the Earth; but a bright star far away may seem less bright than one (really less bright) which is nearer. The absolute m.e is the comparative brightness which the stars would have if they were all at the same distance away.

absolute units - electrical units (of current, pressure, etc.) which are based on the † centimetre-gramme-second system. The practical units (e.g. ampere) are absolute units multiplied by certain figures.

absolute zero - $0^{\circ}C$ on a centigrade thermometer is the temperature at which water freezes, but ice has some heat, e.g. ice is hotter than liquid air. At absolute zero there is no movement of the molecules and so no heat at all. -273.13 degrees centigrade. †Kelvin.

absorb - take in, e.g. dry table-salt absorbs water on a wet day, the gas CO_2 (carbon dioxide) is absorbed by water as in soda-water. Heat and light are absorbed by a dark surface; sound is absorbed by a soft surface.

absorption - being absorbed, act of absorbing. When light passes through certain substances (e.g. a solution or gas) some of the colours which make up the light are absorbed so that there are dark lines or bands in the spectrum. These dark lines (called absorption bands or absorption lines) tell the scientist what substance the light has passed through. †absorb.

abutment - that part of a wall which carries the weight of an arch.

abyssal rocks = † plutonic.

acanthus - plant whose leaves are seen carved on the top of Greek and Roman pillars.

acarus - mite (=small spider-like creature) e.g. †mange, scabies.

<u>acceleration</u> - going or becoming faster, e.g. a thing falling down towards the Earth falls 32 feet per second faster in every second; if it starts from rest ite speed is 32 feet persecond at the end of the first second, 64 at the end of the second, etc. Its acceleration is 32 ft. per sec. per sec. So also of a car, bullet, or of a process, e.g. reproduction of bacteria, spread of a chemical change through an explosive, etc.

<u>accelerator</u> - substance used to speed up a chemical change, e.g. calcium chloride used to make cement become solid quickly, magnesium, aniline (and many other substances) used to speed up the vulcanizing (sulphur hardening) of rubber.

<u>accelerator-pedal</u> - bar pressed with the foot to make a motor-car go faster.

<u>acceptor circuit</u> - An electric circuit (especially in radio) may contain a condenser and a coil as shown. If an electric current is started in this circuit it flows backwards and forwards round the circuit. The frequency of these swings depends upon the sizes of the condenser and the coil; so that the circuit has a <u>natural</u> frequency (natural rate of swing). A is a source of alternating voltage (electric pressure), e.g. from a radio aerial. Its power acts backwards and forwards at a certain frequency. If the frequency of the source is the same as the natural frequency rate of the circuit, a big current flows, and the circuit is an acceptor circuit for this particular frequency. (Compare pushing a pendulum in time with its natural ~~frequency.)~~ swings.)

<u>accessory food factors</u> - substances in food (usually in very small amounts) which are necessary for health, e.g. vitamins.

accommodation - (of the eyes) - changing the shape of the lens of the eye so as to see near and distant things.

accoucher - doctor who attends women in childbirth.

accumulator - electric storage cell - as in a motor-car for starting and lighting. In the common lead-acid accumulator, one plate A is lead, the other plate B is lead covered with lead peroxide; the liquid is sulphuric acid solution. When used to supply electricity, the current flows round the circuit from the plate B. Gradually both plates become alike (because of chemical changes) and the accumulator loses strength. The accumulator can now be re-charged by passing a current in through plate B. ☨ Edison.

accumulator (hydraulic) - large container into which water is pumped for use later in driving machinery (e.g. ☨ hydraulic press).

acetabulum - the cup-like place in the *pelvis into which the round top of the leg bone fits. (*the big ring of bone at the base of the body into which the two legs fit.)

acetic acid - The acid of vinegar is acetic acid (CH_3COOH) but pure a-a. is colourless. acetate - a salt of acetic acid ☨-ate. acetate of lead - used to make light coloured paints dry quickly. acetate rayon - silk made from acetic acid and cellulose (wood fibre).

acetone - a colourless liquid ($CH_3.CO.CH_3$) formed in the process of making alcohol. It is used to dissolve fats and resins; ☨ acetylene gas is dissolved in it for storing.

acetyl - the group of atoms CH_3CO- e.g. acetyl chloride CH_3COCl, acetylsalicylic acid = "Aspirin".

acetylcholine - a chemical substance formed at nerve endings; it carries over the nerve impulse from one nerve to another or from the nerve to muscle. Injected into the body, it causes activity of the ↓ parasympathetic system.

acetylene - gas which burns with a very bright light; got from calcium carbide and water: $CaC_2 + 2\ H_2O \rightarrow C_2H_2$ (acetylene) + $Ca(OH)_2$ (slaked lime).

achene - (a- not, chene=split open) - friut with a thin covering (pericarp) closed round the seeds. The pericarp is not fleshy or made of strong fibres, and does not open to let out the seeds, e.g. a burr.

achlorhydria - lack of hydrochloric acid in the liquid of the stomach.

achondro-plasiac dwarf - person with a full-sized body but very small arms and legs (a- = without, chondro = ↓cartilage, plasia = growth).

achromatic lens - lens which does not produce a coloured ~~image~~ edge in its image; made by joining two kinds of glass.

achromatin - substance in a cell (plant or animal) which is not coloured by dyes.

acid - a substance which, when dissolved in water, gives one or more hydrogen ions H^+. These ions join with water to form ion group H_3O^+, e.g. hydrogen chloride (HCl) dissolved in water (H_2O) makes H_3O ions and Cl ions. If caustic soda (NaOH) is added, sodium chloride (=common salt) (NaCl) and water are made. ↓pH.

acid radical - A molecule of sulphuric acid is H_2SO_4. The group of atoms SO_4 is the acid radical. Nitriv acid is HNO_3 ; the a-r. is NO_3.

acidosis - a state of the body in which excessive acid is found in the blood.

aclinic line - a line near the equator where the compass needle does not dip (go down more one end than the other). ↓dip.

acne - scattered spots on the face and neck especially in persons aged 13 - 20; cause unknown.

aconite - drug obtained from the plant Monkshood, used chiefly to put on the skin to lessen pain; very poisonous.

acoustic properties of a hall - (acou- = hear) -the effect which the hall has on sound, so that people can (or cannot) hear well in it.

acquired character - change in the body of an animal or plant during life, e.g. because of disease or work or food etc. ↓hereditary.

acriflavine - yellow antiseptic made from coal-tar, powerful in its action but harmful to nervous tissue, and it may irritate the skin.

acro- - top, furthest; e.g. acrocarpous - having fruit at the end of the branch.

acromegaly - disease of the ↓ pituitary gland which causes the head, hands and feet to be very large.

acromnion process - the part of the shoulder blade which can be felt at the top of the arm, slightly to the back.

acrylic resins - glass-like plastics (e.g. Perspex) which are made from acrylic acid, the simplest of the oleic acids (acids which form oils and fats). ↓ methylmethacrylate. acrylic acid CH_2:CH.COOH.

entropy - A certain amount of heat (measured in calories) may be thought of as spread out through a large volume of matter, e.g. through 1 gallon of warm (rather low temperature) water, or as brought together in a small space e.g. a fraction of a gallon of water at a higher temperature (e.g.boiling), or through a still smaller amount of water at a still higher temperature e.g. hot steam. The higher the temperature (measured in degrees) the more work can be done in cooling to a lower temperature; steam can do more work than warm water. The relation between the total amount of heat and the temperature is called entropy. Entropy = $\frac{\text{heat}}{\text{temperature}}$. An increase of e.y means a levelling or equalizing of heat in a system (set of things). When a steam engine works, its hot steam is gradually brought down to the temperature level of e.g. the surrounding air by changing heat into work; the higher the temperature of the steam, the greater the drop, and the more the work. If the steam cannot cool (e.g. if the surrounding air is at the same temperature as the steam) there is no drop and no work; the steam still has heat but the heat is not available. Any system, including the universe, tends to distribute (spread out) its heat so that entropy is increased (so that the heat is levelled out). The Nernst heat theorem. - Near absolute zero (no heat at all) chemical, electrical (etc.) changes take place "at constant entropy" (without any levelling out of heat, because there is no heat to level out); they are isentropic.

entropy diagram - figure showing the change of entropy (= heat divided by temperature) during the working of an engine. In a refrigerator (for keeping food cool), (1) compressed air at room temperature expands (= does work without loss of heat so temperature falls). (2) The cold gas goes into the warm food-container and takes in heat. (3) The gas is compressed by an electric motor. Work is done on it, so it increases in temperature but it gains no total heat. (4) The gas is cooled to room temperature.

enucleation - cutting out a thing (e.g. tumour = diseased growth, eye) so that it comes out whole.

enuresis - letting out urine against one's will, e.g. nocturnal enuresis - bed wetting.

envelope - outer cover. (1)The bag of an airship or balloon. (2)The glass container of a radio valve. (3) The curve which shows the outer shape of a modulated wave. (4) The curve marked out by a group of similar curves.

environment - What a person (or animal) is now depends upon (1) his heredity (the desires, tendencies, powers born in him) and (2) his environment = surroundings = everything which makes him grow in a certain way.

enzyme - substances (catalysts) produced by living cells which cause certain chemical changes to happen, e.g. yeast is a living cell which produces enzymes which change sugar into alcohol; ptyalin is an enzyme produced in the saliva (liquid of the mouth) which changes starch into sugar.

eo-/- ("dawn, day-break") e.g. eocene system - layers of sand and clay in Britain in which are found the earliest signs of life as it is now (not giant lizards etc.) about 70 - 45 million years ago.

eolith - (lith = stone) - very early stone tool.

eosin - red dye used in microscope work; eosinphil - cell (e.g. white blood cell) which stains easily with e.n.

ephebic - of a fully grown animal.

ephedrine - drug obtained from a Chinese plant, used to lessen congestion (state of being too full of blood) of the throat and nose during a cold in the head and asthma, also to strengthen the heart-beat.

ephemeral - lasting only a short time, e.g. ephemeridae, ephemeroptera - May flies (which live only for one day); ephemeris - book showing the day-to-day position of the sun, moon, planets for a certain time (until the next book is printed)

epi-/ - on, upon, over. epicentre - place on the surface of the Earth just over the part inside the Earth where an earthquake (movement, shaking on the e.h) begins.

epicritic sensation - fine sensations of touch, heat, cold, pain in the skin and the power of localizing them (knowing just where the touch etc. is). Such s.ns are the last to come back after a wound heals. ↓protopathic.

epicyclic gear - one or more gear wheels travelling round the outside (or inside) of a certain wheel.

epicycloid curve - the curve obtained if you roll circle A round the edge of circle B and mark the position of dot D as it goes. The shape of the teeth of a gear wheel (e.g. in a watch) are e.d and the teeth of the pinion (small driven or criving wheel) are ↓hypocycloid.

epidemic disease - an outbreak of a number of cases of a certain disease in a certain place at about the same time, e.g. an epidemic of measles in a school.

epidermis - the outside payer of the skin , or of a leaf.

epidiascope, episcope - instrumeńt used to throw light onto (=epi) a thing and through lenses and so show it on a white sheet. An epidiascope is able also to throw light through (=dia) a glass *slide onto a sheet. (* picture glass as in a magic lantern.)

epigeal - bringing its seed leaves (cotyledons) above the ground as in the castor-oil plant.

epiglottis - a little shield which protects the top of the glottis (upper part of the larynx O breath-pipe); when food is swallowed the epiglottis moves upwards and takes shelter behind the glottis so that food may not go down into the larynx.

epinathous - having the upper jaw longer than the lower jaw.

epigynous - having the petals, stamens etc. of the flower above the ovary (in which the seeds are formed) e.g. fuchsia.

epilepsy - disease of the brain in which there are sudden uncontrolled outbreaks of energy - crying out, tightening of muscles, noisy breathing, loss of consciousness.

epiphysis- soft, undeveloped end of bone, made of sponge-like material; in a grown-up person it becomes hardened into bone.

epiphyte - a plant which grows on another plant but does not take food from it e.g. a fern which grows on a tree.

episcope - v epidiascope.

epistaxis - bleeding from the nose.

epithelial tissue - surface cells, e.g. stratified epithelium - the surface cells of the skin,eye,throat, and other parts; ciliated epithelium - e.m covered with little hair-like growths as in the throat; columnar epithelium - e.m lining the bowel, urinary passages, glands, etc. epithelioma - diseased growth (cancer) of the surface cells of the body.

epithermal deposits - layers of metal ore formed at low temperature and pressure.

epizootics - widespread outbreaks of disease (epidemics) among animals.

epulis - a diseased growth on the gums (membrane covering the jaw below/above the teeth).

equation - a mathematical statement that two quantities are equal, e.g. $x = 2y + 3$; this means that, to work out (find) the value of x, you must take twice the value of y and add 3.

chemical equation - way of writing down a chemical action, e.g. $Zn + 2HCl \rightarrow ZnCl_2 + H_2$. (Zinc and hydrochloric acid combine to form zinc chloride and hydrogen). ☨ personal equation.

equator - imaginary line mid-way between the poles, dividing the Earth into two halves, Northern and Southern. ☨ Celestial

equatorial -Telescope, equatorial mounting - a telescope so set up that, once it is pointed to a certain star, it need only be steadily turned on one axle (A) for it always to point to that star.

equilibrant - a force which balances or holds several other forces. Example - two ropes pull down on a post. The *resultant of the forces is a downward force. The equilibrant E is the upward force by the post, balancing or acting against the resultant. (*single force which would produce the same result as the several forces acting together.)

equilibrium - state of being steady or still because forces balance. Examples - (1) a book on a table is in equilibrium.

upward force due to table = weight of book. (2) a lever with balancing weights; the turning power of the forces on each side balance. stable equilibrium - a state of equilibrium such that if the Body is slightly moved it comes back to its first position e.f. a box on the table.

unstable equilibrium - a state of equilibrium such that if the Body is slightly moved it moves further away and the equilibrium is upset, e.g. a pencil balanced on its point. neutral equilibrium - a state of equilibrium such that if the Body is slightly moved it stays in equilibrium in its new place, e.g. a ball on a level table.

equipartition of energy - a molecule of a gas can move backwards forwards, from side to side, up and down, or with 2 or 3 of these movements together. It may be able to spin in one or more ways, and parts of it may be able to vibrate in and out. All these different kinds of movement are called degrees of freedom. If energy is given to a gas, e.g. by heating it, the energy is equally divided among the possible degrees of freedom.

equivalence, principle of - *v* gravitation.

equivalent - of equal value, different yet able to produce the same result, e.g. equivalent lens - a simple lens which gives a picture of the same size and in the same place as a combined group of lenses.

equivalent weight - the weight of an element (or *radical) which can take the place of unit weight (e.g. 1 grm.) of hydrogen, or can join with 8 grms. of oxygen. Example - if zinc is dissolved in an acid (e.g. hydrochloric acid) it takes the place of the hydrogen, which is set free. $32\frac{1}{2}$ grms of zinc take the place of 1 grm of hydrogen; the e.w. of zinc is $32\frac{1}{2}$. When zinc joins with oxygen to make zinc oxide, $32\frac{1}{2}$ grms of zinc combin join with 8 grms of oxygen. The equivalent weight in grammes is the gramme-equivalent.

(* group of atoms found in a number of compounds but not existing alone, e.g. SO_4 - the acid radical in sulphuric acid.)

erg - a measuring unit of work. One dyne = the force which makes one gramme move 1 centimetre per second faster every second; one erg is the work done when a force of 1 dyne moves through one centimetre. Example; about 140 eargs are done in lifting one pin through a distance of one centimetre (not including the work of moving the hand and arm).

ergate - a worker ant.

ergosterol - substance in plant and animal fat (and in yeast) which, with the help of sunlight, becomes vitamin D. (Lack of vitamin D causes rickets, = disease causing soft bones in children).

ergot - substance produced by a fungus which grows on grain. As a drug it is used to stop bleeding and to tighten muscles (e.g. of the uterus =female organ, after childbirth).

erode, erosion - "biting away" e.g. of the coast by the sea.

Eros - small planet (= asteroids) which, at times, comes nearer to the Earth than any other planet. Its distance can be found more easily than that of any other planet or star, and from its distance, the distance of the sun, etc. can be worked our.

erratics - stones of various sizes carried by moving sheets of ice in ancient times and left when the ice melted.

error - ∛ probable error.

eructation - letting gas come up from the mouth; belching.

erysipelas - an infectious inflammation of the skin due to ∛ streptococcus.

eryth-/-r-/ - red - e.g. erythema - redness of the skin.

erythrocyte - red blood-cell.

escalator - moving staircase which goes up (down) as you stand on it.

escape, velocity of - the spped at which a thing (e.g. shot from a gun) must be going at the start if it is to get free from the attraction of the Earth - 7 miles per second; so also from any other Body, e.g. Moon, planet.

escapement - part of a clock or watch in which circular movement is changed into to-and-fro movement (oscillating) movement by the movement of a pendulum. This oscillating movement is constant (unchanging) and can be fixed so as to mark off time into exact seconds, minutes, hours - e.g. by making the pendulum exactly the right length. The Impulse pallet (driven by the power of the clock) presses against a tooth of the escape wheel; this keeps the pendulum swinging. The other pallet catches a tooth on the other side of the wheel, so the turning of the wheel is kept in time with the swinging of the pendulum, and the pendulum is set to swing in some exact unit of time. ∛ chronometer, circular escapement, lever escapement.

escarpment - step of hard rock standing out from a mountain-side.

/-escent - becoming, growing, e.g. nigrescent - becoming black.

eserine - =∛ physostigmine.

esparto - grass used in paper making.

espundia - infection of the mouth and nose by ↓ leischmania bacteria.

essential oils - the oils which give flowers their smell.

essential amino-acids - those ↓ amino-acids which the body cannot make for itself but must get in its food.

ester - substance formed by combining an acid and an alcohol, e.g. ethyl alcohol (ordinary alcohol) + acetic acid (the acid of vinegar) → the ester named ethyl acetate. Esters are used to make scents (perfumes) and flavours (tastes), also quick drying paint. esterification - making into an ester (see diagram).

ethane - CH_3CH_3 - a colourless gas with no smell; ↓hydrocarbon.

ethanol - ethyl alcohol

ethenoid plastics, ethenoid polymers - plastics such as acrylic resin, styrene, vinyl, made by joining together chains of ethylene molecules as shown.

ether, aether - substance thought of as filling all space through which light and radio waves (etc) might travel.

ether - liquid which very easily becomes vapour, made from alcohol; used to produce unconsciousness for surgery, able also to dissolve ~~fts~~ fats. Ordinary ether is diethyl ether $C_2H_5.O.C_2H_5$. Other ethers contain other ↓alkyl radicals, e.g. $C_2H_5.O.CH_3$.

ethmo - sieve e.g. ethmoid sinus - hollow in the e.d (sieve-like) bone at the back of the nose.

ethyl group - the group of atoms C_2H_5- (ethane group less one hydrogen atom). ethyl acetate liquid which smells like fruit used for making paint; for diagram see ↓ ester.

ethyl alcohol - C_2H_5OH - ordinary alcohol as in wine; for diagram see ester.

ethyl chloride - CH_3CH_2Cl - used to make a part of the body so cold that the pain of a small surgical operation is not felt; also as a quick-acting general anaesthetic.

ethylene - a gas, $CH_2:CH_2$, which burns with a yellow flame; coal gas contains some ethylene; also called olefiant gas.

ethylene glycol - liquid used to prvent the cooling-water of a motor-car from freezing. $HOCH_2.CH_2OH$.

ethylene radical - the group of atoms CH_2CH_2: e.g. ethylene chloride $CH_2Cl.CH_2Cl$.

etiolated plant - with small yellow leaves and long stems between them caused by not having enough light.

etiology, aetiology - study of the causes of disease. "What is the e.y of this condition?" = "What caused this illnes?".

eu-/ - well, good. e.g. eucaine - a form of cocaine (pain-preventing drug) which is less dangerous and more easily used than cocaine.

eucalyptus oil - strong smelling oil obtained from Australian tree, used e.g. on the handkerchief when one has a cold.

eudiometer - instrument for measuring the changes in volume (space filled by) of gases when they act together chemically. (so called because it was first used to find the amount of oxygen - the "good"gas - in the air).

eugenics - (well-born) - the study of ways of producing a better race of men, e.g. by getting children only from healthy parents.

euglena - one of the protozoa (very simple microscopic organisms) it looks like a small green leaf with a tail which is used for swimming; found in the green covering of standing water.

eumycetes - higher (more complicated) fungi. The threads of the plant body are branched and have cross walls.

euphoria - "well-feeling"; state of feeling very healthy and excited and strong; the feeling may be real, but it sometimes only a sign of mental disorder.

Eureka wire - wire made of copper-nickel, used for electrical resistances.

Eusol - an antiseptic containing chlorine.

Eustachian tube - tube joining the ear and throat; swallowing when going up to a height (e.g in an aeroplane) opens the e-t and so causes air-pressure in the ear to be equal on each side of the ear-drum.

eustatic levels - large, wide changes in the level of the sea caused by the melting (or forming) of ice at the poles.

eutectic mixture - (e.g. of metals); mixture in which the diferent substances crystallize out at the same time, and the melting point (temperature of melting) is the lowest possible for a mixture of those substances.

eutectic ~~mixture~~ structure - (of an alloy) - the size and arrangement of crystals found when all the different metals in the alloy crystallize out at the same time.

euthanasia - easy death; the idea that persone suffering from a painful and not curable disease should be allowed to be given a painless death.

evaginate - turn a tube inside out.

evaporate - become a vapour, cause to become vapour, e.g. motor spirit (petrol) evaporates quickly.

even keel, on - (ship) at the same depth in the water at the front and at the back; (sometimes - wrongly - used to mean not down at one side = listing).

Evipan - = hexobarbitone, a drug injected into a vein to produce general unconsciousness for surgery. √barbituric acid.

eviscerate - take out the bowels (and other organs).

evoc-/ -"out call" - e.g. evocative words - words which carry an emotion as well as their meaning, e.g. "Red" = communist + dislike.

evocator - substance which causes tissue near it to grow in a certain way, e.g. the eye cup (which develops into retina = nerve cells of the eye) contains a substance which causes other cells near it to grow into a lens.

evol-/ - "out roll" - e.g. evolute- with the edges rolled outwards. √ involute.

evolution - the development of more complicated forms of life (plants, animals etc) from simpler forms, e.g. the evolution of man from the simplest and earliest forms of life.

ex-/ - out e.g. √ excise.

exacerbation - of disease, causing to become worse.

exalbuminous seed - Albumin is the food-stuff substance in a seed for the young inside the seed. In e-a seeds (e.g. bean) the food is already inside the embryo (the young undeveloped plant) and there is no further food inside the seed-case.

excipient - inactive substance in which a medicine is mixed, e.g. fat.

excise - cut out by surgery.

excite - cause to be active; supply energy (especially electrical energy) to, e.g. excite a radio aerial. excited molecule - a m.e which has absorbed energy e.g. from an electric discharge; it gives back this energy in the form of light ↓ flourescence.

exciter - (of an electric generator) - a small electrical machine which supplies a direct current to the electromagnets of the generator.

exciting cause - of a disease. The predisposing cause of a d.e is, e.g. tiredness, bad food, lack of sunshine; the exciting cause is the infection (bacteria) which the person catches from from someone else.

excoriate - rub off the surface of the skin.

excreta - waste matter, e.g. from the bowels. excrete - pass out waste matter from the body, from the bowels, through the skin, in the urine, etc.

exfoliation - coming off in thin layers, e.g. thin pieces of bark from a tree, thin pieces of rock in icy weather.

exhale - breathe out.

exhaust - "empty out" - of an engine: burnt gases e.g. from the back of a motor-car. exhaust the air from - pump the air out of of. exhaust fan - wheel with sloping blades used to draw out air e.g. from the upper part of a room. exhaust ↓manifold.

exhibit - a drug - given as a medicine medicine.

exhibitionism - disorder of the mind in which the sufferer shows in public place parts of the body usually kept hidden.

exo-/ - outside e.g. exoderm - outerderm.

exogamy - marrying outside the family or tribe.

exogenous - formed outside

exogens - trees whose new growth is in the outer layers (as in most trees). † endo-

exophthalmic goitre - disease of the † thyroid gland which causes the eyes to stand out (ex - out, ophthalm - eye) and the neck to be swollen.

exoskeleton - outside horny covering and support of the tissues as in insects etc. In birds and animals the nails and feathers are e.n.

exostosis - outgrowth of a bone.

exothermic process - process in which heat is given out, e.g. the burning of coal. exothermic compound - a chemical compound in whose formation heat was given out, e.g. carbon dioxide (formed by burning carbon in air or oxygen).

expand - increase in volume, fill more space.

expanded metal - metal cut as shown, then pulled out to make the cuts diamond shaped holes; used as a metal centre for a cement floor or roof, also to guard windows.

expanding universe - The sun and all the stars which we can see are part of the Galactic System - which we see as a faint white band across the sky (= the Milky Way). There sre other systems of this kind beyond the G.S. Their light is (in most cases) displaced (moved over) towards the red (longer wave) end of the spectrum. († Doppler effect) This makes it seem likely that these systems are moving away from us. (If they were moving inwards the light would be displaced towards the blue - short wave - end of the s.m) If they are moving away the Universe (= the Galactic and all the other systems) is is expanding (spreading outwards) but there may be some other explanation of that displacement.

expansion, coefficient of - a fraction showing the increase in length (area, volume) of a substance ~~when~~ e.g. metal, gas, etc. for each degree rise in temperature. Thus, for steel the C of E is 0.000011. How much longer is a steel bar (e.g. a railway line) 40 ft. ~~long~~ in length, on a warm day (25°C) than when it is freezing? Answer: 40 x 0.000011 x 25 ft. = about $\frac{1}{8}$ inch.

expectorant - drug which causes a free flow of liquid in the throat so as to help getting rid of a cold or sore throat.

expiration - breathing out.

explicit function - If the relation between two quantities y and x is stated in the form " y = some ~~formula~~ expression containing x", y is an explicit function (openly stated relationship). Examples: $y = x^2$, $y = 3x + 1$, ✓ implicit

exponential function - function = relationship, e.g. "$y = x^2$ means "if x is 3, y is 3^2. In an exponential function x shows the power e.g. $y = 2^x$ (y = 2 to the power X). This means that if x is 3, y will be 2^3.

exponential formulae - mathematical statements of exponential functions; they are found especially in dealing with calculations about growth, decay, compound interest; e.g. if the starting number of bacteria is 50 and they double in number every minute, the number after x minutes is 50×2^x. So after 3 minutes the number is $50 \times 2^3 = 50 \times 8 = 400$.

exponential decay - Sometimes a quantity gets less in such a way that at the end of every second (minute etc) its size is a fixed fraction (part) of its size at the beginning of the second (minute, etc). This is an exponential decay. Example:

if the temperature of some water is 25° warmer than the air and it cools to 20° after 1 minute (5° cooling = 1/5 of 25), it cools to 16° in the next minute (4° cooling = 1/5 of 20), and so on. ↓ Newton's law of cooling.

exposure meter - instrument for finding out how long the light should be allowed to fall on a photographic film.

exsiccate - cause land to become dry - by cutting water channels etc.

extenders - "out-pull" - substances such as china clay , silica, barytes, added to paint to make it spread further; also added to plastics to give bulk (make it fill more space).

extension - pulling out, e.g. pulling a broken leg so that the bones come into line.

extensometer - instrument used for measuring the increase in length when a metal bar is stretched.

external circuit- the part of the electric circuit other than the battery (generator etc) itself, i.e. from A round the ~~cir~~ circuit to B.

extr-/-a-/ - outside, more than usual, e.g. extra-galactic system stars outside the group of stars to which the sun belongs.

extract - to draw out; get one substance from a mixture, e.g. iron out of iron-containing rock, sugar from sugar-cane.

an extract - e.g. drug, sweet smelling oil etc taken out from e.g. a plant. Attar of roses (rose oil) is an e.t of roses.

extrados - the outside (outer) curve of an arch.

extraneous - from outside, e.g. a bit of extraneous = an impurity, a bit of dirt in a pure substance.

extrapolate - ↓ /-polate

extravasation of blood - escape of blood from the blood vessels, e.g. fro a "black eye" (caused by a blow) is an e.n of blood into the tissue below the eye.

extravert - person who attends to people and things outside himself (not, like an introvert, to his own inner thoughts and feelings).

extrorse - (of a part of a plant) opening outwards away from the centre.

extrude - push a liquid out through a hole, e.g. melted metal or plastic to make bars. extrusion,n.

extrusive rocks - rocks formed by the solidifying of volcanic liquid pushed up out of the surface.

exudate ,exudation - "out sweat" - ;liquid which comes out through the wall of a diseased or damaged blood vessel (or organ).

exuvia - cast-off skin, e.g. of a snake.

eye - loop at the end of a rope; hole in a block (e.g. on a ship) through which a rope is put; place (bud) on a potato from which the growth comes

eye-bolt - ring screwed in with a nut and bolt.

eyelet - small holed lined with metal, e.g. in a shoe.

eye-piece - the lens or lenses in an instrument (e.g. telescope, microscope) at whic the end where a man puts his eye.
