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or which might be made, to bridge the gap between scientific advances and public knowledge and information, apart from those which take place within school systems and in higher education.

The process of popularization involves three factors: the topics to be considered, the sections of the public it is wished to interest in the topics, and the media to be used in the processes of communication. To help in the making of consequent choices there will be a clear need to identify specific aims and criteria for decision-making.

No topic should be excluded *a priori*. Whenever there is a real advance in science it has to be known outside the small circle of specialists which participated in that advance — or it risks becoming lost. Any effort to make it known, to explain its meaning to a wider audience, is part of the process of popularization which can take place at a number of levels. At the highest level, the dissemination of advanced topics (through, say, expository papers) is an extreme, but an essential, stage in the general process. Yet there are many other topics of interest apart from contemporary research: for example, the history of a subject, its applications (particularly any of a novel character) and an understanding of the type of people involved in that science and of their motivation.

Similarly, no section of the public should be excluded. Children of all ages, workers, citizens, all types of professionals, even other scientists. All motivations have to be considered: professional interest, curiosity, general knowledge, ... , but also prejudices and fears.

All channels, too, must be exploited: books, newspapers, periodicals, films, exhibits, TV and radio programmes, software, ... Education and continuing education will play a decisive rôle complementary to that of popularization. Games and competitions will have a part to play — particularly in mathematics. Whatever the medium, popularization will be analogous to translation, and its quality will depend upon the skills and experience of the translator. Some of these are professionals: scientific writers and journalists. These may well have a catalytic rôle to play in involving scientists, teachers and other professionals in the general process of popularization.

2. Special features of the popularization of mathematics

The popularization of mathematics gives rise to certain special problems. First, many people's relationship to mathematics is governed by what happened to them in school. The affective consequences were often considerable: love, interest, dislike, hatred and, all too often, fear. It has to do with success in school mathematics and with the common belief that mathematics needs a special kind of mind and attracts only those of a particular disposition.

Mathematicians may reinforce this belief, either by refusing to participate in the subject's popularization, or by the way in which they behave or explain things to laymen.

"Mark all Mathematical heads which be wholly and only bent on these sciences, how solitary they be themselves, how unfit to live with others, how unapt to serve the world".

This view of mathematicians, expressed by Roger Ascham, 16th century educator and tutor to Queen Elizabeth I of England, is one which is echoed in many later writings. Blaise Pascal, who was himself intimately concerned with mathematics, used to contrast "esprit de géométrie" (a mathematical mind) with "esprit de finesse" (an accurate mind). The latter was an attribute of "honnêtes gens" (nobility and the high bourgeoisie), whereas the former was poorly regarded. This contrast has been a favourite theme for dissertations in French high schools, and has contributed to the view of mathematicians as strange characters, divorced from the real world.

Mathematicians may well reinforce this view when they speak or write about themselves and the mathematical world. As H. E. Robbins, himself a noted popularizer, puts it in his review of Ulam's *Adventures of a Mathematician*: if mathematicians appear as "thinking machines on the make, without discernible relation to parents, spouses or children, and oblivious to the human concerns of our times, ... if mathematical intelligence is strongly associated with emotional deprivation and social alienation, then ... we ... are in for trouble".

Let us raise a few questions for discussion. What is the popular view of a mathematician? To what extent does that view influence both the wish to study mathematics, or, should the possibility arise, to support mathematicians in their work? To what extent do books or films about mathematics or mathematicians reinforce unfortunate beliefs?

Given the importance of the affective relation of individuals with mathematics, can we agree that one purpose of popularization must be to create a favourable mental association with mathematics whenever and wherever it might arise?

A second special feature of mathematics which hinders popularization is the kind of topics on which mathematicians work.

Even the most abstract parts of physics or biology have a direct connection with some practically important and familiar subject, such as energy, space, the environment, or health. Topology in 3- or 4- dimensional spaces, finite groups, or properties of $\zeta(s)$ in the critical strip cannot be connected as easily with important, real life problems. (And attempts to link them with unimportant real-life situations may well prove counter-productive.) As L. A. Steen has pointed out ("Mathematics; our invisible culture") it may well be that the research frontier of mathematics is yet another order of magnitude more difficult to communicate than other frontiers of science, and that in many instances not even a professional scientist will attempt to comprehend a new mathematical direction.

This apparently contradicts our previous ruling that no topic should automatically be excluded from popularization. It raises the question: "In the present state of mathematics and mathematical research, are there topics which can be explained only to an audience of mathematicians?"

Even at the level of an expository article for mathematicians there is another difficulty. Science is never a mere accumulation of results, but this is even more the case in mathematics than for any other science. When a theorem is produced, the most important result may be the lemmas. When a problem is solved, then it immediately loses its interest — the new focus of interest are the methods used in the solution. Theorems and problems have, in the main, but a limited time in the spotlight. It is the lemmas and methods which provide the matter for new theories, new concepts, new definitions.

How is it possible convincingly to present the real dynamics of mathematics as a living science?

The public image of mathematics and mathematicians and the esoteric character of advanced topics make its popularization extremely difficult. Yet other features of mathematics may ease our task.

(a) *The rôle of problems*

Problem-solving is a part of school mathematics, as well as a part of the activity of professional mathematicians. In no school activity can the activity of the professional researcher be more closely mirrored. "How to solve it" is a natural and powerful introduction to results and methods. Popularization, then, is not concerned solely with transmitting information, but also includes the involvement of the public in mathematical activities.

(b) *Historical and cultural links*

No other science can boast such a history nor can exhibit so many cultural links. For example, ICMI Study 1 *(The influence of computers and informatics on mathematics and its teaching)* showed how these historical links can be reinforced by the use of computers, for under their influence many parts of mathematics have come to life again after a long period of lying dormant. To trace the history of a topic may be an easy and useful approach to popularization at every level. Alternatively, to see how the same demands in different societies have led to similar, even if superficially different, mathematical ideas can show the extent to which mathematics is culturally based.

(c) *New applications*

In the past twenty years mathematics has been recognised as a useful, indeed essential, tool in many disciplines and technologies. ICMI Study 3 *(Mathematics as a service subject)* considers the implications of this within higher education. Yet the implications are equally great for continuing education and for popularization. The interest of the public in the applications of mathematics — in their contribution to societal well-being — can well stimulate an interest in the mathematics involved.

What other "positive" features are there to be considered?

3. THE METHODS OF POPULARIZATION

The methods used must depend on the kind of public on which particular efforts are being targetted. We want to set the switches so that people will look forward to mathematics, and to the use of mathematics, in a great variety of circumstances. If one is young, this means that one looks forward to mathematics in one's own education; if older, to the use of mathematics in everyday life, in one's job and in civic responsibilities, and to the part mathematics will play in the education of one's children or grandchildren.

Popular lectures, television, museums, travelling exhibitions, films, plays, ... may all be used in order to create this favourable mental association with mathematics. We hope that one outcome of this study will be the collection of a set of good examples coming from different parts of the world. We suggest that there should be a careful study of specific displays, films or books about mathematics or mathematicians from different points of view: their aims and objectives, their quality, the positive impact they have made ("favourable mental association"), their negative impact ("mark all Mathematical heads ...") and, in general, the reactions of the target audience.

Many people, through their careers and professions, are provided with important motivation for renewing contact with some areas of mathematics. Popularization may provide a "second chance" for those whose previous