CINEMATOGRAPHY and SCIENTIFIC RESEARCH
Virgilio Tosi

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The purpose of this publication is to provide some ready information on the optimization and development of audio-visual techniques in scientific research.

The material here presented has been written and prepared, at the request of Unesco, by Mr. Virgilio Tosi, director of scientific films and television programmes and currently secretary-general of the International Scientific Film Association (ISFA). Contributions have also been provided by several members of ISFA and, in particular, by members of its Committee for Research Films.

This report was discussed at the joint round-table organized by Unesco and ISFA, in which participated Mr. Aart Gisolf (Netherlands), director of the Audio-visual Centre of the Erasmus University at Rotterdam; Mr. Zoltan Nemes (Hungary), director of the Research Film Centre of the Academy of Sciences of Budapest, and chairman of the ISFA Committee for Research Films; Mr. Cristoffel G. Sluijter (Netherlands), Philips Research Laboratories, Eindhoven, and secretary of the ISFA Committee for Research Films; Mr. Virgilio Tosi and Mr. Augusto Forti of the Unesco Secretariat.
1. The series of synchronized photographs of a galloping horse taken almost a century ago by E.J. Muybridge (a British photographer who emigrated to the USA) marks the first attempt to analyse the phases of a rapid movement by visual recording. Here scientific film was born, several years before entertainment film (Palo Alto, Calif. 1878).
2. The movements of man studied by the French physiologist J.E. Marey, using the "fixed plate chronophotograph". This apparatus (preceded by the 'photographic gun', also made by Marey, after the 'astronomical revolver' of Janssen) was followed by a film roll model, the first real cine camera (Paris, around 1885)

Top image: Jump
Bottom image: Silhouette of a man running. The man is wearing black and is photographed against a black background; the white traces mask his profile.
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INTRODUCTION

The aim of this publication is to delineate the essential characteristics of cinematography considered as a means of scientific investigation. The historical background given here as well as the examples chosen by way of illustration are obviously far from complete. They have been included only when they may throw light on the present state of research film, an exhaustive study of which would in fact be difficult since the bibliography, divided amongst the diverse scientific disciplines, is widely scattered.

The second part gives several particularly representative examples of structures which have lent themselves to, and influenced the development of, research film.

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3. Scientific film has permitted the study, analysis, or discovery of several phenomena. In biological sciences, the possibilities offered by the property of scientific film to shorten a time span by time lapse filming have been widely exploited. This technique makes it possible to screen lengthy processes such as growth, metamorphosis, etc. These pictures show three phases of the development of a chick embryo, extracted from a film 'Dal uovo alla gallina', made by the Italian Roberto Omegna (Rome, Istituto Luce, early 30's).
Cinematography can be used as a tool of scientific research in all cases where movement is implied, whether it be a question of behaviour, of transformations of matter, or of any other kind of change occurring in time or in space.

Its utilization is complex because a choice has to be made in each case (of film stock, speed, light source, equipment, etc.) and because of the constant adaptations of the visualization procedures used. Complexity is increased by the fact that visualization techniques are continually developing. In the last few years, for example, a whole series of new techniques (electronic recording and transmission systems, optical fibres, computers, etc.) have been either integrated or added to the traditional methods so as to offer an ever-widening range of possibilities for identifying, analysing and understanding phenomena which could not previously be observed or measured.

The origins of scientific cinematography

The spectacular growth – unexpected at its beginnings – of the cinema as an entertainment industry and an art form too often obscures the fact that: “Cinematography originated from the demands of scientific research” (1).

In fact, cinematography has twin roots: in research on retinal persistence and in technological developments required for research into the physiology of movement. This is a useful reminder in a period when pure scientific research is often considered in terms of its effects on applied science.

Scientific cinema was born well before cinema as entertainment. The famous public projection of the Lumière cinematograph on 28 December, 1895 is generally thought to mark the beginning of cinema. Nevertheless, more than twenty years earlier, Jules Janssen,
an astronomer and the Director of the Meudon Observatory, had recorded the phases of the transit of Venus across the sun’s disc. To observe this phenomenon in 1874, he had gone to Japan and had a ‘photographic revolver’ constructed. This instrument worked on the basis of a circular photographic plate coated with wet collodion (the only type available at the time) on which successive images, each exposed for 70 seconds, were recorded.

Janssen’s technique is in many ways similar to that now known as time lapse filming. Even though it is no more than a series of successive still photographs, the working principles of the instrument with automatic movement, coupled with the movement of the light-sensitive surface, is at the very foundations of the cinema, in the etymological sense of the word, and corresponds to the analytical and documentational aims of the research undertaken.

In the 70’s an English photographer, Eadweard J. Muybridge, living in the United States, carried out a series of photographic experiments in order to settle an argument over the successive positions of a horse’s legs, and their contact with the turf of the racetrack. The argument had arisen between horse owners, and it seems that a bet of $25,000 was attached to it. Muybridge was hired by the Governor of California to try to settle the dispute by photography.

The problem had cropped up after examination of drawings showing the movements of a horse during a race. These drawings were made using mechanically produced sketches based on the graphic method created by the French physiologist Jules-Etienne Marey.

Muybridge’s experiments were carried out at Palo Alto, on a private racetrack belonging to Governor Stanford, on the site of the University campus which now bears his name. A series of cameras was spread out along the length of the track, each one being triggered by the horse itself as it passed. The pictures, still taken on wet collodion plates, gave the successive positions of the horse’s legs.

The scientific significance of these photographs is perhaps questionable from the point of view of their motivation and no doubt the operation and synchronization of the camera shutters were not perfect. Nonetheless Marey, having seen the results of these photographs, recorded at short intervals, to study the physiology of movement. For this purpose, he invented what he called a ‘photographic gun’ (developed from that designed by Janssen), which he operated in 1882 with newly available silver bromide dry plates, which were much more sensitive than the earlier wet collodion variety.
Cinematography and scientific research

The French physiologist then applied himself to the study of the wing movements in the flight of birds. Taking the camera he had just built, he set out for Naples, where he owned a winter residence. There he took his first pictures of gulls’ flight. He was able, thanks to the exceptional light conditions of the Naples region, and to the only recently invented silver bromide plates, to take silhouette pictures at the then exceptional speed of ten images per second. One of Marey’s assistants told how he was nicknamed ‘the mad man of Pausilipe’ by those who had seen him, armed with his bizarre ‘gun’, aiming at flying birds without ever once hitting one, and afterwards putting down his ‘weapon’, visibly satisfied with the results.

In the following years, Marey made, and often used, a ‘chrono-photograph’, first of all using fixed plates, and later on using a film roll, to pursue his study of the physiology of human movement. Technological developments had, in the meantime, substituted flexible film mounted on a roller for the fragile glass plates.

The film roll chronophotograph, which Marey presented to the Academy of Sciences, had all the basic features of a modern cine camera. It was a photographic camera equipped with a shutter in the form of a windowed disc moved by a crank, and a film moved on in jerks, stopping several times a second to allow a picture to be taken each time.

There can be no doubt about the importance of the contribution made by the cinema to scientific research and documentation at this early stage. The numerous scientific articles and reviews which appeared in the last quarter of the nineteenth century confirm this fact. Examples are the reports of the Academy of Sciences, articles in Nature, La revue générale des sciences pure et appliquée, as well as the publications of J.E. Marey, Le mouvement (1894) and La chronophotographie (1889) and of A. Londe La photographie moderne (1895).

Nobody, not even Lumière, had the slightest idea at the time that such an extraordinary future was in store for the cinema as a means of education, communication and artistic expression.

The point of interest for the researcher was the breaking up of the different phases of a phenomenon in order to study each one separately. He was practically never concerned with the idea of synthetically reproducing a phenomenon by the kinetic motion of recorded images. If Marey practically invented the cine camera, he never posed himself the question of projection, as Lumière was to do later on, since he was not the least bit interested in viewing a phenom-
enon as it had really occurred, the important thing for him was to analyse it.

What Marey wanted from the cinematographic technique was the slowing down of the motion as much as possible. His closest collaborator, Lucien Bull, pursued this objective and perfected in 1902 a system automatically recording 500 frames per second (the normal speed was 16 frames per second). In 1904, he attained 1,500 frames per second, permitting him to analyse the flight of a fly.

These studies were carried out in a rigorously scientific manner. The idea never occurred to Marey that his inventions might be profitable in any way. The technological advances that he made resulted from 'the demands of research'. He obviously wanted his priorities and his results to be known, but only through the medium of his minutely detailed publications, precisely describing his devices and their working so that any other researcher might repeat and profit from his experiments.

The object of this publication is not to trace the history of research film; for this it would be necessary to mention the work of British pioneers, as for example, F. Martin-Duncan, and many other experiments carried out in different countries: in 1880, Anschutz in Germany studied the action of a horse jumping and the throwing of a javelin by the cinematographic method; in Austria, in 1881, Lendenfeld recorded the flight of various insects; Pfeffer filmed in 1900 at the University of Leipzig the geotropic movements of plants over a 28-day period; at the beginning of the century, the Italian Omegna recorded the different phases of the metamorphosis of a butterfly; Dr. Marinescu of Bucharest Hospital applied Marey’s techniques to the study of the movement of hemiplegic subjects... A multitude of other examples could be given to illustrate the interest shown by scientific researchers, from the very beginning, in cinematography as a research tool. We have cited the work of Marey with a certain amount of detail only to show how the birth of cinema was linked to scientific research.

While almost all the general works on the history of cinema mention the pioneering work of Janssen, Muybridge, Marey and a few others, they completely neglect the history of scientific cinema beyond the beginning of the century.

The investment since then of huge amounts of money for technological research in the field of projection and in the entertainment industry, has led, of course, to great secrecy in order to protect patents. This research has borne fruit in the form of increasingly
sensitive film and increasingly perfect and highly flexible equipment, capable of performances undreamt of by the early pioneers in the field.

Two important consequences, among others, have resulted from this change:

Technological research has been carried on outside the scientific milieu, hence researchers have often lost touch with developments;

The specialists interested in this research have left scientific laboratories to work on technological research, which paid far better salaries. To cite only a single example, one of Marey’s assistants, Georges Demeny, left the Physiology Laboratory to work on the commercial and industrial applications of cinema. He became one of the most important competitors of the Lumière brothers at the time of the cinema patents war; but he did not succeed in carving out a place for himself in the field, and finally devoted himself to creating a system of rational gymnastics.

Cases in which film is the only possible means to obtain certain data

The use of cinematographic techniques in scientific laboratories has made it possible to obtain certain research data which could not be obtained in any other way.

The recording of dynamic events or phenomena offers possibilities such as:

- Shortening their time-span (time lapse recording of slow phenomena);
- Lengthening their time-span (accelerated, high-speed shots of phenomena occurring at varying degrees of rapidity);
- Observing or studying phenomena which occur in inaccessible places (underwater and space exploration, filming in dark places, endoscopy, very high or very low temperature media);
- Obtaining the enlargement of phenomena (cinemicrography, cinemacrography, enlargement of details through the use of very high definition emulsions);
- Observing phenomena occurring at great distances (telephoto lens, astronomical telescope, telescope);
Observing phenomena occurring at wavelengths invisible to the human eye (infra-red, ultraviolet, X-rays, gamma-radiography);
Visualizing differences of density and temperature (strioscopy, sonography, thermography);
Viewing the reproduction of a phenomenon any number of times;
conserving a fugitive phenomenon, or one that would be difficult or costly to repeat;
Studying, analysing and measuring a phenomenon, plotting curves.

These various possibilities can be combined, for example by using a particular visualization process whilst at the same time modifying the time factor. In other words, film allows us to ‘throw off the limitation of time’(3) or of space.

In the First World War, film was used in ballistic research. Since then, military, aeronautical and nuclear power establishments have used film a great deal, and they have, in fact, brought about important advances in the field of high-speed cinematography, as witnessed by the results presented at the Congresses of High-Speed Photography.

Similarly, in the fields of physics and chemistry, film has permitted observations to be made of metallic dislocations, electron interaction in inorganic crystals, the transformation phases of solids, and the polymorphous transformations of crystalline solids.

Biology — the science of observation par excellence — is naturally an important domain for research film. Since the work of Dr. Comandon, who at the beginning of this century applied cinemicrography to the study of cell karyokinesis for example, and up to the recent film studies on the lysomes, the number of research films in the field of biology (not to mention those on animal and vegetable behaviour) has been very large. The following classic examples will serve to recall the wide range of discoveries made by means of cinematography: the rotation of a cell which accompanies its division by mitosis; the autonomous movement of plants; the role played by gaseous formations in the chrysalids of certain insects undergoing complete metamorphosis.

Medical applications are mainly found in the use of cineradiography, the use of infra-red, of thermography and often overlap applications in biology, as far as the study of cell biology is concerned.

Finally, there are also a very large number of applications in the field of technology.
Towards a definition of research film

Depending on the use made of it, film may provide a means of revealing new knowledge, of confirming an assumption, or merely demonstrating a theory. It is therefore difficult to determine the precise field of research film.

As a result, there are wide divergences in the different definitions which have been attempted up to now. All leave some gaps or are subject to errors of interpretation.

More than a century ago, the astronomer Janssen gave a succinct formula summarizing what he saw as the scientific range of photography: 'It is the retina of the savant'.

Marey's assistant, Lucien Bull, defined research film as being 'made with the purpose of resolving a scientific problem which cannot be investigated by any other means'. This idea is shared by Dr. Pierre Thévenard: 'A film which, thanks to the inherent properties of the cinematographic technique, allows us to display a previously unknown phenomenon'.

There is general agreement on this aspect of research film. Controversy begins when one tries to broaden the definition to include what might be called the 'documentation' of research, which does not necessarily give results, but which may suggest a new approach to research. M. Jean Painlevé wrote: 'Research films may be defined as any film whose aim is a discovery, even if unsuccessful in this aim, plus any film which leads to a discovery even if this was not its original aim'.(4)

Professor Gotthard Wolf believes that the definition of a research film should include: 'the use of cinematography as a means of scientific investigation and also the conditions in which the shooting was made, the recording of a phenomenon discovered during research but which can only be made visible by an appropriate cinematographic method, and research material filmed for the purpose of subsequent comparative studies'.

An even wider definition is favoured by some British and American writers. For example, Dr. Randall M. Whaley has proposed: 'This category of film may be defined as one resulting from the use of cinematography as a research tool, as a data-recording technique, or as a reporting medium in pure and applied science'.

The fact that the word 'film' is used sometimes to connote the instrumental method, i.e. the method of investigation, and at other times to connote its end-product, i.e. the communicating document, serves only to accentuate the ambiguïté of definitions.
4. In botany, special techniques have made it possible to visualize and therefore to interpret the movements of plants. Here, a series of photograms of 'autonomous movements' of a plant; the next picture shows the trajectory of the movements recorded automatically on film by means of a camera placed above the plant. (Extracts from scientific films made by the Czech Professor Jan Calabek (Brno, 1955/60).
II – THE SITUATION OF SCIENTIFIC CINEMATOGRAPHY
WITHIN EXISTING STRUCTURES

It is difficult to present an over-all picture of the various types of structure within which film is used as a means of scientific investigation, since they differ so widely, not only in their aims but also in their juridical and economic aspects.

Nevertheless, the different situations may be grouped, in a somewhat arbitrary manner, in three categories of organization in order to facilitate discussion:

1) Scientific organizations in which film is an everyday tool of the trade;
2) National organizations which specialize in the making of research films;
3) Scientific film organizations having advisory, co-ordination, liaison or promotional functions.

The cine camera as part of the equipment of a scientific organization

When the camera does form part of the research equipment of an institute, laboratory, university or other scientific body, it is frequently used only as a means of obtaining precise data which will supplement results obtained by other means. These data may in some cases provide new information; in others they may confirm a result. Once the data has been abstracted from the film, it is filed in an archive, often in a degraded condition because the original was used carelessly and because no one took the precaution of making a duplicate copy.

According to the results of the survey carried out by the American Science Film Association in 1964, covering 509 American universities, some 250,000 feet of 16 mm film were recorded over a period of 5 years, dealing with 81 different subjects but this activity did not result in a single titled research film(5).
The British Scientific Film Association reports a similar situation and explains it as follows:

Security, either national or commercial;
Once the data has been abstracted from the film, the data is included in a research report and it is the report that is filed. The film may be kept, but it may be badly scratched because the data is usually read directly from the original negative;
The producer often feels that his research film is so specialized that no one else will want to see it, and therefore feels no obligation to list, file or distribute it;
The work entailed in providing shot-by-shot complete descriptions is not usually felt to be worthwhile, as the scientist would rather move on to the next experiment.

These arguments, which are perfectly valid and justifiable from the scientist's point of view, invite several comments.

In cases in which film supplies only a strictly quantitative analysis, the total data given by the images can be adequately represented by figures, curves and other symbols. But the situation is quite different in the case of qualitative analyses. The viewing of a phenomenon has persuasive power far superior to that of verbal interpretation. Furthermore, it can change the orientation of the research itself. In this case the quality of the image demands particular care and great mastery of the cinematographic technique.

Lastly, the visualization of a phenomenon may demand technical skills which are not always within the reach of the scientist or his team. In a report on scientific film at the Moscow State University, Professor V. Pell states: Requiring both scientific and technological abilities that scientists of various disciplines do not always possess, specialized film-makers are in charge of making research and teaching films for various university departments. Research films are used not only to record objectively scientific experiments, but also to reveal new information on the subjects under study and to constitute basic documentation for qualitative and quantitative analysis. The Department of Scientific Photography and Cinematography of the Lomonosov University in Moscow works in close cooperation with all other university departments. It was founded twenty years ago. Its activities cover three main directions: the training of students in photographic and cinematographic techniques, the making of teaching films and the setting up of new methods to record phenomena for research purposes.
One of the main tasks of the department is to make available technical data and methods of applying film techniques to scientific investigations undertaken in the various departments of the university.

In the early days of the department’s existence, demands from scientists were rare, but now the situation is reversed and the services of the film department are in great demand from scientists.

The problem to be dealt with is first clearly defined. It is then studied in detail before any decision is made as to the most appropriate method for dealing with it. Equipment, technique, format and sensitivity of the film to be used are then determined; problems of lighting and exposure are worked out, and special equipment is often set up in collaboration with the other departments concerned.

Tests are then made, and if the chosen method proves to be inappropriate, it is sometimes necessary to change it for an entirely different one. Once shooting has been started, the scientists involved are given all the necessary practical information for them to be able to carry on on their own.

To analyse the rushes obtained, the film is first screened several times and a visual and qualitative evaluation is made. Next comes a quantitative frame by frame analysis, with measurements of the displacements occurring from one frame to the next, of changes of light intensity, colour, etc.

Decisions concerning method, output, film stock, processing, etc. are often made with the aid of computers. If shooting is to last a long time, it is carried out by the scientists of the department concerned, either using their own film equipment or else under the control of the cinematographic department. If the projection is of short duration, it is carried out entirely by the specialists of the film department.

Once the results have been analysed, and an evaluation of possible and permissible error made with the aid of the film specialists, then the final analyses and interpretations of the results are made by the scientists who requested the making of the film\(^{(6)}\).

Cine film units exist within a great number of scientific research institutions.

In the United Kingdom more than 950 research establishments have film units (130 government installations, 150 hospitals and medical research centres, 118 universities, polytechnics and other educational institutions, plus over 500 in industry).

In the Netherlands, a survey carried out some years ago by the Dutch Photonic Association revealed 18 scientific institutes,
21 universities and 19 industrial research units using film as a research tool.

More than 660,000 feet of 16 mm film is shot per year in the United States of America in universities alone.

However the role, the importance and the level of skill of these different film units vary considerably from one institution to the next, and they are all the more difficult to evaluate since their productions are little known, for the reasons stated above.

All the surveys which have been carried out by the ISFA national branches in this connexion bear witness to the problems encountered in trying to obtain precise and complete results.

A working party appointed in the early 60s by the United Kingdom Department of Scientific and Industrial Research to carry out a survey in that country proceeded in the following manner(7). A questionnaire was sent out to 680 government research establishments, university departments and industrial units, inviting responses on the following subjects:

a) The value of cine-photography in their research and the kind of filming work done;
b) The value to them of information about other people's research film and the need for special editing and titling facilities;
c) The need for a technical information service on scientific cinemaphotography;
d) Their willingness to give information about their film and research film techniques;
e) Their views on the need for a research film centre.

Of the 680 organizations approached, 490 replied. Analysis of the replies was supplemented by a survey under the direction of a consultant appointed by the Department of Scientific and Industrial Research, who spoke with interested people in a selection of the establishments contacted. The aims of his survey were to discover:

whether failure to make full use of scientific film or photography was due to ignorance of the available possibilities or rather to a need for readier access to, or further development of equipment for shooting, or analysing and interpreting film;
in what way film shots made for analytic or recording purposes could, if desirable, be made intelligible to people other than the researchers who made them, and in what way could better photographic habits in such matters as making copies of original material, editing and distributing be fostered;
the kind of organization which could carry out such tasks and how it might be financed.

Such is notably the case of the Commonwealth Scientific and Industrial Research Organisation (CSIRO) (Australia) which employs 6,700 people, including 1,100 researchers. A Video and Film Centre functions in the framework of the Central Communication Unit, one of the six services in the general secretariat. It employs ten people who are qualified in the technical field and have gained experience in film production. The role of the Centre is to produce films to publicize the research projects of the different departments of the CSIRO and their results. It is in this way that biological research on the reproduction of the kangaroo led to the making of a scientific film which is now distributed throughout the entire world.

The work of the Video and Film Centre goes on in close cooperation with scientists from the various scientific departments, whose job it is to monitor the scientific quality of the productions. Moreover, almost all the scientific departments have their own photographic section, more closely linked to their particular needs; it is these sections which actually record research documents. Thus the role of the Video and Film Centre is rather that of a department of information and scientific documentation.

A similar situation exists in different industrial establishments in many countries.

From the above we can conclude:

that film is widely employed as a research tool by scientific institutions;
that the film documents made in these institutions remain for the most part little known, or even completely unknown outside the laboratory in which they were produced;
that all surveys that have been carried out in various countries have shown that these institutions would be favourable to the setting up of a National Research Film Centre.

National organisations specialised in the making of research films

The Scientific Film Institute of the Federal Republic of Germany (Institut für den Wissenschaftlichen Film) is the most representative example of this type of organization.

Its success is due to the combination of the following factors: a precise and well-defined orientation which is rigorously kept to;
The conclusions reached through this survey are given below. The result was the creation of a National Research Film Centre within the framework of an important scientific organization which already possessed a film department. This centre was closed down in 1974 owing to a reduction in government spending.

A survey was also carried out in 1965 by the Italian National Research Council, covering 2,408 university institutions, with the aim of finding out what use they made of cinematography as a research tool. Eight hundred and seventy six replies, of which 68 per cent were positive, were received. It must be pointed out here that more than a third of these replies stated that the films made were not suitable for projection, their aims being rather to analyse a phenomenon, to make a clinical diagnosis, or to conserve data in order to use them later as scientific documentation.

Apart from the above surveys, there are relatively few official and precise data on the use of film as a research tool by scientific institutions. The situation is further confused by the fact that budgetary credits for the making of films are often hidden or diverted, because cinema is still viewed with suspicion by some administrative services, due on the one hand to its cost, and on the other to a certain scepticism about its usefulness. Furthermore, the equipment bought for scientific research film making is sometimes little or badly used, due to its having been bought without sufficient consideration for the uses to which it was to be put (a problem which is doubtless not confined to the cinema). Anecdotes concerning such errors are legion: a group bought a camera for shooting thousands of images per second when what was needed was a much lower frequency; another bought film stock quite inadequate for the work in hand; yet another set itself up with equipment for cinemicrography without realizing that no one in the group was qualified to use it, and so on.

Technical errors, and the resulting wastage, can be avoided when a film unit with competent personnel exists in a scientific organisation. This implies of course that the organisation is sufficiently large to justify the setting up of such a unit.

Apart from the example of Moscow University’s Chair of Cinematography cited above, the aims of which extend considerably beyond the needs of research alone, film departments do exist in a certain number of state or industrial scientific bodies.

Such is notably the case of the Commonwealth Scientific and Industrial Research Organisation (CSIRO) (Australia) which employs...
ample financial resources and the contribution of a highly qualified personnel.

After the second world war the 'Reichanstalt für Film und Bild' which had been set up in the 30's in Berlin was split into two separate bodies: the 'Institut für Film und Bild' located at München was charged with the making of primary and secondary school teaching films, and the 'Institut für den Wissenschaftlichen Film' (IWF) at present located in Göttingen is responsible for the application of film to scientific research and the production of university teaching films.

The structure of this establishment is of a semi-public nature, having legal status and financial autonomy. As regards the making of university teaching films, its funds come principally in the form of subventions from the ten states which make up the Federal Republic and from the Federal Government in Bonn. Research work is financed in part by a grant from the German Research Centre (Deutsche Forschungsgemeinschaft) and in part by aid from industry.

The staff of the Göttingen Institute consists of about one hundred people, 19 of whom are specialists in those subjects which are most important from the point of view of research film: medicine, biology, physics, chemistry, engineering sciences, ethnography, ethology, history, mathematics and psychology.

These specialists have not only a deep scientific background in one or other of these disciplines but they are also highly qualified in the domain of cinematography and capable of building efficient links between scientists with a research problem to be solved, and technical personnel qualified to solve it. They fill a role similar to that of a specialized production director. In addition, there are ten people responsible for shooting, of whom three work in cinemicrography and the other seven in cinemacrography.

Since 1961, the IWF has been installed in a building specially designed to meet its particular needs: a central unit houses offices, film archives, projection rooms, work and meeting rooms; a wing of the building contains the shooting facilities: laboratories, film studios (one of which is devoted to biology and two others to cinemicrography), recording studio with neighbouring rooms and laboratories for the operators. A greenhouse permits the raising of plants for biological research filming. There is also a laboratory for high speed filming, a mechanical workshop and a photographic laboratory with developing facilities.

The equipment comprises a very wide range of apparatus,
permitting the filming of phenomena at rates ranging from one frame per hour to 2,000,000 frames per second, cinemicrography and cinemacrography, Schlieren shots, holography, etc. These instruments are continuously undergoing modifications to adapt them to new demands and new problems.

This technical research, carried out by the physicists, electronics experts and mechanical engineers of the Institute can only be carried out in an organization of the size and importance of the IWF.

Furthermore, the analysis of results and the interpretation of data also requires special equipment and skills in which the IWF has attained a very high level.

In practical terms, when a scientific body finds a need for film in its research, the following possibilities are open to it: either it possesses the skills and equipment necessary to make the film on its own; or else it needs help from outside and can then call on the IWF which, depending on the case in question will supply the scientific organization with the required equipment and personnel, or else will make the film itself. If production costs are relatively low the IWF covers them out of its own funds; in cases where costs are heavy it may either ask for a special grant or seek financial assistance from an industrial body. Lastly, if the demand comes from an industrial group, then this group usually finances the project itself.

The result of this situation is, above all, the exceptional quality of the IWF’s productions, thanks to the great competence of its staff and the constant improvements which its equipment undergoes. Furthermore, the material filmed being handled in the best possible way can be made available to others and may be used either as basic documentation for demonstration purposes, or as a teaching aid for university teachers.

All documents which illustrate the behaviour of human, animal, vegetable or inert matter are grouped together in a collection entitled *Encyclopaedia Cinematographica*, which contains more than 2,200 entries. This remarkable collection is the fruit of collaboration between 422 research film experts in 28 countries, and is available, in whole or in part, in 14 countries.

Each of the films which make it up deals with only one well defined process or phenomenon, without any documentary preamble or any interpretation on the part of the author. Each unit is accompanied by a text; it consists of an introduction stating the object of the research and all the filming data, but makes no reference whatsoever to the personal interpretations of the author.
The situation of scientific cinematography within existing structures

The criteria used to select films for admission to the Encyclopaedia Cinematographica are inherent in the phenomenon under study: the impossibility of observing it otherwise than by means of film; the probability that it will not be repeated or will disappear; the need for a comparison to be made.

The films of the Encyclopaedia — all in 16 mm format — may be distinguished from scientific documents in the traditional sense of the term only in that they use the language of film. They may also be distinguished from ‘single concept film’ because they are not presented in a didactic form, with the aid of animated sequences or of the demonstration of experiments for example. They are film documents presenting a phenomenon as it actually happens. Nevertheless, although they are not aimed at teaching in the strict sense of the term, they may be integrated into a course by the teacher and allow the student to participate in the unfolding process or phenomenon.

The Encyclopaedia Cinematographica allows both horizontal consultation: the study of all manifestations of a given individual or material, and vertical consultation: by the study of processes and phenomena as they occur in differing subjects.

Scientific cinematography in Austria has very closely followed the development of the Göttingen Scientific Film Institute. The Federal Centre for Educational Photography and Cinematography, established in 1945, played an important role in the development of educational films. A special department for scientific films was inaugurated within the Federal Centre in 1962. Its main activities over the following ten years were:

The shooting and producing of films with scientific aims, be it in connexion with research work, in the form of documents filmed for study purposes, or for science teaching;
The development of a film lending library, which grew from 381 to 1,827 films during this period; 1,390 of these films are from the Encyclopaedia Cinematographica;
The promotion of contacts with foreign countries and the forging of links with international bodies so as to stimulate exchanges of film and information on research film methods.

In June 1972 the department became autonomous; it is now named the ‘Federal Scientific Film Centre’, and is attached to the Ministry of Science and Research.
The Research Film Centre of the Hungarian Academy of Sciences differs from that of Göttingen in that it was created at a relatively recent date, and that it sprang from a scientific and not a cinematographic body. In 1962, the Hungarian Academy of Sciences had decided to acquire within the framework of the Instrumentation Service the necessary equipment for making films. At first, it restricted itself to the rôle of renting this equipment to bodies which had need of it. However, the inconvenience of this set-up soon became apparent, on the one hand, because the hire of the material was not accompanied by the supply of the indispensable film stock, and on the other hand, because of the lack of personnel qualified in film techniques.

It was therefore decided in 1963 to create a Research Film Centre, whose functions would be:

- to carry out film work directed towards research;
- or: to aid the author of a research project by putting the necessary equipment and the technical assistance of a skilled team at his disposal;
- or: simply to make available various pieces of equipment.

The financing of this equipment, valued at over $60,000 was borne by the State, in the form of a grant accorded to the Centre until 1969. Running expenses were to be covered by the Centre's own income.

From 1962 to 1967, the Centre basically concentrated on building up a 'clientele', setting up contacts with all the bodies which up until then had been operating in a dispersed way. It should here be pointed out that, unlike the IWF in Göttingen, the Centre did not benefit from capital funds brought in for the making of university teaching films. Moreover, there exists in Hungary as in most other socialist countries—a studio for making films for the popularization of science. This produces teaching films as well.

It was therefore necessary to take advantage of a very specialized material, acquired for the purpose of aiding research, but which was nevertheless used in the production of sequences with a different object in view.

The Centre succeeded in paying off the debts on its material and now works for more than 500 different organizations: industry, universities, research institutes as well as film studios and television stations (for the shooting of sequences requiring the use of specialized material which cannot be obtained elsewhere in the country).
Independently of these economic problems, the Centre had the question of skills to resolve. It was essential for it to train a technically qualified working team. Efforts made to this end were of two types: liaison with the foreign organizations specialized in research film, notably through the meetings organized by the International Scientific Film Association (ISFA) and by the Congresses of High-Speed Photography and Cinematography; and also stimulation of interest in research film and its problems by means of publications, translations of specialized foreign works, and the constitution of a film library consisting, among others, of some 300 films from the Encyclopaedia Cinematographica. Meetings on a national level were also organized, in particular a National Conference of Film Technique which takes place every two years since 1969. At the last gathering of this kind, in May 1974, 26 papers were delivered on the results of research film and their meaning.

In spite of the difficulties it has had to face, the Budapest Research Film Centre is developing well. Its total annual receipts are of the order of $20,000, which allows it to bear the considerable costs which cinematography entails. Production costs are increased by the fact that the staff have not yet been able to attain the required level of skill, and therefore take longer to carry out the necessary technical and theoretical preparation for special shots. The institutes, more or less well endowed, cannot always assume the totality of these expenses, and if certain projects are not carried out for financial reasons, this results in a reduced use of the Centre’s equipment, which is contrary to the objectives of the Centre.

So as to ensure optimum growth conditions for the Centre, a study group was created with the job of planning, on the basis of the ten preceding years’ experience, investments, the training of qualified specialists, documentation, and international and national contacts.

The staff, which now comprises 12 people, is due to grow to 20 in 1979-80, at which date new premises, totalling 800 m² in area, will be obtained. Much care will be given to the training of personnel, indispensable if the equipment is to be utilized rationally.

The organizations described above represent the most significant examples of autonomous research film centres at the disposal of all scientific bodies in a country.

In several other countries, national bodies for the production
The situation of scientific cinematography within existing structures

of scientific films exist, but they are not so specifically oriented towards the development of research film. In France, the Scientific Research Film Service has recently been incorporated into the French Office of Modern Educational Techniques. It supplies scientists with the technical aid they need to allow them to use film as a research tool and it distributes the resulting films. In addition, a Service for the Study, Production and Distribution of audio-visual documents was set up very recently under the auspices of the Centre National de la Recherche Scientifique. In The Netherlands, the Science and Film Foundation’s principal aim is to encourage the use and the development of audio-visual methods in university teaching. Because it disposes of considerable production and documentation facilities and is in permanent liaison with the various universities, its role is rather similar to that of the organizations described below, as far as research films are concerned.

Organizations having advisory, informational, liaison or promotional functions

The International Scientific Film Association (ISFA) was established at a time when very few countries possessed an organization capable of developing research cinematography. Its aim was to bring together people interested in the use of film as a means of investigation and as a means of communicating scientific information. For this reason, the constitution of the ISFA stipulates that each country may be represented by only one body, whose function is to group together at the national level all activities pertaining to scientific film. It is considered that a special effort must be made to remedy the dispersion of existing work and to create liaison, co-ordination and promotion groups, capable of advising, informing and orienting.

The Research Film Section was the first specialized section to be set up within the Association. Starting in 1952, it undertook the publication of a bi-annual review under the editorship of Professor Wolf, director of the IWF, assisted at first by Professor Jean Dragesco, and then by Dr. Roger Robineaux. Le Film de Recherche – Research Film – Forschungsfilm has always acted as a link between members, published articles on new techniques or original applications of cinema

1. The use of film in higher education and for the popularization of science has since been added to the aims stated initially.
The situation of scientific cinematography within existing structures

or television as a research tool, and publicized new films in the Encyclopaedia Cinematographica.

At meetings of the Research Film Section, either at the annual congresses of the ISFA, or on other occasions, unreleased research films are screened, their technical aspects discussed and their contents described in the reports of these meetings.

This action has certainly played an important promotional rôle at the international level, but it cannot do more than coordinate the achievements attained at the national level.

Each national branch of the ISFA naturally has its own specific character which depends on the existing national structures, the financial and other support it receives from the State or private industry, the resources it has built up and lastly the specific aims it has set itself in relation to the most urgent needs of the country concerned. It is for this reason that each branch has sprung from very different origins.

During the very first years of the ISFA's existence, a Cinematographic Institute was set up at the University of Montevideo (ICUR). In spite of the modesty of its financial and technical resources, research films were made, a team formed and a collection of films brought together from different countries in a film library for the use of university workers. These activities contributed much to arouse interest in other milieus and create favorable conditions for the development of scientific cinematography. The work of the Institute has now been interrupted by external problems.

This is an example of a movement originating in the university, but subsequently extending its activities outside university circles.

A very different situation exists in Bulgaria where scientific cinema developed essentially within the framework of a State Studio for Science Popularization Films. All available means of production are concentrated within this organization, with the basic aim of using film to heighten the cultural level of the entire country. This centralization has achieved excellent results due to the fact that it has brought together all the skills and financial resources available, to the benefit not only of the public at large but of teaching and scientific research as well. This results from the fact that scientists not only have access to the studio's facilities but they also participate as scientific advisers. The situation has been beneficial for the development of Bulgarian scientific film, but the country also enjoys a very particular geographical, economic and political situation.

By way of contrast, the Japanese Scientific Film Association faces
difficulties in co-ordinating activities concerning scientific films, even though — or perhaps because — it operates in a country where technology is highly developed. Whereas the production of science information films reaches a very high standard, research films remain dispersed, as is the case in the United States of America.

The Canadian Scientific Film Association was created on the occasion of the 1967 ISFA Congress which was held in Montreal. The initiative was taken when it was noticed that there were few Canadian scientists present at the meetings of the Research Film Section of the ISFA during the Congress. The need for a co-ordinating body led to the setting up of a National Association, which was previously non-existent. The functions of ISFA national branch had until then been carried out by the Canadian Science Film Library (an organization which plays a leading rôle in the distribution of scientific films in Canada). The Canadian Scientific Film Association has now brought together competent scientists, but liaisons are still difficult due to the geographical situation of the country and the lack of a centralized structure.

Without enumerating the specific characteristics of each national branch of the ISFA, we can say that where a national centre does not exist, the associations which have been set up with the aim of co-ordinating activities in their respective countries fulfil a rôle of information and liaison by creating contacts between research film specialists, by making known the appropriate techniques or equipment for filming phenomena and by disseminating information received from other countries. Despite the moderate funds which they are generally accorded, they direct their efforts towards wider understanding of the techniques demanded by research film production. The Belgian, French, Netherlands, Spanish, Italian, and other associations organize regular meetings at the national level with the aim of stimulating interest and promoting the production of research films.

Outside the activities of the ISFA and its national branches, specialists in high-speed cinematography and photography come together every two years in a Congress in order to exchange ideas and discuss the latest developments in this highly specialized technique.
5. Since the invention of cinematography, applying the camera to different types of microscopes has made possible numerous investigations, including the recording of dynamic phenomena occurring at scales below the normal limit of vision, for scientific diagnosis or pedagogical documentation. The three photographs reproduced here show the elimination of a chain of bacteria by a white cell of human blood. Extracts from a film 'Leucocytes (Homo sapiens) Phagocytosis of bacteria' (E 449) belonging to Encyclopaedia Cinematographica, produced by the I.W.F., Göttingen.
6. Cinematography as a research tool has been widely used in physics and chemistry. A lot of new information which can only be revealed with the aid of an optical system has thus been observed by film. The three pictures (a, b, c) show the phases of spiral growth in crystals. Extract from a university teaching film: 'Spiralwachstum der Kristalle', made in cooperation by the Pharmakognostisches Institut der Universität Innsbruck and the Institut für den Wissenschaftlichen Film (IWF), Göttingen. The other pictures show the photoclastic visualisation of tensions and pressures exerted on different materials (Extracts from a film by the I.W.F., Göttingen).
III – PRESENT NEEDS AND SUGGESTIONS FOR FUTURE ACTION:

Generally speaking, the following three features characterize film and distinguish it from other tools of scientific investigation:

- the particularities of its 'language';
- the continual process of adaptation which it undergoes and the constant evolution of its technology;
- the fact that, over and above being a research tool, it constitutes a means of communication.

Understanding and analysing the information contained in the cinematographic image

We have already pointed out that the cinematographic image is not only a source of information to be measured and counted, but that the visual observation of a phenomenon under way may give a new direction to research by showing up the relationship between cause and effect. This implies that the scientist is capable of unravelling and then interpreting an ensemble of strictly visual data. Other investigations may then be carried out to confirm or refute his interpretation.

Such an attitude is not an inborn gift; it requires a certain background and a certain training in order to be able to put aside preconceived ideas and observe the unfolding of a process with perfect objectivity. Without this capacity, the usefulness of the image as a source of information may be underestimated, and some of its elements neglected.

Because of the complexity of the methods used, 'the requirement of optimizing the information compels us to test link for link for its contribution, in other words, the balance between various links of the chain also determines the final quality of the information collected. Hence, the accent lies on the interplay of the parts of the chain'.(8)
An in-depth knowledge of the recording conditions is thus necessary so that all parameters revealed by them can be taken into consideration when working out the possible errors of analysis.

**Knowledge and adaptation of visual recording techniques**

The fact that a very wide range of technical options exists makes necessary skills which are not always possessed by the scientist. Only with the collaboration of a very competent technician can he find the best way of visually recording the phenomena he is dealing with, and then carry out trials, adaptations and adjustments which alone he would not have time for. In effect, the rapid evolution of recording systems makes the technology of this field more and more complex. Advances in electronic recording over the last few years have for example yielded considerable possibilities for picking up, recording and reproducing moving images.

The combination of these new possibilities with more classical technologies using traditional visual recording procedures is continually opening up new vistas. The improvements made to the image intensifier have already made possible important advances in radiological research. Night shooting in colour without lighting is now a reality thanks to lenses equipped with electronic systems. The laser has opened the way to new memory storage techniques in the form of holograms and to investigations in fields not yet explored. Optical fibres make the conducting of light and images through very thin flexible channels possible and permit the exploration of phenomena in cavities or zones hitherto inaccessible due to their very small size. It is possible, using computer technology, to obtain moving images giving a visual representation of answers to specific problems solved only by means of calculations.

**Film as a means of communication**

Cinematography is not only an investigatory tool; once data obtained from a film have been used in research, the filmed document may still be of value as a means of communication.

It may, according to needs, be used to communicate results and to prove their validity or teaching purposes, which may necessitate re-editing, the addition of diagrams or other modifications or finally it
may constitute a basic document for science popularization, for the
purpose of illustrating a talk, or be used in the form of extracts
included in a film or a television science programme.

The three characteristics enumerated above all imply the need
for specialized technicians working in close collaboration with
research teams.

The necessity of organizing specialized training

In Marey’s time, film and scientific research were so closely linked, so
mutually dependent that the researcher himself became a technician
and completely mastered the techniques he developed. Scientific and
technological research was carried out in teams and made up one single
structure. It may be said that the Marey Institute was at the same time
a laboratory of experimental physiology and a scientific film centre.

We have seen how this situation has totally changed. Who are
today’s science film-makers? On the one hand, they are biologists,
doctors, engineers who have applied cinematographic techniques to
their own research, who have studied cinematographic methods in
relation to their own needs and have acquired equipment and fam-
iliarized themselves with its practical applications; on the other hand,
they are technicians who have developed skills in various cinematic
disciplines (optics, photo-chemistry, photo-physics) and who, in the
course of their professional experience, have picked up a basic scien-
tific knowledge.

The difference between the training and the state of mind of the
two categories constitutes an obstacle to the close collaboration which
is indispensable if film is to be used rationally and efficiently as an
investigatory tool.

Scientists, once they have been initiated in the cinematographic
technique appropriate to their discipline, and fitted out with equip-
ment adapted to their needs, hardly have the time, and are usually
not prepared to go into developments and new adaptations of tech-
nique. They tend to apply film methods in a routine way and to
ignore possibilities which might bring new technologies to bear on
their field. The situation is thus exactly the opposite of that which
existed in the early days of cinematographic research.

As for the audio-visual specialists associated with scientific research
teams, they have a tendency, owing to their training, to sacrifice
objectivity and scientific rigour to formal considerations, even more so
inasmuch as they are rarely integrated into the scientific team, who consider them as no more than operators.

Of course there are exceptions. We have already seen how in certain specialized centres, such as the Göttingen Scientific Film Institute, for example, the collaboration of film technicians and scientists poses no problems. NASA was able to exploit all the possibilities opened up by audio-visual methods, to recruit the most competent technicians and collaborate with them. But the latter case is exceptional, because money was no object and no effort was spared to achieve the required ends.

So long as specialized teaching, oriented towards the training of 'Scientific film-makers' is lacking, it will be difficult to change the situation described above.

Within the framework of the Ninth International Congress of High-speed Photography and Cinematography, held in 1970, a special Commission made up of members of the teaching profession, directed its attention to questions concerning 'the courses of study of photographic science for engineers, scientists and photographic technologists who plan to establish their professional careers in research, development, testing and instrumentation for fields in which photography is not the end product.'

In the opinion of Professor L.J. Poldervaart of the Technological University in Eindhoven, one question should have been asked beforehand: 'why is it that hardly anywhere have training courses arisen that answer what is stated in the theme?'. Having become acquainted with the teaching programmes of various countries, he suggested that a new definition of the field should be adopted, and tried to find a term appropriate for such a definition. 'Scientific photography, which was regarded as a section of photography or of optics, has now grown to such an extent that a need for a new name is felt'.(8)

He thus proposes to use the term 'photonics' to describe all systems in which photons are used as carriers of information. It is not our purpose here to go into the detailed pros and cons of this neologism, nor to make a critical study of the scientific fields which its author proposes to include in it.

It is indisputable that the lack of specialized teaching in audio-visual technology, now so complex, has been the cause of great recruitment problems and forms an obstacle to the development of research cinematography.

The evolution of the meetings of ISFA, which reflect the international situation in research cinema over the last thirty years,
confirms this conclusion. After a long period during which scientists participated in the research film section meetings, reporting their experiments and cinematic results, a sort of withdrawal on their part was noted. In many cases the cinematic method, once learned, had been applied in a routine manner, without any adaptation to new techniques for use in research. A revival of interest has been noticed recently, and certain research laboratories have shown interest in cooperating with specialists in cinematographic techniques.

Demands of this kind will probably become more pressing in the coming years. The development of audio-visual techniques in all fields, the need to promote interdisciplinary relations and the importance of these new technologies for international co-operation demand the creation of a specialized training so as to permit close collaboration between scientists and audiovisual technologists in the field of scientific research.

This implies that, in the first place, scientists must become aware of the possibilities which film (and all the visual techniques under consideration) opens up for them, be introduced to visual analytic methods, and acquire the elementary skills of cinematic technique. On the other hand, technicians trained in one of the basic scientific disciplines in which cinematography is currently used must acquire specialization in the film techniques required for research in the discipline involved.

Specialized high-level technological training should moreover be organized with the aim of preparing those who will be called upon to develop research methods using cinematography, and to teach these methods.

Through the process of writing and completing this report, including the analytical stage and the synthesis of collected documentation, it has been possible to draw attention to certain needs, some possible directions for future development and several concrete proposals for action.

A joint UNESCO/ISFA meeting was held to discuss current problems and the possible means of solving them. An international panel of experts was able to draw up several precise recommendations. It is certainly to be hoped that an appropriate teaching programme be instituted at the university level, both within the curricula of science students who intend to go into research and those of technical students who wish to specialize in the audio-visual technologies used for research. But if this goal is to be reached, the training of skilled teachers will above all be necessary, as well as the wider
distribution of technical structures essential to a programme which cannot remain purely theoretical but which will essentially become a sound practical and experimental one.

In the meantime, while developing a trend in this direction, we can proceed step by step. A first stage could be put into operation as follows:

Seminars to introduce to scientists the potentialities, uses and applications of various film techniques for research. This training differs greatly from an audio-visual training with an educational aim in which the problem is that of adapting the audio-visual message for a better understanding of a phenomenon or process. In scientific research, on the contrary, the aim is to analyse a phenomenon as it is visualized, so as to extract the maximum data from it.

Courses organized in those scientific institutions in which cinematographic techniques have been the most highly developed, for the benefit of those who would like to specialize in the application of these techniques.

Training, to the highest level of specialization, those who intend to devote themselves to the development of research film methods and their teaching. Such classes would, of course, only appeal to a very limited number of candidates. Studies should be carried out at an international level in order to discover the size of the demand, the contents and the level of the programmes.

The ISFA would be in a position to participate in such a programme of training by organizing seminars for the scientists, by identifying through its national branches those bodies in which the application of film techniques is highly developed, and by setting up contacts on an international level to discuss the contents of programmes which could be recommended at a high level of specialization.

The international group of experts at the joint UNESCO/ISFA meeting recommended two points in particular.

One short-term initiative which Unesco could encourage would be to start, on an experimental basis a number of post-graduate courses for small groups of scientists and technicians willing to specialize in the field of film and similar technologies applied to scientific research. These courses should be based essentially on co-ordinated training on the job, in well equipped experimental centres, but naturally would
include some lectures to provide the theoretical basis and the introduction to the subject.

The introductory seminars for scientists should serve to develop a form of audio-visual literacy and could take the form of multi-media packages, including films, slides, audio- and possibly video-tapes, and printed materials. These packages should serve to shape and transmit basic knowledge, in order to encourage a deeper approach on the part of those interested and to lay the groundwork for further initiatives. This type of activity could adequately resolve the problem of non-professional qualification, that is, the preparation needed by a researcher who does not intend to make professional use of cinematographic and audio-visual techniques in his work, but who wishes to know what useful possibilities he may have open to him, where and whom to turn to for competent advice.

The organization of research film

In the second part of this report it is noted that there is great organizational diversity between the different countries in which film is being used as a research tool.

In those countries in which a central body has been set up, we can see that it plays an important part in the development of research film and fulfills functions which are not dealt with when the use of cinematography is dispersed amongst different scientific bodies. All surveys carried out on this question confirm this observation. In the United Kingdom, for example, the inquiry to which we have already referred stated that adequate facilities for the training of technicians, researchers and administrators in this field do not exist, that the low salaries offered to technicians discourage them from specializing in it and that researchers in need of information on the application of cinematographic methods do not know where to go to get the assistance they need.

It must be pointed out that the existence of a central body does not preclude the carrying on of research cinematography in laboratories in which its use is regularly and frequently required.

For example, in the field of biological and natural sciences, it is often more convenient to carry out filming on site; the necessary technology can be more easily placed at the disposal of personnel who, in this field, are familiar with the necessary operations regularly used in experimentation. The scientist will be more at ease in mastering what he wants to obtain.
In the physical sciences, on the other hand, a whole range of high-speed methods is often called for, implying the use of costly and less frequently utilized equipment. This demands specialized technical skills and raises delicate questions concerning synchronization of the phenomenon and of shooting. Unless imperatives of national or industrial secrecy demand the making of the film by a team strictly attached to the body carrying out the research, the most economical solution would be to put this costly and complex equipment into the care of a central organization which would make them available to individual scientific bodies as and when they are needed.

We can define the different functions that a national centre should be capable of fulfilling as follows:

1) Informing scientists about the use of cinematography as a research tool; initiating them in new techniques, comparing results obtained from the projection of films produced using these techniques, and demonstrating recently developed equipment;

2) Promoting the installation of appropriate and relatively simple equipment in university, industrial or hospital research organizations, in cases in which the use of such equipment on a regular basis justifies its installation. It is in fact always preferable, and sometimes indispensable, that filming should take place on the site, with personnel who are familiar with the problems raised by the research under way;

3) Bringing together and making available specialized equipment involving considerable investment and requiring high-level technical skills, so that the maximum amount of use is made of it;

4) Carrying out research into new adaptations and visual recording methods for phenomena;

5) Ensuring the conservation of research film documents by the various bodies of the country concerned, planning for the eventual use of such documents for teaching or popularization, and distributing them as needed;

6) Establishing the indispensable links, at the national and international levels, between scientists from different disciplines called upon to use cinematographic techniques.

These functions, taken as a whole, are no doubt too heavy an undertaking for a country in which research film is little developed or non-existent.

In cases in which it would not be adequate to set up a central body charged with the functions enumerated above, other solutions can be envisaged. For example, a liaison centre would make it possible to collect and disseminate technological information for the benefit
of interested scientific bodies, and would facilitate the setting up of links with foreign establishments, the collecting of filmed documents with a view to a more or less wide distribution according to their content, and the constitution of a scientific film library to be used for scientific documentation and available to the country’s scientists.

The role of such a centre would thus, at least to start with, be limited to stimulating and promoting the use of film as a means of investigation. Its success would largely depend upon the nature of its relationship with scientific organizations, whose members would have to be convinced of the utility of cinematographic methods. It would therefore be important to appoint members of the scientific community to take charge of the centre.

It may be tempting to attach the centre to some other, already existing one. Such a solution may have advantages, but it is preferable to avoid the seemingly logical step of attaching it to a body specialized in the use of audio-visual technology for education, within which educational aims would easily deflect attention from the needs of research.

It is of course impossible to recommend a structure suitable in all cases. Solutions depend on multiple factors connected with the organization of scientific research, to the particular nature (geographical, economic, or other) of the country concerned. The models described here are intended only as examples to aid in finding a solution, and should be adapted to fit the particular needs of each country.

The panel which met on the occasion of the UNESCO/ISFA joint meeting examined practical means to encourage the development of efficient organizational structures capable of spreading and improving the use of visualization techniques in scientific research, also in those countries where the training facilities of the scientific community are still comparatively limited.

Technical-scientific and historical material, as well as structural data on the existing situation, have already been gathered and elaborated upon, and it is hoped that publication of such material will lead to further advances.

The circulation of this material amongst the most qualified bodies (such as universities, research institutes, government bodies concerned with science policies, Unesco, national commissions, etc.) could serve to attract fresh attention and contribute to greater knowledge of the problems involved, as well as producing a feed-back of information from the institutions and persons most interested.
Finally it is advisable to guarantee, through collaboration between Unesco and ISFA, a concrete means of responding to the new needs as they arise. This might be achieved through an advisory group of an international nature capable of providing assistance and technical-scientific documentation.
7. Scientific cinematography has opened up new possibilities for the investigation of inaccessible domains, either by means of radiations not visible to the naked eye, or by using a technology that allows the transfer of pictures and light through glass fibres smaller than a hair. In the upper image, the digestive track of the blue fly (*Calliphora erythrocephala*) feeding on a piece of sugar, filmed by direct recording on film of the X-ray image of small objects or animals. Extract from ‘The blue fly’, filmed in 1954 by Dr. Thévenard, Paris.

*Bottom image:* Endoscopic photograph showing the subdivision of the lower left bronchus lobe in a patient suffering from emphysema. The prominent aspect of the longitudinal fibres is visible. Recorded by Professor Dubois de Montreyaud, Reims.
8. Recording at high speed and ultra-high speed is one of the exclusive resources of scientific film: by this means, the time scale may be changed, thus 'slowing down' phenomena which due to their speed cannot be observed or analysed in any other way. In almost every domain of science and technology, this possibility has permitted discoveries, investigations and applications. Pictures a, b, c, d show the release of seeds from a cucumber fruit filmed at 8,000 frames per second. The picture e represents the equipment used to make this experiment with the stimulation of the fruit. The frame by frame analysis of high speed photographs makes it possible to draw diagrams and graphs (pictures f, g) from the qualitative and quantitative data of the phenomenon. Extracts from the film 'Ecballium elaterium (Cucurbitaceae) - Ejaculation of seeds' (E 331) belonging to the Encyclopaedia Cinematographica, produced by the I.W.F., Göttingen.
CONCLUSION

Film, as a means of scientific research, is still not well enough known, in spite of the fact that in its historical origins it grew out of the demands of fundamental research, to which it contributed by making possible the observation, study and analysis of phenomena which could not be apprehended by any other means.

Improvements made on the classical methods of recording images thanks to electronics and other technologies, have widened the scope of possibilities for visualizing phenomena. The need to apply these now very complex methods, with the greatest possible rigour, makes close collaboration between highly skilled technicians and scientific research teams indispensable. This collaboration implies the training of qualified scientific film experts. In fact, no teaching facilities specifically adapted to their training actually exist. Some suggestions have been put forward here as to how this gap may be filled.

The need for cooperation and information is felt wherever the use of cinematographic methods for scientific research remains dispersed. A comparative study of the very diverse structures into which research film is integrated shows that the existence of a national, autonomous and independent centre specializing in research film has allowed its applications and techniques to be developed.

The considerable development of audio-visual methods for teaching and educative ends is tending to make the image more and more a primal means of communication. Scientific research must become aware of this development, especially when the spoken word constitutes nothing more than an intermediary for transmitting information about visual elements.

The moving image, as a result of scientific research, has become a direct and immediate factor contributing to knowledge and information. Moreover, it contains an element of creativity and stimulation which can play an important part in the development of international cooperation.
9. The origin of cinematography is linked to the demands of physiological research on the movements of animals and man; today, the camera remains an aid to the discovery and recording of dynamic phenomena occurring in the physical world. These include the important need for scientific film to document ethnological and folkloric events, thus ensuring the preservation of fast disappearing cultures. The photographs reproduced here are two striking instants in the predatory behaviour of a bird capturing insects, filmed in the open air. Extracts from the film 'Phoenicurus, phoenicurus (Turdidae) - Flight manœuvre' (E 1844) belonging to the Encyclopaedia Cinematographica, produced by the I.W.F., Göttingen, photographed by Dr. G. Rüppell.
10. Television techniques have been closely associated with special technologies of scientific film. Linked with a film camera, electronic tubes and video recording equipment used as light intensifier or directly, play an important role in research and in scientific documentation, especially in the medical field. These pictures show a special application of a television camera to study nystagmus, recorded on video tape by the Audio-Visual Centre of the Medical School of the University of Rotterdam.
GLOSSARY OF SOME TECHNICAL TERMS

This glossary is intended for non-specialist readers, and it explains only the more specialized terms used in the text referring to technical aspects of scientific cinematography.

ANIMATION (computer based)
By inserting the input data of a number of problems and the appropriate operational programme into the computer, it is possible to obtain on the computer's video-output a display of the various solutions, and thus to represent figures in movement, the various phases of a process, the evolution of a form, etc.

CINEMACROGRAPHY
Cinematographic shots taken with special optical systems (or with additional lenses) designed to attain or to exceed the 1:1 relationship between the dimension of an object and its image recorded on film. During the projection phase, the larger the screen, the greater the enlargement will be with respect to the dimension of the frame. Permits the study and analysis of phenomena, the scale of which is too small for normal lenses and too large for the microscope.

CINEMICROGRAPHY
A shooting technique in which a camera is attached to a microscope. The optical devices of the microscope itself are used, not those of the cinecamera. Microcinematographic technology often includes alteration of the time factor (time-lapse, high-speed) and the use of particular lighting systems.

CINERADIOGRAPHY
A cinecamera or television recording system connected to an X-radioscopy plant. By means of an image intensifier it is possible to analyse dynamic phenomena, slowing them down considerably with high-speed shooting.
FILM ANALYSIS
Devices for obtaining qualitative and quantitative data from scientific films (and possibly comparisons with other recordings) concerning the research done (or recorded) by means of the film. Special equipment is used and one proceeds frame by frame. Can be connected to a computer for storage and processing of the information obtained.

FRAME BY FRAME
Technique of shooting a single frame at a time. Basic method used in making animated drawings, diagrams, etc.

HIGH SPEED MOTION PICTURES
Among the various existing terms this one is the most often used to describe accelerated shooting which permits the breaking down and analysis of rapid and ultrarapid phenomena that are otherwise unobservable. Different techniques are used according to the degree of expansion of the time factor required. Special cinecameras exist which can work at speeds of several hundred frames per second and still others take several thousands of frames per second; other shooting devices allow the recording of the phases of a phenomenon at a ratio of millions of frames per second.

HOLOGRAPHY
The hologram is the recorded image of an object observed by means of a monochromatic coherent light source (or radiation source), i.e. the laser. Projection of the hologram (using an analogous source) permits three-dimensional viewing of the object and its examination from various angles and viewpoints.

IMAGE INTENSIFIER
Other names, such as brilliance amplifier, may also be used. This is an electronic device based essentially on a cathodic tube and optical fibres, which 'multiplies' a weak or extremely weak light signal until it attains a level high enough for recording on video-tape or motion picture film. Used for night shots without artificial lighting, or in poorly illuminated places. In cineradiography such devices are used both to decrease radiation intensity and to increase the shooting speed when the analysis of a very rapid phenomenon is necessary.
OPTICAL FIBRES
Flexible, glass-like fibres, finer than a hair, which permit a light wave to travel from one end of the fibre to the other by a series of internal reflections, thus transmitting a light source and/or an image. Bands of optical fibres are used in some image intensifiers and they form the basis of modern endoscopic and endocinematographic devices, utilized both in the medical field and in various technological sectors.

SCHLIEREN SHOTS
See STRIOSCOPY

SINGLE CONCEPT FILM
A short film, lasting a few minutes and generally silent, which presents a single phenomenon, experiment, or situation. As a general rule for teaching purposes they are made in loop-film cassettes so that they may be shown several times in succession and the image stopped at particular points. They are suitable for lessons commented by the teacher, but are also useful for self-teaching and programmed teaching.

SINGLE FRAME EXPOSURE
See FRAME BY FRAME and TIME LAPSE

SLOW MOTION PICTURES
The film is shot at a speed faster than the normal projection speed (24 frames per second), thus giving the effect of slowing down the action filmed when it is shown. Shooting at 48 and 72 frames per second is also often possible with normal commercial cinecameras. (See also HIGH SPEED MOTION PICTURES)

SONOGRAPHY
Visualization of otherwise invisible phenomena by means of ultrasonic sources.

STRIOSCOPY
A visualization method based essentially on the Schlieren effect, this is an optical technique making use of variations of the refractive index and interferential phenomena. Allows cinematographic recording of the dynamics of such a disturbance and of existing differences in fluids.
STROBOSCOPY
Cinematographic application of the stroboscopic effect. Through the use of extremely short light flashes, the recording and analysis of very rapid phenomena is made possible.

THERMOGRAPHY
Method of visualizing phenomena having as a parameter differences in temperature.

TIME LAPSE
A shooting technique which makes very slow and otherwise imperceptible movement visible, or which compresses the essential phases occurring in a phenomenon of long duration. It is the opposite of high-speed shooting and consists of filming at the speed of only a few frames per second or even per minute, at intervals predetermined by special timers.
The International Scientific Film Association (ISFA) was founded in 1947. Its statutes accept open membership of any organization which has aims akin to those of the Association and represents in its country the scientific film movement. In countries where a suitable organization does not exist, corresponding members may join the Association on a personal basis.

National organizations of the following countries are at present members of the ISFA: Australia, Austria, Belgium, Brazil, Bulgaria, Canada, Czechoslovakia, France, Federal Republic of Germany, German Democratic Republic, Hungary, Israel, Italy, Japan, Netherlands, People's Democratic Republic of Korea, Poland, Romania, Spain, U.S.S.R., the United Kingdom and the U.S.A. Corresponding members from Switzerland, Argentina, Columbia and Uruguay have also joined the ISFA.

The aims of the Association are to encourage international cooperation in the following fields:
Scientific and technical research for the development and improvement of cinematography;
Research in all branches of science and technology by means of film processes, materials and techniques;
Exposition by means of cinematography of the achievements of scientific research and theories;
Popular interpretation by means of cinematography of knowledge about science and technology.

The ISFA holds an annual congress in one of the member countries of the association. Almost all national branches have been the host of the congress, during which over 100 films selected by the national branches were screened, discussed and analysed, so as to detect the characteristics which would make the various categories of films most effective according to their target audience.

The work of the Association is carried on in three sections: the
Research Film Section deals with new techniques and new applications of film for research purposes, the Higher Education Film Section studies the form to be given to film in order to integrate it in the range of audio-visual means used in university teaching; the Popular Science Film Section analyses the various ways of presenting science to a lay audience.

The Association publishes two reviews: Research Film, Göttingen, appears twice a year; and Science Film, Paris, appears quarterly.

An International Scientific Film Library was set up in Brussels under the auspices of the ISFA, with the assistance of the Belgian Government. It collects films deposited by the national branches of the ISFA and offers facilities for viewing them.

The address of the headquarters of ISFA is 38, avenue des Ternes, 75017 Paris.
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