VOL. 5, No. 1

Royal Meteorological Society

METEOROLOGICAL RESEARCH and EDUCATION in CANADA

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CANADIAN BRANCH

25¢

VOL. 5 NO. 1

Published by

ROYAL METEOROLOGICAL SOCIETY, CANADIAN BRANCH

Copies of this publication at 25¢ each are obtainable by writing to:

The Secretary,
Royal Meteorological Society, Canadian Branch,
315 Bloor Street West,
Toronto 5, Ontario.

METEOROLOGICAL RESEARCH AND EDUCATION IN CANADA

by

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Presidential address presented to the Royal
Meteorological Society, Canadian Branch, at
its regular meeting, Thursday, January 28, 1954.

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D. P. McIntyre

INTRODUCTION

One of the major functions of a scientific society such as ours, is the development of the science in all its phases. Indeed this idea is written into our by-laws and I quote: "The Canadian Branch of the Royal Meteorological Society was established for the advancement of meteorological science in Canada.".

It is axiomatic that this end cannot be achieved without free expression of opinion and it would be useless therefore for every speaker in a country which adheres as closely to the single service system as ours does to echo the current official policy. Tonight I wish to express freely my own opinions on meteorological research and education in Canada and what I shall say will not necessarily reflect the views of the organization which employs me. While some of these ideas may appear radical at the present stage of development of meteorology in Canada, it should not be interpreted that I am advocating a complete and immediate revision of policy by the institutions involved. My purpose is rather to engender thought and discussion on important basic principles. Some of these ideas may prove worthless. Others, I hope, will ultimately be accepted as basic planks in any meteorological platform.

If we in Canada agree to work for the full development of our science for its own sake, as well as for its applications, I foresee a great future for us realizable within a few short years. If we do not, I believe we will fail to develop our scientific potential and our research brains will continue to drift away. My hope is that the analysis I shall give tonight may help to clarify some of the major issues and aid in some small way the maturing of our science

TYPES OF METEOROLOGICAL RESEARCH

Fundamental research is concerned with the determination of the laws of nature for their own sake, for the better understanding of the physical machine which has been built by the Creator. Ideally the fundamental researcher should be concerned only with the workings of that machine. Yet the growth of civilization cannot be achieved without the development of means for the application of the physical machine (or laws of nature) for the use of man. This too is a form of research, a difficult and important one — one beset with problems

requiring the attention of first-class brains. These two classes of scientists complement each other and between them they produce the ideas and tools for the practical use of the science. In the case of the science of meteorology for example, these ideas and tools might be applied to the development of techniques for weather forecasting. Between these research men and the practicing professionals, who must use the science in their daily practice, there is another group which is engaged in what has been termed "development". Development cannot properly be called research though it requires a high degree of ingenuity. Its purpose is rather the engineering of existing methods to fit operational requirements. The development scientist is therefore not concerned with the development of the science, but rather with the development of suitable procedures for the practical application of established methods. As such he forms the link between the research scientist and the practicing professional whose duty it is to provide some form of service.

From this we see that original scientific work may take the forms of fundamental research, applied research, development and professional (or operational) practice. The first two of these may properly be termed research and all are necessary for the successful practice of the science.

In the early days of a science two or more of these four phases, from fundamental research to operational application, are often practiced by the same men. As the science develops each of these phases becomes more specialized, and it is no longer possible for any one individual to bridge the entire range of activity. Experts in each phase then arise. Meteorology is now passing through this stage in its growth, and we may expect to see increasing specialization in the various phases of the science, and even within these phases themselves.

THE AGENCIES RESPONSIBLE FOR RESEARCH

Having considered the nature and types of research which must be undertaken in the full development of a science, let us now consider the agencies or institutions which undertake to prosecute research. In particular I wish to consider the place of meteorological research in these institutions.

The traditional strongholds of research, as well as higher education, are the Universities. These institutions have earned this place in our society by maintaining an environment conducive to freedom of thought and by providing sufficient time, unencumbered with other duties, for first-class brains to develop and exploit their ideas. In this technological world of ours, dedicated to the exploitation of science, the pure scientist, the discoverer of new philosophies in fundamental science, needs a refuge where he will not be concerned with applications of science. This refuge can still be found in our universities. Let us hope that this will always be so for if fundamental research loses its favourable environment, technology cannot long survive.

In many countries meteorology has grown in scientific stature and has taken its rightful place in the academic environment of the universities. The universities of the United States contribute over 50% of the papers published in the Journal of Meteorology of the American Meteorological Society. This is a healthy sign for meteorology in that country. Meteorology in Canada has not yet progressed to that state, although several universities are engaged in some form of research dealing with the atmosphere, usually with the very high atmosphere. In particular the rapid rise of McGill University as an energetic and thriving contender in the fields of climatology and cloud physics is promising. It is fitting that this great university, a pioneer in Canadian scientific development, should have the honour of introducing tropospheric meteorology into the universities as a subject worthy of major research. Canada will have achieved a high degree of maturity in the science of meteorology when other universities follow McGill's lead and begin to conduct first-rate research into various phases of meteorology, not forgetting synoptic research. The universities will largely be concerned with fundamental research leaving the application of the science to other agencies.

Industry too has been active in scientific research on a rather large scale. It is natural that a progressive industry should exploit the utilitarian side of the science for the improvement of its product. It might not be expected that large industries should realize the importance of fundamental research as a field worth their attention and participation. Yet such is certainly the case. It is difficult to imagine a more practical or down-to-earth company than the Dunlop Rubber Company, yet these are the views of Lord Baillieu of that Company, as found in the report of the third conference of Industrial Research Directors and the Research Managers held in 1953: "Research programmes should be conceived and keenly reviewed in terms of the conditions which a new idea or discovery must meet to achieve success; but we should not lose sight of the wider horizons and fundamental researches which have challenged the ingenuity and courage of men, and to which the British genius has responded so outstandingly". [x]

There is no lack of examples of the contributions of industry to fundamental science. The Bell Telephone laboratories have made countless contributions of this nature. So has the General Electric Company of the United States. Meteorologists will long remember the important work of this great company in the field of cloud physics under the competent and inspired direction of Drs. Irving Langmuir and Vincent Schaefer. The beliefs of the Company in this regard are

[x] Nature, Vol. 172, Oct. 24, 1953, p757.

summed up in this quotation from the article "Seventy-Five Years of Research in General Electric", by C. G. Suits: "The Leaders of the Company felt the need to participate in the fundamental research on which the industry was based. Why should not General Electric itself engage in fundamental research and so contribute to this source of its most essential raw material for future growth?". [x]

These illustrations point up the broad interests of modern industrial research and are all the more impressive when one realizes that these companies are mainly interested in the quality of their product. While the great body of industrial research activity must necessarily go into applied research and development, the participation of industry in all fields of research is tremendous. I predict that in meteorology the day is not far distant when industry in Canada will employ its own meteorological scientists to solve the meteorological problems pertaining to its field of interest. Probably this stage in the development of the science will begin with the establishment of firms of consulting meteorologists. If Canada fails to establish truly Canadian enterprise in this field, it may be sure that consultants from other countries will be ready and able to fill the gap.

Now let us turn to the goal of Government research. As with industry, Government must primarily concern itself with the practical side of science. While industry applies its science for the improvement of a saleable product, the government normally applies its science for the improvement of its services. In some cases the Government must also develop certain phases of science which are of importance to the country but which lie outside either the interests or financial capabilities of other agencies, but this will not conern us here. As with industry, the Government must of necessity also concern itself with fundamental research in the fields in which it provides scientific services. It seems that practical research cannot remain healthy without reasonable proximity to basic research. Consider carefully the words of Sir Edward Appleton in his Presidential address to the British Association: "it is the purpose of a Government Research Agency to develop the useful aspects of science, but one should never forget that true science has as its goal — truth — not utility, and if utility is made the primary goal to the exclusion of a search for truth it is a truism that neither objective will be reached. For full and economical development of science and technology, the search for truth must take first priority though the application of truth to practical ends should not be ignored." [xx] From this, I think it is clear that if the Meteorological Service is to participate in research it must participate in all phases of the activity of its science including fundamental research.

[x] Science, Vol. 118, Oct. 23, 1953.

[xx] Nature, Sep. 5, 1953.

Meteorology is a science which lends itself to a production of a service rather than a saleable product. For this reason it has received much of its support and growth under the auspices of Governments. Also in the case of meteorology a large financial budget is required to produce the data necessary for the full development of the science. Such monies are beyond the resources of nearly all agencies but governments. It is therefore natural that much of the early work in science should be done by Government scientists. When a science approaches maturity as meteorology is now doing, some of the fundamental research should pass to the Universities. Ultimately a portion of the very specialized forms of research should pass to industry. It is fitting that our national weather service through secondment should retain control of meteorological research directed towards other sciences — at least for a time. This is the conservative and safe approach. Ultimately, as application of the science progresses, I feel that the national weather service might relinquish control of some of these scientists working on the fringe of meteorology and allow them to be absorbed into the organizations for which they work.

NEED FOR ACTIVE RESEARCH IN CANADA

To this point I have discussed the types of meteorological research and the agencies which may undertake investigations of these various types. The question must now be squarely faced — is there a need for meteorological research in Canada? This is but to ask — can we not get by on the fruits of the research of others?

The answer to these questions must be tempered by the requirements for such research and this will vary with the type of agency. Certainly our universities can, and for the most part do, ignore research in meteorology, though I believe they are the poorer for it. Industry too can get by with very little in the way of meteorological research. The time is coming, I believe, when they will find a greater need for this research, but I will leave this for the present.

For a national weather service, which must provide services to the country, the answer is clear and more immediate in importance. We are all proud of the Meteorological Service of Canada. Its modern organization has been boldly conceived and boldly built. Its personnel are young, well-trained and of a high level of intelligence. Very high standards have been set and maintained for the professional meteorological candidate. High standards also have been set and maintained for the "selling" of its product to the end that it now has an enviable list of satisfied customers. All of this has been established with little or no organized research activity. Such research of importance as has been carried on has been largely the product of active individuals working in spare time. Is this not proof that we can get by on the fruits of the research of others?

Our national weather service has achieved a high degree of operational success and superficially this would appear to assure us that we need not establish a well-organized research section. Let us think on the degree of permanency such success may hold. The question, I think, is this — can a scientific service maintain a high standard unless its structure is built on a firm foundation of scientific knowledge, a foundation kept constantly in good repair? I think not — for two reasons. Firstly the maintenance of that foundation of scientific knowledge requires the workmanship of skilled scientists. Without this workmanship the foundation repairs will be faulty and the structure may crumble. Secondly, the morale of the professional operating personnel depends to no small extent on the scientific prestige of the service. How can this scientific prestige be maintained without active research minds of highest calibre?

To elaborate on these thoughts, let me speak briefly on the first point — the need for a strong core of trained scientists in the maintenance of good service. To keep the finest of scientific service one must have a fund of the latest knowledge together with the know-how which permits one to use it profitably. This knowledge and know-how can only be stored in the minds of men who are working in the forefront of the science. Let us never forget, he who follows is always behind. If one does not keep a stock-pile of know-how, this know-how must later — much later — be acquired on the battle front of operational usage.

My second point is that the service must have scientific prestige as well as prestige based on its methods. This prestige can derive only from its hard core of scientific activity, responsibility for which rests with its research scientists. Prestige, the great morale builder, cannot be maintained indefinitely solely on a reputation for operational efficiency and salesmanship.

As a corollary to these concepts there follows the need for a national weather service to provide for its specially endowed scientific minds. A forecaster, for example, whose interests and abilities lie in the field of research must be provided with the opportunity for research. Otherwise, the service will lose this valuable man. The existence of an active and well-organized research section provides a goal towards which such men may work. In these remarks some may feel that I am over-emphasizing an accepted need for a strong research organization. They may feel I am advocating precedence for research over the more practical operations. This is not my intention. The reasons for the rapid post-war development of the operational services in Canada are sound. I would not suggest that a national weather service which aims to provide services begin by establishing a large research section. On the contrary, a National Weather Service composed solely of a research section would be as ridiculous as a national weather service composed solely of operational services. I merely wish to

emphasize that research is important and that the establishment of a strong operational organization should be accompanied, or followed in short order, by the establishment of a strong and active research organization and that the operational staff must not be over-developed at the expense of a corresponding development of a research staff.

There is a great danger in delaying too long the building of a research establishment. While a properly trained man may quickly achieve a high degree of operational proficiency, it takes five to ten years for a scientist to reach his prime. First-class work cannot therefore be expected from a research organization immediately after its establishment.

In addition to the research required for the national weather service's own operations, there is a need for research as a form of service in itself. In its simplest shape such service may be the provision of scientific advice in response to request. Advice of this type can be readily provided if a well-organized research organization exists. In many cases the request is of a nature which requires research before an answer can be provided. In order to handle efficiently requests for research service from a variety of sources a research organization of some versatility is essential.

To sum up, my feeling is that there is a definite need for research in any national weather service. Furthermore, the establishment of a research organization of wide scope should be afforded a high priority in the development of that Service. The Meteorological Service of Canada has, in recent years, established and begun to build up its Research Section. Ultimately it is hoped to have a seasoned Research organization of the scope envisaged here. There is a need too for meteorological research in industry and the university and these needs will increase in the coming years.

SOME BASIC PRINCIPLES FOR AN EFFICIENT RESEARCH ORGANIZATION

Having reached the conclusion that research is important to Canada, I should like to discuss some ideas which I feel are necessary for the development of an efficient research organization. The size of a particular organization should be sufficient to do a satisfactory job and no money is better spent than in the establishment of a well designed research organization. The type of organization, in structure and features, which I will describe will be that for Government meteorological research. It might require some alteration for use in other agencies, but time does not permit discussion of these variations.

Although the organization may have, as its primary purpose, the provision of service, some arrangement must be made for fundamental research. I have established this point already, but its importance cannot be over-emphasized since, particularly in a publicly supported

service, there is a tendency to consider fundamental research as an expensive luxury rather than a stark necessity. Let us therefore accept the fact that our research organization, to be healthy, must embody fundamental as well as technological research. It may also embody developmental work though a portion of this may, and perhaps should, be done by the operational sections of the organization. These two (or three, if we include development) types of research must be designed for in establishing our research section. Probably they should constitute separate units of a section as they do in the Meteorological Service of Canada.

The types of work, both fundamental and utilitarian, must be carefully analyzed and sufficient personnel of adequate ability and education planned for. In doing so, care should be taken to supply sufficient additional scientific personnel to take care of the numerous special duties which will inevitably fall to these men. Failure to do so will result in their time being wasted by decimation as they try to cope with urgent special problems, requests, training committments, etc. In this connection it should be pointed out that it is money in the bank for the organization to ensure that its scientists are not fully, or even nearly fully, occupied with current projects. This important point is often misunderstood, but it should be remembered that the value of a scientist lies in what he knows and what he thinks. Knowledge and fruitful thoughts do not come easily to a man who is continually bombarded with questions requiring an urgent reply. We must, therefore, build into the organization sufficient time for undisturbed thinking. If my eloquence is insufficient to bring this point firmly home, permit me to quote once more from Sir Edward Appleton: "Scientific advance depends on the individual (for brilliant ideas and intuition leading to big jumps ahead) but also on team work in exploiting the jumps ahead and consolidating gains."[x] It follows that we must design both for the jumps ahead, providing time for thought, and for the mopping-up operations of the team work.

The research programme should be broad in scope. It should include investigations in all the various branches of meteorological science. These need not all be large and weighty projects for it would require a very elaborate organization indeed to permit intensive study in all of these fields. Nevertheless, one aim of a properly balanced research section should be to have on hand a body of knowledge, ability and know-how, of sufficient diversity to permit it to answer intelligently questions in any phase of meteorology. Thus, in addition to providing through research the solutions to specific practical problems and adding to the fundamental knowledge of science, the research section must prepare itself to answer questions which may be put to it in the future. It must therefore be versatile, it must be bold in the planning of its programme and in the allotment of personnel to carry it out.

[x] Nature, Sep. 5, 1953.

When a research organization has been established and is operating it is found that a fair amount of administrative work must be done to keep it functioning properly. This includes a great variety of jobs such as routine correspondence with field staff, consumers of research, and the government department of which the national weather service is a part. Research reports must be prepared and decisions made on the methods of publication. Requests for scientific advice and assistance must be assigned to personnel and the resulting action taken. Scientific papers written by members outside the research section must be reviewed and the authors provided with advice. Supervision must be provided for sub-professional personnel. Now the best brains of the research section should be elevated to positions of authority in the planning and production of the work of the section. This necessarily carries with it a modicum of administrative work. On the other hand it seems to me a matter of elementary logic that having, at great expense in time and money, acquired a brain of superior scientific ability we should endeavour to apply that brain to the solution of scientific problems for a maximum proportion of its working time. From this it follows by equally elementary logic that additional administrative staff should be supplied to carry out as much of the administrative work of the section as possible. In this way, the scientific brain may be reserved for: (a) direct solution of scientific problems and, (b) the planning and policy making which will permit the section to solve such problems more efficiently. In short my thesis is this: scientific brain power is a valuable, rare, and expensive asset. It is foolish to waste it on tasks which can be performed by brains of lesser scientific ability or training. Regarding the class of personnel to be used for this administrative work, I am strongly in favour of using professional personnel, preferably with some research background or ability. Naturally they should also possess ability in the field of administration. Personnel of this type would be better able to translate the ideas of the senior research officials into practical administrative action. In many ways such positions would provide excellent training ground for both research and administration.

It goes, or should go, without saying that the research section should be provided with adequate plotting, clerical, typing and other sub-professional staff. To waste research brain power through lack of supporting staff is a form of false economy which should not be tolerated.

No discussion of the organization of a research section would be complete without mention of facilities and morale. Facilities will vary with the types of research carried on and I will say nothing here except they should be sufficient for the job on hand. Morale is that indefinable something which we all recognize as the major factor which determines whether or not an organization will be a first-class or a mediocre one. The morale of a man may be described as a feeling of belonging — not just belonging to his research group but also belonging to the organization of which it is a part. I recall a play written by Noel Coward during World War II. It dealt with the lives of the crew of a British ship of war.

I recall particularly the part in which the Captain spoke to his crew after the commissioning of the ship. His theme was this. He wanted a happy and efficient ship. Unless the ship were happy it would not be efficient. Unless it were efficient it would not be happy. I believe this theme is the basis of high morale in any organization. In our case it means that our research scientists must be happy. If this condition is not met the better ones will not remain. There is no lack of positions where their needs are well understood and catered to. Let me quote once more from C. G. Suits of the General Electric Company: "If the research chemist, for example, can work only towards results that fit like a glove into the capabilities of a specialized industry, little room is left for the play of his originality, for following the by-ways of research in the investigation of the unexpected result, and for the exploration of the nearby area of a great but speculative promise. Worse still, scientists of skill and imagination will not long work within a closely limited scope; if one must be certain of the results of research in advance, the objective must be of such short range that it hardly partakes of a research character. The net result is likely to be frustrating to the scientist and disappointing to the sponsor." [x] I interpret these words in the broader sense to mean that good scientific working conditions must exist.

The truth of this is well illustrated by the steady exodus of research-minded men from the Meteorological Service of Canada prior to the formal establishment of a research section. If one adds them up, there have been a surprising number who have decided to apply their talents elsewhere. There are indeed in the government at the present time only two scientists having Ph.D.'s in meteorology and engaged in scientific research. It is logical to assume that at the time these men resigned they did not find within the organization the conditions for research they felt they required. They therefore searched for these conditions in other places. Those who wished to remain in meteorology emigrated. Those who wished to remain in Canada transferred to other fields of physics. All were lost to Canadian meteorology.

Regarding the future, I would say that the type of physical organization I have outlined here must be considered a minimum if we are to retain our finest scientific brains. In addition we must ensure that there is no suggestion, implied by action or otherwise, that research is of secondary importance, else it will attract and retain only second-class minds. Thus the ideal research section calls for suitable organization, staff, facilities, and salaries, to be given priorities at least as high as those of the operational branches, and a place in the service where its voice may be heard on all policy matters involving research.

Much progress has been made on these matters in Canada. Much remains to be done.

[x] Science, Vol. 118, Oct. 23, 1953.

RESEARCH — PAST AND FUTURE

It is fitting that a discussion of research in Canada should contain some mention, albeit a brief one, of past achievements and trends for the future. A glance at the accomplishments of Canadian meteorological scientists in the past should assure us that there has been no lack of men of great ability. Nor is there any reason to assume that men of equal ability are not available for future work.

A complete account of past achievements could occupy a full lecture. In the short time available, let me but mention a small selection of works and workers. We have significant contributions to the theory of large scale atmospheric motions by Haurwitz and by Neamton and to radiation theory by Godson. Theory and practice of isentropic analysis was advanced by Neamton. His work in atmospheric pollution has made Hewson a world authority in this subject. Research in cloud physics by the Stormy Weather Group under Marshall at McGill University has been outstanding and is the first significant attack on troposphere meteorological problems in a Canadian university. Gowan of the University of Alberta has become a recognized authority in radiation and ozone in the atmosphere. Currie of the University of Saskatchewan has achieved similar recognition for the work of his group in auroral physics. Jacobsen developed a Canadian radiosonde of high quality. Middleton's work in instruments and visibility is well known. Thomson has made significant contributions to our knowledge of lunar atmospheric tides. The development of the frontal contour analysis technique by Penner, Crocker and Godson is an outstanding contribution to synoptic meteorology which lead to the three-front model.

Meteorological text books published by Canadians include the following: B. Haurwitz — Dynamic Meteorology; Hewson & Longley — Meteorology, Theoretical and Applied; Middleton — Meteorological Instruments; Middleton — Visibility; Middleton — Vision through the Atmosphere; Hare — The Restless Atmosphere. This list of achievements is necessarily incomplete but does show the scope and ability of Canadian meteorological scientists.

Looking to the future, I should like to indicate, not only the trends in research which I expect to see, but also the trends in the development of research institutions. Taking, first, governmental research in meteorology I hope to see a qualified continuation of the single service system. A major portion of governmental research in meteorology should be carried out by the Meteorological Service of Canada. In some special cases where meteorological research is incidental to the problem, my personal feelings are that some institutions may ultimately find it worthwhile to employ scientists with training in both fields. Research in the Meteorological Service should cover all fields of fundamental and applied meteorological science including radiation, turbulence, air pollution, cloud physics and energy transformation.

In particular it should not neglect the rapidly developing field of numerical prediction which will almost certainly become a part of the operational technique of forecasting within a few years. It should of course participate strongly in all phases of synoptic research particularly in jet stream analysis and its relationship to frontal and air mass analysis, a field particularly well suited to research by Canadians. In these studies I also include less pretentious investigations by professional Meteorologists of the operational type for this is necessary to a healthy service.

Quite rightly the universities have approached meteorological research by way of physics. I expect that participation of the universities in studies of this type will expand, greatly assisted, I hope, by financial support of government and other institutions. In addition I believe that fundamental research by the universities into other fields of meteorology including the synoptic field must come before meteorological science in Canada will have achieved maturity.

Industry will be the last important agency to enter the field of meteorological research. Probably it will do so through the efforts of the ex-meteorologists of superior ability it employs. Such men having training in two fields will be well qualified for development of projects which will be designed for the improvement of the services or products of the industry involved. In addition I predict that there will ultimately emerge industrial meteorological research organizations which will, for a fee, solve problems in applied meteorology for the benefit of their clients. As these organizations increase in size and experience, it is to be expected that they will also participate in certain phases of fundamental research.

EDUCATION AND EDUCATIONAL INSTITUTIONS

One can scarcely discuss research without also discussing education. The two are joined by the closest of ties as exemplified in our universities where research and education traditionally have existed side by side in natural relationship, one to the other.

Education may be defined as the acquisition of knowledge through instruction or study. It is important to note that no mention is made of a purpose for this knowledge. When we become specific as to the purpose of education we narrow the goal considerably. We are then speaking of that type of education known as training. Training may be defined as practical education in some art or profession. It is important to draw a careful distinction between education in its broader sense, and training, each of which has its special place in our civilization.

Education may take various forms depending on the level of knowledge and skill of the class for which it is intended. Thus one may speak of education in meteorology for the layman. This would be education

at an elementary level intended, perhaps, for the general public, perhaps for persons such as airmen who have to deal with meteorology in their daily work. This is an important phase of education with which we will not concern ourselves tonight.

At a higher level meteorological education is provided for prospective professionals or for research workers. This must be education in the broader sense and not merely training. The proper agency in our society to provide this education is the university. This education supplies the budding meteorologist with a broad background to serve as a basis for his continued development and self education. After completion of his formal education the government department or industry may, before assigning him to his ultimate duties, provide the meteorologist with a training course designed to fit him for his specific job within the organization.

In Canada meteorology has not yet developed to this stage and a rather interesting and unique relationship has developed between the University of Toronto and the Meteorological Service of Canada. In the early 1930's the Meteorological Service was faced with the need of obtaining fully educated meteorologists which the universities were not yet prepared to provide. With remarkable care and understanding on both sides, a scheme was developed whereby the University of Toronto offered a post-graduate course in meteorology leading to a degree of Master of Arts in Physics (Meteorology). To make this possible the Meteorological Service provided the University with needed lecturers in meteorological subjects. This arrangement has proved so successful that it is still in operation some 20 years after its beginning.

Now the University of Toronto is a great educational institution and it has been most concerned that this course should not degenerate into a mere training course. To allay these fears, lecturers provided by the Meteorological Service have always kept firmly in mind the fact that they are providing an education in meteorology. This has paid dividends to the service also, particularly when it instituted its own training courses for meteorologists having somewhat lesser academic qualifications than those for the M.A. degree course, and as a result this course has a higher educational content than it might otherwise have had.

On the whole then, scientific education is a function of the universities. Training for a specific professional job is normally a function of the employer, be it industry or government.

EDUCATION AND TRAINING IN A GOVERNMENT SERVICE

The national weather service must provide education and training at various levels. I shall concern myself only with the professional level. It must, of course, train its incoming professional personnel in the professional methods and government procedures, in order that they may be able to apply their knowledge to the particular job for which they have been employed. This aspect I have already discussed briefly.

Another type of training of at least equal importance is that required to maintain the scientific knowledge of professional personnel at an acceptably high level. In a science which is developing at a tremendous rate there is grave danger that the practicing professional will be left behind. Through careful selection and education, a national weather service should be staffed by men of superior mental equipment. This has been done in the Meteorological Service of Canada. Nevertheless, the demands made on the practicing meteorologist by his daily work are such that he cannot hope, unaided, to keep abreast of the development of his science in all its phases. The situation places a responsibility on his employer to see that channels are provided through which the basic ideas of new researches may flow to him. Otherwise he will dry up, not because he is unable to drink the well-water of knowledge, but because he is removed from its source without a compensating pipe line. This end can be accomplished only by providing personnel of ability whose job it is to sift the output of research for solid ideas and facts and to convey these ideas and facts to the operating professional in a form which he can readily grasp in a minimum of time. Undoubtedly the best means of doing this is by refresher courses. It is, however, not practicable to bring in to one centre, at one time, any sizeable proportion of the operating personnel. This method must therefore be supplemented by other methods such as travelling teams of instructors and carefully prepared educational literature based on a thorough study of the available material on each topic. An expenditure on work of this sort can be considered as nothing more than a wise protection of a rather heavy and valuable investment.

Professional training as described above must be closely associated with research. Indeed the research section and the professional training section must be sister sections whose duties blend into one another. The Meteorological Service of Canada has wisely joined these sections in its Research and Training Services. It is apparent that the professional training section, to remain vital, must be thoroughly familiar with the work of the researchers. It must in fact, draw on the services of individual research men in much of its work. The research section too, will be inspired by the work of the training section and the operational problems with which the latter must be familiar. The training section is thus the link which binds together the research and operational phases of the meteorological service, and without which neither can perform efficiently. It is the life blood of the organism which brings fresh, revitalizing, material to its cells.

From this it will be seen that the professional training section has two functions which may be described as initial training (for incoming professionals) and refresher training (for seasoned practicing professionals). The organization of the professional training section of the Meteorological Service of Canada provides for separate units to handle these functions. The unit for refresher training has not yet been staffed, though very excellent work has been done in supplying high quality education and training for new professional employees.

High morale is just as important for the professional training section as it is for the research section and care must be taken to ensure that working conditions are such as to allow the section scope for exercise of creative imagination. In short, the remarks on morale made above apply equally well to the professional training section.

FUTURE OF METEOROLOGICAL EDUCATION IN CANADA

If I may be permitted one more prediction, it is this. The universities of Canada will continue to develop their educational programmes in meteorology. This will come about by way of their own researches, with the result that emphasis in the early stages will be placed on the physical and climatological aspects. Later, as their programmes expand, the larger universities will offer complete courses leading to meteorological degrees. At first this will be done by adding a meteorological branch to the mathematics and physics course. Ultimately I am sure we will see the establishment of chairs in meteorology, perhaps within the next five to ten years.

Government and industry will also continue to expand their facilities for meteorological education to meet expanding needs. These will be largely in the training field.

When all these things have been accomplished, meteorology in Canada will have reached the maturity for which it has been striving so vigorously.