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MAN LIVING IN THE ARCTIC

Proceedings of a Conference
QUARTERMASTER RESEARCH
AND
ENGINEERING CENTER
NATICK, MASSACHUSETTS
1, 2 DECEMBER 1960

Sponsored by
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U. S. ARMY QUARTERMASTER CORPS
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FOREWORD

At the approach of World War II the U. S. Army Quartermaster Corps began a review of clothing for cold weather operations. Not only were the meager stocks for possible Arctic use of World War I vintage, but some items, such as buffalo and pony skin overcoats, dated back so far that their origin was uncertain. To meet emergency requirements of troops moving into Greenland, Iceland, Alaska, and the Aleutians, it was necessary to purchase many off-the-shelf civilian items. Advice was sought from mountaineers and polar explorers; however, subjective taste so varied their recommendations that the resulting composite ensembles were ineffective, confusing, and militarily impractical. Physiologists who were consulted for an objective evaluation of clothing admitted that clothing interfered with body function during tests and had been routinely eliminated from their studies of the human body. Therefore, lacking any true, objective evaluation of the effectiveness of clothing, the Quartermaster Corps set up its own Climatic Research Laboratory at Lawrence, Massachusetts, for the scientific study of clothing. Other physiological laboratories in the United States and Canada initiated similar efforts. The National Academy of Sciences—National Research Council assisted these efforts through consultation and coordination.

The problem of preparing man to live in the Arctic became a major concern of the Quartermaster. By the end of World War II the Quartermaster Corps had attained unquestioned leadership in both scientific theory and items produced. Later development of the Natick Laboratories and Cold Chambers continued to provide the Quartermaster Corps with superior facilities to pursue research in this area.

Knowing that no field of research can safely lie dormant, the Quartermaster Corps maintained its effort to advance the capabilities for Arctic living. Recent expansion in polar interest has increased the requirements for improved living conditions, food, clothing, and shelter. Solutions, once considered adequate because of their substantial advance over current standards, had to be re-examined in due course for deficiencies. Garments and equipment which required that men be extensively trained in their safe, efficient use or needed elaborate care and maintenance in order to provide optimum protection often were too troublesome or dangerous. New knowledge of human physiological and psychological requirements and adjustments suggested new means of preparing for Arctic living. New materials and devices made new approaches possible. Therefore, the concept of a conference to discuss Man Living in the Arctic was considered desirable by the Army, the National Academy of Sciences—National Research Council Advisory Board on Quartermaster Research and Development, and The Arctic Institute of North America.

The large attendance by outstanding authorities on many facets of polar living was most encouraging. The Army, the Academy-Research Council, and The Arctic Institute of North America express appreciation for the interest shown, the high standards of papers presented, and the splendid cooperation of the Boston Museum of Science and others who contributed to the success of the conference. Appreciation is also extended to Mr. Lowell Thomas, who so ably presided at the dinner honoring American Arctic pioneers. The slides shown at the dinner were made available through the courtesy of the National Geographic Society and the National Archives.

At the dinner meeting Bradford Washburn expressed very effectively our tendency to neglect the past: "There is a tragic and dangerous philosophy growing in America today which tends to focus all our attention on the present and the future and to relegate the past and its heroes into a role of minor importance on a dynamic scene where today and tomorrow are all that amount to anything at all." We felt accordingly that at this occasion we could "bear witness to our enthusiasm for the past and its heroes and to rededicate ourselves to remind our country that without the past and its succession of leaders in affairs and science and exploration, we should have neither a present nor a future that amounted to anything at all."

This conference was an effort to honor the contributions of our Arctic pioneers, take stock of our present capabilities, and look forward to the military and civilian needs of the future. In contrast to the former concept of the Arctic as a hostile wasteland, avoided by all but bold adventurers, we believe that we are striving for continued advance of man's successful conquest of an area of the world that will sometime be a populated and essential part of man's habitat.

PAUL A. SIPLE

Chairman

Conference Planning Committee

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Proceedings of the Conference
on
MAN LIVING IN THE ARCTIC

SESSION No. 1

THEME: THE ARCTIC

PAUL A. SIPLE, *presiding*

Chairman Siple: Ladies and gentlemen it is with pleasure that I welcome you to this conference on "Man Living in the Arctic," jointly sponsored by the National Academy of Sciences—National Research Council Advisory Board on Quartermaster Research and Development, The Arctic Institute of North America, and the United States Army Quartermaster Corps. The address of welcome will be given by Brig. General Merrill L. Tribe, Commanding General, Quartermaster Research and Engineering Command.

ADDRESS OF WELCOME

BRIGADIER GENERAL MERRILL L. TRIBE
Commanding General

Quartermaster Research and Engineering Command
Natick, Massachusetts

I am not only pleased but delighted to welcome you to this conference on "Man Living in the Arctic." I am especially happy to welcome so many visitors and conferees from Canada.

At a conference such as this one, we have the opportunity to see old friends and to make new ones. Most important, however, is our opportunity to exchange ideas; and it is from this free interchange of ideas that we derive the greatest and most lasting benefits of such a conference.

We are continuously progressing in knowledge and techniques for coping with cold climate living, building upon work done and outlined by keen and far-sighted people such as the late Sir Hubert Wilkins.

Those of us at Natick are intensely proud to be part of the Army Research and Development effort. We have a singular purpose; namely, to do whatever is necessary to better all facets of the life of the combat soldier on the field of battle. While many incidental benefits may accrue as a result of our work here, our sole objective is to insure that the combat soldier is an efficient, effective fighting man.

From today's newspapers and newscasts one can easily be led to believe that the future of the world is most uncertain. Though there is much uncertainty, it is my firm conviction that we are living at a

magnificent time in history. I believe that for us and for our children the future has never held more promise. I believe that the people of this country and our allies are keen and courageous and have the wisdom to do those things which can and will accomplish the ideals of free men. The future presents us with the greatest challenge ever, and we in the research and development field are keenly aware of the need to meet it.

We are pleased that this conference is a joint effort by the National Academy of Sciences—National Research Council Advisory Board on Quartermaster Research and Development as well as the Arctic Institute of North America. It is in groups such as these that the objectives of free men will be accomplished.

At this time it is my pleasure to introduce to you The Quartermaster General, Major General Andrew T. McNamara.

THE SIGNIFICANCE OF LOGISTICS IN THE ARCTIC

MAJOR GENERAL ANDREW T. MCNAMARA

The Quartermaster General

Department of the Army

Washington, D. C.

Any conference such as ours here today involves a tremendous amount of planning and preparation. One of the toughest jobs is establishing an orderly and comprehensive agenda that covers all aspects of the subject and yet does not unduly restrict any individual speaker.

Since I did not personally participate in the detailed development of our program, I am free to compliment all concerned on a masterful job. If everything comes off as scheduled, this is likely to be the most worth-while and productive meeting of its kind ever held.

As a matter of fact, the only touch of confusion I noted throughout the entire evolution of our agenda was over the topic assigned The Quartermaster General. The words always remained the same, but somehow the sequence wouldn't stay put.

When General Tribe first discussed my taking part in this conference, he suggested I speak on "The Significance of *Logistics* in the *Arctic*." The next time the subject came up, it had been changed to "The Significance of the *Arctic* in *Logistics*." When the first draft of the official program reached my office, I was listed to talk on "The *Logistical* Significance of the *Arctic*." The last letter I received just before I left Washington put it back to "The Significance of *Logistics* in the *Arctic*."

The reason for this apparent confusion, of course, is that all these approaches to the subject are valid and, in fact, imperative. Certainly, we must consider the importance of the Arctic in any over-all discussion of logistics. We must also consider supplies and equipment

and support services—what we in the military call logistics—in any discussion of operations in the Arctic.

For the purposes of this conference, I think we can dispense with a detailed analysis of why the Arctic is important to our national security. Your presence here today bespeaks your appreciation of that fact. The late General "Hap" Arnold, who commanded the Army Air Force in World War II, said that if World War III ever came, its strategic center would be the North Pole. His prophetic insight has been borne out by the way the Arctic has evolved during these intervening years from a fringe area in our defense concept to a major line of defense. From the military standpoint, the question is not any longer: "Are we going to set up shop in the Arctic?" We already have. The problem now is: "How can we continue to do it most efficiently and effectively?"

Those of you who knew the Arctic in the days of the American Pioneers of Arctic Exploration, whom we are honoring in this conference, may find the Arctic difficult to recognize today. The Arctic is no longer thought of as a mysterious, hostile area. Every year increasing numbers of Americans, together with our Canadian friends, are learning to live in the Arctic and to feel at home there. Today more than a hundred thousand passengers a year fly over the polar route between Europe and North America. If you like, you can fly your own plane to the north country as our Quartermaster consultant Dr. Terris Moore did merely for a summer jaunt, flying up to the north of Ellesmere Island, Northwest Greenland and back by way of Alaska.

For successful existence in the Arctic, a steadfast respect for its peculiar characteristics is essential. In my opinion, the purpose of our gathering here this week is to understand those characteristics more clearly and to see how we can better adjust to them.

Before I outline some of the basic problems the Army faces in living and operating in the Arctic, I would like to explain why the Quartermaster Corps is particularly concerned with this subject. The ironic truth is that the Quartermaster Corps, which provides such routine items as food, clothing, and field shelter, is the most taken-for-granted technical service in the Army. Yet when all else fails in the field, the Quartermaster Corps is the service the soldier falls back on as his court of last resort. Nowhere is this truer than in the Arctic. If there is no normal water supply, it is up to the Quartermaster Corps to provide drinkable water with the use of purification tablets. If a lighting system does not work, the Quartermaster Corps is expected to have lamps or candles available. When power heating gives out the Quartermaster Corps must have stoves in assorted sizes. When shelter is not available the Quartermaster Corps must provide tents. If there is no vehicular transportation, the Quartermaster Corps is expected to provide sleds, skis, snow shoes, and packboards so that troops and supplies can get through. If there is no chaplain available to conduct the burial service, an officer of the Quartermaster Corps assumes the

responsibility. In other words, when the going gets rough the Quartermaster Corps must take care of the troops in the Arctic as well as in the other parts of the world. The Quartermaster Corps must be ready to meet all the foregoing needs.

Supplies and equipment have always been of prime importance in any pattern of human life in the Arctic. The aborigine was self-sufficient from local resources, getting his food largely from the ocean or from the hunt, obtaining his transportation from his dogs, and making his shelter from the snow when necessary. The early explorer with great effort had a year's supplies brought up by boat, laboriously moved them overland by dog team sled, and cached them on the trail for use on the return trip. Next came the early commercial enterprises like the Hudson's Bay Company, which developed a distinctive but simple supply system for their trading posts with the natives, exchanging the products of civilization for furs. Finally, we have the pattern our present military services have developed, with our vast and intricate supply system supporting such military endeavors as the DEW line and our other northern military bases.

Our future Arctic logistic pattern will be influenced in part by the future economic exploitation of the area and by the extent to which regular commercial and industrial facilities, adaptable to the military in time of emergency, are developed. Today, however, the Arctic must be considered as virgin territory in which the military services must be more self-supporting than anywhere else on earth.

Weather and terrain will always partially determine military capabilities and the kind of logistic support required in the Arctic. In the past, Arctic and Sub-Arctic environments have prohibited military operations requiring large bodies of troops. Since small forces can be used most effectively in such areas without serious impairment of their striking power or maneuverability, our first concern is the support of these small mobile forces, up to a battle group of around 1,000 men, with the potential capability to support larger forces under special circumstances.

There is a tendency to oversimplify the problem of logistic support for combat forces in Arctic and Sub-Arctic areas by saying it is entirely a matter of transportation. While transportation is important there are other critical elements which must also be considered.

Logistic operations in the Arctic must be so planned that troops have adequate supplies to fall back on no matter what tactical situation develops, no matter how the weather may change through sudden storms or during the transition periods of spring and autumn, and no matter what distances may be involved. This is no small order. It will require the highest degree of careful planning if it is to be successfully achieved.

The axiom in Arctic logistic planning is that we must get along without anything which is not absolutely needed. Attempting to supply every desirable item may lead to an intolerable aggregate burden on the

logistic system. It can prove as disastrous to provide too much as too little. The determination of what is really needed is the responsibility of the local commander and the supply service. Manpower will probably be the scarcest resource in any Arctic combat situation. Local availability of men is likely to be so limited that human effort, in terms of the expenditure of physical and mental energy, must be conserved at all cost. In short, the basic problem of logistics may well be not supplies and equipment but the lack of people to handle them. Limited manpower makes it imperative that tonnage capacity in the transport system and for replacement and repair be held to an absolute minimum. The equipment with which a man starts a campaign must see him through it. Replacement needs should be obviated by durability and reliability of the initial equipment. Only those weapons or items of equipment which can clearly contribute to victory in combat should be supplied. Everything else should be kept out of the supply system so as not to build up storage of unnecessary items at the base points of combat units.

The need to eliminate non-essentials from the supply system is reinforced because there are special items which must be available if troops and equipment are to function in the extreme cold. These special items must be supplied on a priority basis and include such equipment as skis, snow shoes, sleds, ski wax, ice augers, ice saws, spare ski bindings, crampons, tents, tent stoves, and fuel. Where there is a need for such special equipment, the first job of both the local commander and his supply unit is to determine what items can be left behind without impairing the combat capability of the unit.

Another major point concerned with logistics in the Arctic is aerial delivery of supplies in the event other means of transportation are not available. Equipment or equipment components must fit economically into loading space of big cargo planes and also into smaller planes which may have to do their unloading from water onto an unprepared beach. This "economic fit" requires the utmost care in planning.

Because of the uncertainties of weather, the enormous span of the Arctic, and the inevitable separation of combat units, each unit must be capable of independent operations without contact with its normal base of supplies. In effect, many tactical units will have to be self-contained in the field.

Now I come to what I feel is the gist of the problem in Arctic operations. In the Arctic the individual soldier comes into his own as the critical element of our combat forces as he does in few if any other areas.

However successfully a native or a dedicated explorer may combat the environmental forces of the Arctic and come out on top, we cannot expect the average soldier to do as well unless he has been properly trained and unless he has supply support adequate to meet his essential needs.

By training and discipline, the Arctic soldier must be taught to be

self-reliant and resourceful, must be able to operate by himself, and must be prepared to utilize his surroundings to the maximum advantage. I do not insist that he be able to shift over on a day's notice to eating the Eskimo's muk-tuk, or blubber, or the lichens from the rocks which some of the early explorers had to resort to for food. But being temporarily cut off from his logistic support should not preclude his ability to function as an effective soldier. Similarly, the unit to which he belongs should be able to man-carry its entire combat gear and supplies, if the situation requires it, and still remain effective.

The significance of logistics in the Arctic is that nowhere else on earth is an Army so completely dependent upon its logistics system—not only for its effectiveness as a fighting force but for its very existence as a community of human beings.

What are we going to do about logistics in the Arctic?

Some of the answers will come out of this conference; but the vast majority, I am sure, will come only through weeks and months and years of determined thought and effort around the planning tables, in our research laboratories, and in our plants and factories. Every major element of the military, just as every major industry and branch of science, has a role to play in this seeking of solutions. Of all the elements of the Army concerned with logistic problems, there is none more directly and specifically responsible than the Army's vast research and development network. If we are to roll back the frontiers of technology and emerge into a brave new world of Arctic logistics, the spearhead of our attack must be our research program.

There is no one more intimately acquainted with the Army's current research and development problems nor more directly responsible for the Army's dynamic new approach to their solution than the man we are privileged and honored to have with us today. He is Lieutenant General Arthur G. Trudeau, Army Chief of Research and Development.

Heading one of the largest and most complex military subdivisions in existence, General Trudeau is an outspoken advocate of efficiency, effectiveness, and economy.

A formidable opponent of the *status quo* attitude in research and development, this ex-Vermonters was a guiding figure in Army's recent reorganization of its five-year-old research and development set-up. The purpose of the reorganization is to cut drastically lead-time in hardware development from concept to production—or as he says it: "from womb to boom."

His effect on Army's research and development people and machinery has already been, and promises in the future to be, significant and far reaching.

A West Point graduate, an engineer, a topflight staff officer, and a combat commander who has twice been decorated for gallantry in action, he is uniquely qualified to present the over-all Army picture to this conference.

SIGNIFICANCE OF RESEARCH AND DEVELOPMENT IN THE ARCTIC

LIEUTENANT GENERAL ARTHUR G. TRUDEAU
Chief of Research and Development
Department of the Army
Washington, D. C.

I was truly pleased when General McNamara invited me, on behalf of the Quartermaster Research and Engineering Command, to address this conference. While I have been in all of our Arctic test areas at least twice, I have the feeling that for me to come up here to talk to you distinguished "frigid-airs" on the subject of the significance of research and development in the Arctic is—to coin a phrase—like carrying ice cubes to Natick! After all, you are the recognized experts to whom I turn for advice.

I regard a situation like this as a charter for me to cover, in general, our Army Research and Development Program, emphasizing our concepts in the hope of arousing in you that deeply-needed, ever-increasing interest in our problems. In this connection, I know your deliberations here these next two days will give you added insight and will stimulate you further in your efforts to develop and refine the protective devices we so desperately need to do a job in an almost fantastically hostile environment.

Certainly, man must press on to dominate the Arctic. This geographical area has long resisted the most heroic attempts of man in ships, sleds, and planes. Historically, thousands of lives have been sacrificed to cold, hunger, and disease in a no-quarter, never-ending battle against nature in one of her most extreme and implacable forms.

Today at long last, with modern science and technology literally exploding in all fields, we are developing the means to conquer this beautiful but biting environment. We must conquer it because there are military overtones of great importance. Any map projection but Mercator shows that the Arctic route is the most direct line of attack between the North American continent and the heart of the Eurasian land mass. A strategic fact of such importance will not be neglected by those enemies of the Free World who would use it to their own advantage.

It is known that the Communists are expending great energy in learning how to overcome the natural barriers of the arctic and polar regions; and we know the Reds will not hesitate, if need be, to employ their combat forces in this environment. For that reason, our Army must match this growing Soviet capability and continually strive to better it.

We dare not be complacent. Our past and present achievements must be recognized clearly for what they are: beginnings, just beginnings.

Although we had a brief taste of Arctic operations after World War I in Siberia and northern Russia, our Army activities there really

date back to World War II. During that war we had sizable military forces in Alaska and Greenland and learned from their experiences that the permanently ice-covered Arctic is no military play-pen. In fact, winter combat operations in other areas—Western Europe, the Aleutians, and later in Korea—strongly pointed up the problem that even moderately low temperatures seriously impede the movement and effectiveness of ground forces. Trenchfoot and frostbite were daily terrors to the troops. Even equipment froze to a staggering halt.

After World War II we moved to improve our capacity to live and operate under Arctic conditions by establishing both a training and testing facility at Fort Greely, Alaska. During the same early postwar period we collaborated with the Canadian Army in establishing a research, development, and engineering test site at Fort Churchill in far north Manitoba. In the early fifties our Transportation Corps started field testing equipment in Greenland. The responsibility for coordinating all Greenland tests later passed to the Corps of Engineers, now assigned primary responsibility for Arctic construction as well as field experimentation in the arctic and polar regions.

We of Army Research and Development have continued to support an Arctic Program at Fort Greely and Fort Churchill and a Polar Program at Camp Tuto in Greenland and out on the icecap. At these sites with long periods of continuous cold, our test schedules worked out many months in advance are not upset by the effects of "unusual winter thaw."

Next month the Army will take over most of the Air Force facilities at Ladd Field in Alaska. We shall start transferring to Alaska some of our testing previously based at Fort Churchill. We plan gradually to extend our quest for knowledge to other parts of the Arctic in Alaska, including the Arctic Basin itself. We have already entered into a contract with The Arctic Institute of North America to analyze the problems which the Army anticipates in operating on the polar pack ice.

Army research and development efforts are focused primarily on the means for ground forces to win on any future battlefield. Our forces must have the means to move, shoot, and communicate concurrently any time, any place, and under any conditions. Our Army must have the finest firepower, mobility, and communications for its forces wherever they fight—valley, plain, mountain, desert, swamp, jungle, or in frozen polar wastes. It is with this sense of mission that the Army's current research and development program supports extensive investigations in basic research as well as in applied research and development. The scope of our program is as broad as man's imagination, for our primary interest is in the soldier and what it takes to sustain him in any hostile environment.

The Army's efforts in basic research, to penetrate the ever-shifting boundaries of science, are extensive. We devote about 50 million dollars per year to this effort, expended through more than 550 labora-

tries, universities, and industries; 80 Army and other governmental installations; and two overseas research offices—one in Frankfurt, Germany and the other in Tokyo, Japan. The Army is particularly aware of the necessity for basic research and will continue to stress it to the limit of available funding. Basic research is the key to future developments and to the realization of radically new development concepts and designs.

One of our most important basic areas is cold regions research. Here, the Quartermaster Corps, the Corps of Engineers, and other Army technical services are conducting a program to determine the requirements for successful arctic and polar operations. The emphasis is placed on meteorology, on physiological and psychological problems associated with small unit operations, and on the physical properties of snow, ice, and frozen ground. An interesting part of this investigation is in Greenland, where the concept of living, working, and traveling beneath the snow surface is now being studied.

The Army's approach to research and development in Greenland has been unique. We have not only supported basic research there, but we have been successful in attracting many outstanding scientists to take advantage of this opportunity to study the region. In return, we have derived rich dividends. We have improved our equipment and techniques for living in the arctic and polar regions and have conceived many useful concepts for possible military application. The scientists attracted to Greenland were challenged by the characteristics and behavior of snow, ice, and permafrost. In time they learned to work with these phenomena and to develop various means of handling them. As a result, we now are able to live beneath the snow, to fly from its surface, to find our way over it.

I know you all are acquainted with Camp Century, the city under the ice, a product of this scientific endeavor. Although Camp Century of today is an experiment in living on the Greenland Icecap, it may well be the prototype of actual defense posts in the future. I had the good fortune to visit Greenland and Camp Century in October and would like to share with you some thoughts about two interesting developments now taking place there.

One is the testing of a nuclear reactor presently furnishing about 1600 kw of electricity and over a million Btu of heat per hour to this research city under the snow. This reactor is performing exceedingly well and is proving that military installations in remote, relatively inaccessible locations can be freed from continual fuel supply. Consider, if you will, the important promise nuclear energy holds for Arctic operations.

The second is the deep drilling technique our Greenland glaciologists are using. Through funds supplied by the National Science Foundation, our Snow, Ice, Permafrost Research Engineering organization developed a thermal drill which will be capable of penetrating the thickest portion of the icecap. This drill, while I was there, was

reaching a depth of several hundred feet and extracting core samples which, by the best estimation, were dated as formed in about the year 1066, when William the Conqueror landed in England. This is only the beginning. With this drill we hope to reach depths in the ice of over 10,000 feet and by isotopic dating of the cores and possibly pollen analysis learn more about the climatic changes over the ages. At the bottom of the icecap will be other data, unmarred by the elements and civilization, that can provide valuable information about the geological structure of the earth. The implications of this drilling technique are truly impressive to physical and social scientists alike.

Army research work in Greenland has already contributed to other national efforts. Not only did the Army work there plan an active role in the International Geophysical Year of 1957-58, but the Navy is now applying many of the under-the-snow construction techniques developed in Greenland to its rebuilding of the Byrd and South Pole Stations in Antarctica. Adoption of these techniques will probably extend the life of the Navy under-snow stations on the polar icecap from an expected three or four years to at least ten years, and, in addition, result in substantial savings in money. Also, the techniques used in the installation of the portable nuclear power reactor at Camp Century are being adopted by the Navy at McMurdo Sound and other stations in Antarctica.

Another research area of related interest to the Arctic is materials research. We know that our engineering design prospects are intimately bound up with the improvement of existing materials and with the discovery of new materials with greatly enhanced properties under all extremes of temperature. In materials research in plastics, polymers, ceramics, and metallurgy, we are working on a variety of cold-weather approaches. I am pleased to report that we are achieving unusually good cold-weather performance with plastics and polymers.

Other significant basic research of interest here which our Army is conducting in medicine, chemistry, or thermodynamics are too numerous for me to cover in the brief time for this talk. However, what I have covered should indicate that basic research is essential for advancing the knowledge of Arctic living as well as for increasing the operational capability of military forces in cold regions. These advances illustrate, moreover, the kind of basic research effort which is necessary to feed the insatiable appetite of applied research and development. For without new knowledge, without new science, applied research and development is limited to product improvement. Product improvement, important as it is, will not put us out in front where we belong, nor keep us there.

I am certain that to this audience I need not emphasize the importance of learning about summer conditions in the Arctic. The tundra, the muskeg, the boulder fields, and the countless swamps, lakes, and ponds provide the greatest barriers to summertime travel in the high Arctic. The ice break-up season poses even worse problems. Also,

rugged terrain and electro-magnetic phenomena in some regions interfere severely with communications. And the presence of continuous daylight in summer is almost as unique as the long hours of darkness in winter.

Environmental research is also important, and we are pushing it forward to the greatest extent possible.

Let us now look at the general areas of interest in our applied research and development effort in the classic fields of military endeavor: firepower, communications, and mobility.

All the new equipment soon to be in the hands of troops—whether it be a missile boosting our firepower range or a surveillance drone improving our target acquisition capability—must meet certain low temperature criteria. These criteria require satisfactory operation of equipment at -25°F in mid latitude regions and at -65°F for equipment designed for use in polar and arctic regions. Utilization of these temperature extremes has resulted in certain problems. We have found that some new equipment under development will perform in the field under slightly less severe condition than design criteria. Strange as it may seem, many items which perform well in laboratory, engineering, and user tests, including the use of cold chambers for components, have failed in the field to meet specifications. Currently, we are taking steps to correct these deficiencies.

Communications and electronics are a most important part of our applied research and development effort. We recognize that a land force cannot navigate on or over any terrain, particularly in the Arctic, without some special means of communication control. Also, missiles cannot be fired effectively without electronic devices to collect target information and to guide the missiles to the target. Here, communication satellites will ultimately provide a reliable and efficient means of spanning the oceans and polar regions for both military and commercial purposes.

Just two months ago, the Advance Research Projects Agency (ARPA) in our Defense Department turned over to the U. S. Army the \$23 million COURIER and the \$174 million ADVENT communication satellite programs.

COURIER is the first important satellite communication system to be put through the research and development paces. This delayed-repeater type of active relay system is capable of receiving and transmitting in one pass (about a five-minute period) almost 340,000 words or the equivalent of the contents of the Sunday edition of "The New York Times." This amounts to over 1,400 words per second, a tremendous increase over any of our present systems. COURIER will contribute immeasurably to all future communication systems, civil as well as military.

During the next three-year period, it is expected that several COURIER satellites will be launched. Each communications "package" will be developed by the U.S. Army. Indispensable to the success

of COURIER, I must add, has been the solar battery. The more than 19,000 solar cells which give the COURIER satellite a cellular appearance represent one of the real achievements of our time.

Now the satellite communication system offering the most advantages, particularly in the Arctic, is the so-called 24-hour satellite that completes one revolution around the earth in the same time period that the point below it on the earth completes one revolution. This system is known as Project ADVENT, designed to position a microwave communications relay package 19,300 nautical miles above the earth in a 24-hour orbit. This is truly an ambitious program, which will probably take from five to as many as ten years to complete successfully. We are well on our way; and when the project has been brought to a successful conclusion, we will have practically a "real-time" global communications capability, something that seemed impossible a few short years ago.

I turn now to mobility in the Arctic.

On the ground we are seeking to improve all our surface vehicles. We are working toward the utilization of large wheels and low profile, the utilization of low pressure tires, and the utilization of a family of articulated vehicles such as the RAT, the MUSK-RAT, and the MUSK-CAT.

Yet, paradoxically, for better ground or battlefield mobility in the Arctic, we are concentrating on the air!

We are working to develop true air vehicles that will fly just above the "nap of the earth," permitting the combat soldier of tomorrow to overcome normal terrain obstacles such as snow, mud, swamps, rivers, and forests. This type of vehicle will have the take-off and landing characteristics of the helicopter coupled with the advantages of the fixed-wing aircraft in forward flight. You have probably seen pictures of some of our flying test beds that look like disks or platforms propelled by unusual power plants. These are the experimental vehicles that promise to give the answer to flying low, fast or slow, and quietly just above the battlefield.

Today, we have several research test beds under study. These test beds are only an approach to optimum mobility, not in any sense operable military aircraft. Some have wings that tilt, others have ducted fans, and a few use conventional power sources and schemes of flight. We are confident that some of these approaches can be developed into high-performance vertical and short-take-off and -landing aircraft of all sizes, capacities, and ranges to be used for numerous ground support missions.

There is one other area with which we are most concerned, and that is the most important factor on any battlefield in any future time—the soldier. In the Army of tomorrow, the soldier will still play the predominant role, regardless of the nature of the conflict. In any war between two nations, I submit to you that men, well-trained and well-led, are still the key to final victory on the decisive battlefield and

that a strong Army is a necessary and fundamental part of our national military posture. Despite conflicting theories of strategy, I know of none brash enough to maintain that hostile or contested territory can be taken and controlled by people who are not physically present, even in the Arctic.

The soldier on the ground is the man for whom we try not only to develop the finest weapons systems but also the best rations, clothing, shelter and protective devices; for whom we are constantly striving to secure every possible advantage in future combat so that he can perform his vital missions and carry on to victory. An important objective in this respect is to lighten the load the soldier must carry.

At this time I would like to congratulate the Quartermaster Corps for its many achievements which have aided immeasurably in improving man's operational capabilities in the Arctic. I refer particularly to the development of improved shelter, clothing, and food.

Now, I have given you as much of an insight into the Army Research and Development Program for the Arctic as the clock will allow. All our work is being done to insure the continued defense of our Nation. We view all these contributions to the defensive might of America with pride. Equally important, we know that many of these contributions will be used for the peaceful benefit of mankind.

We must never forget for a minute the reason, the underlying cause, for our tremendous military effort. We must not relax our guard nor our efforts to build continually better defensive forces.

Today, in this surging era of great change, in this age of seeming grayness and indecision, the development of adequate means to advance the progress and security of this country, as well as the Free World, is well within our capabilities if we but know our strength.

It is important to remember that in the fields of science and technology we still have significant advantages over the Communists. We must be more aware of these superiorities and must strive not only to maintain but to extend them.

Yours is a field of effort that can do much for our country. Look ahead with more optimism and push Arctic research forward, gentlemen. This is a satisfying and productive service you can render to your country in this era of the cold war. The field is still relatively untouched. While you are considering the possibilities for better utilization of these areas, don't fail to consider concurrently the denial of such areas to an enemy.

For every ounce of deterrence we build, we need to add a pound of determination. I am confident that as the new year dawns and America restudies her road map to chart a new route there will be a resurgence of those spiritual qualities, bolstered by integrity and initiative and by selflessness and sacrifice, that made our nation great. Let us with pride and dauntless courage contribute our humble efforts to this end. The goal of America can be no finer than the soul of America.

and this approaching Christmas Season should be a time for both national and individual contemplation. Time is not on our side unless we use it wisely.

Thank you very much.

LIMITATIONS TO LIVING IN THE POLAR REGIONS

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Our conference on Man Living in the Arctic sets up fundamental goals for our contemplation. We could proceed to discuss the time-honored individual factors which limit so-called normal operations; however, they seem to be so obvious that they need hardly be mentioned before an audience of this nature. Darkness, cold, vast unpopulated areas, wind, snow, ice, crevasses, swampy tundra, taiga-forests, over-abundance of water, ice break-up, insects, sparsity of economic opportunities, and high cost of transportation are among the many factors which cause limitations on living. Through ingenuity we have overcome some of these obstacles, but progress is still required in our continued search for improved well-being.

What is it we seek toward making the Arctic more livable? Certainly, in the last decade food, clothing, shelter, lighting, power, sanitation, communications, and mobility have been improved immeasurably; yet in all of these items further improvement is desirable. In fact, those people in research and development may have cause for dismay. Each time the standard of living is elevated, the demand for still more refined improvement doubles. There may never be a satisfactory final solution to the unending evolution of requirements for adapting to living in the Arctic.

This concept of a progressive need for more complex solutions is contrary to the need of simple, austere, and practical solutions necessary for the military problems clearly outlined by Generals Trudeau and McNamara in the preceding two papers. The military's prime concern is the soldier as an effective fighting man. Logistic problems inherently restrict the soldier to essentials. For man to establish a normal civilization in the Arctic, it will be necessary to provide the comforts, conveniences, and social mores obtainable elsewhere over and above the means for solving the unique problems of the Arctic. The pioneers of civilization have always solved their problems on their own initiative. We at this conference are pioneering to make this hostile region livable.

It is only when man attempts to conquer his environment that progress is made. Had the proverbial Garden of Eden persisted on earth, making no demands on the inhabitants to obtain food, clothing,

or shelter, there might have been no civilization as we know it. The aborigines of Australia have existed for ages unclothed, unsheltered, and reasonably well fed by gleaning. They are, however, generally accepted by anthropologists to be the least advanced members of the human race.

As Dr. Stefansson pointed out in his "Northward Course of Empire," civilization has progressed to harsher environments where greater ingenuity is required to survive. Historically weak peoples vanquished by a powerful nation were forced into harsher environments to which they were forced to adapt. Upon meeting that challenge they became sufficiently powerful not only to regain their lost lands but to push beyond their original boundaries and in turn force others into harsh environments. Step by step we can trace this pattern from Egypt, Crete, Greece, Rome, France, the Byzantine Empire, the Germanic nations, England, and finally to other continents. The history of our own country in overcoming the problems of vastness, forested regions, severe winters, led to the development of railroads, highways, automobiles, airplanes, radio, TV, and a host of other means to improve the standard of living. We too have become powerful. Other nations, such as the USSR, have been forced in a similar manner to develop their resources to solve difficult living problems. They also have become powerful. It is obvious that once a nation becomes complacent and ceases to apply its ingenuity, it may face the decline that other nations have suffered in the past. However, positive reasoning carried to a logical conclusion can but lead us to the recognition that the future of life in the polar regions may eventually become brighter than appears today. Harshness of environment is a limitation; but if overcome, it becomes a source of strength. After all who is to say that the temperate regions are always to be considered the optimum environment when at one time they were less desirable than the tropical locations?

If a higher civilization is feasible in the Arctic, why has it not developed there? The Arctic aborigines possessed crafts, arts, and skills superior to those of the more isolated aborigines in temperate regions; but being ignorant of more favorable environs and higher living standards elsewhere, they were content to accept the many limitations which their severe climate imposed. Today as the Eskimos learn more about life in other parts of the world, they become increasingly discontent with their simple way of life. Thus in order to realize a contented future Arctic population, it will be necessary to provide all "the best of everything" that other cultures have to offer.

We recognize the major motivating forces that have taken modern civilized man into the polar regions: adventure, economic hopes, population pressure, national security, scientific quest, premium wages, and even escape. But what keeps a population in a pioneer region permanently? First of all there must be normal family life. Most of our current Arctic military and scientific activities have not recognized

this requirement. Therefore, even the men who enjoy Arctic existence are forced for personal reasons to retreat. Secondly, there must be a stable means of providing a livelihood. Military and scientific work can be maintained indefinitely, but current assignments do not provide a sufficiently secure career basis to encourage a man and his family to make their home in the Arctic. Economic pursuits such as agriculture and mining cannot yet be counted on to provide stable employment. The third requirement is the provision of ample communication and transportation networks. Radio does permit reasonably good communications, and airplanes have gone a long way toward solving problems of isolated communities; but neither of these has reached the stage of fulfilling the daily requirements of living as we know them in the temperate regions.

The large concentration of population in southern Canada is contented and stable. At one time southern Canada, where pioneer living was very difficult, was considered the approach to the Arctic. However, the inhabitants have long since developed the three basic requirements of family life, livelihood, and a communication and road network. Southern Canada is now accepted as part of the temperate domain. As the road and communication networks press northward, accompanied by suitable economic and social foundations for life, attainment of the Arctic becomes real. This progress is advancing steadily into Alaska, parts of Greenland, the Scandinavian countries, and the USSR. Our own North American Arctic, however, is very sparsely populated and will continue to be so until we can supply the fundamental demands.

For the near future, particularly in order to solve military needs, we must accept stages of development which fall short of the ideal for permanency. The Home Guard of Finmark who protects Northern Norway is a stable population living in the Arctic region. We must eventually look to Home Guards of Alaska, Northern Canada, and the entire Scandinavian Arctic as the sound long-range basis for military protection. In the meantime we shall have to accept a transient military population to guard the Arctic frontiers of western civilization. For obvious economic reasons we shall have to meet the military requirements of austerity and simple, economic solutions far short of our long-range requirements.

Actually, civilization of the Arctic is being accelerated by this military effort because our forces must live and function in the Arctic and adapt to its limitations. If our neighbors across the Arctic Ocean were completely friendly and the only stimulation toward progress were that of economic trade, development of the region might be extended over many generations and be slow by comparison with the strides we are making today.

In conclusion, Man Living in the Arctic is a problem with no simple, quick solution. We have to solve some of the same problems over and over again until we can finally fulfill the basic requirements to make

the region acceptable to modern man and give him motivation to stay there permanently.

CHAIRMAN SIPLE: The next speaker this morning is someone who has had experience in looking at Man in many parts of the world and seeing how he reacts to his environments. Our speaker is well-equipped to ascribe accurately the Cold Climate Man. It is a pleasure to introduce to you Dr. H. T. Hammel, Department of Physiology, University of Pennsylvania. Dr. Hammel.

THE COLD CLIMATE MAN

H. T. HAMMEL

University of Pennsylvania Medical School
Philadelphia, Pennsylvania

Many cultures of men experience exposure to the cold to varying degrees. Not only men living in the Arctic but men of cultures found in temperate and even sub-tropical zones of the earth may be cold exposed during some time of the day or year. Physiologists have long been asking the question, "Has this exposure made these men, in any way, different in their internal physiological adjustment to their cold environment?"

We believe that man is essentially a tropical animal. Yet cultures of men have been making excursions into colder parts of the earth for tens if not hundreds of thousands of years. For the pole-ward movements, he has depended largely upon a primitive technology, employing fire, garments of fur, and shelters constructed of available materials. Since his technology was not always sufficient for the climate, some degree of cold exposure was experienced by these roving cultures; so our question is, again, "In what way and to what extent has exposure to cold rendered these men different from the tropical inhabitants?"

Many investigators have attempted to find answers to this question. I am going to bias this presentation by limiting my discussion to those studies which have been accomplished under the direction of Scholander and his collaborators who have undertaken a physiological survey of many cultures of men exposed to cold. The first chore was to devise some simple field technique which would be adequate for getting the answers. This task was accomplished while working with a group of eight Norwegian young men who were exposed to moderate cold during autumn in the mountains of Norway (1). These men were exposed to cold simply by withholding from them adequate insulation for the type of climate they were to endure for six weeks. At ten-day intervals they would return to a laboratory set up in a resort hotel in the mountains of southern Norway where both oxygen consumption and body temperatures were measured throughout eight hours of moderate cold exposure at night.

During the experimental period, the subject lay on a cot with his

head in a ventilated hood similar to that shown in Fig. 1. Since the night temperature was near freezing (average about 3°C), the micro-environment was moderated by placing the cot in an unheated tent and enclosing the subject in a single woolen blanket and windproof cloth (insulation of blanket, thin cloth, and overlying air was 2.0 clo.). The volume of air ventilating the hood was collected in a spirometer for ten minute periods and analyzed for O_2 and CO_2 content. Fig. 2 illustrates the methods used for metabolic determinations, although the scene is from a later expedition to southern Chile. Rectal and skin temperatures were measured at half hour intervals throughout the night with thermocouples.

The thermal and metabolic responses of the acclimatized and the control groups are exemplified in Fig. 3 by results for one individual from each group. The metabolism and heat production of the acclimatized group was a little higher than the metabolism of the control group especially during the first part of the night, and the skin temperatures were a little higher in the acclimatized individuals. There was no difference in the rectal temperatures of the two groups. These findings were interpreted to mean that modern Europeans exposed nightly to moderate cold for a few weeks become acclimatized by increasing their capacity to produce heat in order to maintain a warmer skin temperature. This is metabolic acclimatization rather than insulative acclimatization wherein the metabolism would remain basal or resting as the skin temperature cooled.

One of the results of the study on the young men exposed to cold on the Hardanger Vidda of southern Norway was that we had a discriminating field method which could be used to survey the thermal and metabolic responses of a number of ethnic and cultural groups. The first such group investigated was the aborigine of central Australia in the wintertime.

Winter is the dry season in the semi-desert of central Australia. The minimum night temperature ranges from a few degrees below freezing up to 12°C with a mean minimum temperature of 4°C . The sky is always very clear, and the radiant temperature of the zenith is nearly always 20°C below the air temperature. The sleeping habit of the aborigine was to lie naked between two small fires behind a low windbreak of brush and unshielded from the cold sky. With sufficient attention given to the fire, the micro-environment of the sleeper can be maintained within the thermal neutral zone for even the white man. Although the experience of excessive warmth on one side and marked coolness on another is strange indeed to the latter, there is, however, inherent in this manner of sleeping a tendency to cold exposure. The fire is unattended and diminishes its radiant heat output. When sleeping, the sleeper cools until he is aroused by the discomfort to attend the fire again. A lifetime of this pattern of sleeping leads to an individual who is chronically exposed to periodic cold. Genera-



FIGURE 1. Ventilated hood and thermocouples on cot inside tent. Subjects lay on cot inside a woolen blanket bag with thin wind protector.



FIGURE 2. Inside field laboratory at Puerto Eden, Wellington Island, Chile showing portable spirometers and Scholander 0.5cc gas analyzer in use.

tions of this "proper bush" sleeping has produced a culture of cold exposed people.

Using methods similar to those employed with the young Norwegians, the thermal and metabolic responses of the central Australian aborigine were measured during a night of moderate cold exposure (2). The natives and the control white subjects slept on cots and

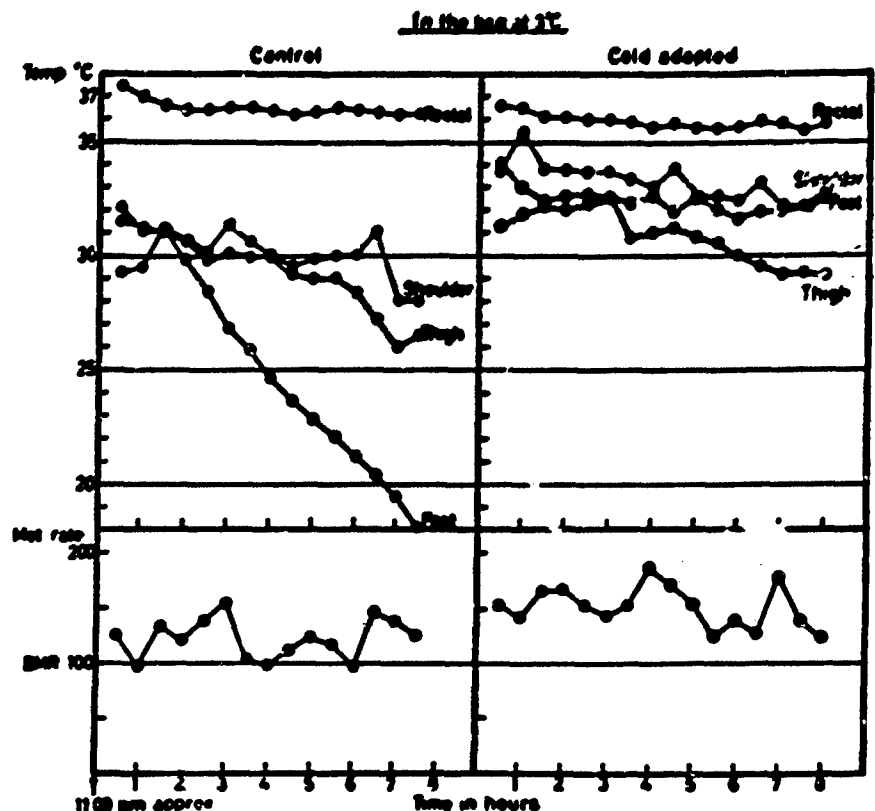


FIGURE 3. Oxygen consumption and body temperatures of acclimatized Norwegian student (right) and control subject (left) during a night of moderate cold exposure. Air Temperature about 3°C.

inside a blanket and a thin cloth wind protector (total insulation, including still air, equal to 1.9 clo). They were shielded from the sky and wind so that the thermal stress came only from the low night air temperature (0 to 5°C) moderated by the woolen blanket.

The average responses of six natives and four white subjects are shown in Fig. 4. After the first hour, the controls responded by bursts of shivering or other muscular activity which increased their metabolic rate from 10% to 90% above basal, averaging about 30% above basal. The natives responded with little or no metabolic compensation resulting in a greater fall in core and skin temperatures. By increased heat production, the white subjects were approaching thermal equilibrium with the environment while the natives continued to lose heat content throughout the night. The cold exposed Australian aborigine exhibits insulative acclimatization rather than metabolic acclimatization as was seen in the cold exposed Norwegians. The conductance of the body shell between the core and skin surface was approx-

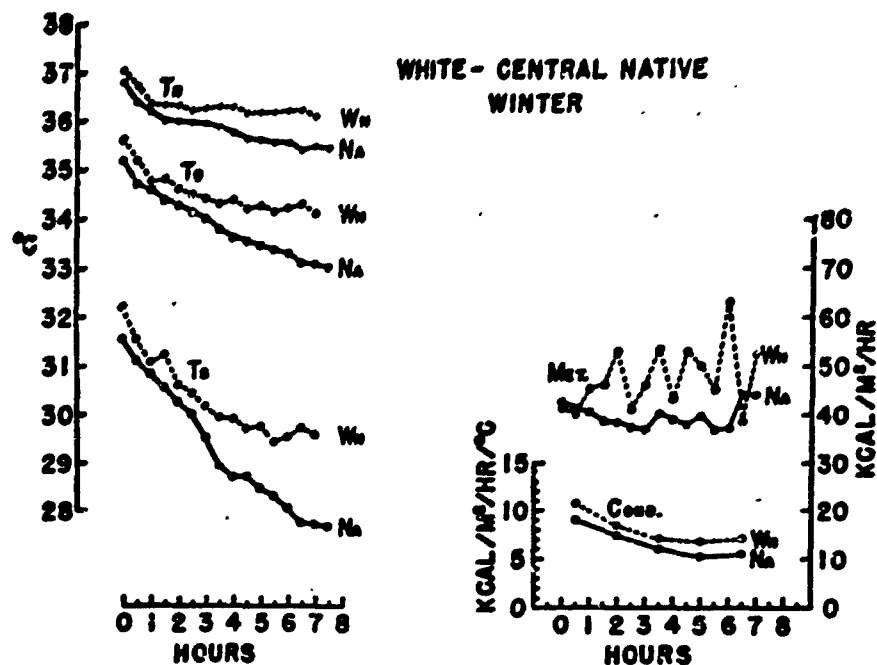


FIGURE 4. Average thermal and metabolic responses of six central Australian aborigines (solid lines) and four control white subjects (broken lines) during a night of moderate cold exposure in the winter season. T_r = rectal temperature, T_b = mean body temperature, T_s = average skin temperature, Met. = heat production in Cal/m²/hr, and Cond. = conductance of heat from core to skin in Cal/m²/hr/°C. Air temperature about 3°C.

imately 30% less in the natives than in the white subjects, supporting the statement that the natives showed insulative acclimatization.

A second expedition to Australia (3) was undertaken to determine a) whether the greater body cooling without metabolic compensation was seasonal in the central aborigine, or persisted in the summer to the same degree as in the winter and b) whether this condition would be found in the tropical coastal tribes of northern Australia where the natives do not experience cold exposure during the summer nights and may not experience chronic cold during any period of their lives. The experimental procedure for the second Australian study differed in no essential way from the first except that the thermal stress in the summer study was obtained by placing the sleeping cots inside a refrigerated meat van, maintained at 5°C throughout the night.

The average thermal and metabolic responses of seven central Australian aborigines in the summer and six white subjects to moderate cold exposure at night are shown in Fig. 5. The response of the native was the same in the summer as in the winter, that is, greater body cooling than the control whites and no metabolic compensation.

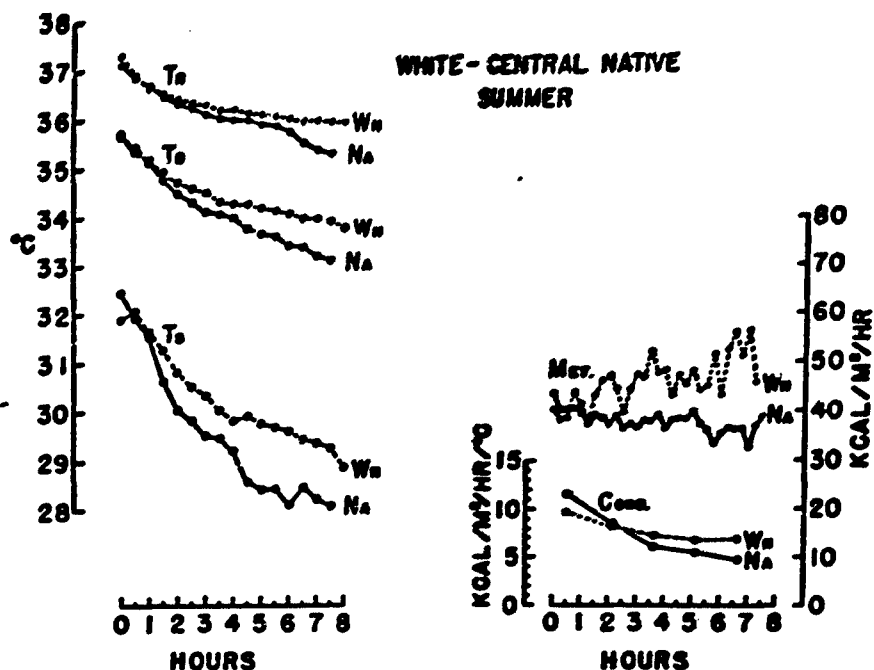


FIGURE 5. Average thermal and metabolic responses of seven central Australian aborigines (solid lines) and six control white subjects (broken lines) during a night of moderate cold exposure in the summer season. Air temperature about 5°C.

The absence of seasonal variation in responses to cold indicates that the insulative acclimatization is either a racial characteristic or that there was no seasonal difference in the cold exposure in the sleeping environment so that the response was due to a lifetime of cold exposure which would be reduced or absent in central natives moving to the tropics or in tropical natives. The combined meteorological data and the sleeping customs of the desert natives indicate that there was probably little or no seasonal variation in the sleeping environment. The minimum night temperatures in summer ranged from 11°C to 27°C. The annual rainfall of about 10 inches fell in the summer. However, the sky was mostly clear with a radiant temperature of 20°C below ambient temperature, when not raining. The natives use fires less in summer than in winter and may be as cold exposed in summer as in winter.

To learn if, or to what extent, the insulative acclimatization is a racial characteristic and, therefore, an adaptation to cold, similar measurements were made on aborigines living around Darwin. In summer, these natives experienced no cold exposure at all since they were sleeping in enclosures and the mean minimum night temperature was 26°C, ranging from 22°C to 29°C. Summer was the monsoon season; the air was humid and the sky hazy. In winter, however,

they could have experienced cold, and some of our subjects had been cold. The minimum night temperature was $20^{\circ} \pm 4^{\circ}\text{C}$, and the sky was clear and cold.

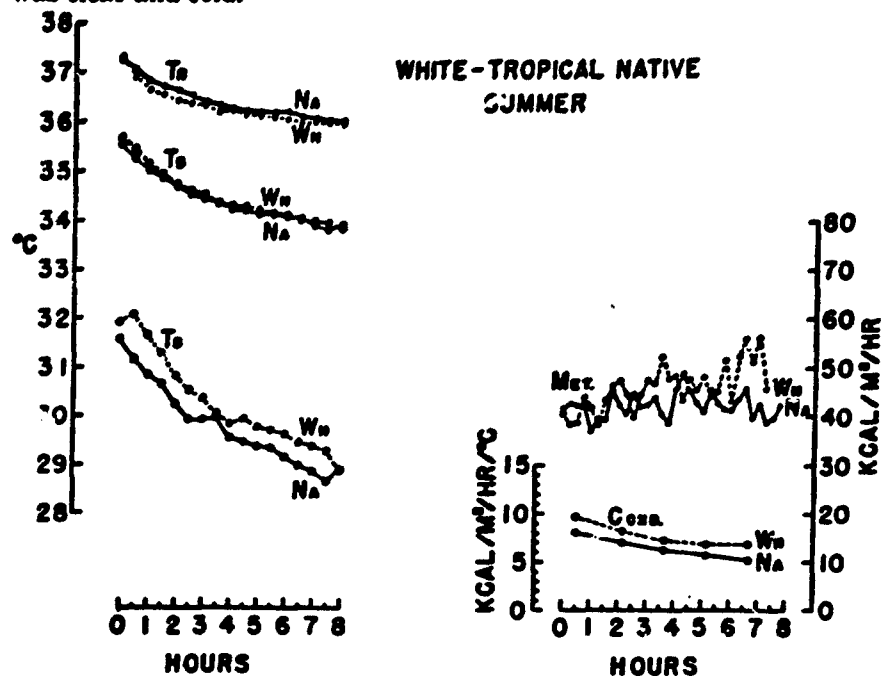


FIGURE 6. Average thermal and metabolic responses of nine tropical Australian aborigines (solid lines) and six control white subjects (broken lines) during a night of moderate cold exposure in the summer season. Air temperature about 5°C .

The average thermal and metabolic responses of nine tropical aborigines to cold are shown in Fig. 6 and are compared with the control whites. The metabolic response of the tropical natives was intermediate between the central natives and the control white. The average skin temperature fell a little more than the skin of the whites. The rectal temperatures were not significantly different throughout the night. The conductance of heat through the shell was about 30% less than for the white and the same as for the central natives both summer and winter. The intermediate position of the tropical aborigines suggests that insulative acclimatization is a racial characteristic although the extent of body cooling before metabolic responses occur may be increased by chronic cold exposure in the night environment.

Is insulative cooling the only type of acclimatization or adaptation to cold to be found in primitive cold exposed cultures or is metabolic acclimatization to be found also? The answer to this question was obtained by proceeding to the Strait of Magellan (4).

Living on the islands in the Archipelago south and west of continental South America were three primitive Indian tribes: Ona,

Yaghan, and Alacaluf. The Ona Indians lived in the interior of the Grand Island of Tierra del Fuego; the Yaghans lived along the Beagle Channel on the southern coast of Grand Island of Tierra del Fuego and along the coasts of islands running westward to Brecknock Peninsula. Along the channels, among the islands stretching northward for approximately 300 miles, was another culture of canoe Indians, the Alacaluf. At present there are probably no more than two or three Onas, a half dozen Yaghans and approximately 50 Alacalufs.

The climate of the Archipelago is largely determined by the low southern latitude and the winds off the Antarctic Ocean. The temperatures recorded at Meteorological Station at Puerto Eden on Wellington Island reveal that diurnal variations and seasonal variations are remarkably small. Even in winter the ambient temperature is regularly a little above freezing. The unpleasant aspect of this climate, which is now legendary, results from the rain frequently mixed with sleet or snow and the wind. The rainfall for Puerto Eden is over 100 inches annually and falls nearly uniformly throughout the year. Not infrequently, the winter precipitation will fall as a light, short-lived cover of snow at sea level.

To the chilling influence of the rain, the overcast skies, and the near-freezing temperatures are added the frequent winds. Winds through the channels can blow with sufficient vigor to make life in an open canoe a chilling, if not a treacherous, experience. Although the climate can be little more than wretched to a poorly clothed man caught on the open channel or isolated on a barren rocky island, the weather can also be as comforting or as invigorating as a day in spring in the more temperate regions of the earth if the air should be calm and the sun shining. Even at its worst, a dry wind-tight shelter with a modest fire is enough to mitigate the chill that exists outside.

The average heat production and body temperatures of nine Alacaluf Indians during a night of cold exposure are shown in Fig. 7. The methods employed for measuring oxygen consumption and body temperatures were identical to those used in the previous studies on the Australian aborigine. During the cold exposure, the subjects slept or rested on a canvas cot in an unheated tent. The temperature inside the tent was in all cases between 2° and 5°C. Each subject was inside a sleeping bag made of a woolen blanket and a wind cover (total insulation about 2 clo). Also shown in Fig. 7 are the average responses of six Indians who were studied again while sleeping without cold exposure. For these measurements, the subjects lay on a mattress and were free to use as many blankets as required to remain comfortable.

The metabolic rate was found to start at about 60 Cal/m²/hr or about 160% of the average white man's basal metabolic rate. The metabolism gradually declined throughout the night of cold exposure

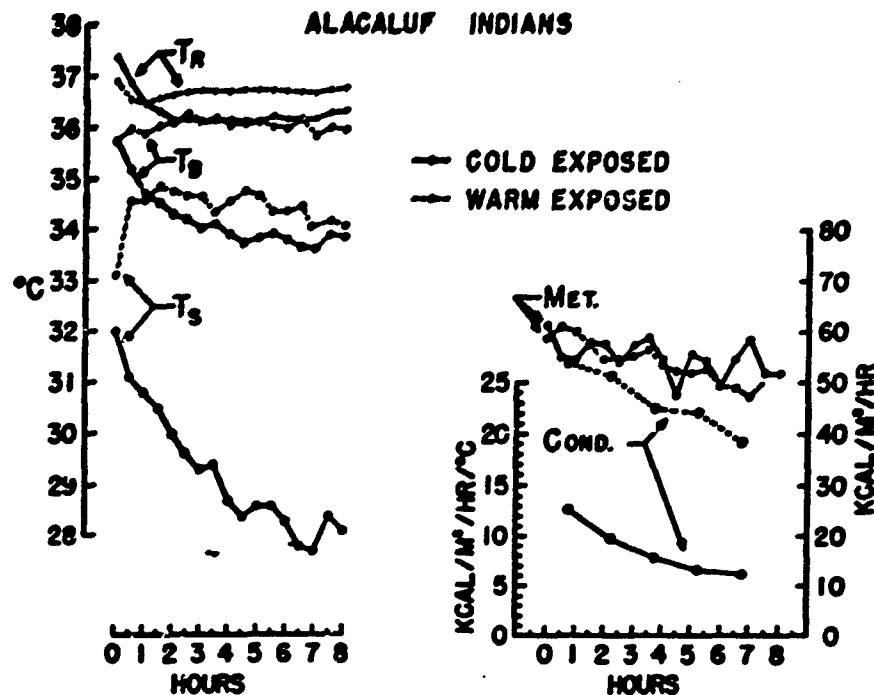


FIGURE 7. Average thermal and metabolic responses of nine Alacaluf Indians during a night of moderate cold exposure (solid lines) and of six Indians during a night of warm exposure (broken lines) in the winter season. Air temperature about 3°C.

to about 50 Cal/m²/hr. Although the Alacaluf would add a few bcuts of shivering on top of his resting or sleeping metabolism, the trend in his metabolism was downward as the night progressed, falling to about the same level of heat production to which the white man would increase his metabolism by the end of a night of moderate cold exposure.

The course of the rectal temperature of the Alacaluf was not different from the white man's temperature, starting above 37°C and falling to and remaining at 36.2°C for most of the night. The average skin temperature fell to about 28°C the last hours of the night or about 1°C below the white man's average skin temperature after a night of cold exposure. On the other hand, the foot temperatures of the Alacaluf did not fall below 19°C, a level that is 2° to 3°C higher than the white man's foot temperature. The integrated effect of the higher over-all metabolism and the slightly lower average skin temperature was a body conductance for heat flowing from core to periphery which was a little higher than the body conductance of the unacclimatized white man during the latter half of the night.

The Alacalufs show some similarity to the cold acclimatized Norwegian students in that both groups initiated the night's sleep with a very high metabolic rate. Both groups were able to sleep better than control white men. The rectal temperature of both groups was the same and the foot temperature of both groups was higher than that of the unacclimatized white man.

The metabolic rate of the average Alacaluf during a warm night was not distinguishable from the rate during a cold night. His rectal temperature leveled off to about 36.7°C in the warm run and his average skin temperature was between 34° and 35°C . There was a gradual increase in body heat content for the first two hours of the warm night; thereafter, it was nearly constant. The body conductance while sleeping warm was 2 to 3 times the conductance in the cold environment showing that the vascular system is vasodilated during comfortable sleep.

Both native North American Arctic inhabitants, the Indian and the Eskimo, have been studied by methods similar to those already discussed. The thermal and metabolic responses of the Old Crow Indians of the Yukon Territory, during a night of moderate cold exposure were measured by Irving (5) in the autumn and again in the spring by Elsner (6). The average metabolic response of nine Arctic Indians in the autumn during a night of cold exposure is shown in Fig. 8. For comparison, the average response of the same Indians during a warm night and the average response of seven urban white control subjects to both warm and cold exposure are also shown in Fig. 8. In the same figure, the average metabolic response of the Indians measured in the autumn (solid circles) is compared with the average response of eight of the same Indians measured in the spring (X's), following a winter of intermittent exposure and occasional sleeping in cool environments while traveling, hunting, trapping, and wood-cutting.

The rectal temperatures and the average skin temperatures measured in the Arctic Indians in the spring are compared with the average results obtained in the autumn in Fig. 9.

Little or no seasonal differences were found in the metabolic rates of these Indians although there was a tendency for a slightly higher rate of heat production in the spring especially in the early part of the night before the thermal stress was fully effective. There does appear to be a higher rate of heat production in Indians in both the fall and in the spring than was found in the urban white subjects. This small difference in metabolism between the Indians and whites (about 15%) was evident in both the warm and the cold nights. There was no seasonal difference found in the rectal temperature of the Indians; for both fall and spring, the rectal temperature of the average Indian was about 0.5°C below the temperature for the average white subjects. The average skin temperature of the white subjects and Indians was the same throughout the cold night although the foot temperature of the whites fell about 2°C more than the Indians' foot temperature. In

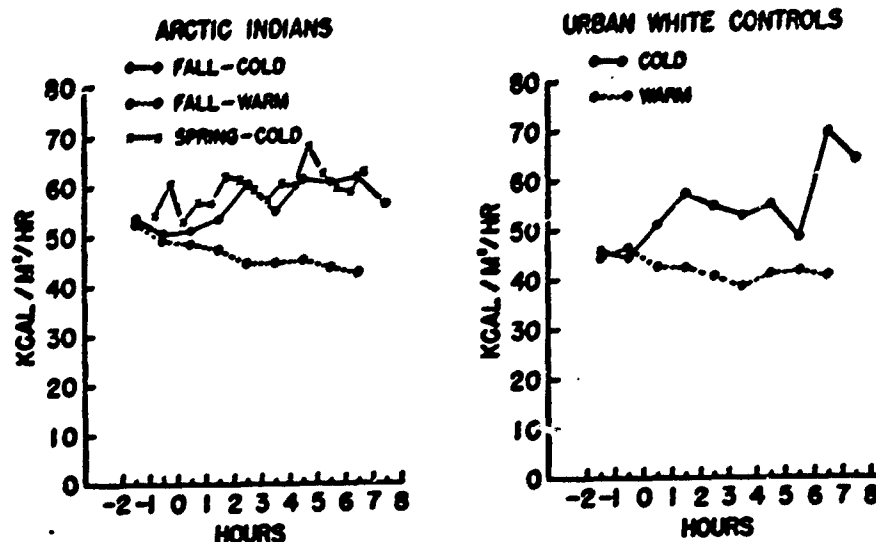


FIGURE 8. Left. Average metabolic responses of nine Arctic Indians during a night exposed to cold in the fall (solid circles), exposed to warm (open circles) and eight of the same Indians exposed to cold in spring (X's).

Right. Average metabolic responses of seven control white subjects during a night exposed to cold (solid circles) and exposed to warm (open circles). Air temperature about 0°C. Redrawn from Irving (5) and Elsner (6).

the spring, the average skin temperature of the Indians was roughly 2°C below the average skin temperature in autumn due largely to lower thigh and arm temperatures.

Although the authors (5, 6) conclude that some small but significant physiological variations have been found in this isolated and homogeneous Arctic population, they do not know whether these variations have adaptive value. It is puzzling to understand why the slightly greater resting metabolic rate of the Arctic Indian was accompanied by a lower rectal temperature and by a lower average skin temperature. On the other hand, the greater resting metabolic rate accompanied by a higher foot temperature is suggestive of the same type of metabolic acclimatization seen in the Norwegian students and must differ only in degree from the adaptation to cold described in the Alacaluf where a high resting metabolic rate accompanied by a high foot temperature was characteristic of this group.

Another group of North American Arctic natives, the Eskimo hunters of Cumberland Sound, were also studied by the methods at hand (7) and appear to show a response to cold similar in some ways to that seen in the Arctic Indians. In Figs. 10 and 11, the average metabolic and thermal responses of ten Eskimos and three white subjects are compared during a night of moderate cold exposure and again during warm exposure. The higher resting metabolism of the Eskimo was accompanied during the cold night by a rectal

ARCTIC INDIANS

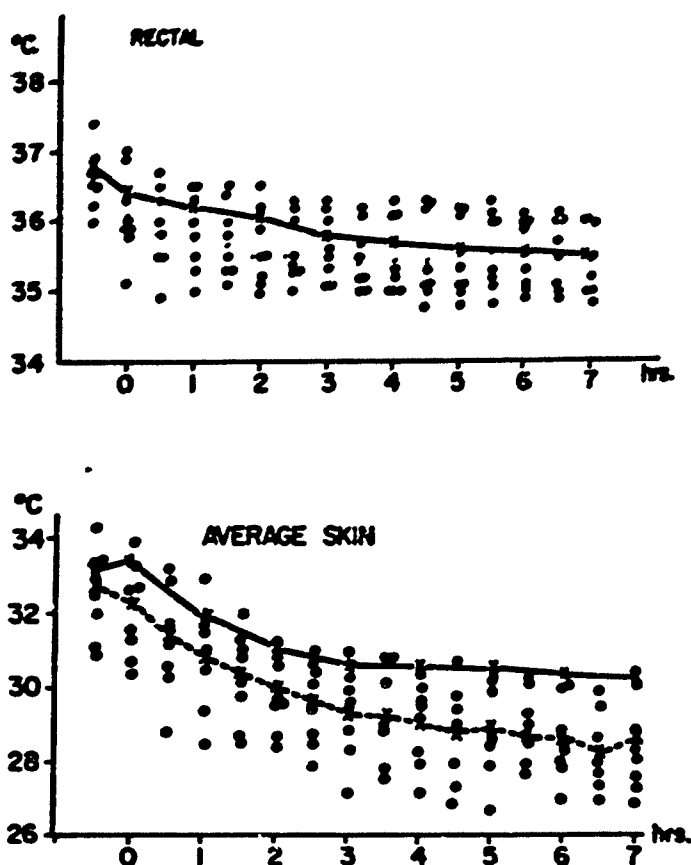


FIGURE 9. Upper. Rectal temperatures of eight Arctic Indians exposed to cold in the spring (solid circles) and the average rectal temperature of nine Indians exposed to cold in the fall (X's).

Lower. Average skin temperatures while exposed to cold in the spring (solid circles; broken line for group average) and while exposed to cold in the fall (X's with solid line for group average). From Elaner (6).

temperature slightly lower than the control white subjects, an average skin temperature 1 to 2°C higher than the white skin temperature and a slightly higher body conductance.

The final group investigated in this physiological survey of cold exposed people was another Arctic culture, the nomadic Lapps of Finnmark, Norway and the village Lapps living in Kautokeino (8). The nomads were reindeer herders and hunters spending most of their time outdoors or in poorly heated Lapp tents. The village Lapps were farmers living in rather modern houses. The average metabolic response of seven shepherd-hunters, five villagers, and five control

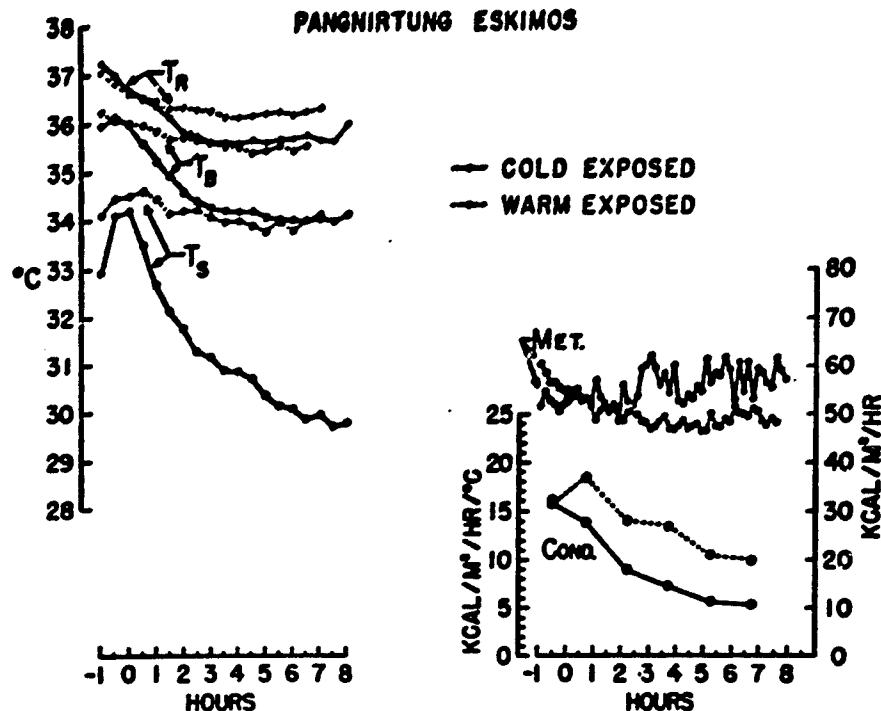


FIGURE 10. Average thermal and metabolic responses of ten Eskimos during a night of moderate cold exposure (solid lines) and during a warm night (broken lines) in the winter season. Air temperature about 3°C. Redrawn from Hart (7).

white members of the research team during a night of cold exposure is shown in Fig. 12. Only the nomadic Lapps were different from the controls by producing a substantially smaller metabolic response accompanied by 1°C greater fall in rectal temperature, Fig. 13. In this respect the nomadic Lapps were more like the Australian aborigine than like the other natives of the Arctic.

In summary, a comparison of most of the ethnic groups discussed in this survey may be made in terms of the average metabolic response of each group plotted as a function of the mean body temperature, Figs. 14 and 15. Three distinct patterns of response to moderate cold exposure are shown: a) the unacclimatized, urban European or American starts the period of cold exposure with a metabolic rate at or near a basal level and increases it markedly as his body temperature falls, b) the central Australian aborigine starts with a metabolic rate near basal and slides slowly downward as his rectal and skin temperatures fall to a little lower values than those of urbanized white controls, and c) the Alacaluf Indian starts with a high metabolic rate which declines slightly and is accompanied by a rectal temperature falling no lower than the rectal temperature of the white control, the skin temperatures of the trunk falling a little more and the foot

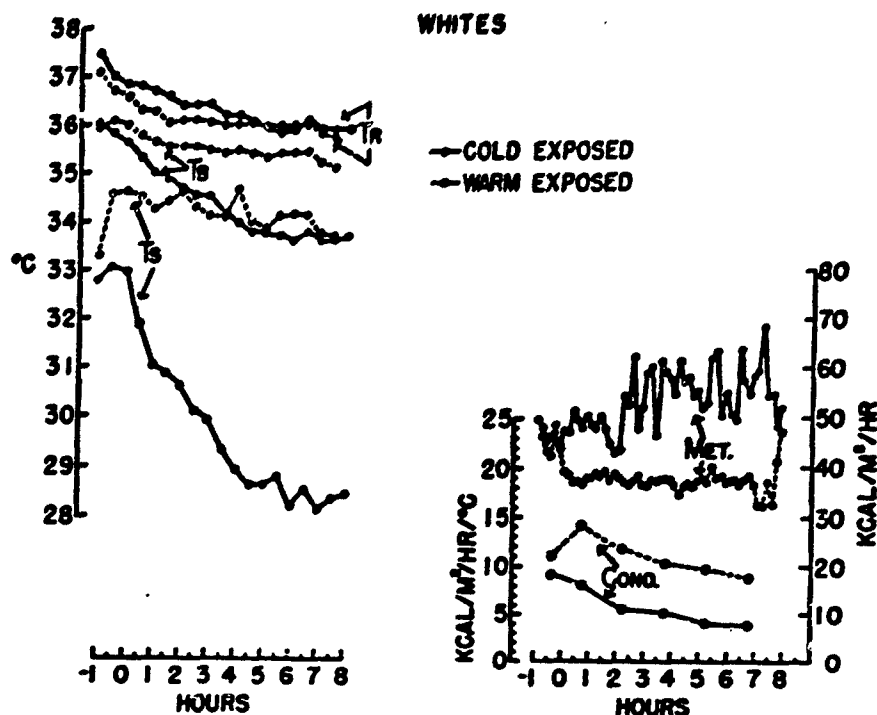


FIGURE 11. Average thermal and metabolic responses of three control white subjects during a night of moderate cold exposure (solid lines) and two whites during a warm night (broken lines). Air temperature about 3°C. Redrawn from Hart (7).

temperature falls a little less than those of the white man. This response may be called metabolic acclimatization or adaptation. The responses of the Eskimos and the Old Crow Indians were in some ways intermediate between the responses of the Alacaluf Indians and the unacclimatized urban white man. The initial metabolic rate was intermediate but, unlike the Alacaluf's response and like the unacclimatized white man's response, the metabolic rate of both the Arctic Indians and the Eskimos increased slightly as the body temperatures of the Arctic Indians (except the foot temperature) fell more than those of the control whites and the rectal temperature of the Eskimos fell slightly more than that of the whites while the average skin temperature fell less. The response to cold of the Arctic Indian and the Eskimo may represent a fourth pattern of response but there remains some doubt as to whether it can be classed as an acclimatization to cold. The response of the tropical Australian aborigine and the nomadic Lapp herder was intermediate between the response of the unacclimatized white man and the Australian aborigine of the central desert. The response of the latter group may be termed insulative acclimatization or adaptation.

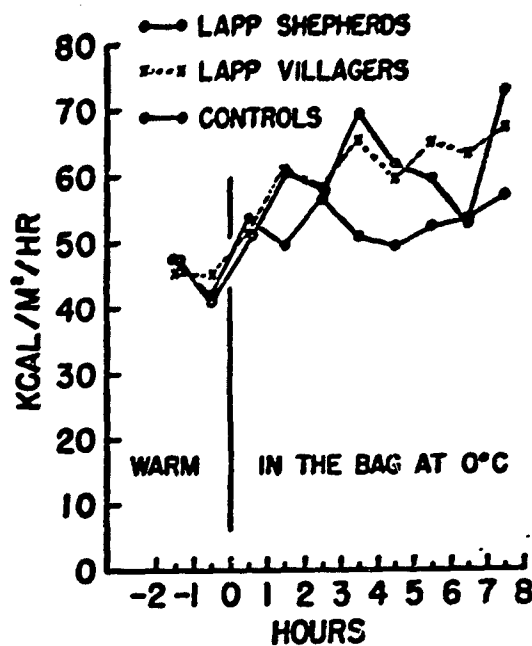


FIGURE 12. The average metabolic response of seven nomadic Lapp shepherds (solid circles), five village Lapps, (X's) and five control white subjects (open circles) during a night of cold exposure. Air temperature 0°C.

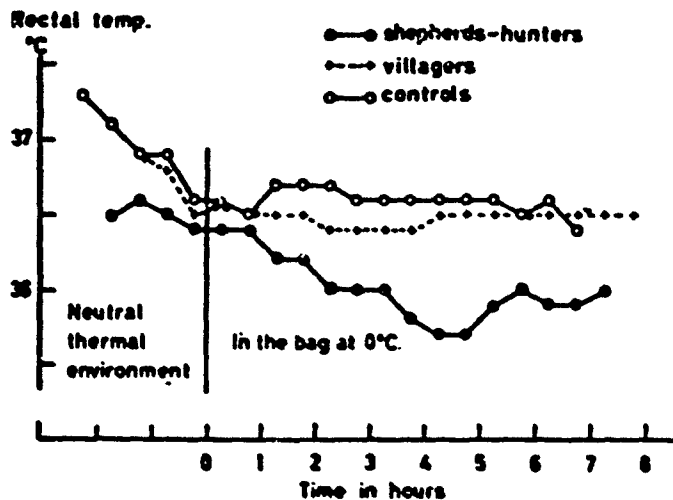


FIGURE 13. Average rectal temperatures of nomadic Lapps (solid circles), village Lapps (+s) and control white subjects (open circles) during night of cold exposure.

Although certain small differences are easily recognized in the metabolic and temperature responses of the several groups investigated while living under more or less natural conditions, it is difficult to go further than this and inquire into the nature of these small

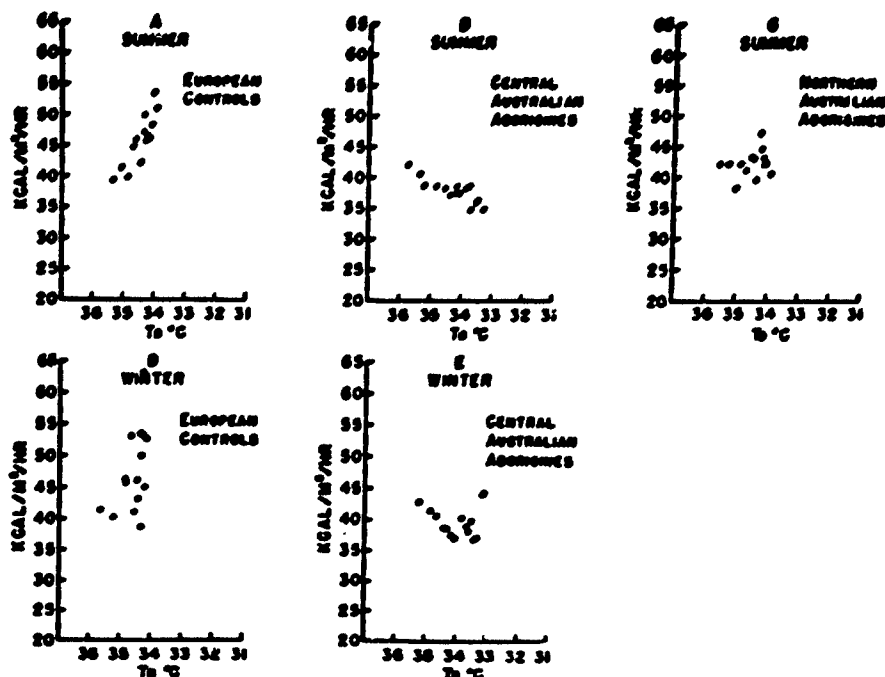


FIGURE 14. Heat production versus mean body temperature of control white subjects, A and D; central Australian aborigine in summer, B; tropical Australian aborigine in summer, C; central Australian aborigine in winter, E.

differences. It is possible that all differences would vanish should it be possible to maintain all groups under exactly the same conditions as to kind of food ingested, degree of cold exposure prior to testing, physical fitness, physical and mental health, etc., and after this, study them with exactly the same tests. Only in the laboratory would one wish to attempt to meet these exacting conditions.

In the laboratory any minor differences in the degree of cold exposure during the testing period can be eliminated. Such differences are known to exist between the several field studies that have been conducted on the different groups referred to above. There were small differences in the average dry bulb temperature which each group attempted to maintain during the night. There were small differences in the insulation of the sleeping bags used in each test. In addition, there were differences in the cooling coefficient of the air surrounding the sleeping bag due to air movement. We can say, therefore, that the degree of cold exposure was only approximately the same in these several studies due to the varying circumstances that each field team had to deal with.

Should it be possible to eliminate all these variations, the uncertainties as to the origin of similarities or differences would not vanish since the problem of obtaining a representative sample still persists,

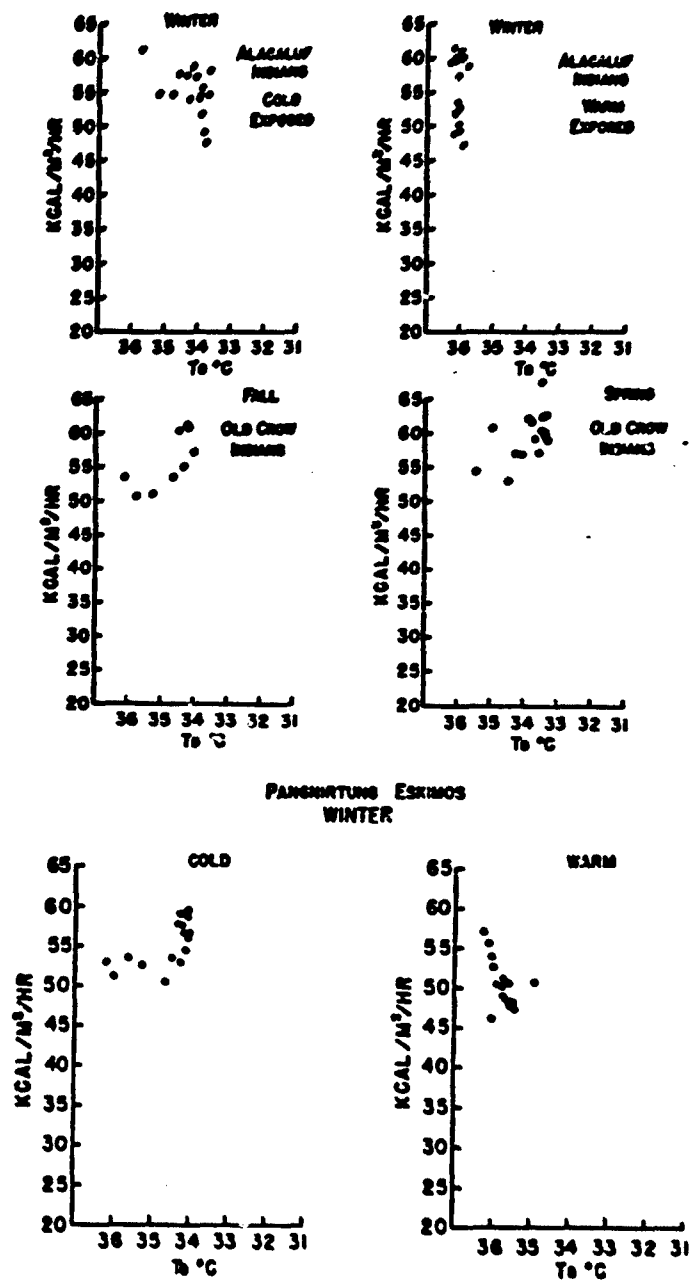


FIGURE 15. Heat production versus mean body temperature of Alacaluf Indians cold in winter (upper left) and warm (upper right), Arctic Indians cold in fall (middle left) and cold in spring (middle right), and Eskimos cold in winter (lower left) and warm (lower right).

especially when selecting from such a heterogeneous population as the white European. Furthermore, one would not be able to determine which similarities or differences were genetically fixed and which were acquired without a comparative study of populations of each group that were exposed to cold for generations, for a lifetime, for short periods, and to no cold at all.

Although we would like to bring these studies into the laboratory where a long series of systematic studies could be made under well-controlled conditions, it may be that results of equal value can be had by recognizing and accepting the limitations of the field type study and by continuing to examine as many racial groups living under as many varied climatic conditions as possible. If enough races of man are investigated and if within each race a range of environmental conditions are encountered, it may be possible, in the end, to sort out the causes for the small differences in responses to cold already described. It may even be possible to decide whether a particular response endows the group possessing a characteristic response with any advantage over the groups not possessing it.

Finally, all investigators of the cold exposed groups included in this survey have commented upon the greater ability of the cold exposed natives to sleep during the cold stress. This fact alone is sufficient to support the view that habituation to cold also occurs in cold exposed races of man showing markedly different types of physiological acclimatization or adaptation to cold.

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CHAIRMAN SIPLE: Our last speaker of this morning's session will be Colonel Willard Pearson of the United States Army, Alaska, who will speak on "Alaska, the Gibraltar of the North." Colonel Pearson,

ALASKA—GIBRALTAR OF THE NORTH

COLONEL WILLARD PEARSON
Headquarters, United States Army
Alaska

Introduction

The airplane flying the polar routes initially focused attention on the military importance of the Arctic regions. This interest has heightened with the development of the long-range land based missile. More recently the nuclear powered submarine, a mobile missile base cruising in the northern waters, has brought the strategic importance of the Far North into sharper focus. Should there be a general war, these new weapons—jet aircraft, land based missiles, and missile carrying submarines—will transform the Arctic Ocean into the Mediterranean of World War II.

The gateways to the Arctic (Fig. 1) are the Bering Straits on the west, the only sea link between the Arctic and Pacific Oceans, and the Norwegian Sea on the east. These entrances bear the same relationship to the Arctic as do the Straits of Gibraltar and the Red Sea to the Mediterranean. Alaska, the Gibraltar of the North, is separated from Russia by 35 miles of water. The United States' Little Diomedea Island and Russia's Big Diomedea Island in the Bering Straits are less than 3 miles apart.

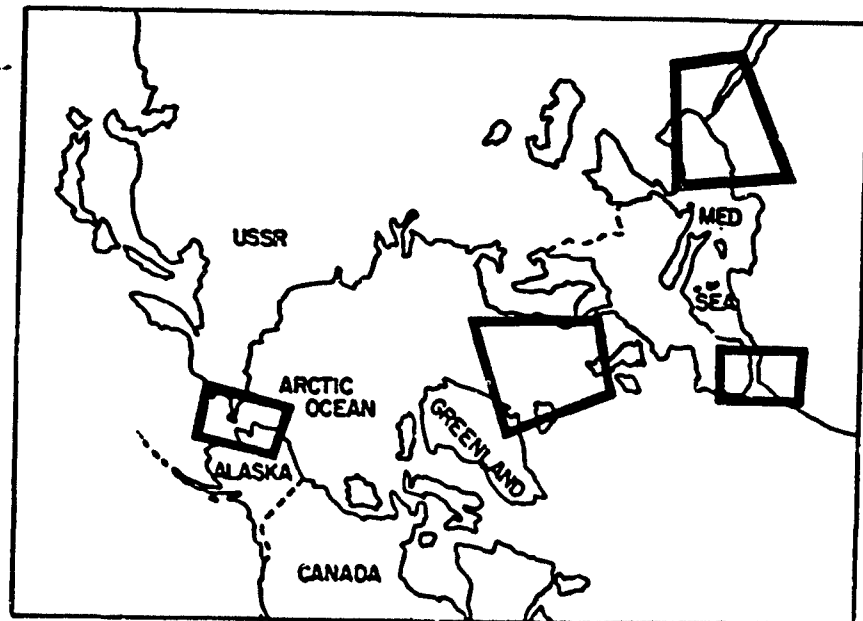


FIGURE 1. Gateways to the Arctic.

The strategic significance of the northern regions has not been fully appreciated considering weapons now available and potential new developments in weapons, transportation, communications, and nuclear power. The purpose of my presentation is threefold:

First: To point out the strategic importance of the Far North with special reference to Alaska.

Second: To examine the implications of the Far North to the United States Army.

Third: To recommend an Army program to improve the ability of the ground forces to operate in the north.

The Strategic Significance of the Far North

The Military defines the area of Northern Operations as that area enclosed by the 50° isotherm for the warmest four months of the year (Fig. 2). It covers all of Alaska, Canada, a part of the upper midwest, Greenland, the upper Scandinavian Peninsula, 65% of Russia including all of Siberia, and half of Korea. This is the area I shall discuss. Its strategic significance can best be appreciated from an analysis of the following factors:

1. Geographic.
2. Political.
3. Economic.
4. Psychological.

Geographic. A glance at a polar projection of the globe shows that Europe, Asia, and North America (shown within the enclosed circle) come closest together at the North Pole (Fig. 3). The shortest distance between the principal population and industrial centers of Eurasia and North America is over the polar regions. Note the difference in distance from the center of the United States to Moscow via the great circle route versus the polar route. Fig. 4 shows another comparison. Again we see that the distance from the center of the United States to Moscow via the polar route is roughly 4,500 miles whereas from Thule, Greenland to Moscow is a mere 2,300 miles. An ICBM located in Fairbanks, Alaska, having a range of 5,000 miles could easily engage targets in most of Western Europe, Russia, and China. A missile firing from Alaska to China has a significant range advantage over a missile located on the West Coast of the United States firing on the same target. Note range differences.

The Polaris equipped submarine, operating from Alaska bases (Fig. 5) and using the Arctic Ocean as an underwater airfield to achieve concealment, dispersion, and surprise, can launch missiles south into Eurasia generally as far as the 50° of latitude. This distance would encompass the British Isles, France, northwest Europe including the Scandinavian Peninsula, and a huge chunk of Russia

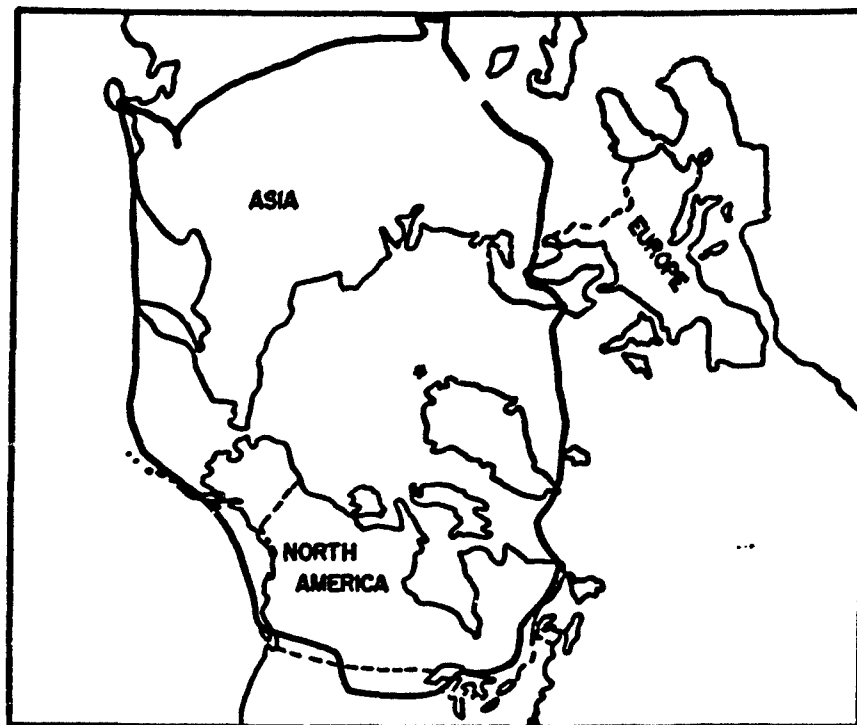


FIGURE 2. Area of Northern Operations.

including the trans Siberian Railroad. From the Barents Sea the Polaris can be fired over Moscow and hit the Black Sea.

These shorter distances to the heartland of the United States and Eurasia from Arctic bases insure greater accuracy for missiles, heavier payloads, less time in flight, as well as fewer failures in flight. Greater accuracy and heavier payloads reduce the over-all force requirements. The reduction in flight time to target increases the chance of achieving surprise and shortens the time a missile is subject to attack. It also reduces the time the enemy has to react to a surprise attack. These shorter distances via the Polar Route bring the strategic importance of the Far North into sharp focus when viewed through the lens of our rapidly developing ability to travel above, across, or under the Arctic.

We must be able to get maximum warning of an air or missile attack on the United States launched from Eurasia. To get maximum warning, the curvature of the earth requires us to locate our warning stations as near the top of the world as possible in order to lock down on the other side (Fig. 6). This schematic drawing shows the point where radar located in the United States might first pick up a missile launched from Eurasia versus the point of pick-up when the radar is located in the Arctic. The DEW Line was located along the Arctic

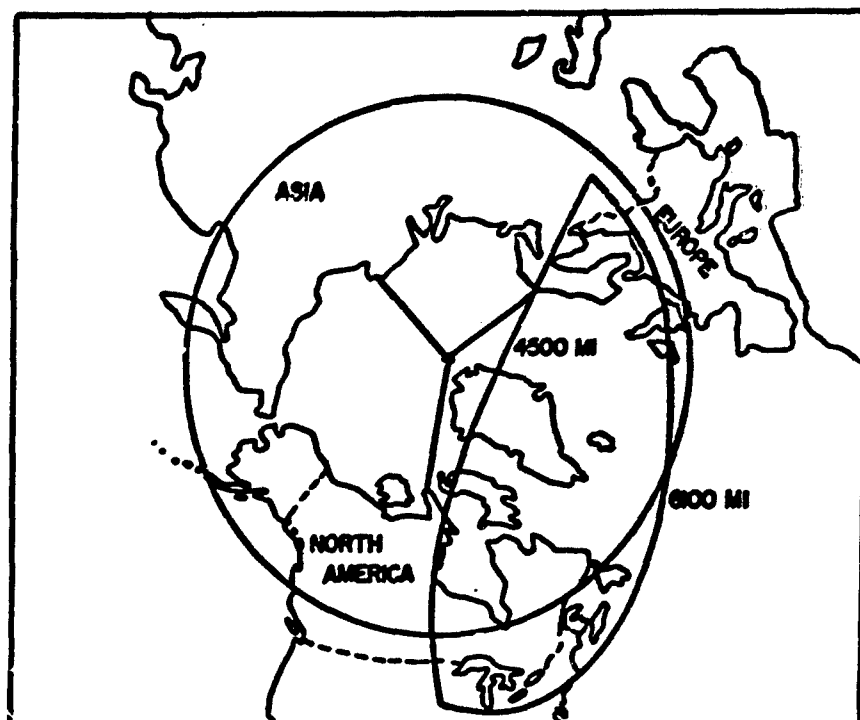


FIGURE 3. Polar Route versus Great Circle Route.

Circle for this reason. For the same reason our BMEWS (Ballistic Missile Early Warning System) and MIDAS (Missile Detection Alarm System) sites are being located in the Far North. These BMEWS and MIDAS sites become strategic targets because of their limited number, criticality in the early days of a general war, and the long lead-time required to replace them if destroyed. The location of these strategic targets on our northern outposts obviously increases the strategic significance of these outposts.

Thus in the Far North, geography combines with the increased range of modern weapons to highlight the strategic importance of the area as an advanced outpost for early warning, interception of air missile or satellite attacks, and for launching attacks or counter-attacks.

Political. Since the end of World War II, United States rights in many bases overseas have been either restricted or revoked outright. Even our position in the Caribbean, once considered impregnable, is under political attack.

Forces in Alaska, on the other hand, are on United States soil. They are not subject to pressures by foreign political complications.

Economic. A modern power must protect its economic potential and mobilization base in a nuclear war. A nation will seek to fight a

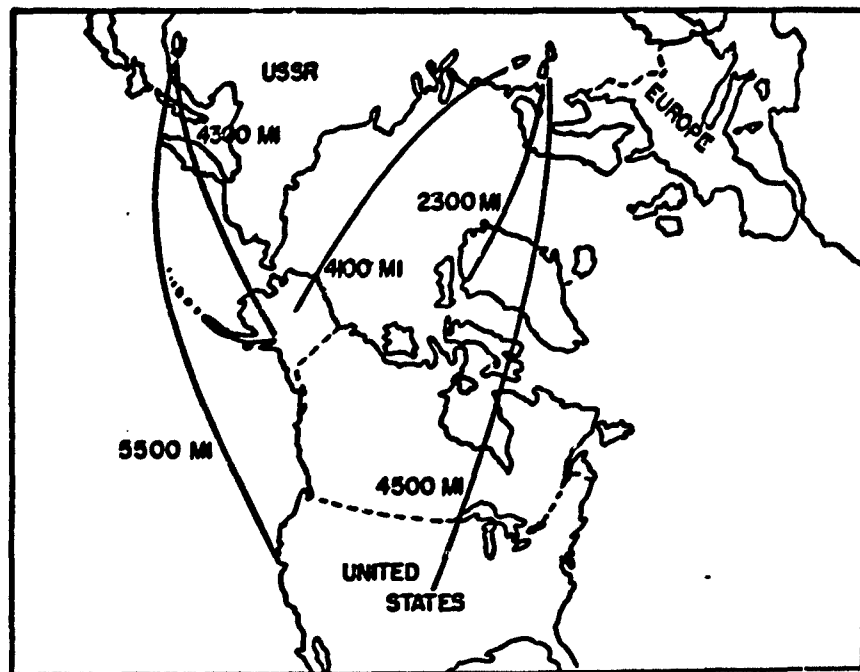


FIGURE 4. Comparative distances to Eurasia.

war as far as possible from its heavily populated and industrialized areas. The vast undeveloped areas of the Far North permit the dispersion of military forces away from heavily populated and industrial centers. This sparsely settled area not only provides passive protection to these forces, but also reduces the vulnerability of our industries and civilians to missile counter battery fire and radioactive fallout.

Higher initial costs for military operation in Alaska are offset by the political stability which assures retention of bases over the long term. Funds spent in the 49th State are retained in the United States economy rather than being spent in overseas areas where political affiliations are subject to change. Furthermore, the drain on United States gold reserves caused by stationing large forces in foreign countries was dramatically illustrated by a Presidential decision in November 1960 to evacuate a large number of military dependents from overseas bases. This directive does not apply to Alaska.

Psychological. Should an enemy secure even a limited beachhead on the most bleak coast of northern Alaska, she could proclaim to the world that United States territory has been successfully invaded. Invasion of United States soil would adversely influence the uncommitted nations in the early stages of a general war. Even nuisance raids on United States soil would be of great psychological and propaganda value. Remember, if you will, the near panic and hysteria that developed

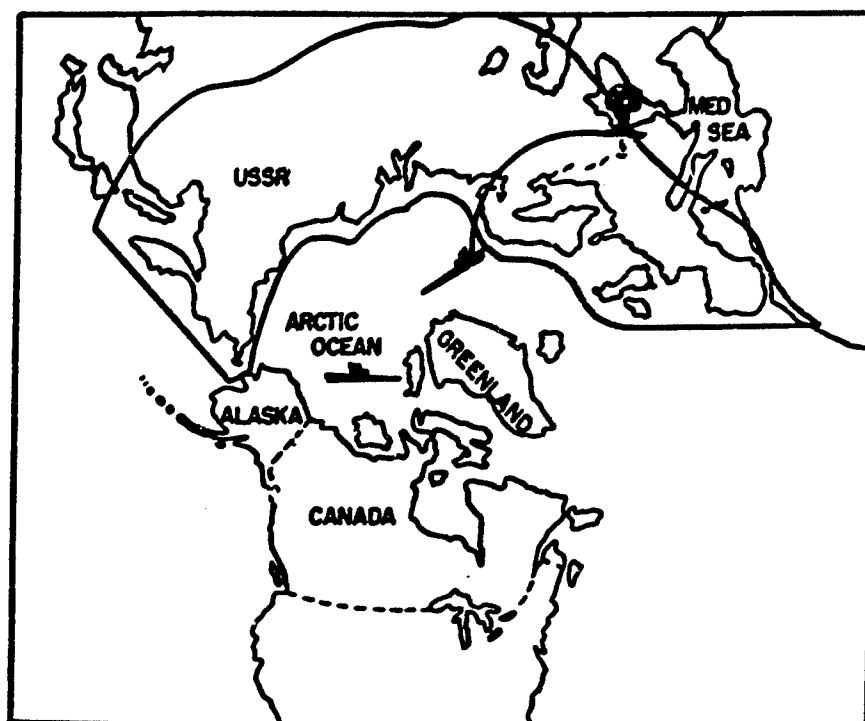


FIGURE 5. Area coverage—Polaris submarine.

on the West Coast following the attack on Pearl Harbor at the outbreak of World War II. To counteract political or psychological defeat, public opinion would press for an early counterattack against enemy lodgments on the Alaskan periphery.

The strategic importance of the Far North arises from its geographic location on the shortest route between North America and Eurasia. This military significance is further increased by important political, economic, and psychological factors.

So much for the strategic importance of the Far North!

The Implications of the Far North to the Army

The Army's objective in war is destruction of the enemy and occupation of the enemy's heartland. Before the decisive battle for the heartland is fought, there are strategic outposts which must be first seized or neutralized (Fig. 7).

In World War II, for example, the Japanese considered capture of the dense, steaming, fever infested jungles of New Guinea strategically necessary. Why? This island became a strategic base for

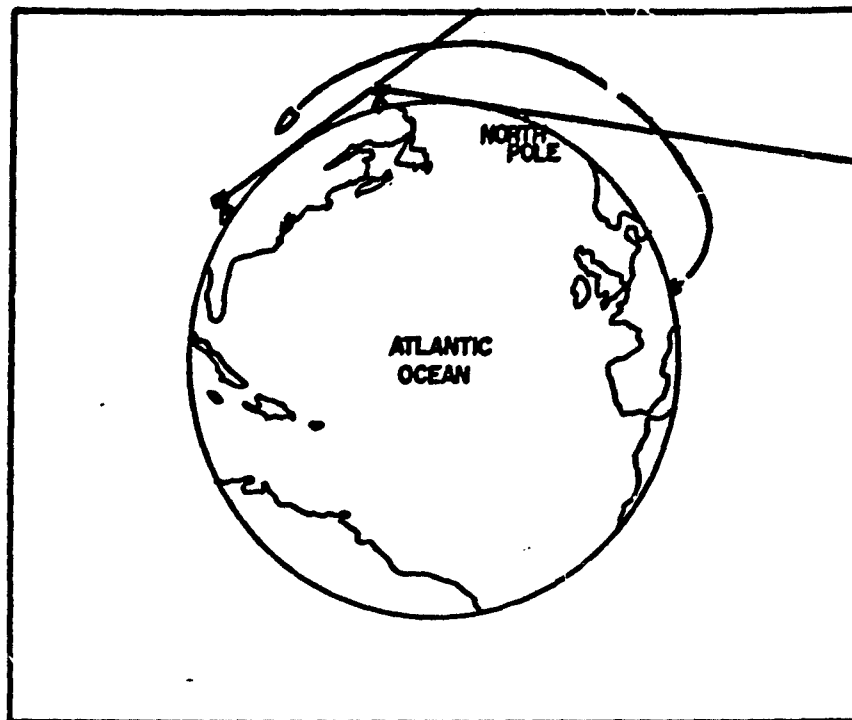


FIGURE 6. Radar pick-up points.

blocking the principal United States overseas supply route into Australia as well as a staging area for attacking that continent.

On the other side of the globe, the Allies and the Axis were at the same time fighting for control of the hot, barren, deserts of North Africa. The strategic North African coastland provided bases for ground, sea, and air forces to control the Mediterranean as well as staging areas for attacking the "soft underbelly" of Europe.

In the Far North the Germans captured Norway and attempted to cut the Allies' northern sea route to the Soviet Union. The Japanese likewise struck in the North and attacked the Aleutian Islands.

You can see that in World War II major forces were thus deeply engaged in jungle, desert, and Arctic (environmental) warfare on strategic outposts long before fighting the final battle in the more temperate climate of Europe. Similarly, in any future war between the United States and a power on the Eurasian land mass, significant air, sea, and land battles will be fought over the Arctic Basin as the opposing forces contest for this strategic outpost.

In the early stages of a general war, opposing forces would strike swiftly to:

1. Destroy or neutralize each other's military potential in the Far North.

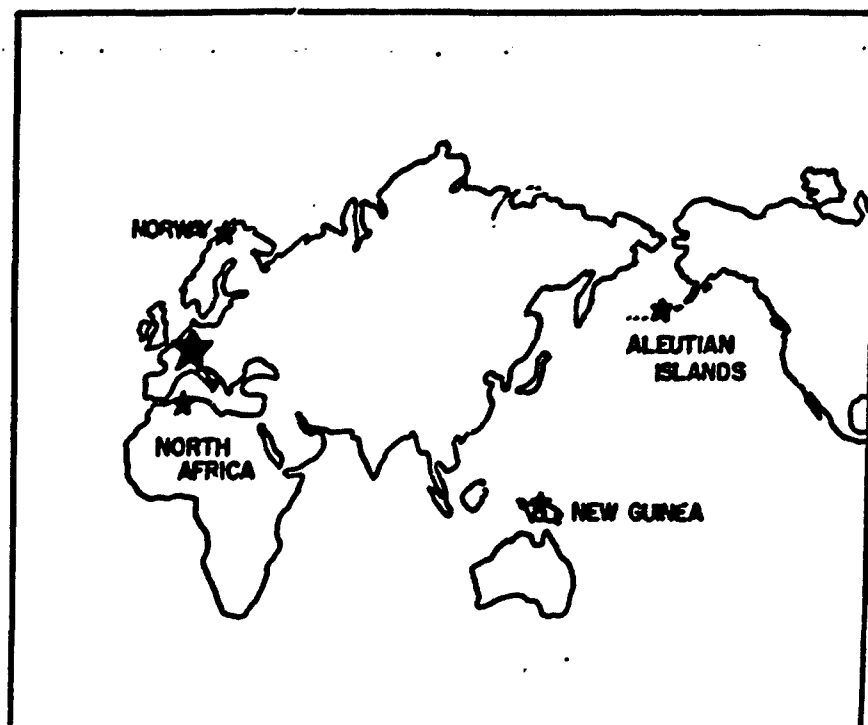


FIGURE 7. Battles for World War II outposts.

2. Protect their northern flanks by dominating the Arctic regions.
3. Develop offensive bases to provide missile fire support for invasions by land, sea, and air of the enemy's heartland.

Possession of the Arctic Basin by an unfriendly power jeopardizes the security of the United States. For example, in the initial phases of a general war, it would be important to neutralize missiles located on the Arctic rimland firing megaton weapons on the industrial complex in the United States (Fig. 8). It is doubtful if this neutralization could be successfully or completely accomplished by bombs or missiles alone. Recall that in World War II, German V-2 rockets, firing on London from the northern coast of Europe, were neutralized only after the Army overran and occupied the sites. Early neutralization is even more critical today than it was in the days of the "Model T," V-2 rocket because of the tremendously higher yield of modern weapons.

The enemy will likewise attempt to neutralize our military potential in the Far North. Initially he may attempt this neutralization with nuclear missiles. He may supplement his missile fire by limited air- and sea-borne attacks, submarine-borne patrols landed at night, guerrillas parachuted at night into sensitive areas, or by major air-borne and amphibious attacks to seize critical ports, bases, and centers of

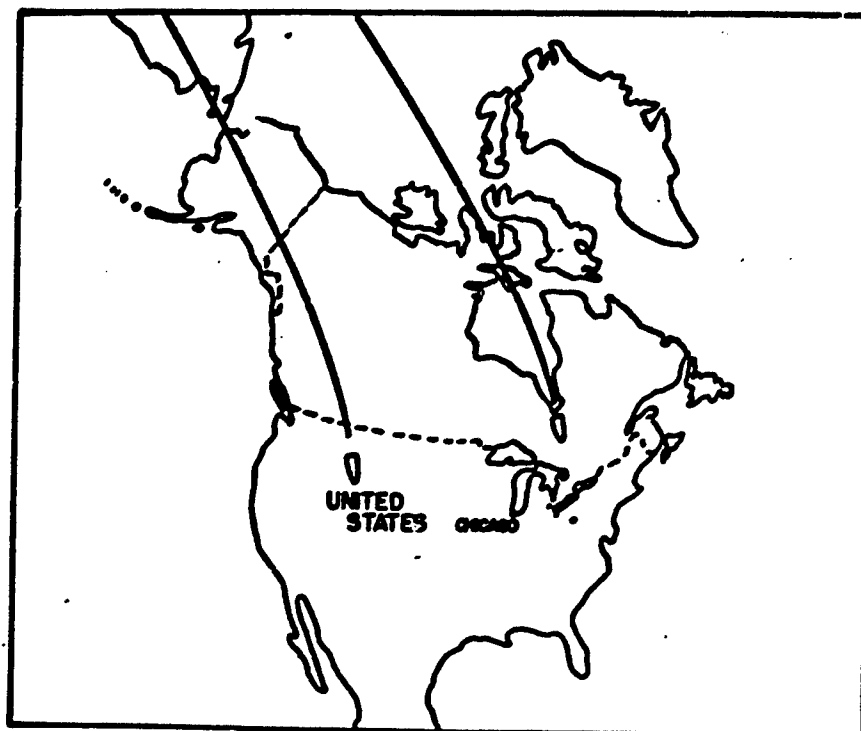


FIGURE 8. Missile attack from the North.

communications. Our military installations must be defended against all forms of attack. A large measure of this task will fall to the Army.

The implication to the Army is obvious. The Army must be prepared to conduct offensive and defensive operations in the Far North. This capability should exist now to provide swift reaction in the early stages of a general war when control of our strategic outposts is essential.

In improving its ability to fight in northern latitudes, other important advantages would accrue to the Army. These should not be overlooked:

- a. Enhance the Army's ability to operate in the more temperate zones. Consider winter warfare in the mountains of Western Europe, Northern Italy, Greece, Turkey, the Urais in Russia, the Himalayas separating China and India, and the mountains of Korea. The problems in these areas associated with extreme altitudes, weather, and climate; the undeveloped transportation and communication; and remoteness from source of supply are identical with problems encountered in the Far North.
- b. Improve Army's ability to conduct a limited war. Experience of the last decade shows that the most likely locales for limited wars are the undeveloped countries around the periphery of the

Sino Soviet Bloc. By improving our ability to operate over the undeveloped areas of the north where primitive communications exist, the Army will enhance its ability to fight limited wars in other undeveloped areas.

- c. **Provide an excellent area to test new equipment.** Alaska has the terrain, climate, and environment found to a large degree in the northern areas of the Eurasian land mass. It is probable that major ground operations will, at some future date, be conducted on terrain similar to that found in the 49th State. An appreciation of mobility, fire power, and communication problems that exist in the north is essential for the planning and development of material to be used by the Army of the future.

Considered alone, these advantages provide adequate justification for improving the Army's ability to fight in northern latitudes.

These are the implications of the strategic importance of the Far North!

The Kind of an Army Program Needed

An Army program is certainly needed! The following three-point program is recommended:

- I. **Greater research and development effort and year-round testing of materiel under both winter and summer conditions.**

The most promising areas for improving the Army's operational capabilities is the development of specialized equipment. We need to increase the tactical mobility of the combat units and their necessary logistical support units. To do this, special equipment is needed. In his book "The Red Army" Liddell Hart states, "Hitler lost his chance of victory against Russia because the mobility of his Army was based on wheels instead of tracks." For ground mobility on the battlefield, we need improved tracked transportation with year-round mobility. The optimum tracked vehicle will negotiate the snow in winter, the water in the spring break-up, and the muskeg and rocks in the summer. Allied with this problem of ground mobility is the need to develop navigational aids and techniques for movement across the uncharted wasteland of the north.

Exploitation of the potentialities of air mobility for moving troops, equipment, and supplies promises to be a decisive factor in establishing supremacy in the north. We must develop equipment and techniques to capitalize on the mobility of Army aviation.

For soldiers in any theater of operations, it is necessary to reduce the diversity, volume, and weight of clothing and equipment. It is of special importance to the soldier in the north because of the heavy clothing worn and the difficulty of moving over rugged terrain under adverse weather conditions. Progress in this area will not only enhance

soldier morale and efficiency but will also increase individual and unit mobility.

Northern operations will be characterized by dispersion of units over vast areas, creating a communications problem. For adequate control of these units, radios of greater range, reduced weight, and increased reliability are needed. Ways must be found to increase battery life in sub-zero weather.

Other important areas for research are employment of nuclear weapons, adequacy of conventional weapons, operational rations, resupply techniques, and maintenance of all types of equipment.

II. More rugged, realistic training in northern operations.

Past maneuvers in Alaska have provided outstanding training for participating units from CONUS. The locale of these maneuvers has been in south and central Alaska. These exercises must be made progressively more difficult by conducting them in the Brooks Mountain Range, in the tundra of northern Alaska, and along the Arctic coast.

The usual winter maneuvers reveal the obvious or superficial shortcomings but are not long enough to uncover more fundamental weaknesses and strengths in personnel, equipment, and doctrine. Annual expeditions of one or more months' duration should be conducted during the winter and summer. Movement of tactical units over the old pioneer sled trails from Fairbanks to Nome, from Nome to Point Barrow, and from Point Barrow to Fairbanks through the Anaktuvuk Pass in the Brooks Range is needed. Overland movement from Alaska across northern Canada to Greenland is recommended. The Army should seek to develop trained men and equipment by retracing Admiral Feary's route to the North Pole periodically.

A hard core of expert mountain climbers must be trained. Training can be conducted on the many mountains in Alaska, with an ascent of Mount McKinley as the graduation exercise.

Expeditions of this type would provide:

- (1) Superior training in land navigation, communications, resupply procedures, physical conditioning, living in the field, and small unit leadership.
- (2) Rugged test of equipment under prolonged stress more nearly approaching combat conditions.
- (3) Realistic test of tactics and techniques.

III. Improved personnel procedures which will attract, motivate, and retain individuals trained in cold weather techniques.

Quality rather than quantity must be the goal in training personnel. With limited personnel ceilings and further cuts in prospect, a small number of highly trained individuals and units should be developed to provide the nucleus for rapid expansion during mobilization

or "as forces in being" for immediate deployment to key strategic areas in event of war.

This aim can be achieved as follows:

1. Designate the two battle groups in Alaska and one or two STRAC battle groups as "Ski and Mountain" units. The words "Ski and Mountain" should appear as part of the unit's designation to clearly identify it as a special unit. No major changes in organization would be required. The battle groups would be issued the necessary specialized equipment. These "Ski and Mountain" battle groups would conduct annual maneuvers and expeditions in the Far North along the lines I have just suggested. They would do so periodically to attain the highest degree of individual and unit proficiency and esprit.
2. Provide qualification badges for expert skiers and mountaineers. Why not give badges to recognize these skills which in some cases are more difficult to attain than badges currently authorized for vehicle driving, marksmanship, parachuting, rangers, and explosive disposal? These badges, which are common in European armies, would:
 - a. Provide incentives to achieve higher standards of individual skill.
 - b. Develop pride by giving recognition to individuals achieving these standards.
 - c. Facilitate mobilization and peacetime assignments to the "Ski and Mountain" units, the Army's Cold Weather and Mountain School, and to staffs of higher headquarters requiring their specialized knowledge—in the same manner parachutists are assigned to air-borne units, the Air-borne School, and staffs of higher headquarters.
3. Expand and publicize the current program of screening incoming replacements having experience in the National Ski Association and the American Alpine Club and assigning them to Alaska upon completion of their basic training.
4. Permit repetitive assignments of personnel possessing skiing and mountaineering skills to Alaska or to other areas where these skills may be applied.

The Army recognizes "MAN" as the ultimate and decisive weapon. These personnel procedures will attract, retain, and motivate the soldier to become more professionally skilled in the specialized techniques of northern operations. This three-point program is feasible and practical.

With the acquisition of Ladd AFB at Fairbanks, Alaska, the Army now has facilities immediately available to support increased research and development activities in Alaska.

The training program and personnel control procedures discussed above can be adopted within present personnel ceilings. The number of troops participating in the current maneuver program can be

reduced to permit execution of the revised program within the present budget.

Examples of failures to prepare for northern operations can be found from the Napoleonic Wars to the Korean conflict. Adoption of such a program is necessary to insure the Army's readiness to meet the challenge of operating in the Far North in the missile age.

Summary

I. The Far North, including a large section of North America and Eurasia, is of great military significance in the missile age, particularly as a strategic outpost in the initial stage of a general war.

II. The Army must be prepared to conduct offensive and defensive operations in the Far North, since opposing forces will attempt to neutralize each other's military potential in the strategic outpost of the Arctic. This objective will be accomplished only when the army forces occupy the ground.

III. The Army must have a program to improve its operational potential in the Far North—a realistic program that will prepare the Army to fight at any time or anywhere in the northern areas.

Alaska can serve as the Army's testing and training ground to achieve this objective. Alaska, the Gibraltar of the North, is destined to play an increasingly important role in the strategic planning for the defense of the Free World.

SESSION No. 2

THEME: QUARTERMASTER CORPS CONTRIBUTIONS TO MAN LIVING IN THE ARCTIC

J. C. REED, presiding

CHAIRMAN REED: The title of the first paper is "Physiological Principles for Protection of Man in the Cold." It is my pleasure to introduce the speaker, Dr. Harwood S. Belding, Professor of Environmental Physiology at the University of Pittsburgh.

PHYSIOLOGICAL PRINCIPLES FOR PROTECTION OF MAN IN THE COLD

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In May 1942 Terris Moore and seven fellow-mountaineers, the New England Advisory Committee on Cold Weather Clothing and Equipment to the Quartermaster Corps, had a problem. They had received eight different Arctic sleeping bags from the Office of the Quartermaster General for test on Mount Washington, and the cold weather had run out on them. W. H. Forbes, the Acting Director of the Harvard Fatigue Laboratory, offered a solution to their problem: "Bring the Committee and its bags into our new cold room and test the bags at 40 below zero." The invitation was accepted. We, the physiologists at the Laboratory, looked upon these eight mountaineers as potential human "guinea pigs." If they were to be shut up in our refrigerator, we wanted to make some physiological measurements of their cooling. We therefore applied some skin thermocouples and asked our victims to insert rectal thermometers.

The report to the Office of the Quartermaster General from that study not only showed the judgment of the eight men on the relative worth of each bag but also gave data on skin and rectal temperatures—data which indicated rates of body cooling. I believe that the Office of the Quartermaster General was really surprised to find out that useful, objective information could be obtained in this way. In any event, we were immediately deluged with requests to provide similar data on 75 different kinds of sleeping bags and on all kinds of cold weather clothing.

As a result of this experiment the Quartermaster Climatic Research Laboratory was established a year later. It made use of the largest cold room (-89°F) then available. (The room had been constructed in the Pacific Woolen Mills, Lawrence, Massachusetts, to freeze the lanolin out of raw wool and thus avoid the expensive scrubbing

operation). Subsequently the Environmental Protection Division was formed at Natick, equipped with the most versatile cold room in history, the chamber just dedicated to Sir Hubert Wilkins.

I first met Sir Hubert Wilkins a month or so after those initial sleeping bag tests. He arrived at the Fatigue Laboratory with two bags of alpaca pile clothing designed to conform as closely as possible to good Eskimo clothing made of caribou fur. His wish: to use our new cold room to test the alpaca pile clothing. We worked out a protocol. Sid Robinson was in charge and Steve Horvath was there. The test program was to consist of two hours of marching "on the trail" to see whether the "Eskimo suits" would ventilate better than conventional cold weather clothing and thus reduce both sweating of the wearer and moisture pick-up of the clothing. Following "the march" the subjects were to lie down on a rug while observers measured the fall in their rectal and skin temperatures. The control outfit, the Army's then best cold weather ensemble, consisted of closely fitted long woolen underwear, overalls, and jacket, the latter two lined with wool blanketing. Since there was no category of soldier test subject, we were the subjects. Sid Robinson, an Olympic two-miler, and Sir Hubert set the treadmill for "mushing," walking at 3.5 miles per hour up a 9 per cent grade and classified as Heavy Work by any standard.

Sir Hubert and I stripped down for placement of the thermocouples. One look at Sir Hubert told me he was no longer young and that he was "soft." This worried me enough that I volunteered to walk behind Sir Hubert on the treadmill in case he should get in trouble. Eventually, we were clothed, Sir Hubert in the "Eskimo suit" and I in the control outfit; we started mushing. In 20 minutes I had had enough. At the end of an hour a box lunch was brought in to us—a wonderful excuse for stopping to catch my wind. I asked Sir Hubert, "Well, shall we stop and eat?" "No," he replied, "let's eat on the trail," and he did. I was too busy mushing to have any stomach for food. Since then I have resisted the temptation to predict fitness on the basis of appearance!

The two hours finally passed, and we reclined in accordance with plan. If I had only had the Eskimo suit! After five minutes Sir Hubert was asleep; I began to shiver and shake. Word from the control room was that Sir Hubert's rectal and skin temperatures were falling, while my rectal temperature was rising slightly. Obviously, I couldn't be cold!

Had we used soldiers for this test, we might have gone months without considering the third essential factor (heat production) in thermal evaluation of Quartermaster Corps clothing. As it was, I was personally motivated to insist that it be measured. I knew that I was worse off than Sir Hubert. The only way this situation could be explained was by combining the heat production, as determined from oxygen utilization, with the body heat loss as measured by change in rectal and skin temperatures. Subsequently oxygen utilization was

measured. About that time Alan Burton visited us from Canada and helped us work out a system for computing insulation values for the items we were evaluating.

$$\text{Insulation} = \frac{K \Delta T}{\text{Heat Loss}}$$

$$\text{Clothing Insulation} = \frac{K(T_{\text{skin}} - T_{\text{air}})}{\text{Metabolic heat minus lung loss and skin loss by vaporization of H}_2\text{O} + \text{Loss of stored body heat}} - \text{Air Insulation}$$

Use of an appropriate constant yielded insulation values in "clo," the unit of insulation previously recommended by Gagge, Burton, and Bazett. One clo is approximately the insulation provided by a business suit.

Through the following months this system of evaluation of clothing was evolved further. It was later described in detail in a book prepared under guidance of a Committee of the National Research Council (1). Among other things, it was found that an electrically heated copper manikin could serve as a substitute for test subjects in certain static tests of insulation, thus conserving manpower.

Clothing for Arctic activities. In cold weather a man usually finds himself wearing more insulation than he needs during work and less than he needs during rest. The biophysics of the situation suggests why this is so. For any given environment the optimum insulation for maintaining thermal balance is about five or six times as much at rest as at work. In addition are the vagaries: 1) of temperature, which makes the insulation requirement for a given activity at least twice as great at -40°F as it is at 20°F ; and 2) of wind, which can easily halve the protective efficiency of the clothing that is worn. The suggestion that clothing for cold weather should incorporate a "thermostatically controlled venetian blind" principle to control heat flow is sensible, but engineers have as yet produced no practical design.

This principle brings us back to the Eskimo-type clothing, which proved so markedly superior in the test involving Sir Hubert (2). Worn without underwear, tailored to fit loosely, and with readily adjustable closures, Sir Hubert's assembly permitted relatively free ventilation of the skin during periods of activity. As a result subjects sweated less and a smaller amount of moisture was collected in the clothing. During rest and with the apertures closed, the two layers of pile fabric and covering of closely woven windbreak material immobilized a considerable thickness of insulating air.

These principles have been emulated with considerable success in present Quartermaster Corps issue clothing. Unfortunately, the designers have been handicapped by the requirement for underwear (for

sanitary reasons) and the need to carry a load on the back, both of which result in obstruction of ventilation during work.

Since 1942, the Quartermaster Corps has initiated and/or sponsored hundreds of investigations on physiological response of man in the cold (3). I must limit my discussion to a few of the studies which have enhanced our knowledge of the principles of cold weather protection. These studies have been greatly aided by the "enlisted men" who have served as test subjects. Many of them have endured protracted discomfort to help establish these principles.

Sleeping bags. In sleeping bags, our first challenge, we learned many lessons (4). Warmth depends on thickness of air entrapped and rendered "still." Under optimum conditions about 4 clo of insulation are obtainable per inch. Actually, the best sleeping bag we ever tested offered only about 12 clo of protection, enough to maintain thermal equilibrium at a temperature no lower than -20°F . The Quartermaster Corps double-layer Arctic bag is very good, but equilibrium is not maintained below about 0°F . The extra heat that flows under colder conditions derives from cooling of the body tissues. At -40°F , a man wakes up cold a few hours after entering the "sack." The lesson here is to warm up beforehand, so that there will be body heat to lose. It also follows that a casualty cannot be left in a sleeping bag for any long period under these conditions without compounding his injuries with frostbite.

If the requirement is a warm sleeping bag, the air-trapping material must fluff out to three inches or more of thickness. If, in addition, the bag must be portable, it must be compressible for packing. This means that it will also compress under the sleeper, necessitating auxiliary padding underneath. Can the bag itself have a built-in, incompressible "bottom"? Mummy case bags don't. They are most efficient because they conform closely to the shape of the body. A sleeper puts out heat equivalent to a 75 watt bulb. If the size of the bag is increased so that he can roll over without shifting the position of the bottom padding, the 75 watts will be heating a larger "room." In fact, anything that is done to increase the surface area of a bag (independent of thickness) is reflected in large loss in insulative efficiency. This was shown in experimental "Front Line" sleeping bags which had a division below the trunk to accommodate the two legs so that a soldier could get up and run, or at least walk. This bag was heavier, but more important it was cold, even at 20°F . With these restrictions in mind, I can suggest only one possibility for providing an efficient Arctic bag with a "bottom." This solution is to have separate head protection and a rotatable "collar" at the neck of the bag so that the sleeper can turn over without disturbing the bag.

Blood flow to extremities. Quartermaster Corps physiologists have made substantial contributions to knowledge of the control of blood flow to the extremities, particularly to the hands and feet. The principle which has emerged is that flow of warming blood to the hands

and feet is determined by over-all "need" of the body to dissipate or conserve heat in order to keep core temperature stable (5).

This principle of blood distribution to the extremities was learned by venous occlusion plethysmography, i.e., sealing a limb in a "tin can" to see how fast it would fill with higher pressure arterial blood after instantaneous interruption of lower pressure venous outflow by a tourniquet. In one study, subjects were rapidly transferred from a warm to a cold environment (6). Blood flow to the hand fell from a high to a very low level in moments. In nontechnical terms, it fell to less than a teaspoonful per whole hand per minute. Other fingers cooled at the same rapid rate as a finger with a tight rubber band around it.

Such observations led a Quartermaster Corps mathematician to compute the thickness of insulation necessary in the finger of a glove to maintain hand warmth of an inactive man at below zero temperatures. It was so enormous that no one since has made any serious effort to provide all the needed thermal protection in this way. Excessive cooling of the extremities must be avoided by periodic recourse to physical activity or shelter, or by provision of auxiliary heat.

Quartermaster Corps scientists later studied the importance of a periodic "automatic" opening of blood vessels in cooled extremities for keeping these extremities from freezing. This reflex phenomenon, earlier described by Sir Thomas Lewis for a finger immersed in crushed ice, provides a periodic flush of warming blood (7). It was suggested that this response, which is much better developed in some men than in others, might be used in selection of personnel for duties in extreme cold.

This control of blood flow to the extremities poses a dilemma to the body. From the viewpoint of body survival it may be better to maintain warmth of central organs by cutting off flow to the limbs, even if it means their sacrifice. However, the body's solution of the dilemma in this way is not an unmixed blessing. It goes without saying that a man with frozen hands and feet is severely handicapped; certainly he is a liability to a military effort.

Rewarming. Another related practical question that Quartermaster Corps physiologists have attempted to answer concerns the efficiency of various methods of warming the body following exposure (8). In one study men cooled for an hour at -40°F , then marched or entered a sleeping bag in that same environment, or went into a warm room and sat. While skin temperature rose most rapidly while they sat in the warm room, that did not mean early comfort or restoration of body heat; the subjects shivered intermittently and their rectal temperatures actually fell for nearly an hour. This procedure turned out to be far less effective for rewarming than exercise in the cold; the latter restored core temperature and comfort in a few minutes.

Nowadays the Quartermaster Corps doesn't always have to use test subjects to find such answers. It has an electrical analog into which

can be plugged the information about temperature, wind, and activity; hopefully, the computer will respond electrically as a man does thermally, but in a fraction of the time (9). It did so react when this same problem was posed to it, several years after the hard work had been done.

Auxiliary heating. Provision of a limited amount of supplemental protection through local application of heat inside the clothing is a matter of on-going concern to the Quartermaster Corps. Some associated physiological problems (quite apart from logistic ones of how to supply the electrical or other energy) have received attention. One approach involved finding the maximum tolerable safe level to which skin temperature could be raised by a heating pad; the hope was that enough heat could be put into the skin of a local area to compensate for excessive losses from the unheated remainder of the body (10). Unfortunately, the maximum safe temperature turned out to be only about 104°F, and it became clear that an area as large as the entire trunk would have to be heated to achieve heat balance for inactive men at below zero temperatures. Another and current approach is the provision of limited heat to prevent excessive cooling of the extremities. This is not as easy as it sounds. I remember seeing frostbite on the palmar surface of two fingers under circumstances in which the wires heating the backs of the hands and fingers had been hot enough to raise red welts. Clearly, the stated principle that blood flow to the hands depends on over-all need to conserve heat balance was operating here; good hand circulation had not been achieved.

Sweat retention in clothing. Arctic explorers have referred again and again to the danger of sweating profusely because of later excessive evaporative cooling while inactive. The Quartermaster Corps has supported a quantitative investigation of this phenomenon (11). The trouble arises because the outer clothing is cold and sweat, even if evaporated at the skin, condenses out on the cold cloth. For example, in zero weather it was found that 80% or more of sweat produced during two hours at levels of activity from sitting quietly (sweat production 1 ounce or less) to hard work (sweat 1 to 2 quarts) remained in the clothing. The sweat mechanism's aim is to achieve skin cooling. If what the skin secretes does not achieve the aim, more sweat is produced. In this study the effectiveness of the sweat for skin cooling averaged only about 50%; we may infer an approximate doubling of the burden on the sweating mechanism (and body water economy) and a corresponding increase in uptake of moisture in the clothing. The only relatively bright spot in this picture was the further demonstration that at all moderate rates of sweating the moisture accumulation was restricted to the outer layers of clothing. During subsequent periods of rest evaporation of this moisture occurred so far from the skin and so slowly that the normal rate of body cooling was not greatly accelerated. The over-all effect of these demonstrations was to point up the requirement for better ventilation of cold weather field uni-

forms and to show how success in achieving this goal could be evaluated. The study also supported a radical new principle for the control of moisture, namely, the provision of an inner vapor barrier in the clothing to prevent the sweat from reaching the outer layers. This principle has been under investigation and is in use in the "Korean" waterproof boot.

Thus, in many ways the Quartermaster Corps has helped to develop a firm physiological and biophysical basis for design of cold weather clothing and equipment. Profit from these studies must eventually accrue not only to the soldier who is equipped by the Quartermaster Corps, but to all who face the elements in the development of Arctic areas.

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CHAIRMAN REED: It is a special pleasure to introduce our next speaker who is the Research Director of the Textile, Clothing, and Footwear Division of the Quartermaster Research and Engineering Command. He is Dr. S. J. Kennedy. Dr. Kennedy has had a great deal to do with the planning and arranging of this conference. At this time he will speak on the subject "Clothing and Personal Protection." Dr. Kennedy.

CLOTHING AND PERSONAL PROTECTION

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Ironically, on the very day the Japanese struck Pearl Harbor, an action which immediately compelled our Army to think about the defense of Alaska, the German war machine was being frozen in its tracks by -32°F cold and deep snow right in front of Moscow and Leningrad. How completely unprepared the Germans were for fighting under such Arctic conditions has been clearly brought out in the war memoirs of General Heinz Guderian, Commander of one of Hitler's Panzer Armies in the invasion of Russia. Lack of proper clothing, he stated, caused them twice as many casualties as the enemy's fire and lost them their chance for success.

In retrospect, we can be thankful for Hitler's miscalculations. However, we should also realize that in 1941 the American Army was even less prepared than the Germans for winter fighting. Our regular Army winter uniform was inadequate for combat troops anywhere in the world. As pointed out by Lieutenant General E. B. Gregory, the World War II Quartermaster General, our Army uniform had been gradually converted from a comparatively loose-fitting field uniform into a tightly fitted uniform suitable only for garrison wear. Soldiers usually had local tailors shape their loose-fitting uniforms so tightly that the buttons were always under strain. This undesirable conversion has been embraced by all Armies in peacetime. Unfortunately our Army was no exception.

Thus we had no cold weather combat uniform when war broke out. All we had was the so-called Alaskan List—a tabulation of some thirty supplementary items of clothing and equipment. These extra items (e.g., lined coat and cap) were in limited supply and had undergone little change in 20 years.

Except for a change in the collar, our 1941 Army uniform was not significantly different from the one used in the fighting of World War I. We did have canvas leggings in place of spiral wound puttees and trousers in place of breeches. With the elimination of the blue dress uniform for reasons of economy, the olive drab wool serge uniform served both for field and garrison wear in the winter months.

For summer wear we had cotton khakis, with which our officers wore tightly fitted, trim-looking cavalry boots, which would have

proved thoroughly unsatisfactory and conducive to cold injury if worn in cold climates.

From the outbreak of the war it was apparent that unlike previous wars in which fighting had either lessened considerably or come to a complete halt during winter, the extremes of climate were not going to stop fighting in this war; rather, both sides were going to take advantage of the environment and use it as a weapon. Hence, adequate and effective cold climate clothing was a matter of urgency for protection from cold injury or loss in fighting efficiency in any potential front in the northern hemisphere as well as in Alaska or in other true Arctic or sub-Arctic areas.

What approach to take toward developing such clothing presented a difficult problem. There was strong opinion among those consulted that the best solution was to adapt native type clothing and use furs as did the Eskimos. The Scandinavian forces in the Russo-Finnish War of 1939-40 had used fur-lined clothing, employing furs, however, in quite a different way from that of the Eskimos.

There was also the question of whether to use a long overcoat for protection of the legs and for general body warmth, as was done by the Germans, the Russians, and Scandinavians, or whether to use a short thigh-length jacket. If the latter were used, how were the legs to be kept warm and dry in wet weather when the coat shed its water onto the legs?

It was in tackling these problems and many related ones, that the Quartermaster Corps made its foremost contribution during World War II toward extending the capability of man living in the Arctic and at the same time gave impetus to a program which has since continued to pioneer in contributions to cold climate clothing for both civilians and the military services.

Rather than look to the past empirical solutions of cold weather clothing problems by either Arctic natives or textile and clothing industries of other countries, the Quartermaster Corps turned to scientific data from the fields of physiology, physics, and textile technology; and using materials available from mass production, sought to improve cold weather clothing.

Shortly after the outbreak of the war, Dr. Paul A. Siple, who had just returned from the Antarctic Service Expedition with Rear Admiral Richard E. Byrd, was asked to prepare a general statement of the principles governing the selection of clothing for cold climates. That report summarized what was known at that time from the fields of physiology and climatology about the functioning of clothing assemblies in cold climates, as well as Dr. Siple's practical experience gained in these expeditions to the Antarctic.

To apply these principles, a research and development program was launched by the Office of The Quartermaster General under the leadership of Colonel (later Brigadier General) Georges F. Doriot. This program included, in addition to the actual development of the items,

a basic research project directed toward the further elucidation of these principles, not only to learn how to prevent cold injury, but also to make positive contributions toward augmenting the physical efficiency of the troops. As part of this project, provision was made for physiological testing in the Climatic Research Laboratory at Lawrence, Massachusetts, and for accelerated serviceability testing at the Quartermaster Board at Fort Lee, Virginia. At Fort Lee items were worn on controlled test courses that reproduced the actual stresses and strains of combat conditions. The results of the testing were then analyzed statistically to determine which of several alternate solutions would be the best.

The resources of the scientific world were enlisted particularly through the Committee on Aviation Medicine of the National Academy of Sciences—National Research Council and the corresponding Canadian Committee. A part of the work of these committees was directed specifically toward the scientific study of the soldier's clothing. Their work and that of a large number of scientists in both countries yielded a great deal of information that could be utilized by equipment designers and textile technologists in development of what the Army needed.

When this program was launched in the spring of 1942, there was an urgent need to arrive at some conclusions in order that immediate large-scale procurement of clothing could be made for troops being sent north for the defense of Alaska. Accordingly, in May 1942, in order to resolve questions as to suitability of newly developed experimental Arctic items, a test team of seventeen highly qualified mountaineers and Arctic specialists was flown to Mt. McKinley, Alaska, the only place under U. S. control where Arctic conditions (down to -20°F) prevail during the late spring season. Here for two months, these men lived with and tested over 100 items of Arctic clothing, tents, and other equipment. Included in this group, which was supplied in one of the first large-scale Army air drop operations, were Major Robert Bates in command; Brad Washburn, whose name will always be associated with Mt. McKinley; Terris Moore; Al Jackman; Wing Commander Peter Webb of the RCAF; and others who distinguished themselves during the war for their contributions to the improvement of Quartermaster cold climate equipment.

Tests like this yielded two important by-products. One was that we needed a much clearer definition of the clothing requirements, preferably in quantitative terms. Instead of making a garment which someone thought would meet the need, we had to know if it actually would do so. The other was the discovery that, regardless of prior experience with any clothing, soldiers could not be depended upon to use the new clothing properly; they had to be completely re-educated in the use of the new items.

Two major principles employed in the cold weather clothing developed at this time are worthy of mention for their subsequent impact

upon both military and civilian cold weather clothing design. The first was the principle that cold climate clothing derives its efficiency in protecting against the cold, not from the weight or mass of the material used, but from its entrapment of still air. For the system to be effective, a windproof and water repellent outer "shield" fabric is needed to serve as a baffle against the wind and to keep the insulating layers dry from external moisture. The insulating layers can then be as light as technology permits so long as the air spaces do not exceed approximately $\frac{1}{8}$ " in cross section.

Thus, in place of the wool overcoat, made from a fabric weighing 32 oz/sq yd and which would absorb more than its own weight of water, a wind resistant and water repellent cotton jacket and trousers were adopted for the outer garment. Wool, as a fiber, was then used for the task it could perform extremely well—providing insulation in the underlayers of clothing.

The second fundamental principle followed was that of going to a "layer" system of clothing. This system provided one way of dealing with the 130° temperature range (from 65° F to -65° F) over which cold climate clothing had to be effective and the range in activity levels of the soldier from hard manual labor or running to being completely inactive for as long as six hours at a time. Thus, a layer could be removed or added, or vents at the wrists, neck, and waist could be opened or closed, depending on whether the man needed to cool off or to conserve his body heat. The system was also more efficient than a single layer system would have been, because it permitted extra air-entrapment along the fabric surfaces which gave "free" insulation.

The full functional efficiency of this system was, unfortunately, compromised by the necessity for including in the ensemble an item of semidress uniform in the style of the so-called Eisenhower jacket and wool trousers. This jacket was designed to serve a functional purpose when worn over certain insulating layers in the clothing system and also a dress purpose as the Army Service uniform. Actually it served neither purpose satisfactorily.

To protect against outright cold injury the Army footgear needed radical changes. The history of trench foot in World War I and the long record of frostbite in all previous wars made it clear that means must be found to prevent such injuries again on a large scale.

Redevelopment of the Army leather shoe to a cuff-type boot that could easily be removed for change of socks and for foot massage, with elimination of leggings, was one approach. Shoepacs with removable felt insoles and multiple sockgear were developed for use by troops in wet cold climates. Using the Eskimo mukluk as a model, a military mukluk with removable felt insoles and heavy wool socks in place of the native furs was developed.

While these types of footgear alone were not fully adequate to prevent cold injury, the cold injuries that occurred were mainly caused by other factors. Actually, the World War II footgear of our Army,

as developed by Quartermaster research and development was the best functional design to date.

Fortunately, a fundamental solution to the problem of cold injury to the feet was discovered in the course of this Quartermaster research and development program.

In 1944, Major Paul Siple and the late Dr. H. C. Bazett hit upon the revolutionary concept of sealed insulation type footgear. There was no time during the war to work out this concept in actual production. Despite efforts in the early postwar years, it was not successfully achieved until 1951, when the Hood Rubber Company first developed a practical sealed insulation boot. It was then immediately made available to our forces in Korea and contributed to the almost complete elimination of this source of cold injury in the winter of 1952-53 and subsequent years. This concept has been perhaps the most important breakthrough in recent years in the whole field of military cold climate clothing and has made possible the effective control of cold injury to the feet under most combat conditions.

It is impossible here to dwell on the many other developments in cold climate clothing, equipment, and combat materials which contributed significantly to the preparation of the U.S. Army soldier for effective operations in cold climate environments during World War II. Two items, however, should be mentioned. One was the sleeping bag for use of troops in cold climates, which replaced blankets that at best were inadequate.

The other was the development of a lightweight 4- to 6-man tent, following principles advanced by Sir Hubert Wilkins. This 4- to 6-man pyramidal tent was compact and yet fully adequate for field needs, capable of being man-carried, and represented the austerity practiced by experienced Arctic explorers. It served as a model for the kind of functional approach which the Army needed to extend its capabilities in such a region.

This review of Quartermaster World War II contributions may seem to some of you to be repeating the obvious, as would be the case in telling of the work of early Arctic explorers, so easy is it, after the fact, to accept unappreciatively the achievements of pioneer workers in a field.

However, we should recognize that even the development by the Quartermaster Corps of a simple and practical method for shrink-proofing of wool textiles in order to make the Army cushion-sole sock truly washable—a long-wanted improvement in civilian woollens—was a major departure from industry practice.

Never before tried by the textile and clothing industries, the Quartermaster Corps research and development's approach of controlled testing and application of scientific data to design and development of clothing was indeed revolutionary. It marked the beginning of an era in which the application of scientific methods would make practicable

the use of many new textile fibers through the engineering of fabrics and the development of a science of clothing.

It rendered our Army capable of successful defense of Alaska, had that become necessary, and would have enabled our troops to fight successfully through winters much colder than those of western Europe. This feat was accomplished by developing, procuring, producing, and distributing a completely new clothing assembly and getting it into the hands of troops in less than two years' time. In contrast to our present long development cycle, this was no small achievement.

Despite the improvements which had been made as a result of the wartime effort in the Army's cold climate clothing, it would have been most unfortunate had this development program been concluded with the end of the war. The sheer magnitude of the task of changing over the Army clothing system from what it had been to the newly developed assembly had resulted in compromises and substitutions which left the job only partly completed. That the job was incomplete was recognized generally by the users who in 1947 launched the comprehensive re-examination of all cold weather equipment in the triple test program of "Frost", "Frigid", and "Williwaw". Here the Army's cold weather clothing, as developed during World War II, was subjected to a complete re-evaluation in controlled field operations.

Based upon those tests, a modified cold climate clothing assembly was developed in 1948-49 in which complete separation was made of the functional clothing of the Army from its service uniform. In place of the Eisenhower jacket, a comfortable, sport-style shirt made from a heavy wool flannel was adopted as a general utility garment in which the soldier would be presentable for any normal theater conditions in time of war, and which also would serve as a functional insulating garment in the clothing system. I am glad to say that this item has become one of the best liked clothing items ever developed by the Quartermaster Corps.

Extra "free" insulation was made available by the adoption of loose-fitting, pajama-type underwear made from the Army's standard 50/50 wool/cotton fabric and by generally loosening up the fit of all of the garments in the system.

A new type of face and neck protection was adopted based on an extendable hood with a malleable wire stiffener that could be bent in any suitable way to protect against the prevailing wind.

This new clothing assembly, although not different in principle from that adopted in 1943, represented a very considerable advance in improved fit and the use of better materials. Also, it exploited to a greater extent the previous experience of the military population of wearing civilian-type clothing in order to reduce training time and to make it easier to use the new items properly. This facility was accomplished by designing the clothing so that all layers would open down the front for ventilation when needed for cooling off or

preventing overheating. This new clothing underwent its first large-scale trial in the Korean War.

While much of the World War II clothing was still in the system, large quantities of this new clothing did get to Korea and it was pronounced an excellent cold weather clothing system—by far the best which our Army had ever been provided.

That the basic principles and construction of this assembly were sound is attested to by the fact that the Canadian Army had adopted a quite similar cold weather uniform system which is actually functionally interchangeable with that of the U. S. Army. More recently, the British Army has also adopted a similar type of cold weather clothing. This same clothing was also selected for the support of the U. S. civilian scientific personnel in the Antarctic during the International Geophysical Year.

While this clothing system, adopted as the M-1950 model, represented a major advance in our capabilities for effective military operation in the Arctic, there were still many things about it that needed basic improvement.

Since the Korean War, our cold climate clothing has been subjected to thorough scrutiny in order to correct its obvious deficiencies and also to take account of changing requirements and the very substantial technological advances which have been occurring in the textile industry.

Among its serious deficiencies have been its weight, which is unquestionably beyond what the man should have to carry; lack of adequate water repellency, requiring frequent re-treatment of the clothing; the inability to wear the helmet, because of an inadequate solution of the problem of the spatial configuration about the head; imbalance between the insulation provided to the hands and feet and the rest of the ensemble; and the inadequacy of the footgear for use with skis.

In addition, new concepts have developed for the deployment of troops and their weapons which add substantially to the problem of protection in the cold. The need for rapid dispersion of troops to avoid their becoming a profitable enemy target calls for mobility characteristics which are difficult to achieve in the Arctic and places a premium on mobility of the individual soldier.

Further, other requirements in recently established Military Characteristics call for better integration of warm climate clothing with cold climate clothing so that a man will be prepared for operation at any time in any place; for incorporation of chemical warfare protection into the cold climate clothing; for protection against thermal effects of nuclear weapons; and for the capability of wearing body armor with the cold climate clothing.

Successful solutions to several of the above problems have greatly improved the efficiency of the entire clothing system.

One recent improvement has been a substantial weight reduction

in the basic extreme cold or cold-dry area clothing from 26 lb to 20 lb (23%). Careful examination of the entire system showed that weight could be reduced by using newly engineered lighter weight fabrics of comparable wear- and water-resistance and insulating properties. Because of the present technological revolution in the textile and clothing industries, these new materials are not considered the ultimate; but they have been tested and approved for adoption.

A second significant contribution to the capabilities of military forces in Arctic areas was the development in our laboratories of QUARPEL, a water-repellent functional finish for textiles and of exceptional performance and durability. When applied to the shield fabric of the cold weather clothing assembly, QUARPEL withstood continuous rainfall for over seven days and permitted no seepage. It retains its water repellency after laundering so that clothes need not be re-treated in the field. Even after 15 launderings QUARPEL-treated fabric is as good as the best present commercially treated fabrics when new. Cold climate clothing made from QUARPEL-treated fabrics, and sewn with QUARPEL-treated thread, is now going into production testing in the industry.

To reduce the imbalance in the insulation between the hands and feet and the rest of the assembly, two actions have been taken. The principle of the sealed insulation boot has been extended to extreme cold Arctic areas by the adoption of a white insulated boot having a higher amount of insulation than the present black boot. This new boot will replace the mukluk with its sockgear and removable in-soles, the last of the native-type items in our cold weather clothing system. This new white insulated boot was worn by Dr. Siple at the South Pole two winters ago at temperatures of -102°F without serious discomfort or cold injury. However, these boots have only limited compatibility with the present Army cross country ski binding and none with the mountain ski binding. The new requirement for a high degree of individual over-snow mobility in the Arctic will necessitate the development of a modified version of the vapor barrier boot with a variety of experimental ski bindings and superior to the prototypes that were provided to the Mountain and Cold Weather Training Command for evaluation this winter.

New types of handgear are presently under development incorporating principles of shaping according to the natural, relaxed hand and with differential insulation so that more insulation is placed over the back of the hand where blood vessels lie close to the skin surface. These gloves, used with mitten-type inserts, now under test act primarily as hand warmers. To perform any special mission other than gross handling, the hand must be removed. These gloves partially solve the conflicting requirements of warmth, dexterity, and tactility.

Sometimes men's duties force them to remain inactive for long periods when high manipulative skills are required, i.e., operation of exposed fire control radars and associated computers. Here the hands

become chilled and stiff and incapable of fine manipulations after a while. Occasionally soldiers are exposed on open vehicles and self-propelled weapons, such as the M-56, full-tracked, 90 mm Howitzer, and may be subjected to high wind chills while the vehicle or weapon is in motion.

For these special conditions we are developing auxiliary heating devices. It is expected that these will significantly increase the efficiency of man/machine systems in the cold and enable men to perform missions with the present cold weather clothing which could not otherwise be done. Chamber studies already completed, using electrically wired socks and handgear powered by an 8-lb rechargeable battery vest, have shown that the heat furnished will eliminate excessive chill of the extremities under cold weather conditions for an indefinite period. The successful development of a practical field auxiliary heating system depends principally upon the development of a miniaturized thermostatic control system of high reliability. Presently available systems have the limitation of being either too large to provide reliable control of temperature at the critical points or of being delicate, laboratory-type potentiometers.

The problem of the protection of the face and head area in the Arctic remains to be solved. All of the conventional approaches which work well for civilians, including the use of well-engineered fur ruffs around the hood to insure proper fit and functioning, fall down when the full military requirements are added to them. The natural furs are flame and thermal hazards and can be readily contaminated with chemical warfare agents. The close-fitting hood is not compatible with the helmet as it makes it unstable. Face protection in Arctic areas reduces seeing and wearing ability, both of which are of the utmost importance from a military standpoint; and the force of the wind, which causes the eyes to water or the cheeks to freeze, necessitates the kind of face protection which will accomplish something none has done so far.

While there is much more that could be said to reflect the improvements being made in cold climate clothing to increase the capability of man living in the Arctic, it would probably be well at this point to summarize briefly the lines along which we feel future research and development would be fruitful. We would suggest three such lines: one in the area which we refer to as the biophysics of clothing; a second in the science of functional clothing design; and, third, materials research, exploiting the present tremendous capabilities of the textile industries for providing specific properties in textile fibers.

The biophysics of clothing is significant today because it is an interdisciplinary approach (physiology, psychology, physics, clothing design, and textile science) which relates the human work efficiency and comfort to the military task in a particular environment. In earlier efforts to apply the principles of science to clothing develop-

ment, we looked to the physiologist for information about the man and to the climatologist for knowledge of the environment. However, little or nothing was known about the physics of how clothing materials interacted with each other or with the complex man-clothing-environment system. Moreover, experimental measurements were made almost entirely under "steady state" conditions for simplicity and reduction of the number of variables. Using the comprehensive biophysical approach, the end product should be a clothing system in which all of the elements—man, environment, and clothing—are compatibly related.

In 1947 Dr. Harwood Belding measured the decrease in effective insulation with movement in the Arctic clothing of that time. Work in recent years has been concentrated on developing a quantitative understanding of the physical mechanisms involved so that clothing can be designed that optimizes the balance between static and dynamic insulating efficiencies. A specific problem here is that of minimizing the rate of heat loss when the activity level is low and of increasing the rate of heat loss as the activity level rises.

Studies conducted by the Harris Research Laboratory on the effects of spacing dimensions in body clothing in relation to body activity have pointed a way toward controlling the rate of air movement within the clothing system when the man becomes active, through controlling, in turn, the spacing factors in the clothing system. These studies of the effects of relative movement of the body and the clothing have revealed that motion, per se, does not necessarily result in ventilation. It may result merely in mixing of the air between the body and the clothing.

However, where sizable temperature differences exist between spaced layers of clothing, as would be the case in an Arctic winter environment, this mixing effect could be expected to transport relatively warm moisture-laden air to the cold side where the moisture will condense, drying the air. Further mixing of this air with air close to the body would result in further evaporation, and this cycle would be repeated with every movement. Application of these new concepts to Arctic clothing might largely eliminate the overheating problem in the Arctic.

Such an approach, if successful, would, indeed, be significant in dealing with what is perhaps the most critical problem in the use of mass produced textiles for Arctic clothing.

Related to this biophysical approach is what we refer to as the science of functional clothing design. Its concepts will largely stem from biophysical studies, but its application will require the conversion of the clothing designer's art into science. In one sense, we can think of this transition as in the same state today that the engineering of textile materials was twenty years ago or environmental physiology thirty years ago.

Thus, a year ago, a kinesiological analysis of clothing at Springfield

College revealed a simple method for determining the increase in five critical dimensions in clothing as a function of postural changes from the position of "attention." Thus, the clothing designer could have specific information on how much "extra" material was required to accommodate the shape and volume changes of selected body regions as a function of changes in position. Furthermore, it was a technique which could be applied for obtaining any further dimensions of this type. It will be apparent that the study is particularly valuable because it obviates the difficulties which are inherent in dynamic anthropometry and shows how such data can be translated into the specific elements of clothing design by measuring directly what happens in the clothing itself. Such a study shows how the non-verbal art of the designer can be converted into a form that can be communicated to the physiologists and vice versa.

In the matter of textile materials research, it would be difficult to overstate the challenge and the opportunities which lie ahead. The textile and clothing industries are presently in a period of the most profound change that they have ever known. The rate of development of new fibers and textile finishes is more rapid today than ever before. The number of possible combinations of these fibers with each other, with the application of functional finishes on top of that, is literally staggering. Determination of how they may serve military uses still lies before us, and the capabilities of the synthetic fiber makers to produce still new fibers having quite different properties from any presently available, and for natural fiber modifications, which may have significant military application, represents a dramatic potential for military clothing.

We need look only at the launching of isotactic polypropylene just four years ago and realize that within that small period five fiber producers in this country are now actually in quantity production of this new fiber to appreciate how fast this kaleidoscopic picture of textile fibers is changing. Since these new fibers have significantly different characteristics, their utility for any particular use cannot be pre-supposed based upon simple analogy, one to another. In fact, even their strength characteristics differ widely depending upon the rate of loading or speed of impact.

How these new fibers may assist in providing cold climate protection may be judged in part by their moisture absorption characteristics. Among the principles developed by Dr. Siple in the report previously referred to, was the need for dealing with the problem of body moisture arising both from insensible perspiration and from high levels of activity. Even after providing for adjustability of the clothing and effective venting, there is still a volume of body moisture, up to 35 g/sq m/hr, which must be dealt with. A recent finding of our laboratory has shown that by moving from the use of fibers in a woven fabric structure to fibers in a lightweight batt, quilted between two layers of very thin cloth, we have been able to achieve thickness

of entrapped air at lower weight per unit of insulation than in any previously developed system. Fortunately, the batts we are working with show good stability to laundering, which is, of course, a requisite in our clothing. This batt has shown a very interesting property. Because of its low level of moisture absorption, body moisture created by high levels of activity passes readily through it to the outer air instead of being absorbed and thereby adding to the body the heat of moisture absorption with subsequent reduction of the insulating value of the insulant.

There is the need for multi-functionality in the military clothing system of the future to deal both with the natural environment and the enemy-imposed environment; the technological developments and new fibers afford possibilities for combinations of fibers having different properties to achieve such multi-functional characteristics. By studies of the biophysics of clothing, we expect to be able to interpret the impact of combinations of fibers and multi-functional finishes in the achievement of the over-all protective shield for the soldier and of his over-all clothing system.

Since our principal military opponent is itself situated largely above the Arctic Circle, with literally millions of people today living in Arctic and sub-Arctic areas, it must be expected that they will have at least an equal or larger interest in enhancing the capabilities of man living in the Arctic. This interest applies to their civilian population as well as for their military forces.

Furthermore, in view of their already demonstrated progress in textile science engineering, there is no doubt that they have the potential for producing new materials and materials systems which will further enhance their capabilities in providing efficient clothing for their Arctic population. That they recognize this important potential is evidenced by their recent appointment of Professor A. N. Nesmeyanov, the discoverer of their new fiber, "Enan", a type of nylon polymer more heat stable than any presently available in the Western world, as the president of the Russian Academy of Sciences.

If we are to continue to make progress in research in this field and in enhancing the efficiency of our soldiers through improved cold climatic clothing, we also shall need to regard this area of research and development as one of major importance for the future of our national defense.

CHAIRMAN REED: Ladies and gentlemen, the title of our next paper is "Arctic Rations". The speaker is also from the Quartermaster Research and Engineering Command. He is the Research Director of the Environmental Protection Division of that Command. Dr. Austin Henschel.

ARCTIC RATIONS

AUSTIN HENSCHEL

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Existing in a cold climate is difficult whether one is there by choice as a native or by necessity as a soldier. A great deal of effort has gone into seeking ways and means to make it just a bit easier to get along in the cold. Food has not been overlooked in this search.

Food takes on a special significance in cold climates because of the need for the internal generation of body heat to keep warm. Food is ultimately the only source of this energy. When one is in Arctic areas, food is frequently not readily obtained—there are no supermarkets every few miles. It is necessary to carry one's total supply along or depend upon hunting and fishing skill and the abundance of game and fish. In the winter season living off the land in the far north can be a precarious business.

Because food is so vital to survival in cold climates, everyone soon becomes a nutrition expert. The success or failure of each venture becomes associated with the type and amount of food that is eaten. As a result food theories for cold climates has become infiltrated with folklore, fads, fancy, and a little common sense. Sifting out the common sense has not been easy. The Army and the Quartermaster Corps have been at it since early in World War II. In general the sifting has been directed along the following three major lines: 1) the total amount of calories needed each day, 2) the nutrient composition of this ration, and 3) the value of supplementing the ration with special substances.

I shall briefly review the research (both in the laboratory and in the field) that has been conducted in these three areas and, on the basis of this research, shall state what I believe is our position today. These opinions are based on my interpretation of the evidence. The evidence may well lead many of you to reach other conclusions.

First I should like to dispose of pemmican. A survey of Arctic literature showed that men did not thrive for long periods on pemmican alone. When pemmican was used, it served as a meat item and was supplemented with such items as biscuits, parched corn, oatmeal, sugar, and tea. Both Peary and Scott used pemmican, but not alone. Many varieties of pemmican were made and field tested early in World War II. None was found acceptable. By 1944 on the basis of the many trials, it was recommended that the concept of using pemmican as a sole or chief constituent of an Army ration be abandoned. Even after this recommendation was made, many test subjects went through the horrors of trying to live on pemmican for a few days. By the end of World War II, pemmican had been, if not abandoned, at least ignored as an item in the Army Arctic ration.

Early in World War II the planning of rations for use in the

Arctic became of concern because of the alarming lack of satisfactory scientific data on nutritional requirements in the cold. There were a lot of individual experiences and lore, but these hardly sufficed as a basis upon which to develop a satisfactory Arctic ration. Tall tales about the astonishing food intakes of 7000 calories or more per day were believed or half believed by many. Nevertheless these tales were retold as facts. On the face of it, it seemed to make sense that more fuel would be needed in cold weather to keep the stove warm. The field ration trials in New Brunswick in the fall of 1942 showed that "caloric deficiency quickly produced deterioration in performance and morale of trained soldiers" and added urgency to the development of an adequate Arctic ration.

Since 1944 seven major Arctic ration trials have been run. The three studies in 1944, 1945, and 1947 pointed out the need for a high calorie Arctic ration, about 5000 calories per day. This amount represents $1\frac{1}{2}$ rations per man per day. The four studies in 1948, 1950, 1954, and 1956 indicated that two-thirds of that amount or about 3500 calories per day is adequate.

What is the explanation for this difference? For one thing, no two studies were exactly alike—weather differed, activities and work level differed, rations differed, methods for measuring food intake differed, changes in body weight were recorded in some studies and not in others. In all these studies the men were allowed at least one full ration. At the end of all these studies (whether of 10 days or 3 months duration), the men were in excellent physical condition. All rations seemed to be providing sufficient calories and nutrients.

Let me briefly describe the conditions of these studies. In the 1944 winter study at Prince Albert, Saskatchewan, each trial ran 10 days. The men lived in the open and used two-man tents and sleeping bags at night. In addition to attack, defense, and withdrawal maneuvers, they carried and hauled all their gear 45 to 65 miles during the 10 days. There is no doubt that they worked hard. Some nights the weather was cold (-38°F).

The 1945 study was a mechanized 3400 mile trip through the Arctic from February to May. From Fort Churchill on Hudson Bay the group went north to Denmark Bay above the Arctic Circle, then west to Norman, and then south to Edmonton. Forty-eight men made the trip in snowmobiles, 4 men to a vehicle. Supplies were air-dropped to them. During the first two-thirds of the journey, temperatures in the vehicles were about 0°F . At night tents were pitched and sleeping bags used. About 5000 calories per day were furnished to each man; 4500 calories were consumed. Except for carbon monoxide poisoning during the first part of the trip, everyone was in good condition. Physical work was not excessive, but the vehicles were on the move for long periods each day.

The winter 1947-48 study at Fort Churchill was really only a mass survey. Food intakes were recorded on about 100 men for a ten-day

period in early winter, mid-winter, and late winter. Activities of the men differed and were not controlled, but were without doubt not excessively strenuous. Food intakes varied from about 5300 to 5700 calories per day and correlated very nicely with windchill values.

In 1947-48 food intakes and energy requirements in the fall at Fort Knox, Kentucky, and in the winter at Fort Churchill were compared using the same group of subjects and a set routine of activity under bivouac conditions. The men were exposed to severe winter conditions at Fort Churchill. Food requirements were similar in both the temperate and Arctic trials. At the end of 14 days the men were in excellent condition. Food intakes (C rations) were about 4000 calories per day.

At Ladd Field in 1950 no winter-summer differences in food intakes were found for infantry, Air Force personnel, or native Eskimos. Infantry men consumed about 3200 calories per day; Air Force personnel, 3000 calories per day; and Eskimos, 3100 calories per day. Previously it was found that trappers in Greenland ate about 2800 calories per day.

Another moving bivouac series of studies at Fort Churchill during mid-winter conditions were conducted in 1956. The men were exposed to both very cold weather and hard work. Calorie needs were found to be 4100 calories per day. After correction for body weight loss, actual intakes were about 3800 calories per day. No relationship was found between air temperature and calorie intakes.

Two recent studies, one in the field at Fort Churchill and one in the climatic chambers here, showed that men kept 24 hours a day in a room held at 50°F needed more calories than men in a room held at 70° to 75°F. The increase was from 250 to 350 calories per man per day in both studies. Men in the 50°F situation were cold much of the time and shivered a great deal or exercised to keep warm. This increased muscular activity accounted for the extra calorie needs.

A common belief is the need for high fat intakes in the cold. There has been some evidence from animal studies indicating this need. However, in all the ration studies reviewed, there was no sign of "fat hunger." The fat content of the diets were constant. On the average about 40% of the calories we consume come from fat. This is true for both our civilian and military populations. In most other countries the percentage is lower; in a few places, higher.

The present Arctic ration appears to be adequate both in composition and in amount for most situations. One must bear in mind that the amount of food needed is proportional to physical expenditure—an intake-output relationship.

Nevertheless, food can be used to enhance night-time comfort in a cold environment. Eating a snack or light meal just before crawling into the sleeping bag will increase the length of sleep one can get before being awakened by the cold. Under controlled conditions of -30°F (climatic chamber), test subjects got between 1 to 1½ hours more sleep when given a 500 calorie meal just before retiring. Whether

this meal was a saved portion of the day's ration ~ an extra supplement made little difference. The beneficial effect of this repast makes scientific sense because heat output is significantly increased for a few hours after a meal regardless of the environment. In the cold this extra heat serves a useful purpose.

The search for special nutrients which would increase man's cold tolerance has been rather disappointing. In some laboratory animals, high vitamin C intake would increase resistance to cold. Unfortunately, the results did not carry over to man. Supplementing the regular Army ration with vitamin C did not prove beneficial. No other special substances tried so far have increased man's resistance to cold.

I shall conclude with the general statement that since 1940 several types of field rations have been developed, modified, and improved. It may be possible to make them more tasty, more acceptable, and more convenient to supply and use, but nutritionally they appear to adequately meet man's needs for all environments.

CHAIRMAN REED: The final speaker today is Dr. W. Robison also of the Environmental Protection Research Division of the Quartermaster Research and Engineering Command. His subject is "Quartermaster Environmental Research in the Arctic". Dr. Robison.

QUARTERMASTER ENVIRONMENTAL RESEARCH IN THE ARCTIC

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Introduction

In addition to the problems of human physiology and personal protection that have been discussed in the previous papers, the Quartermaster Corps has done a considerable amount of research on the Arctic environment itself. This research has been carried on under the Quartermaster General's assigned cognizance for research and development within the Department of the Army in the field of Applied Environmental Research. This mission can best be understood in the light of the definition for Applied Environmental Research as given in the General Staff Memorandum (dated 10 June 1949) in which primary cognizance for the field was assigned to the Quartermaster General:

"the collation of statistical, meteorological, climatic, and geographical data as accumulated by the responsible agencies, the interpretation of these data, and the presentation of the evaluated information in suitable form for application by appropriate agencies to logistics problems of equipment, personnel and operational functions."

The assignment specifically excludes the field of snow, ice and permafrost, for which the Chief of Engineers has primary responsibility. Nor are we engaged in the collection of meteorological data except in the course of specific environmental tests and studies, although our mission frequently requires the interpretation and presentation of data supplied by the Signal Corps, Weather Bureau, and Air Weather Service as well as data obtained from published sources. Other branches of geophysics such as geomagnetism, tectonics, auroras, and oceanography are similarly outside the scope of our activities.

The broad field that remains within the Quartermaster cognizance for Applied Environmental Research includes the study of various aspects of climate, terrain, and vegetation to the extent that these have a demonstrable relation to military problems of equipment, personnel, and operational functions. As most of these studies are essentially geographical, the results are often presented in the form of maps on which the distributional aspects of environmental phenomena are shown. It is apparent that our activities are not limited to problems of interest only to the Quartermaster Corps but rather that we offer service to all elements of the Army. It often happens that environmental data that we have assembled and analyzed for a specific purpose of the Quartermaster Corps or some other technical service are found to meet an unrelated need of some other service. For example, a compilation of the most recent temperature data for northern North America, where most of the stations have not been operating very long, was made at the request of Signal Corps for use in determining areas where cold might hamper the functioning of storage batteries; this information was found to meet so many other needs that two printings of the report were exhausted.

It might be noted at this point that the Quartermaster program in Applied Environmental Research is designed to meet two types of requirement. First, studies are conducted in response to requests for specific types of information needed for the solution of particular problems presented by various elements of the Quartermaster Corps or other technical services. Sometimes we have the information already at hand for a quick answer; at other times research is required to obtain the answer. Second, studies of a more long-range nature are conducted to anticipate future requirements and requests for information.

History of Environmental Research in the Quartermaster Corps

Prior to and during World War II, the environmental research conducted by the Quartermaster Corps was almost entirely concerned with the testing and issue of various items of supply. The exigencies of the war allowed little time for the type of research that is conducted today. In those days the published reports of the forerunners

of the Environmental Protection Research Division dealt entirely with tests, in the field or in cold chambers, of various items of clothing, rations, and field equipment. It was not until 1947 that the first Quartermaster report on the environment as such was published. In that same year a project designated "Study of Environmental Factors of Arctic Regions" was approved by the Quartermaster Corps Technical Committee and the War Department General Staff, officially recognizing Quartermaster's concern with the study of Arctic environments. However, mapping of climatic regions of the world—including the Arctic—as a basis for issuance of Army uniforms was started even before the United States became actively engaged in World War II. Dr. Siple was appointed consultant to the Quartermaster Corps in the summer of 1941. One of the first studies undertaken at his instigation was the preparation of a series of maps showing temperature variations in Arctic regions. When the Climatology Unit was established in the Office of the Quartermaster General it prepared a series of Climate Zone maps showing conditions in each continent by months. These maps, which were published in 1943 by the Army Map Service, have found wide use not only within the Quartermaster Corps but more recently as an instructional aid in many universities.

Between the end of World War II and the consolidation of Quartermaster research activities here at Natick in 1953, the wartime dispersal of activities continued—research on man's responses to the environment being conducted primarily at the Climatic Research Laboratory in Lawrence, Massachusetts, and research on the environment itself carried on by geographers and climatologists in Washington and nearby Cameron Station, Virginia. Since 1953 these activities have all been included in the program of the Environmental Protection Research Division at Natick. Both before and since the move to Natick a substantial part of the program was carried on under contract by various universities and other research institutions.

In the Quartermaster program of environmental research no sharp distinction is made between regions such as the Arctic and sub-Arctic. For administrative convenience our regional research activities are divided into a Polar and Mountain Section and a Tropic and Desert Section, but we recognize that there are deserts in the Arctic and there are cold mountains in the Tropics. Since our primary concern is with extreme environments, the Arctic and sub-Arctic have always received a considerable amount of attention in our program, but the emphasis has been on the distribution of cold environments wherever they occur. It has often been our policy to study particular elements of the environment (e.g. frequency of occurrence of given temperatures or the distribution of certain types of terrain) regardless of whether they exist in a particular geographical region. Thus our "cold environments" projects have included studies of such nearby places as Mt. Washington, New Hampshire, and Devils Lake, North

Dakota, both of which have a seasonally "Arctic" environment. Furthermore, many projects such as the Climate Zone maps have been developed on a continental or hemispheric basis.

The environmental studies that have been completed by the Quartermaster Corps fall into several categories. Between 1945 and 1951 a series of reports was prepared to show areas and months where specific items of clothing would be required. These were known as "clothing almanacs," and Arctic regions were included in those for Alaska, Greenland, the USSR, Northern Europe, and Canada.

Studies of the total natural environment have been made for certain areas that are used by the Department of the Army for testing of materiel. Arctic and sub-Arctic sites for which such studies have been conducted include Fort Greely, Fort Churchill, and Thule, Greenland. A related research program that has been essentially completed is the delineation of areas that are climatically analogous, with respect to one or more elements, with the more intensively used test sites. For cold regions, separate studies were made of northern North America and northern Eurasia to determine the degree to which Fort Churchill and Fort Greely can be said to represent those regions.

The environment of Greenland has received special attention in a series of regional studies of which the first—on Southeast Greenland—is now being printed. Other aspects of our Arctic research program that are still continuing will perhaps be more appropriately considered in connection with two over-all objectives: 1) the delimitation of areas according to their degree of cold stress, and 2) the delimitation of areas presenting special problems associated with terrain.

Determination of Cold Stress

Since extreme cold is the cause of many of the chief problems encountered by the Quartermaster Corps as well as other technical services in the Arctic—whether they are concerned with protection of the soldier or the functioning of a weapon or item of equipment—a large part of our environmental research is concerned with ways of representing the distribution, occurrence, and intensity of cold conditions. The first zonation of the world which the Quartermaster Corps used as a basis for issue of clothing was based largely on the distribution of mean monthly temperatures. Although such means can have considerable value when properly interpreted, they obviously do not fully indicate the requirements for protection from cold in a given area. More recently, areas of clothing issue have been based on the occurrence of minimum rather than mean temperatures, as a more realistic measure of cold stress.

Other more sophisticated measures are also being used by our climatologists to show the degree of cold stress in northern regions. In some situations a useful measure is the frequency of occurrence of given temperatures, expressed in per cent. Since the determination of

frequencies requires either a great deal of hand labor or processing by machine-records equipment, data have heretofore not been very plentiful. However, the Quartermaster Corps now has frequency tabulations of temperature and windspeed for 343 stations in the Northern Hemisphere, most of which were tabulated for us by the Air Weather Service at the National Weather Records Center. During the current year these tabulations have been published, under contract, by McGill University. Climatologists at McGill are now engaged in regionalizing the frequency values, and their results will soon be published in separate atlases for North America and Eurasia. These maps will be based not only on the data tabulations available from the 343 stations but also will use estimates obtained by a method developed here at Natick. This method gives reasonably accurate estimates of the frequency of low temperatures derived from more readily available climatic data. It illustrates one of the objectives of our research: to develop and use techniques for inferring environmental information concerning places for which field observations are not available.

Not only low temperatures in themselves are important, but the occurrence of such temperatures in combination with other elements, particularly wind, is especially significant for military planning. Windchill has received considerable attention in recent years and its significance has become widely recognized. The temperature frequency tabulations already mentioned include values of windspeed in various degrees of magnitude, which can be used to approximate mean windchill. Of course, for more accurate determinations simultaneous values of windspeed and temperature are needed. A method of predicting the frequency distribution of windchill, using simultaneous values over a relatively short period of record, has recently been developed here.

All of the climatic measurements so far discussed can be used for comparing widely separated regions having differing local conditions because the observations are made under standard conditions that minimize the effects of local terrain, soil, vegetation, and the presence or absence of snow cover. Yet these very factors constitute a large part of the environment in which the soldier and his equipment must function. Therefore a substantial part of our program of environmental research consists of study of the microclimate—referred to by various authors by such names as local climate, topoclimate, and climate near the ground. The term is considered by us to refer to the study of climatic differences not shown by standard observations, differences that may in some situations be considerable. For example, under a protective insulating cover of snow, ground temperatures may be only slightly below freezing while the air temperature recorded at standard height (man-high) may be as much as 80°F lower. Even at standard height, horizontal differences between the temperature of a valley station and a nearby slope station may be on the order of

80°F. Microclimatic measurements have been made by Signal Corps teams, at the request of the Quartermaster Corps, in various types of extreme environments from tropical to sub-Arctic. A very detailed comparison of the microclimate of two points near Fort Greely, Alaska—one wooded and the other in a clearing—was made by a Quartermaster Investigator with the cooperation of the Signal Corps. Some of the most intensive observations of this type that have been made in cold environments were those taken by one of our staff members during two years in the Antarctic. When the analysis of these data is completed it is expected to show relationships that will also be applicable to situations in the Arctic. It is hoped that when such studies are available for representative types of cold environments it will be possible to predict the type of climate that will be found near the ground in a given locality when the macroclimate and conditions of terrain are known.

Terrain Problems in Northern Regions

Surface conditions in the Arctic and sub-Arctic offer a contrast to climate in their relation to military activities in that they become a special problem chiefly in summer rather than in winter. Therefore the Quartermaster has a year-round interest in problems of northern environments. Under our cognizance for Applied Environmental Research we recently undertook, at the request of the Transportation Corps, an investigation of the problem of muskeg as an obstacle to military movement in the North. This is a subject of great importance to the Army, though as yet it has not been intensively studied in its geographical aspects. However, a knowledge of where and when difficult surface conditions exist is necessary for planning an adequate capability for year-round overland movement in the North. In recent years muskeg has been increasingly studied by engineers and botanists in Canada, but even the Canadian researches fall far short of the effort that is expended in this field in Russia. To illustrate, the Peat Institute at Moscow is said to have a full-time staff of 400 and about a thousand students. By comparison our efforts seem rather meager, but a start has been made by reviewing the state of knowledge of muskeg and other organic terrains and determining some desirable directions for future research. The study of military aspects of muskeg involves questions of photo-interpretation, plant ecology, effects of human activities, and relations of bogs to climate and permafrost, offering a wide scope for interdisciplinary research.

Like vegetation, the animal life of a region bears a close relationship to its terrain. And like the problems of soft terrain, some types of Arctic fauna, especially insects, constitute a problem peculiar to the summertime. This summer situation is associated with the poor drainage that characterizes much of the Arctic, which thus shares certain problems usually regarded as characteristically tropical. Quartermaster investigations of the problem of insects in the Arctic

go back to a study that was conducted in 1949 on "weather and Alaskan insects." This was followed by preparation of a comprehensive bibliography on the relation of mosquitoes to vegetation on the Eurasian Arctic and sub-Arctic. Since then a long-range program for the study of the geographical distribution of insects and related organisms has been undertaken by Cornell University under a Quartermaster contract. Although not primarily an Arctic study, portions covering Alaska and Canada have been completed with tabulations of the distribution, habitat, and period of activity of all of the species known to affect man. A similar treatment for Greenland and adjacent islands is planned.

One additional aspect of Arctic terrain should be mentioned here. The distinctive terrain type presented by glaciers, while not limited to the Arctic, is found most commonly in northern regions. A comprehensive study of the geographical distribution of glaciers in the Northern Hemisphere was sponsored by the Quartermaster Corps and conducted by the American Geographical Society. The result is a definitive work, including maps and bibliographies, summarizing the known information on this subject.

Conclusion

In conclusion it should be pointed out that I have not attempted to cover every phase of the research that the Quartermaster Corps has conducted in Arctic environments, but rather I have outlined the major programs or areas of investigation with which we have been concerned and the nature of our results so far. I would like to stress again the interservice nature of many of our efforts in this field, involving close cooperation between the Quartermaster Corps and the Signal Corps, Transportation Corps, Corps of Engineers, Air Force, and other agencies of the Defense Establishment. Quartermaster geographers and climatologists have participated in operations sponsored by the Air Force and other technical services of the Army, as well as in projects that were planned for the testing of Quartermaster items.

It is apparent from the foregoing remarks that the field of Applied Environmental Research in the Arctic offers a wide scope for research activities, requiring a flexible approach to meet the changing needs of the Army. By continuing re-examination of our program in the light of these needs, we hope to make a maximum contribution to the efficiency and capability of military units living and operating in the Arctic.

SESSION No. 3

THEME: SCIENTIFIC APPROACHES TO SOLVING THE PROBLEMS OF MAN LIVING IN THE ARCTIC

CARL R. EKLUND, *presiding*

CHAIRMAN EKLUND: This session will be devoted to a discussion of the physiological and psychological problems of the individual living in the Arctic and the scientific means that can be taken to solve these problems. Our first speaker, Colonel Joseph Blair, has long been interested in Polar research. Right after the war he was assigned to a project to improve the thermal boot and that was one of his first research problems concerning the cold. At one time he was Director of the Army Medical Research Laboratory at Fort Knox and is now the Medical Corps representative to the Tripartite Group in Canada. The Army has been fortunate to have a man with Colonel Blair's interest in and knowledge of the problems of the individual living in the Arctic, and it is our pleasure to have him here today to discuss "Health Maintenance".

HEALTH MAINTENANCE

COLONEL JOSEPH R. BLAIR

Medical Corps

**U. S. Army Standardization Group
Ottawa, Ontario, Canada**

Introduction

Health maintenance has been and will continue to be one of the major problems of man living in the Arctic. For people living in the "Far North" maintenance of health can follow no fixed set of rules because of the great variety of conditions to be found there; and research is yet to find answers to many of our questions.

If a man is living in a modern community or military base in the Arctic, many of his health problems have been solved by the movement of civilization into the Arctic area. But man's health problems in the Arctic are many if he is a member of a small isolated group or living in a survival situation somewhere in the "Far North". It is with these latter groups that this presentation will be primarily concerned.

Probably in no part of the world do environmental conditions vary so greatly as in the Arctic—from season to season and in different geographical areas. The Arctic summer presents health problems largely non-existent during the winter months; for example, some of these problems include immobility over Arctic muskeg and the presence of huge numbers of biting insects—mosquitoes, deer flies, etc. Insect control is a major summer problem in the Arctic. A high priority research project of the Army Medical Service is the development of a safe and effective oral insect repellent. It would be a chemical agent taken by mouth and excreted through the sweat glands to

WEATHER STATION	YEARS OF DATA	JANUARY AVERAGES		MINIMUM TEMP (°F)	FROST FREE DAYS
		TEMP (°F)	PRECIP (IN.)		
VERKHNOYANSK, U.S.S.R.	38	- 58	0.16	-90	—
CHURCHILL, CANADA	12	- 19	0.48	-57	52
BARROW, ALASKA	25	- 17	0.15	-56	17
FAIRBANKS, ALASKA	34	- 12	0.97	-66	89
GOOTHAAS, GREENLAND	44	+ 14	3.27	-20	—
ADAK, ALEUTIANS	12	+ 33	6.53	+ 8	165
LANGDON, NO. DAK.	35	- 1	0.63	-51	110
CHICAGO, ILLINOIS	40	+ 25	1.75	-23	196

FIGURE 1. Climatic data at various Arctic and U. S. Weather Stations.

repel insects. It would always be present—not washed off by the rain or rubbed off on the clothing.

Winter in Arctic areas, though eliminating biting insects, creates even more difficult health problems largely associated with the snow and extreme cold. Research programs directed toward maintenance of health and efficiency of personnel in the Arctic must be planned to most widely varying climatic conditions, as shown in Fig. 1:

1. "Wet-cold" of the Aleutians (Adak) where the winter temperatures are warmer than those of northern United States, but produce a severe cold stress on personnel because of the heavy precipitation and high winds present.
2. Dry intense cold of Siberia (Verkhoyansk) and interior Alaska (Fairbanks).
3. Severe "windchill" (combination of low temperatures and high winds) of Churchill and Barrow.

Such temperature extremes present a formidable environment for efficient functioning or even survival of mankind. Effectiveness of man living under such Arctic conditions is largely dependent upon a combination of training, Arctic equipment, and climatic adaptation.

Fig. 2, showing performance of Signal Corps personnel in operation of radar, radio, and switchboard equipment under Arctic conditions, demonstrates that efficiency is affected both by Arctic mittens

and cold exposure (1). Performance in each case could be improved by the development of better mittens and by more complete adaptation of man to the cold.

There are five factors which determine the state of health and efficiency of man living in the Arctic. Research designed to improve any of these will result in an over-all higher level of health and performance. These five factors for maintenance of health in the Arctic are: 1) Selection and training of personnel; 2) Environmental protection of personnel; 3) Adequate supply of food and water; 4) Proper waste disposal; 5) Management of medical emergencies.

Selection and Training of Personnel for Arctic Duty

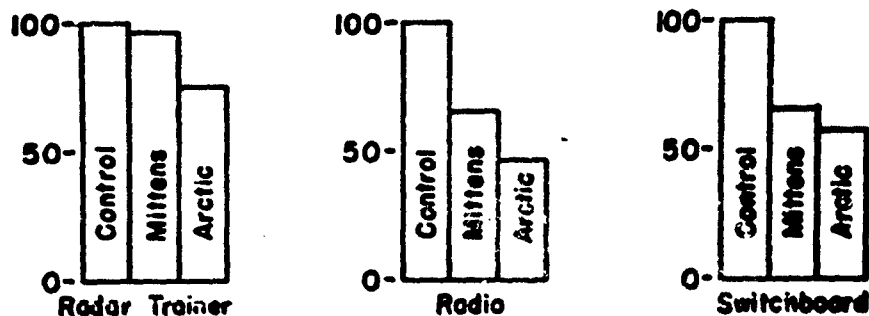
More knowledge is badly needed on the best methods of selection of personnel for Arctic duty, for we know that the elimination of unfit personnel will prevent many problems from ever occurring.

Present knowledge indicates that the following groups are probably unfit for duty in the Arctic:

1. Individuals suffering from circulatory disorders of the extremities (Buerger's disease, Reynard syndrome, arterio-sclerosis).
2. Persons with history of previous severe cold injury; they are twice as susceptible to cold injury as other individuals.

AVERAGE EFFICIENCY

(Percent of Normal)



Controls - in fatigues at 23° C

Mittens - in fatigues & mittens at 23° C

Arctic - in arctic clothing first hour at -15° C

FIGURE 2. Effect of Arctic conditions upon operational efficiency of Signal Corps personnel. From Blair and Gottschalk (1).

3. Persons showing mental instability—a condition which will be increased by the isolation and severe stresses of Arctic duty.
4. Persons belonging to certain racial groups which show an unusually high susceptibility to cold injury. Cold injury experience in Korea revealed that Negroes and Puerto Ricans were six times more likely to suffer cold injuries.

Combat experience in World War II and the Korean conflict has taught us that the "best bet" for Arctic duty is a healthy stable young man who grew up in the rural area of one of our northern states.

Also there must be developed the best possible training program for people on assignment to the Arctic. This training must include physical conditioning and acclimatization in a cold climate. Dr. Davis (2) and his associates at the U. S. Army Medical Research Laboratory have shown that such a program of acclimatization to cold will increase a man's efficiency, endurance, and probably his resistance to the harmful effects of cold. Fig. 3 (from Davis) indicates that there

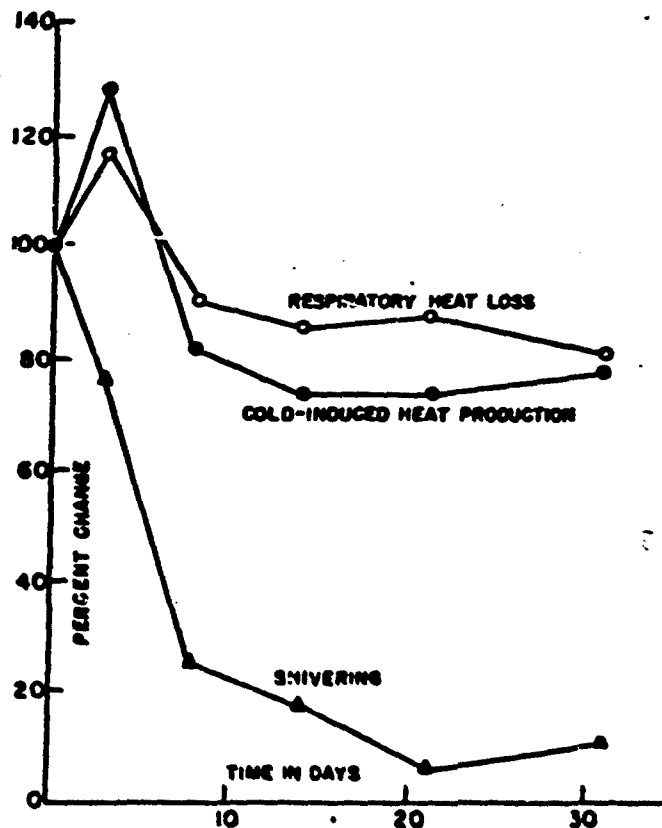


FIGURE 3. Shivering, heat production, and respiratory heat loss in unclothed man exposed to a cold environment (12°C) over a 30-day period. From Davis (2).

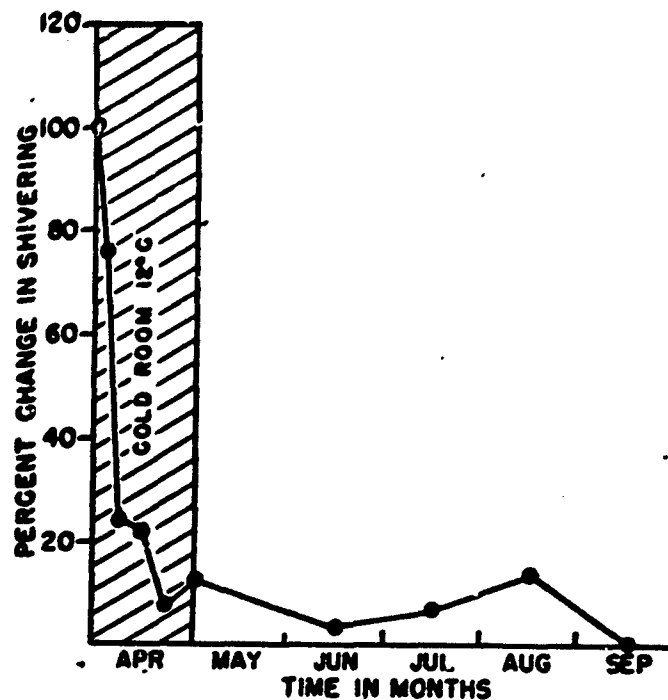


FIGURE 4. Shivering during a 5-month period of men acclimatized to 12°C over a 30-day period. From Davis (2).

is a definite decrease in shivering and in heat production as a man is acclimatized to an environment of 12°C over a 30-day period. Fig. 4 demonstrates that such acclimatization may persist for at least 6 months. These studies support the thesis that man can be conditioned for more effective performance in a cold environment.

Similar changes have been observed in animals (rats and rabbits) and are associated with a definite increase in resistance to the harmful effects of cold exposure (3). Fig. 5 compares cold injuries suffered by non-acclimatized rats and previously "cold-acclimatized" rats (to 23°F for fifty days) after 5 hours exposure at 5°F . The cold-acclimatized rats tolerated this period of exposure without harmful effects, namely, hypothermia and cold injury (frostbite). On the other hand, all non-acclimatized animals suffered progressive hypothermia and frostbite. Fig. 6 shows the type and degree of cold injuries incurred by the non-acclimatized rats.

Fig. 7 compares the survival times of non-acclimatized and cold-acclimatized rats when exposed to -15°C (5°F) until death occurs. Mean survival time for the non-acclimatized rat was 10.1 hours compared to 35.8 hours for the cold-acclimatized rat, representing an increase of 254%. These observations show that animals, under

NORMAL (NON-ACCLIMATIZED) RATS				"COLD-ACCLIMATIZED" RATS			
RAT NO.	COLD INJURY			RAT NO.	COLD INJURY		
	EARS	FEET	TAIL		EARS	FEET	TAIL
9-A	0	0	+++	1-B	0	0	0
10-A	0	0	+++	2-A	0	0	0
10-B	+	+	+++	2-B	0	0	0
11-A	+	++	+++	3-A	0	0	0
11-B	0	+	+++	17-A	0	0	+
12-A	0	+	+++	17-B	0	0	0
12-B	0	0	++	18-A	0	0	0
13-A	0	+	++	18-B	0	0	0
13-B	+	+++	+++	19-A	0	0	0
15-A	0	+	+++	19-B	0	0	0
15-B	0	0	+	20-A	0	0	0
16-B	0	0	++	20-B	0	0	0

+ = FIRST-DEGREE FROSTBITE (ERYTHEMA AND SWELLING).
 ++ = SECOND-DEGREE FROSTBITE (BLISTERING AND FISSURING).
 +++ = THIRD-DEGREE FROSTBITE (GANGRENE AND TISSUE LOSS).

FIGURE 5. Cold injury of normal and cold-acclimatized (to 23°F for 50 days) rats following five hours exposure at 5°F. From Blair (3).

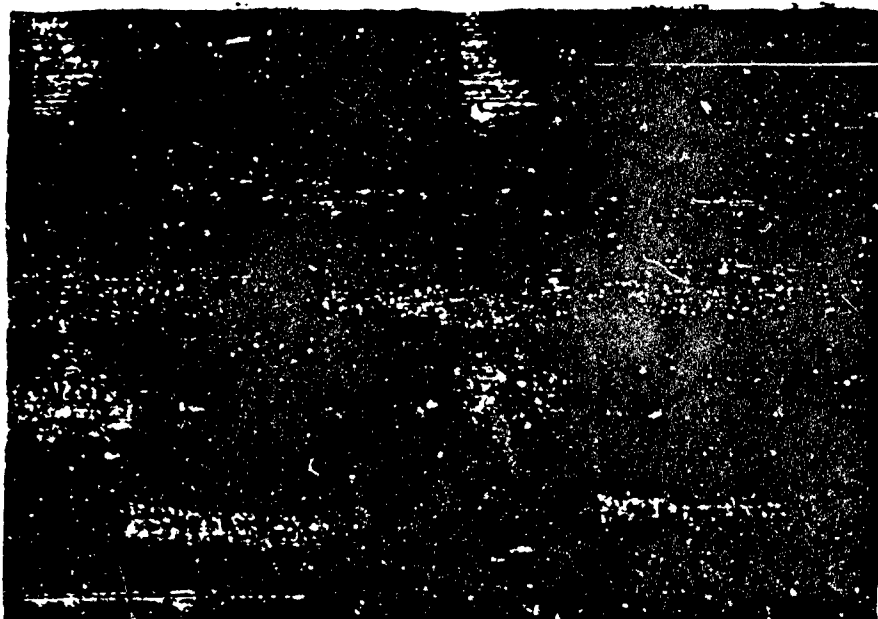


FIGURE 6. Photographs of tails of normal and cold-acclimatized (to 23°F for 50 days) rats taken two weeks after five hours exposure at 5°F. From Blair (3).

"NON-ACCLIMATIZED" RATS				"COLD-ACCLIMATIZED" RATS			
WRS. EX- POSURE	ALIVE	DEAD	% SUR- VIVAL	WRS. EX- POSURE	ALIVE	DEAD	% SUR- VIVAL
0	18	0	100	0	18	0	100
12	4	14	22.2	12	18	0	100
24	0	18	0.0	24	18	0	100
36	-	-	-	36	6	12	33.3
48	-	-	-	48	2	16	11.1
60	-	-	-	60	0	18	0.0

FIGURE 7. Survival times of normal and cold-acclimatized (to 23°F for 50 days) rats when exposed to 5°F - till death occurred. From Blair (3).

appropriate conditioning to moderate cold, acquire an unusual resistance to the pathological effects (hypothermia, frostbite, death) of severe cold exposure. Of course, the important question is: How far do these animal studies apply to man in increasing his resistance to cold?

Environmental Protection of Personnel

Dr. Kennedy, in his presentation, has already discussed many aspects of this subject, therefore I shall take time to state only a few pertinent facts. It is certainly of great importance to a man's health

Date and time	Outside air 3 ft. above snow surface	Ground surface beneath uninsulated snow, 30 ft. from snow shelter	Interior of snow shelter		
			Top	Centre	Floor
Feb. 28, 1938 1530	-17	+19	+16	+13	+16
Feb. 29, 1938 0815	-35	+30	+20	+20	+19
March 1, 1938 0800	-40	+19	+18	+18	+19
March 3, 1938 0800	-36	+16	+16	+16	+16
1630	-12	+17	+15	+14	+16

FIGURE 8. Temperatures of unoccupied snow shelter and environs (°F). From Elsner and Pruitt (4).

that he be given adequate protection against the climatic stresses of the Arctic, especially during the winter months. This protection applies to both shelter and clothing. In an Arctic survival situation protection from wind and use of ground warmth are primary considerations for any shelter. Fig. 8, taken from a paper by Elsner and Pruitt (4), shows that a snow shelter, excavated down to ground level, will assume thermal equilibrium with the ground. Such a shelter, together with its protection from the wind, will give its occupant a very great thermal advantage over the external environment—in this case, up to 60°F. Ground warmth should always be utilized to maximum advantage as a source of heat in the Arctic.

Adequate Supply of Food and Water

An adequate supply of pure food and water is essential to maintenance of health in the Arctic. People assigned to duty in the Far North who sleep in well-heated barracks and carry on sedentary activities in warm buildings often receive but certainly do not require any additional calorie intake over that of similarly employed personnel in temperate zones. But such is not true of men engaged in strenuous outdoor physical activity in the Arctic. They require additional calories because of increased metabolism from cold exposure and heavy

GEOGRAPHICAL LOCATION	MEAN TEMP. (IN °F.)	TOTAL CALORIES	CALORIES SUPPLIED BY		
			PROTEIN	CARBO- HYDRATE	FATS
<u>ARCTIC:</u>					
CHURCHILL, CANADA	- 17	3,235	12%	46%	42%
OPERATION MUSKOK	+ 5	4,400	13%	45%	42%
<u>TEMPERATE:</u>					
CAMP CARSON, COL.	65	3,900	14%	42%	44%
U.S. TRAINING CAMPS	—	3,790	13%	44%	43%
<u>TROPICS:</u>					
PACIFIC ISLANDS	79	3,400	13%	34%	33%
38 TH DIV., LUZON	83	3,200	13%	34%	33%

FIGURE 8. Environment and food intake in man. From Johnson and Kark (5).

physical work in Arctic clothing. The papers of Johnson and Kark (5), LeBlanc (6), Welch, Buskirk, and Lamplero (7) have given us much information on the effect of climate and temperature on the food and water requirement in man. But further information on work load and energy expenditures for various Arctic tasks must be obtained before the optimum nutritional requirements for various types of Arctic duty can be established.

Fig. 9, compiled from world-wide nutrition surveys by Kark and Johnson, gives some idea of nutritional requirements in the Arctic as compared to temperate and tropical areas. The validity of this data as applying to all Arctic areas and conditions is open to question and needs further evaluation.

During the 1957 winter exercises held in Alaska, one of the most important observations was the apparent dehydration of many soldiers, resulting in decreased effectiveness, fatigability, and constipation. This dehydration was probably due to water loss through sweating, cold diuresis, and in the expired air—without adequate replacement because of lack of easily available water and the absence of a strong thirst drive in extreme cold.

That there is a minimal water requirement for maintenance of health in the Arctic can be seen from Fig. 10. These data, compiled from many research reports, show water exchange in soldiers under arctic, temperate, tropical, and desert conditions. Arctic studies at Adak, Fairbanks, and Churchill indicate that soldiers need two liters of water daily in food and drink to maintain a healthy state. Efforts should be made to devise better methods of supplying and distributing drinking water to field troops in the Arctic.

Place	Mean Temp°F	Water in Drink Liters	Water in Food Liters	Urine Vol. Liters	Sweat Vol. Liters
Adak	23	1.16	0.75	1.27	—
Fairbanks	17	1.20	1.13	1.20	—
Churchill	-20	1.20	0.99	1.15	0.85*
Knox	41	2.05	0.91	1.74	0.67*
Desert**	85	5.90	—	0.94	4.95
Tropics**	80	3.26	—	0.92	2.33

* Calculated from weight loss

** Data from Adolph et al.

FIGURE 10. Environment and mean daily water exchanges in man.

Proper Waste Disposal

In Arctic military posts waste disposal is not a problem to the individual soldier, but one for the Post Engineer. However, in the field great care must be taken to dispose of waste properly so that it will not become a hazard to the health of all concerned. Newer and better methods of waste disposal should be constantly sought. Disposal of human excreta is always an Arctic problem. It has been for years and will probably remain so for some time. At present there is no better method for the individual soldier than that employed for many years—collecting in containers and then chemically treating or burning before depositing on the terrain.

Management of Medical Emergencies

All first aid and health procedures normally employed in temperate and tropical areas apply equally well in the Arctic but may be more difficult of application because of the extreme cold and the heavy clothing. However, there are certain medical conditions that are more common or more likely to occur in Arctic and Antarctic areas than in other parts of the world. Among these are cold injuries, snow blindness, and carbon monoxide poisoning.

Prolonged exposure to cold without proper protection and care of the extremities may result in severe cold injuries, such as the approximately 100,000 cases of trench foot suffered by our troops in World War II and the severe frostbite experience in Korea. Either could have been prevented to a large degree had adequate preventive measures been carried out by the individual and the command.

Fig. 11 shows a cold exposure graph, a modification of the original windchill chart of Siple (8). This graph suggests under what weather conditions stringent frostbite or trench foot preventive measures should be carried out. A much more accurate chart can be developed when more knowledge of the epidemiology of cold injury becomes available. Among the preventive measures that may be carried out are: 1) Proper use of cold weather equipment; 2) Drying of clothing and replacing wet socks; 3) Exercise of the extremities; 4) Rest and rewarming; 5) Examining the face, hands, and feet for the first signs of cold injury. That a cold injury prevention program can be very effective is shown by the almost total absence of cold injury in Antarctic operations effected by the preventive medicine program of the Deepfreeze Task Force Surgeon and his staff.

When cold injury does occur, it is mandatory that proper first aid and early treatment be given. Clinical experience with cold injuries in Korea during the winter of 1950-51 (9) has given us certain basic principles of cold injury therapy, as follows:

1. Immediately remove or loosen any constricting clothing, such as boots, gloves, or socks.

2. Avoid trauma to injured part—all casualties with involvement of the lower extremities must be treated as litter cases.
3. Rapidly rewarm frozen part in warm water (45°C or 113°F), or if unavailable, use body heat to thaw part.
4. Walking, massage, exposure to open fire, or rubbing with snow are contraindicated.
5. Give booster dose of tetanus toxoid.
6. Administer penicillin or broad spectrum antibiotics as prophylaxis against infection.
7. Leave all vesicles or bullae intact—only cover with dry gauze for protection.
8. Apply no pressure or petrolatum-impregnated dressings.
9. Maintain general body warmth and encourage sleep and rest.
10. Smoking prohibited.
11. Active physiotherapy (whirlpool baths, Buerger's exercises) should be instituted as early as possible.
12. No surgery should be performed until definitely indicated, such as in the following cases:
 - a. Superficial debridement of necrotic tissue in presence of frank or threatened suppuration.
 - b. Amputation in cases of extensive "wet gangrene" with lymphadenopathy and general infection.

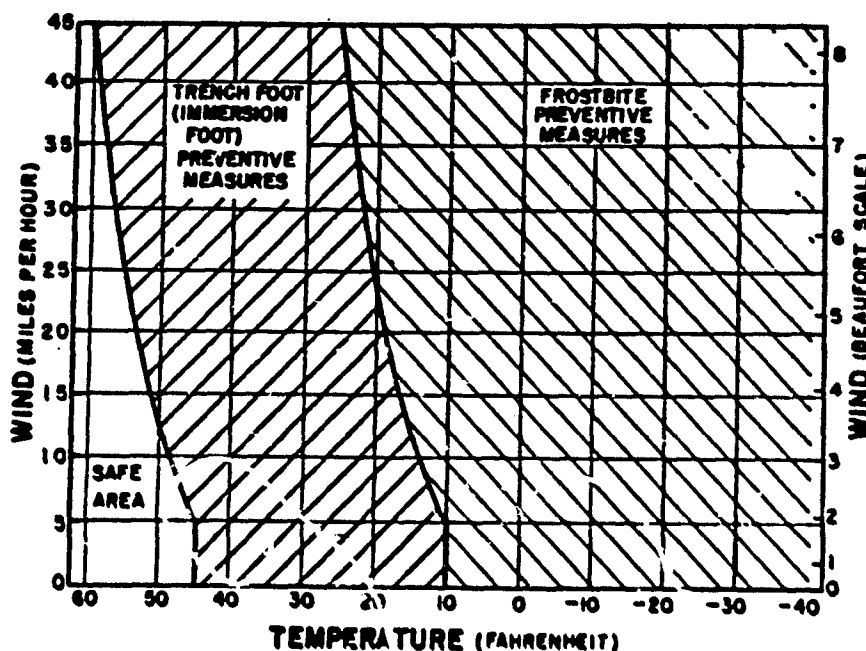


FIGURE 11. Cold exposure graph for prevention of cold injuries.

We should continually explore every possibility in the treatment of cold injury to insure that the best knowledge of medical science is employed in the management of this important military medical problem.

One of the most disabling conditions that may be encountered by man living in the Arctic is snow-blindness. This condition is a painful inflammation of the eye caused by sunburn from ultraviolet rays reflected up from the snow. The position of the eye, together with the eyebrows and eyelashes, protect the eye from the direct rays of the sun but not from snow-reflected rays. Such protection can be accomplished only by wearing dark glasses when outside in Arctic daylight. If one's sunglasses are lost or broken, new ones may be improvised by cutting a narrow horizontal slit in pieces of leather, cloth, or wood, and then tying same in front of the eyes. This has been done by Eskimos for many years and will give adequate protection against snow-blindness. The U. S. Navy has developed in the Antarctic a sunglass which not only prevents snow-blindness but increases contrast and depth perception under "white-out" conditions.

Carbon monoxide is a deadly peril to man living in the Arctic. In small, tight shelters, heated by poorly ventilated stoves, it causes more accidental deaths in the Arctic than any other hazard. Fig. 12 shows the danger levels of carbon monoxide acting over certain periods of time. But since carbon monoxide is an odorless, colorless, tasteless, non-irritating gas, one is seldom aware of these danger levels until he is in serious physical difficulty. A simple alarm system is needed to give adequate warning to unsuspecting victims before it is too late.

In conclusion, it must be pointed out that the secret of good health in the Arctic lies in prevention, not cure. It is in this direction that our research should be oriented. Simple protective measures, which anyone can apply, will keep a person in good health and physically effective. Only the untrained and undisciplined individual becomes unfit as the result of living in the Arctic.

EXPOSURE	10 PPM	Not Perceptible	Absolutely Safe	SAFE	SAFE	Death
	20 PPM	No Apparent Effect	Not Perceptible	SLIGHTLY HAZARDOUS	HAZARDOUS	Death
	30 PPM	No Apparent Effect	No Apparent Effect	HAZARDOUS	HAZARDOUS	Death
	100 PPM	No Apparent Effect	No Apparent Effect	HAZARDOUS	HAZARDOUS	HAZARDOUS
	200 PPM	No Apparent Effect	No Apparent Effect	HAZARDOUS	HAZARDOUS	HAZARDOUS
	0 PPM	30 PPM	100 PPM	200 PPM	400 PPM	1000 PPM

FIGURE 12. Physiologic effects on man of different concentrations of carbon monoxide.

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CHAIRMAN EKLUND: Our next speaker, Dr. Otto Edholm is well known to any of you who have been concerned with human physiology in cold environments. He has been a leader in the United Kingdom in civilian and military research in cold adaptation. He has written extensively on the subject and is a recognized authority in the field. At present he is a Director of the Division of Human Physiology at the National Institute of Medical Research in London. It is my privilege and pleasure to give you Dr. Otto Edholm.

PHYSIOLOGICAL PROBLEMS IN POLAR REGIONS

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This paper will deal briefly with some aspects of Polar physiology as they have been studied in recent years by members or associates of the Division of Human Physiology of the British Medical Research Council. Mention will also be made of plans for future work. There has been developed a close connection between the Medical Research Council and the Falkland Islands Dependencies Survey (F.I.D.S.). The survey, which is under the direction of Sir Vivian Fuchs, has maintained for many years a number of bases on the Antarctic Continent, in Graham Land. Recently F.I.D.S. has also taken over the base at Halley Bay originally established by the Royal Society for the International Geophysical Year (see map, Fig. 1).

A number of the medical officers recruited for F.I.D.S. have been trained at the Division of Human Physiology, several members of which have polar experience. Dr. H. E. Lewis spent a year with the British North Greenland Expedition. Dr. R. Goldsmith was medical

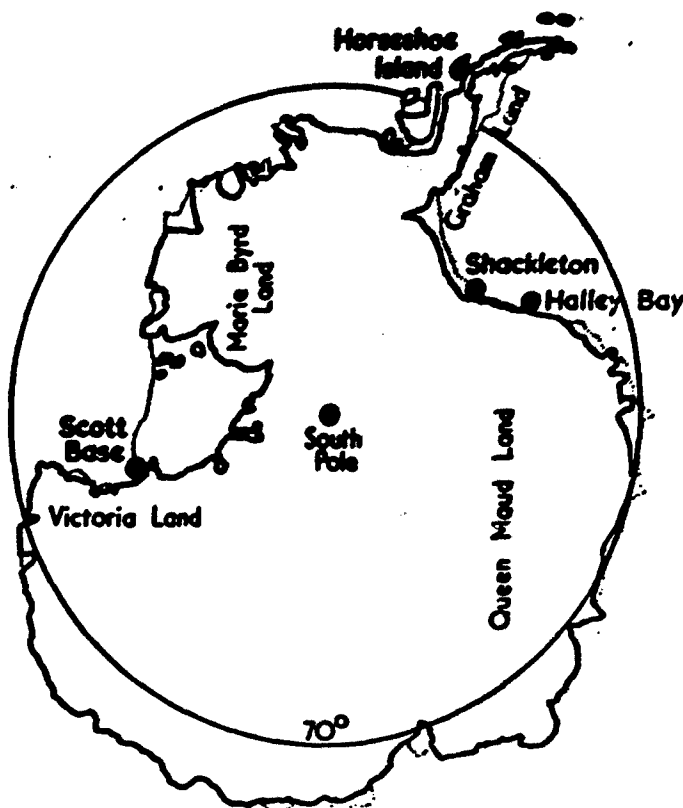


FIGURE 1. Map of Antarctic Continent indicating some of the bases at which physiological observations have been made.

officer for the first-year party of the Trans-Antarctic Expedition. Dr. H. Wyatt spent two years in Graham Land.

The medical officers spend one to two years in the Antarctic making observations on members of their base. Adequate radio contact is maintained, and problems arising in the course of the investigation can be discussed. On return from the South, the results are worked up in the Division of Human Physiology. In this way a considerable volume of data has been acquired, although most of these data deal necessarily with very simple measurements.

Experience in the problems of Polar physiology was gained by Lewis and Masterton, who formed a joint Physiological Medical Team with the British North Greenland Expedition of 1952-54. A number of different factors were studied and included Basal Metabolic Rate; haemoglobin, cell counts, cell fragility; physical fitness assessment, energy expenditure and food intake, body weight and skinfold thickness, and sleep rhythms. The expedition was completely isolated for the greater part of the year, but in the summer a relief party was

flown in to replace some 7 men of the original 29 who were returning to England. This made possible some useful comparisons between first and second year men. In the Antarctic bases the men are isolated for periods of nine to eleven months. In certain cases relief has been difficult owing to ice conditions. Generally there are a number of men who stay over for two years, thus there is usually a mixture of first and second year men.

There are considerable advantages for physiologists in Polar regions. There is a small community physically isolated except for radio for the greater part of the year. Subjects are available for measurement during all of this time, except when on sledging parties. Furthermore, the physiologist can be on the job the whole time. This has made it possible to get extended series of observations which are virtually unique. For example, the measurements made in Greenland on weight changes and skinfold thickness can be quoted (1). Regular records were kept of 26 men for two years. There was evidence of a small seasonal change in body weight and subcutaneous fat thickness. However, no comparable data covering such a range of observations in temperate countries have been found, and it was difficult to know whether a seasonal change in body weight might be a usual observation. A check was obtained by examining the average body weight of recruits on entry to the British Army. Intakes of recruits were received every two weeks throughout the year. Average body weight was similar in all intakes and there was no evidence of a seasonal trend. This example is intended to illustrate the fact that extended series of simple observations on normal human subjects are difficult to obtain and that there is a valuable opportunity offered to make such studies under Polar conditions.

The work which has been done so far has been mainly concerned with attempts to obtain evidence of acclimatization to cold in man. Apart from local response of the hands and feet to cold, where adaptive changes do appear, the results as far as acclimatization is concerned are negative. Some of these results are briefly discussed in a recent report (2).

It gradually became evident that much more detailed knowledge was required of the life and activities of men in these Polar bases. In particular, answers were needed to such questions: "How cold do men become in the Antarctic?" "What is the degree and duration of cold exposure?" "How does the environment affect the performance of physical work?" "How hard do men have to work?"

Dr. Norman has completed a year of such studies at Halley Bay, and a similar investigation was carried out by Dr. Cumming at the Argentine Islands off Graham Land. Both of these bases are essentially static, being concerned with meteorology, high altitude physics, some geology, and surveying. No long sledging journeys were made—at Halley Bay a few trips were made with manhauling sledges as there were no dogs; in the Argentine Islands outdoor activities were largely

recreational and included skiing. A full account of the work will be published later, but some of the main findings which are of importance in the study of human physiology can be briefly described. Four subjects were studied throughout the year for a day each month. A complete time and motion record was kept of activities and of time spent indoors and outdoors. In addition, the environmental conditions inside and outside were measured, including temperature and windspeed. Each subject wore a vest consisting of a resistance thermometer woven into a garment so the sub-clothing temperature could be measured at frequent intervals (3). Similar studies were also made during sledging journeys.

The year was divided into "dark" and "light" months, i.e. May to October as the dark or winter months and November to April the light or summer months. The average time spent outside was 13% in the summer and 5% in the winter at Halley Bay. In the Argentine Islands, outside time was 8% in winter and 15% in summer. Though the time out of doors was related to outside temperature, it was more closely related to windchill. Except for an emergency, outside activity ceased as soon as the wind speed reached 15 knots. The average temperature inside the base hut was 20°C, and the mean exposure temperature for the whole year was 13°C at Halley Bay. In the Argentine Islands the latter temperature was lower (11.5°C), and the bunk room temperature was much lower than 20°C. The sub-clothing temperature, which is almost identical with skin temperature (4), averaged 32.2°C at Halley Bay and 32.5°C in the Argentine Islands.

The figures obtained at Halley Bay and in the Argentine Islands are very similar although there is a difference of 10° in latitude. The computed energy expenditure is higher for the Argentine Islands than for Halley Bay, the annual average being 3,500 kcal and 3,300 kcal, respectively. It was possible to be out of doors skiing and climbing for rather longer periods in the Argentine Islands than in Halley Bay, and this accounts for the higher energy expenditure.

The energy expenditure during sledging was estimated to be approximately 5,000 kcal which is nearly identical with the estimate made by Masterton, Lewis, and Widdowson (5) for sledging in North Greenland. The sub-clothing temperature during sledging was irregular and tended to fall when activity diminished. Shivering out of doors was not observed.

Some tentative conclusions can be drawn from these observations of Norman and Cumming and from other data obtained at other Antarctic bases. At static bases, the time spent out of doors is short and is related to windchill. Men are adequately dressed for the climate and do not experience body cooling except for brief periods. Under the conditions studied, the degree of cold exposure is unlikely to be adequate to stimulate any physiological adaptation to cold.

Estimates of energy expenditure give figures which are comparable with those of military personnel both in the United Kingdom and the

U.S.A. Sledging is an activity with a high energy expenditure. However, it can be provisionally concluded that the relatively high energy expenditure, and hence high food intake, is due to the demands made by the environment and the work required to meet these demands, rather than a direct effect of cold stimulating metabolism.

The problems of physical work in Polar regions have only been studied indirectly. The opinion of those who have made time and motion studies is that heavy work, such as load carrying and digging, is carried out as efficiently in Polar as in temperate climates. With high wind and drifting snow, work can be slowed because snow can accumulate in apertures of the clothing. Manipulative work, in which delicate work with the hands must be done, is frequently much slower in the cold. The ability to work in the cold with bare hands or wearing thin gloves varies greatly among individuals. As an example of the slowing of fine work, Norman describes the taking of magnetic observations by two men using an instrument which required delicate manipulation. The particular operation was usually completed within 15 minutes at temperatures about -20°C . On one occasion when the temperature dropped to -33°C , the same operation required 50 minutes. It has been suggested that even with fine manipulative work it is not the time spent on the job itself which becomes longer, but that, as temperatures fall, an increasing length of time is spent in rewarming the hands.

Mackworth (6) has shown that local adaptation to cold can develop in the hands, and this finding has been confirmed by Massey (7) in the Antarctic. Further work is needed, however, to establish how such local adaptation improves the ability to work in the cold. A moderate number of subjects will be required for such a study because of the wide variation among individuals.

This brief account of some of the work currently being undertaken by the Division of Human Physiology in the Antarctic has been given as an introduction to the wider problem of the range of physiological investigations which could fruitfully be carried out in Polar regions. Some suggestions concerning further work are therefore given.

1. *Repetition of activity and exposure study.* The work of Norman and Cumming indicates very convincingly that man effectively shields himself from a cold environment by use of clothing and shelter. In particular, the time spent out of doors is short. These findings need to be checked by studies at bases where more traveling is done and where outside activity is likely to be much longer in time. It would clearly be important for such studies to be made at U.S.A. bases as well as British ones. Such studies would gain in value if agreement could be reached on the methods to be employed.

2. *Problems of outdoor work in the cold.* A comprehensive review of the problem of hand protection and hand function in the cold was published in 1957 by the Advisory Board on Quartermaster Research and Development (8). This report was based largely on laboratory

work and field trials of handgear. It is still necessary to make more observations in the field to determine the actual conditions under which work is done and the limitations experienced.

3. *Windchill.* The evaluation of meteorological data in terms of the cooling effects on man is still far from adequate. Siple's windchill scale has proved to be of considerable value, but a revision is overdue since it is clear that the effect of windchill is exaggerated at least in the larger figures for windchill.

4. *Energy expenditure and food intake.* Dr. Austin Henschel has already discussed the food intake of men in the cold (see p. 68). His conclusion, which is shared by many, was that there is no demonstrable effect of cold climates on food intake. However, there does appear to be a need for further investigation. The surveys described by Dr. Henschel were made on men under carefully controlled conditions. The activity pattern was in most respects dictated. In addition, information is needed on what men actually do in the Arctic or Antarctic and on what they eat under such conditions, particularly over long periods. Such a study would be difficult and laborious since it would require a sizable team to spend a great deal of time in the field. It is undoubtedly important to get such information if only to resolve the present controversy on the importance of cold on food intake. The figures available from studies at Polar bases indicate that energy expenditure and food intake are moderately high. If Norman and Cumming's results are confirmed at other Polar bases, then the question of the effect of cold on food consumption becomes academic. If cold exposure and body cooling are as limited as Norman and Cumming's findings indicate, then further studies may be needed in which the degree of cold exposure is deliberately increased. There are clearly two problems: a) What happens under existing conditions at Polar bases? b) What might happen under conditions of emergency, including military, when the degree and duration of cold exposure may be severe?

5. *Weight change and skinfold thickness.* A number of studies at different Polar bases have shown that there is a small seasonal fluctuation in body weight and skinfold thickness, rising in the winter and falling in the summer (1). It would be interesting to know if similar changes are found in bases manned by personnel from the U.S.A.

6. *Water balance.* The assessment of calorie balance should include measurement of water balance and sodium chloride balance. Preliminary observations indicate that there are considerable falls in body weight during sledging journeys. There is some evidence that the fall is due to water imbalance. This preliminary finding requires confirmation and further investigation.

7. The following problems have been studied only briefly or in particular circumstances and warrant more detailed work.

a. *Stress of Polar environment.* There are many references on the effects of Polar life; a large number consists of assessment of

selection techniques. Actually, relatively few studies have been made in Polar bases by physiologists on men. This general field of work overlaps with psychological research. There are a number of ways in which the field can be divided.

b. *Effects of polar pattern of day and night.* Lewis and Masterton (9) recorded sleep in North Greenland and showed that there was a disruption of the normal pattern both in periods of 24 hour daylight and 24 hour darkness. The average number of hours of sleep did not appear to alter with the seasons. During continuous daylight or night, sleep was not taken in one period but was broken into two or more periods separated by several hours. Similar findings have been reported from other Polar bases, however, the degree of disruption has usually been less marked. All the results agree that there is little, if any, seasonal change in sleep duration. On the other hand, there are frequent hearsay accounts of the difficulty experienced by men in sleeping during the continuous daylight of the summer. The phenomenon of "big eye", when the day length may be unwittingly extended to more than 24 hours, has been described. A repetition of the type of studies made by Lewis and Masterton, at U.S.A. bases, would be of great interest since there may be sociological and not physiological differences. The phenomenon of "big eye" does not appear to have been observed at British bases in Antarctica.

c. *Disturbances or changes in other diurnal rhythms.* The effect of the pattern of light and darkness on body temperature and renal rhythms should be investigated. Lobban (10), who has studied renal rhythms at a high latitude (79°N) in Spitzbergen, observed a temporary disturbance in rhythm during the journey to Spitzbergen when the subjects just entered the zone of continuous daylight. The disrupted sleep rhythm and hence the irregular pattern of rest and activity is likely to affect the diurnal rhythm of body temperature. Other body rhythms, such as adrenocortical activity, may also be altered.

d. *Other evidence of stress.* Eosinophil levels have been studied in the Antarctic by Simpson (11). Considerable changes were observed during sledging journeys and also on occasions at base. Simpson concluded, however, that these changes represented emotional responses rather than a direct environmental effect of cold. The leader of the sledging party, who had a difficult and responsible task, had the largest change during the sledging journey. Pace and his colleagues (12) carried out a detailed investigation of men prior to departure for the Antarctic and during a part of their time in the Antarctic. Detailed urinary analyses were made. Relatively small but none-the-less suggestive changes were found, indicating an increased adrenocortical activity.

There has been mention of hypertension in members of Polar expeditions although no precise evidence appears to be available. Some accounts have been published of hypertension in labor-camps

in Siberia, including details of a marked rise in blood pressure on days of very severe weather (13, 14).

A preliminary study of blood lipids at an Antarctic base is currently being undertaken. The ratio of protein, fat, and carbohydrate in polar diets (at British bases) is similar to those found in the United Kingdom, but the total intake of fat is relatively high since food intake is on the average greater. Further work in this field could well be correlated with studies of dietary intake and with investigations of stress.

a. *The effects of isolation.* Psychological studies in the Antarctic have already started in American bases. Such studies could be of great interest if they were linked with physiological observations, including sleep and diurnal rhythms.

8. There are a number of practical problems related to physiology whose solution require work in several disciplines, including physiology.

a. *The desirable environment in Polar regions.* What is the most satisfactory design of shelter, and what thermal conditions are required in Polar buildings? In the past and probably in many cases today, carbon monoxide has provided a serious hazard, owing to the problems of heating with inadequate ventilation. The conditions observed indoors in temperate houses may well be the most suitable for Polar shelters, but these conditions are frequently difficult to achieve. Suitable compromises are required. There are data on conditions actually experienced in Polar bases, but it seems uncertain how far these data have been interpreted and can be used by designers.

b. *Clinico-physiological problems.* The incidence of illness and trauma experienced in Polar regions needs to be evaluated. This evaluation would have been an academic task twenty years ago as the number who had been at risk was so very small. The total number of men who have spent three months or more in the Arctic or Antarctic is now sufficient to make such a survey worthwhile. The incidence of cold injury is of particular interest to the physiologists, especially in view of the frequent reports that frostbite is less frequent amongst those who have experience in the cold.

c. *Bacteriology and virology.* The story of Polar explorers being completely free from upper respiratory tract infection until they come into contact with the outside world again, and then all get severe colds immediately, has sufficient basis to warrant investigation. It is clear, however, that there are many departures from the conventional account, such as the failure to develop a cold at the end of the period of isolation and the development of various infections during the period of isolation. Although primarily a problem for the microbiologist and the allergist, the physiological aspects should not be overlooked. The mucosa of the upper respiratory tract overlies a well developed vascular network which plays an important part in temperature regulation. If adaptation to cold does take place, it seems probable

that the vascular reactions in the nasal mucosa may be considerably modified. If such modification does occur, then the local conditions for the proliferation of bacteria or viruses may be profoundly changed.

d. *Physical fitness.* This subject is introduced with some trepidation since definitions of physical fitness are so inadequate. The question is: "How much physical activity is required of men stationed at high latitudes to maintain the optimum state of efficiency?" Perhaps to a greater extent than hitherto suspected, the polar life is an indoor, sedentary one. This situation is also true of the great majority of people living in more temperate climates; but the difference is that emergencies are not unusual in the Arctic, and the man in the hut has to get out and be active. How efficient is he likely to be? Another way to ask a similar question is: "What effect does physical fitness have on the ability to adapt to low temperatures?" In field experiments on cold adaptation, Carlson (15) has shown that changes in physical fitness can mask the effects of cold. Further investigation of this difficult problem would seem to be of considerable interest to the physiologist and of practical importance to those interested in Arctic life.

Summary

The foregoing suggestions concerning future research are not put forward as a complete program. The ideas are based on discussions with many colleagues who have worked in Polar regions. Admittedly, the suggestions do not have much originality. Many of the problems have been tested in the field. A number of proposals have been rejected because of the difficulties of field work. The quality of simplicity should be considered of paramount importance in connection with future studies. Unless it is essential to attempt some very complex research, field work must be technically easy and carefully designed. The main point, which has been implied throughout this paper, is: Polar physiology must be studied in the field. Laboratory work cannot substitute for field work. In the field, observations must precede any experimental work. We need to know, and at present we do not know, the details of activities, food consumption, and all the other aspects of life in Polar regions. Until we have these facts, laboratory work can be unrealistic and field experiments unrewarding.

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CHAIRMAN EKLUND: Our next speaker, Dr. John Meehan, spent almost three years in physiological research at the AeroMed Laboratory at Ladd Field, Alaska, and is now Associate Professor of Physiology at the School of Medicine at the University of Southern California. His topic today is "Auxiliary Heating". Dr. Meehan.

AUXILIARY HEATING

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The soldier's ability to operate effectively in very cold environments is largely determined by the performance of the clothing he is wearing. This clothing must not only provide the physiologically acceptable personal environment for the man, but must also permit him to perform efficiently all of the many tasks required of him. Providing adequate cold weather protection for the hand and at the same time maintaining useful and desirable dexterity presents a particularly difficult problem. The subject of this paper is the special problems associated with hand protection in cold environment.

The blood circulating through the tissues of the hands and fingers is the primary source of heat for these tissues. When one is exposed to a cool "personal" environment, the blood flow to the hands and feet is reduced. The consequence is that the hands and feet, particularly the fingers and toes, will cool more than any other part of the body (1). It has been observed that when finger temperatures drop below

60°F the loss in manual performance is very large and painful fingers become a primary complaint (2). Further, tactile sensitivity is impaired thus making the problem even greater (3).

In addition to reduction in the heat supply to the hands and fingers resulting from general body cooling, significant and critical reductions in hand temperatures will occur when the adequately protected man removes part or all of his hand protection in order to perform some manual task. The problem here is particularly acute if materials of high heat conductivity, such as metals, are handled.

The problem of hand protection is two-fold. If sufficient insulation is provided to give adequate protection, manual dexterity is impaired if not completely inhibited. On the other hand, to retain the highly desired manual dexterity necessitates a compromise in insulation resulting in good performance while the hand is warm but falling performance as the hand cools. The many physiological and psychological problems associated with hand function and protection were all thoroughly discussed at a conference on the "Protection and Functioning of the Hands in Cold Climates" sponsored by the Advisory Board on Quartermaster Research and Development, Committee on Environmental Protection, held in Natick, Massachusetts, in April of 1956. Since the meeting, the Committee on Hand Functioning and Handwear has been actively interested in seeking workable solutions to the problem of hand protection.

After consideration of all possible approaches, the Committee concluded that very serious consideration should be given to some type of heated handwear. The first set of requirements to be met by such an approach must satisfy the pertinent physiology of the hand. We have already discussed the reduction in blood flow to the hand that occurs in whole body cooling. The blood flow may be reduced to less than a teaspoonful per minute in the hand of the cooled individual. In terms of temperature, the same phenomenon may be expressed another way. Suppose a comfortably warm individual has his hand placed in a water bath maintained at a constant comfortable temperature, the finger temperatures will remain several degrees higher than the temperature of the water bath. If the person is cooled, however, a reduction in blood flow to both hands will occur and the hand in the water bath will soon have the same temperature as the water bath (1). This principle is important in the matter of applying heat to the hand since the blood flow to the hand will not only supply heat, it also will dissipate excessive heat, within limits, of course. If heat is to be applied to the hand, it must be controlled thermostatically at the hand in order to avoid overheating of the tissues. Further, suitable attention must be given to proper distribution of the heat over the hand in order to avoid hot spots that may burn the adjacent tissue. If these criteria can be met, the physiological requirements of the method would be satisfied.

The technical feasibility of providing heated gloves depends on the

materials available for the actual construction of the gloves and also on the amount of power required. A heated glove should supplement, not replace the usual insulated handwear. The heating feature of such a glove assembly should be incorporated in the innermost component of a glove assembly in order to make the most efficient use of the applied heat.

The amount of energy required will depend on the actual temperature that is to be maintained for the hand as well as the amount of exposure of the inner glove assembly component to the environment. Further, the length of time the device is to be operative must be considered. A rechargeable battery-type supply may be desirable for individual use. The individual may be able to use such an assembly for 24 hours and then recharge the batteries at some suitable point—perhaps a charger attached to a convenient vehicle. In some cases, the wearer may be able to receive the necessary power directly from the vehicle or equipment he is operating.

Justification for this type of approach to the handwear problem must rest in better performance on the part of the soldier in carrying out his primary mission. Consideration must be given to the particular tasks required of the soldier in connection with the use of new types of armaments and equipment. The problem of maintaining useful functional hands may be a very important factor in determining the ultimate effectiveness of any such new pieces of equipment.

With the improvement in the technology of providing small power sources, it is entirely feasible to think in terms of providing heated handwear to at least a limited number of field personnel. Presently, there are available small rechargeable batteries with good performance characteristics. In the future we may look toward the development of energy cell and other similar devices that should provide very small lightweight sources of electrical energy. In view of the technical developments that we can foresee at the present time, it is indeed a worth-while venture to look ahead towards the practical design of heating garments for use in very cold weather.

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CHAIRMAN EKLUND: Our next speaker, psychiatrist Dr. David Riech, has had many interesting experiences in the course of his career. I understand that he is the only person ever known to have given ulcers to a monkey. Seriously, though, Dr. Riech has always taken an active interest in the problems associated with

isolated groups. Recently he completed a year with the Advanced Study Group at Princeton and at present is Chief of the Neuro-Psychology Division of the Walter Reed Army Medical Center. It is a pleasure to introduce Dr. David Bloch, who will speak on "Psychiatric Problems of Man in the Arctic."

PSYCHIATRIC PROBLEMS OF MAN IN THE ARCTIC

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The present period of extension of human activities in the Arctic is one of rapid transition. It includes further need for study of the problems of personal survival and of training men to live in the cold, while at the same time introducing new problems, such as those of moderately large units maneuvering independently on the ice and of small groups living for months in isolation in permanent, circumscribed shelters. Surveying reports from men who have experienced these different situations, one may summarize the major stresses on man in the Arctic as: the cold; the narrow margin between relatively comfortable effectiveness and disaster; isolation; and the resulting necessity for changing to a new set of personal values and of patterns of interpersonal relations. The more isolated the group with modern equipment, the more important is the problem of the changed social conventions.

Two rather dramatic psychiatric problems are frequently referred to as possible major concerns. One is the possibility of a member of a small, isolated group becoming psychotic; the other is the report that in isolation "normal" people develop hallucinations and delusions. With regard to the probability of the development of psychosis, it appears that the threat of physical danger is not a precipitating factor. Colonel Albert J. Glass, U. S. Marine Corps, and his associates pointed out that the rate of psychosis in the Army varied negligibly between two and three per 1,000 men per year, over a long period, regardless of war or peace (1). The success of the Navy psychiatric screening program for Antarctica and other evidence (2) indicate that incipient psychotic symptoms can be recognized reasonably accurately. Finally, the availability now of tranquilizing drugs greatly reduces the problems of managing over-active, disturbed behavior if by chance it should occur. One may conclude that with reasonable care psychosis does not represent a probable hazard for man in the Arctic.

It is clear that under certain experimental conditions of isolation, sensory deprivation, and sleep loss normal people may develop hallucinations quite rapidly. Similar phenomena have been reported by people under other circumstances such as solitary sailing, isolation in a meteorological station, trapping, and so on. In such reported experiences it is evident that the symptoms did not prevent adequate function. In some cases one is inclined to suspect that the hallucinations

represented a bland, symbolic structuring of the environment, almost as a substitute for a threatened breakdown, with disorganization of symbolic behavior and resulting panic. However, when two or more people are together hallucinations do not occur.

The dramatic symptoms of psychosis, hallucinations, and so forth, thus do not appear of importance. What is of importance to life, however, and sometimes to the lives of men in rescue parties, is a phenomenon which is rarely mentioned. It was called to my attention by Colonel Frederick W. Timmerman, U. S. Marine Corps, who has had extensive experience in cold weather medical problems. The symptom which costs lives was known earlier but has been more frequent with improved mechanical transportation. It consists essentially of a form of distorted thinking in which, even at times without any warning sensation of "anxiety", a decision is made to act and is promptly put into effect. The disaster results from the decision being the wrong one. The only indication of "panic" may be the failure to scan the total situation and to assess the probable outcome of different possible plans. The symptom appears under conditions in which there is a sudden change in the anticipated course of events, as in the forced landing of a plane, the breakdown of a snow-cat, and so on, far from a fixed installation. Even carefully indoctrinated men who have had Arctic experience, when precipitated from modern, mechanized comfort into the Arctic waste may decide to "walk out". This decision is often made despite knowledge that they could not make the trip on foot and is also put into effect without taking adequate bearings of direction. For many men the life-long tendency "to get home" appears to wipe out knowledge that the machine is the best shelter they have until help comes and that it takes time and preparation to travel in the Arctic. The type of disorganized thinking in which the world is seen and recognized, according to an oversimplified formula derived from earlier experiences and determined by wishes rather than facts, is not a problem on which consistent studies can be performed. The anecdotal evidence is convincing, however, and analogous phenomena are known to occur in other situations involving sudden, unexpected, and threatening change. Thus, well trained surgeons have been known to sew up dirty wounds during the stress following a disaster such as a tornado. Instead of cleaning the wound and leaving it open (in order to prevent buried infection), they acted as though they wanted to deny the problem. This kind of failure in thinking can be greatly reduced by rehearsed planning for emergencies.

Another psychiatric problem which is peculiar to the transition period of Arctic travel and mobility is often labelled "carelessness". It consists of pilots and drivers of vehicles with heated cabs starting on a mission or trip without their cold weather equipment. Even a minor repair job can prove fatal without adequate protection from the cold. The attitudes which result in this type of carelessness vary con-

siderably but always include a lack of personal commitment to the objective of the outfit to which the man belongs. A variety of theoretical motives may be invoked to explain this behavior, such as unconscious suicidal wishes, needs to prove that someone will take care of you, a magical sense of omnipotence to cover up fear of taking responsibility, and so forth. By and large, all men are potentially capable of these attitudes at some time in their lives. Practically, however, such potentialities are reduced to negligible significance by serious emphasis throughout the outfit on the relevant factors in the situation and the development of reasonable expectations of accomplishment by all echelons of command.

In military units there is a clearly observable difference between commanders who give orders, as it were, from a distance but have their minds on other things, and commanders who allow it to become known that they know what is important under the circumstances and that they are genuinely concerned with it. There is little difficulty in pointing out the logic of protective measures, but it may take considerable effort to establish a general expectation in the unit that certain minimal requirements will always be met and that failure to meet these minimal requirements constitutes a threat to the group integrity, i.e., a threat to the safety of one's immediate associates. The importance of the personal attitude of the commander toward preventive measures was discussed by Colonel Eugene R. Inwood, U. S. Marine Corps, at the Symposium on Stress held at the Walter Reed Army Medical Center in 1953 (3). In an infantry division in France in World War II, recommendations were made at Division level for prevention of trenchfoot. One regimental commander transmitted the recommendations verbatim but was privately of the opinion that the men would not carry them out and that they could not be enforced. In the succeeding period trenchfoot remained a major cause of loss of personnel in his regiment. The commander of the other two regiments transmitted the recommendations as commands, with subsidiary commands for foot inspection, and so forth. The message thus implied personal involvement in the effectiveness of the group and in the importance of maintaining this effectiveness. The result was a marked decrease in rate of trenchfoot under conditions similar to those in which the first regiment showed an increase.

Now that larger numbers of troops are being sent to the Arctic, either to fixed installations or on maneuvers, it seems likely that problems due to neuroses and—often of greater nuisance value—due to the “acting out” and asocial symptoms of the so-called character and behavior disorders will be more frequent than when the units were smaller. In part this is a problem of selection, but to a larger extent it is due to the greater efficiency with which a small group, as compared with a large one, can develop intrinsic personal support and control measures. The neurotic symptoms and the forms of asocial behavior will inevitably be characterized by the environment. For

example, an epidemic of cold injury is likely to be accompanied by neurotic complaints of "cold feet" which are regarded by the sufferer as frostbite. Further, it is highly unlikely that AWOL will be of significance, but "accidental" to "premeditated" self-exposure to the cold is likely under certain circumstances. A great deal of work has been done during and since World War II on these problems. The basic principles for dealing with them in combat psychiatry have been formulated and tested (4). Further, these principles have been applied to peacetime neurotic problems in camps (5) by the Mental Hygiene Consultation Service, and also to the problems of more efficient handling of military offenders (1, 6). In general, it appears useful for commanders to regard neurotic and asocial symptoms as an inadequate form of communication for the purpose of getting attention and personal support. Such inadequate communication appears to be increased by lack of clarity in transmission through the chain of command of the immediate objective of the group and of personal commitment to its reasonable accomplishment. These problems, however, are problems of the art of leadership, discussion of which is too general an area to take up here. It should be noted, however, that neurotic and asocial behavior tends to increase under moderate stress and discomfort, particularly if it appears that someone else is receiving preferential treatment or assignments. Nevertheless, when stress increases sharply, such as during rapid movement or under severe threat of survival and it is quite clear that no one can give the desired personal attention, these symptoms are much less likely to occur. Thus, they are unlikely to increase the danger when, as it were, the chips are down.

The difficulties presented by inadequate performance of men on expeditions and isolated stations naturally result in the demand for methods of selection which will eliminate those who are potentially ineffective. A very good case can be made for the proposition that a completely effective selection procedure is impossible. Man lives and behaves according to his symbolic representation of the world around him. Over the course of time every man finds himself in situations with others that he handles less well and from which, under ordinary circumstances, he has socially very appropriate means of escape, so appropriate that neither he nor his associates notice them. Further, with time and experience the symbolic systems for processing social data, i.e., the data of living, change and become more efficient for certain purposes, less for others. Since we cannot predict the future circumstances, it is clear we cannot predict a man's future performance in any absolute sense. We have to settle, therefore, for reasonable probabilities.

The practical problem of selection of personnel reduces to three major questions. The first is the question of the ratio of the number of positions to be filled to the manpower pool available. The second is the accuracy with which the combined job-situation is known for

which selection is made. The last is the knowledge available on the man's previous performance. A study was conducted at the Walter Reed Army Institute of Research under the direction of Colonel Glass on the military performance of 505 men randomly selected on whom detailed psychiatric data were obtained by the Office of the Surgeon General during the first three weeks they were in basic training (2). These authors also reviewed the literature and discussed the general problem of selection. One may estimate that, with a large pool to select from and reasonably adequate information on which to base judgments, some 97 per cent of the selectees or more should perform satisfactorily or better. It further seems clear that an experienced psychiatrist can recognize incipient psychotic reactions and other serious disturbances which are likely to become manifest in the near future. The Navy psychiatric screening program for scientists and Naval personnel going to Antarctica during the IGY and since has proved effective in that no psychotic reactions have developed amongst the wintering-over personnel. None of these selection methods, however, has been practically useful for differentiating between more effective and less effective men within the generally satisfactory group. William M. Smith (7) has reported on the selection procedures used by the U. S. IGY Committee for civilian scientists. A questionnaire devised by men with considerable Arctic experience was used. Answers were obtained from several people with personal knowledge of the applicants, and the data so obtained were analyzed and rated by a panel of judges. The ratings so obtained correlated very well with the performance of the scientists as reported by the scientific leaders of the respective Antarctic stations. The good correlation found indicates the importance of knowing the relevant factors for which selection is made. However, in this case the problem of motivation was very different from that involved in the average military unit under present conditions.

It is clear that from the standpoint of selection and also from that of training, it is important to know what are the relevant stresses that must be dealt with. Since I do not have personal experience in studying this directly, my comments will be limited to certain general principles derived from behavioral research.

A great deal of work has been done on the anatomical, physiological, metabolic, endocrinologic and other changes of animal and human organisms on exposure to cold, acutely and chronically. These studies have provided the necessary data determining the baseline of what has to be provided in the form of food, protective clothing, shelter, and so forth to support life in the Arctic and to permit additional activity. The question of cold acclimation has been of considerable interest and a number of authors are of the opinion that man does not have appreciable capacity in this direction (8, 9). The studies of Davis, 1960 (10), however, suggest that longer, more severe exposure demonstrates such ability in man as well as in animals. It is of interest

in this regard to note that many people living in cold climates are seldom seriously exposed to cold. Their immediate somatic environments—inside their clothing and shelters—tend at times to present the problem of heat dissipation rather than retention.

Physiologists have paid attention to the automatic homeostatic mechanisms, particularly since Walter B. Cannon coined the term "homeostasis". Much less attention has been given to the capacities of animals and men to manipulate the environment in order to survive or to be more effective. Dr. Curt P. Richter is one of the few biologists who has called attention to the latter phenomena. He showed, for example, that rats could select an appropriate diet to compensate for deficiencies, a function which was lost if their taste nerves were cut. Wild Baltimore sewer rats of the same species failed to show this function under the psychological stress of being brought into the strange environment of the laboratory (11). Dr. Richter also showed that thyroidectomized rats would die if kept in a cold laboratory. When, however, they were provided with more nest-building material, they build nests larger than ordinarily and so provided shelters in which they survived (12, 13). Other evidence from field studies of animal behavior also demonstrates that survival depends on adequate manipulation of the environment and not merely on autonomic reflexes and so-called "instincts". This becomes increasingly true for the higher primates, and it is quite clear that manipulation of the environment is a natural procedure, necessary for survival, and is not an accident of civilization nor a cultural artifact.

In contrast, it has also been shown that the so-called automatic, homeostatic mechanisms can become disorganized and lead to illness and death. In experimental studies on monkeys at the Walter Reed Army Institute of Research a considerable number of animals in conditioned reflex experiments—in which the animal was under psychological, but not under physical stress—developed peptic ulcers or other disturbances of the digestive system (14). The mechanisms of these diseases have not yet been identified, though it appears that intermittent stress alternating with relaxation is necessary and that hormonal changes may be involved which occur following and not during the stress (15).

In a recent article Goldstein (16) has pointed out that hormonal effects on the tissues of the body depend on the proportions of hormones circulating rather than on the absolute amounts. He also shows that this secretion of hormones is increasingly under the control of the brain in the phylogenetically higher forms. This control provides greater anticipatory sensitivity but is also less stable. Dr. Richter (17) has demonstrated even more dramatic, lethal effects of psychological reactions. Wild rats were trapped and brought to the laboratory for comparison of their behavior with the laboratory strain of the same species (grey Norwegian). They were subjected to a sequence of threatening and frustrating experiences. A cone-shaped bag of

black velvet was fitted to an opening in the cage and the rat chased into it. He was then held by head and body and the bag drawn back, inside-out, exposing his legs and face. The rat lay still and failed to struggle. The whiskers were cut depriving him of an important sensing device, and he was dropped into a cylinder of water. All of the wild rats died within seconds, swimming to the bottom of the cylinder. On examination no water was found in the lungs, so death was not due to drowning. Taking the electrical record of the heart showed that it suddenly slowed and stopped, probably due to a vagal reflex. Rats which were given *graduated* experience with the successive procedures separately did not die but swam normally when dropped in the water. Dr. Richter's interpretation was that the threat and "hopelessness" of the situation caused the autonomic responses which killed the uninitiated rats.

Experimental work in the field of lethal behavior patterns, whether overt or covert, is rare. However, experienced clinicians have many very convincing anecdotes confirming the occurrence of such behavior in humans. A comprehensive review of the literature concerning observations on humans has recently been presented by Herbert and Mead, 1961 (18) in a panel discussion of the psychophysiology of death. Attention should also be given to observations on combat, such as those of S. L. A. Marshall, Brig. General (ret.). Using a method of debriefing troops soon after particular episodes, he has accumulated a store of eye-witness reports of performance under extreme stress. Marshall (19) reports that the landing at Omaha Beach was accompanied by an extreme, abnormal weakness so that men drowned in two to three feet of water through inability to walk carrying their regular equipment. The common explanation of weakness as due to "fear" is not adequate, since "fear" is also credited in other situations as increasing a man's energy and strength. Further, there are no operational criteria for its measurement. No measurements of vital functions—such as blood pressure, blood sugar, and so forth—were made at Omaha Beach so that the physiological state of the men is not known. All one can say is that under the circumstances the body failed to support the brain. Whether or not the sudden exposure to extreme danger following a long passage in a landing craft, with physical inactivity and plenty of time for ruminative anticipation, is a matter of speculation. It may be noted, however, that equivalent factors would be involved in flying paratroopers from distant fields into the Arctic for a dangerous jump.

I should like to make two comments on the general problem of "the support of the brain by the body" which can also be formulated as "the maintenance of efficiency under changing condition and increasing load". The first concerns the rather widespread concept that the autonomic and endocrine control of visceral functions—in other words, the internal household working of the body—is innate and behaves as a set of stereotyped reflexes, influenced only by emotions,

attitudes, and anticipation of reward or punishment. This concept is probably too extreme. A great deal of work in Russia and scattered observations in Western laboratories indicate that the nervous mechanisms controlling the cardiovascular, visceral, endocrine, and other support systems can learn and change their patterns of function so as to more efficiently meet particular stresses and loads imposed by the environment. It seems probable, for example, that much of athletic training is to "teach" the autonomic system a pattern of activity for supporting a program of action. Training for the 100-yard dash is thus quite different from training for the marathon.

The second comment is related and concerns the importance of attitudes in accomplishing the transition from life in the temperate zone to life in the Arctic. Even with some 10 billion nerve cells in his brain, it is impossible for man to handle all the separate "bits" of information arriving from his sense organs. Hence, he integrates vast quantities of data into relatively few patterns which may be thought of as "images" or conceptual models. The process of integration of data into "images" in large part is controlled by previous experience, including what was done in earlier experience and the resulting pleasure or pain, success or failure. A man's images or conceptual models thus both determine his perception of his situation in the environment and also define his plan of action. The "image" of cold and snow which a man brings with him to the Arctic may be very inadequate. In Washington, D. C., for example, a child observes that six inches of snow is so unmanageable that the schools are closed. He also learns, however, that it is so unimportant that he is supposed to play in it. This is in sharp contrast with the "images" of winter developed by children raised in northern, rural communities where respect for the cold and utilization of the snow and ice for travel in hunting or trapping are part of everyday living and on which social status as an adequate person depends. In southern climates a boy gets concurrence from his peers in his unrealistic attitudes toward cold, but not in unrealistic attitudes towards swimming, care of horses, checking water supplies, and so forth.

On coming into the Arctic a man from a warm climate has to learn a new set of "templates" for processing the routine data of living. If he has previously learned to learn—that is, to commit himself to the environment and to act with it, rather than *fearing-fighting* it—the transition period is rapid. Otherwise his transition requires the supportive pressure of his group associates. When man commits himself to a group and to the group objectives, he demonstrates his sense of identification by learning and using the conceptual models which the group uses. Obtaining a man's commitment to a mission in the Arctic is probably the major task of cold indoctrination. Together with information on the routine of living in the cold, it also reduces apprehension and other attitudes which interfere with his cardiovascular, respiratory, metabolic, and other physical adjustments to

the environment. It is always surprising how quickly physical adjustments to a new set of environmental factors can be accomplished when not interfered with either by misinformation or by fearing-fighting the situation. Attitude thus facilitates or inhibits acclimation and in this sense may be regarded as of prime importance.

A social psychological study of personal and group problems in several stations in Antarctica has been published recently by Rohrer, 1960 (20), and his findings are generally substantiated by other, less formal evidence. Rohrer describes four independent factors which determine different aspects of the social-psychological stress encountered. The first is the accessibility of the station, i.e., whether it is difficult but feasible to reach at any time; whether help is available in emergencies; or whether for a period of time it is completely cut off. The second factor is the size of the group involved, the smaller the group the greater the necessity for maintaining workable personal relationships with all the other members; the larger the group the greater the freedom of personal association, but also the greater the need for formal organization. The third factor is the size of the living and work areas which determines both the possibility of privacy when desired and the efficiency of operation. The fourth factor is danger of extreme cold and the necessity for constant vigilance to maintain the safety of the installation, supplies, and men. This problem of vigilance becomes more acute in certain situations such as occur with a small group traversing dangerous terrain.

In addition to the factors noted by Rohrer, attention must be given to the composition of the group. The structure of a group as measured by its performance is determined largely by the mission or objectives of its members, separately and collectively. In small groups in isolated stations, survival to return "home" becomes dominant and produces a remarkable degree of control of interpersonal relations. The necessity for limiting the ordinary social freedom of direct expression of attitudes results in a closed system, as it were, of intra-group communication with its own values and nuances, its own private language. This inevitably results in an attitude of "us against the world", since the connotations of words change and even direct verbal communication by radio with "home" becomes limited to more general "facts". Under these conditions the customary "planning for the future" must be held in abeyance, a result which is of particular stress for upper echelons of technical and professional personnel. In our presently expanding bureaucratic system the need for reliable friends in the organization at home is acutely sensed. The question "Have they forgotten me at home?" is one of the major modes of expression of the stress of separation, isolation, and limitation of freedom of action.

Other aspects of the role of objectives are important from the standpoint of conflicting interests within the group itself though these aspects are subordinate to the requirements for survival. There

are great differences in attitude between the professional explorer for whom an expedition is part of his life career; the scientist who is going for the purpose of getting particular data and who is dependent on his apparatus working; the trained technician who has a well defined job; less well trained men who volunteer for a curious variety of "reasons" but which amount in general to "being there" rather than to any clearly definable function; men who are ordered to the Arctic "for training" or only to maintain installations; and so forth. The scientist who wants additional help with recalcitrant equipment and personnel who are only concerned with establishing and maintaining the installation can easily set up an anxious dichotomy in a group with a good deal of limited antagonism. It is of interest that, although such groups often express considerable distress and resentment, limited antagonism can prove to be a strong unifying system against external dangers; and the sense of hostility and distress may be unpleasant, but does not necessarily curtail superior productivity during a tour of a definitely limited period of time.

The problems of divergent objectives obviously are reduced in small groups (12 men or less) of technically trained personnel. In such "face-to-face" groups with well defined missions, leadership becomes of little importance and consensus on the course of action can be readily achieved. With groups of 20 to 30 men, vertical channels of communication (command) become necessary but can be maintained by personal, informal contact. In groups of 50 or more, vertical and horizontal formal channels of communication need to be organized. Since the objectives of the subdivisions of such groups vary, the problems of what is called "leadership" also vary, and no inclusive formula will perform the magic which is often wished for from so-called "leadership" with a capital "L". This is an area of human behavior which needs much more study and includes such questions as: What information is relevant at different echelons? What informal channels of information are necessary for maintaining the reliability of the formal channels? What feed-back from the periphery is relevant to the course of action? How can such problems be operationally defined to permit testing and development before they become critical? The facts that the margin of safety is much narrower in the Arctic and that Arctic operations require more specialized equipment and therefore more diversity of technical training make the problems of group organization more acute than they are in temperate zones. Although current academic studies of human information processing and communication can provide certain guide-lines for investigating these problems, operational investigations with careful reporting will be of greater significance in arriving at workable solutions.

It appears quite clear that we may anticipate a considerable increase in the number and size of permanent installations in the Arctic, with improved communications and other facilities. Under such conditions it is inevitable that we will take a great part of our culture

with us. It is to be anticipated that the conventions and mores we take with us—including our neurotic and psychotic problems—will be modified by local factors but will more resemble the forms we have already developed than anything new. The question has been raised as to the problems arising from the introduction of women to life in the Arctic. This is basically a question of cultural roles and limitations imposed on certain roles by the environment. In permanent installations, however, there is no reason to anticipate problems other than those encountered in isolated communities elsewhere. These problems are relatively well known, and most communities accommodate themselves sufficiently well so as not to interfere with the major purpose of the installation. It should be noted, however, that the American culture expects *all* its members—whether higher or lower in the organizational hierarchy—to react with consistent control to practical necessities and also to react against undue discrepancies in the facilities for “self-expression” provided for different levels or for different units.

In brief summary one may say that the present major psychiatric problems of man in the Arctic appear to be those of a transition period—transition from the era of the hero explorers who pitted themselves personally against the cold, isolation, and Arctic waste to the era when we will have virtually “taken our preferred climate with us” by mechanical means and developed a set of acceptable conventions and mores to go with it. We have started on the latter but still have to prepare a considerable proportion of our people in the Arctic in the lore and for the functions of the former. In this transition period we need operational investigation with careful records of the transmission of information through groups operating under different conditions, since organizational effectiveness depends on clear information. This includes the vertical, reciprocal transmission of commands-responses and the horizontal, reciprocal transmission of expectations-responses. Guide-lines for such operational investigations can be provided by the social and behavioral sciences, but there is no magical solution either in modern “science” or in mythological “leadership”.

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CHAIRMAN EKLUND: Now we come to our last presentation—the Summation of Man's Future Conquest of the Arctic. As you heard yesterday, Dr. Horvath was on the treadmill along with Sir Hubert Wilkins and, fortunately, survived. Now he is faced with an equally taxing situation—summing up this conference without any opportunity to read the papers prior to their presentation. Ladies and gentlemen, Dr. Steven M. Horvath.

SUMMATION: MAN'S FUTURE CONQUEST OF THE ARCTIC

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A stress much more extreme than exposure to cold is an attempt to summarize a conference without benefit of the manuscripts contributed by the participants. We are faced with the problem of deciding whether or not man has reached a point where he has become so familiar with the Arctic that he looks upon it with a certain degree of contempt—that the problems of Arctic living are no longer serious because man brings his own environment with him. He lives under ice or, in fact, may soon be living under the permafrost. His only exposure to the Arctic is the fact that he receives an Arctic clothing issue. He flies into the Arctic, wears his clothing from the plane to the point where he is stationed, and then stays there. Approximately three or four per cent of his remaining time is spent going outside and taking pictures of himself to show the people back home that he has been in the Arctic. And to make it even simpler, he need not worry about the cold, the crossing of ice ridges, pressure ridges, or ice hills because he has with him a heating device which constantly clears his path. He flies along gracefully on new air-supported vehicles and never needs to walk any distance. He has nothing to do with the Arctic except as a transient who is there only because he has been, as Dr. Bloch pointed out, properly motivated, properly trained, and completely indoctrinated that he is competent to survive in the Arctic. This is one impression that you can obtain from listening to the papers presented in the last two days, i.e., that we have solved the problems of the Arctic because we have brought our environment with us.

It is my impression that the major difficulty with any environmental situation is that those of us who are concerned with it are so impressed by our ability to manipulate the environment that we forget that the individual human being sometimes refuses to respond in the manner in which we anticipated. He not only fails to utilize properly the clothing and protective devices provided him, but also his attitude is wrong. The fact that he is there in the Arctic tells him that he has survived its rigors, and the fact of survival wrongly makes him feel that he is a superior being. Actually, it is quite possible that Man will one day again be completely at the mercy of the Arctic environment. He may be at the mercy of high winds, low temperatures, and much more continuous exposure to the low environmental temperatures than he is today.

There are two points about the Polar regions which must be remembered. The first is that the environment in these regions is not always as nicely defined as we have been led to believe. The second

is that we do not know Man's capability to perform and survive in the cold.

With regard to definition of environment, our geographers spend a great deal of time looking at the environment of the Polar regions but have not really obtained the information which is absolutely necessary for Man's survival in the Polar regions. They know very little about the so-called microclimates—a term which is used so easily and with such great facility by all of us. They know little about the microclimate of a fully equipped man. Most of our geographic information and meteorological information comes from places where beautifully-arranged standard facilities are available to measure these things without inconvenience to the observer. But, the man, who will have to fight in the cold or will have to survive in the small environments away from these nice facilities, will have a different microclimate. It is absolutely necessary that in the future a very clear-cut delineation of the actual microclimate be obtained. This information cannot be obtained by the facilities which are presently available. We have to take the soldier into the field. We have to obtain analogous microclimate information on the soldier and explorer actually working and living in this environment. Thus we can learn something about the stresses that are placed upon the human being.

Concerning the ability to perform, how much time does a man actually spend in the Cold? With all these years of experience in cold environment, why have we had to wait to obtain information about the precise length of time a man can work at level "A," "B," "C," or "D" out in the cold? All of us here have experienced this difficulty of obtaining precise information. Such information is usually obtained from groups who are isolated with no real need to get out in the cold. We must obtain similar data from those people who must be in the cold and must perform in the wet cold or dry cold extant in Polar regions. Such information we don't have. We have utilized some vague observations obtained in temperate climates on the length of time a man works at certain tasks and the intensity with which he works. But we have not translated this into absolute information about Man in cold or semi-cold environment. No one can tell you, for example, how long a man can work continuously under a certain kind of environmental stress.

If I asked you to define clearly the length of time and the level at which a man can work continuously for two or three weeks, I think you would be hard put to give me any figures. In relationship, for instance, to Man's maximum capacity to work, what is the best pattern for a man to work in cold climate? Is it better for him to work at levels at which he will have energy expenditures of eight or nine times his basal metabolic rate for a period of 5 seconds, 10 minutes, 25 minutes, an hour? Or, is it better for him to be working at these metabolic rates or even higher with rest periods of 5 minutes,

20 minutes, 30 minutes? What do each one of these particular parameters of a working man in a cold environment do to all the protective devices that we are designing for him? Is the clothing we have today adequate and the best type of clothing? Is the nutritional standard we are setting up for the soldier the proper one? The last question was frequently raised in this conference.

Although it is perfectly evident that we all have pretty strong convictions, are we correct in our interpretation in terms of nutritional requirements, in terms of clothing protection, in terms of thermal insulation? There is sufficient available information to prove all of us are somewhat wrong. But, we are basing this information not upon the man who is truly working hard day in and day out and may be faced with the necessity of trying to stem an invasion attempt where he may be caught out on the ice and in the snow just as some of our men were caught in Siberia after the first World War and as the Germans, the Russians, and the Finns were caught. We actually don't know how man will perform in cold environments because we spend too much of our time in setting up a series of problems and never providing the opportunity to get an answer. We actually do not take the information that we have and translate it into the kind of information which we need to solve this basic problem.

How long can you keep a man out in the cold without his incurring certain degrees of frostbite or immersion foot? How long can he be out in the cold before a state of hypothermia develops? What degree of inefficiency can be tolerated in a man? Is efficiency improved by altering the thermal protection to his fingers or his feet in a situation which requires the utmost expenditure of energy? Is it important to know whether his feet might be cooler or warmer than they need be? We really don't know these answers.

We have become rather complacent about the development of our knowledge of Man in the Cold—dry cold, wet cold. I think that we have now attained a state of knowledge where we are beginning to see the need for real facts. So far we have developed vague and nebulous concepts. The Polar region is one that is never going to be conquered simply by moving in our thermal reactors, utilizing heat pumps and ground pumps, or easily transporting Man into and out of this area using primarily low-speed transportation close to the ground where the men are never actually exposed to the Cold.

The only way that we can conquer the Arctic regions is to learn, again, a little bit from the past. Although I have never been an explorer myself, I think that sometimes explorers made their own tasks much more difficult for themselves than they needed to. Yet, I think there is a certain amount of information which can be obtained by repeating some of the episodes explorers went through in order to determine by physiological, by psychiatric, and by psychological measurements the extent to which these men were placed under stress. If this stress is as great as we thought or if it is less than we

thought, then maybe we can organize those training programs that have been mentioned so frequently—the training, the indoctrination, and the development of high level motivation and confidence; competence in the necessary tasks.

We have no basis upon which we can make these beautiful training programs work because our knowledge of what a man needs to do and how he can best function in the Arctic still is in its infancy. I think it is time we grow up. It is time to start thinking about cold environments, not from the standpoint of whether a man is acclimated to the cold or not acclimated; nor whether he has adequate or new types of garments or new types of insulated boots. We have to think about it from the standpoint his being a sociological as well as a physiological instrument. This may become much more important than we realize because if it is true that we will be moving the problem of sex into the Polar regions, then we may have other problems which have to do with successful maintenance of our field of superiority in the Arctic.

We are facing a serious problem; namely, that the amount of effort we are placing upon Polar research, both in terms of the individual man and of men as a colony, is so small that we will be far behind in the race for survival in this particular area. I hope, if there is anything this conference has done is to bring forth the full realization that our knowledge is insufficient and much more work has to be done.

SESSION No. 4

THEME: THE EXPANDING UTILIZATION OF THE ARCTIC

WALTER WOOD, *presiding*

Chairman Wood: Ladies and gentlemen, before we begin the technical portion of the meeting, I want to tell you how happy I am to be here and only regret that a conflict of geographical interests prevented me from attending the entire conference. I am delighted to be here for two reasons; first because of my own former association with the Quartermaster, and second because I see at this meeting the happy marriage of the Military Command and the work of The Arctic Institute of North America.

Our first speaker this afternoon is a man who has led field expeditions into the far northern reaches of the Canadian barren land and is an industrialist who knows what he is talking about when he is talking about resources. He is Vice President of the International Nickel Company and is also a member of the Board of Governors of The Arctic Institute of North America. Mr. Paul Queneau.

UTILIZATION OF THE ARCTIC'S NATURAL RESOURCES

PAUL QUENEAU

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This study confines itself to an examination of the 2,000,000 square miles of the northern hemisphere which the geographer defines as the terrestrial Arctic, a region in which the mean temperature of the warmest month is below 50°F—in effect the area lying north of the tree line. The first necessity in any crystalline discussion of a specific geographic area is circumscription of its boundaries; otherwise the subject becomes elastic and the conclusions amorphous. A clear picture of the specific area under discussion is vital to an understanding of the obstacles which must be overcome in the utilization of the Arctic's natural resources. The engineering and human problems there are of a different order of magnitude than is generally true of the sub-Arctic. Whether in Dawson Creek or Matanuaka, in Moi Rana or Skelleftehamn such problems are of the same general order as in Hibbing or Noranda. The same is not true in Kong Oscar's Fjord or Lancaster Sound.

The sparse life of the Arctic is dominated by the long, cold winters; the summers are too short and cool to permit plant growth in the barren soil other than a scant cover of grasses, lichens, mosses and a few stunted shrubs. The human, fur-bearing, and other native animal population of the land is of low density. Significant economic activity based on agriculture or silviculture is impossible. Insofar as marine

fauna are concerned, commercial fishing is unattractive in the poorly productive waters of the Arctic zone except where they mix with warmer waters from the south, as off the Lofotens, Iceland and southern Greenland. Thus for many years in this remote section of the globe it is not on land or sea that man will reap any rich harvest. It is the Arctic's great non-renewable resources in the bowels of its frozen earth which will be increasingly utilized during the coming decades. This paper is thus inevitably devoted to the mineral industry and the various factors which affect mining, milling, smelting and refining operations in the far north.

In order to get a better understanding of the future, we shall briefly review the present status of mineral resource development in the Arctic. Enumeration of the existing mining operations in the North American Arctic requires little effort. In the United States there is sporadic placer gold mining in the river system which flows into Kotzebue Sound from the western Brooks Range, and coal is mined occasionally on Cape Lisburne and on the Meade River. An accumulation of oil north of the Brooks Range in the 87,000 square mile Naval Petroleum Reserve will some day be brought into production. An exploration program conducted at a cost of \$50,000,000 located several promising structures, the richest of which is believed to be the Umiat field 180 miles southeast of Point Barrow with an estimated 70,000,000 barrels of recoverable reserves. A modest nickel-copper deposit is being exploited at Rankin Inlet, north of Churchill on Hudson Bay, and it constitutes the only mineral production in the Canadian Arctic. Important quantities of petroleum may be present in the sediments of the Queen Elizabeths, for instance, Bathurst Island; and substantial tonnages of iron minerals are known to occur in several areas including Baffin Island. In Greenland there is a small cryolite mining operation on the southwest coast at Ivigtut and a small lead-zinc mining operation at Mestersvig on the east coast.

For reason which will be elaborated below, the mineral industry is notably more active in the Arctic of the eastern hemisphere. On the Barents Sea at Kirkenes, where the Norwegian coast is still influenced by the Gulf Stream, there is a major iron mining enterprise which has one thousand employees and exports a million tons of high grade concentrates yearly. Svalbard produces a considerable amount of coal by a Norwegian effort involving one thousand persons. Presumably the Soviets are also obtaining coal there from concessions which shelter a Russian population of perhaps 2,500. The Norwegian mining operations are at Longyear City and New Aalesund, and the Soviet's are at Barentsburg, Grumant City, and Pyramiden. The mining establishments were destroyed during World War II but have since been reconstructed, and post-war Norwegian coal production has been running at about half a million tons per year. Also on the Barents Sea, near the ice-free port of Petsamo in a region ceded to the Soviets by Finland, there are important nickel-

copper mining and smelting operations with a nickel output amounting to possibly 80,000,000 pounds yearly. Moving eastward toward the Urals, the Pechora Basin is a major producer of high quality coal and of oil and gas, present coal output apparently approaching 20,000,000 tons yearly. The chief mining center is Vorkuta with a population of at least 50,000. The Salekhard region, just east of the Urals, is reportedly a producer of natural gas. Farther eastward near the mouth of the Yenisey is Norilsk, believed to be the main Russian nickel producer with an output of perhaps 50,000,000 pounds yearly, and major concomitant copper, cobalt, and platinum metals output. Over one million tons yearly of coal and, reportedly, oil is produced in the vicinity of this city which has about 100,000 inhabitants and is by all odds the leading Arctic mining center in the world. There are a number of fuel sources of local significance eastward along the coast such as coal at Nordvik, near the delta of the Lena and at the mouth of the Indigirka. Tin and gold are mined in scattered localities in the coastal mountains of the Chukotakiy Range.

A great assistance to the development of the Arctic in the eastern hemisphere is the Gulf Stream and the presence of large rivers which flow northward into the Arctic Ocean, including the Pechora, Ob, Yenisey, Lena, and Kolyma, the middle three of which are among the longest in the world. These rivers constitute extremely valuable transportation links between the coast and Russian population and supply centers since the Trans-Siberian Railroad crosses the upper reaches of the Ob and Yenisey and is close to the head waters of the Lena. The only comparable north-flowing river in the West is the Mackenzie. Another advantage in the East is that ice interference to summer shipping along the Arctic coast is much less than in the straits of the Canadian Archipelago.

Consideration of the above mining operations immediately impresses one with a feature which they possess in common and without exception, that is, location on tidewater or navigable river or short railway connection thereto. This location is no accident and brings us to the main obstacle which must be overcome by industry in the Arctic, namely, the high cost of logistics. The movement of material and personnel to and from the isolated Arctic mining operation constitutes an increment to the expense of production which places it at a distinct disadvantage in competition with mineral exploitation in more readily accessible regions to the south. This expense is the great and all-pervasive deterrent to development of mineral resources in the far north. It multiplies the cost of initial exploration, of plant and townsite construction and operation, of utilities and inventory maintenance, of labor, and, inevitably, of the delivered product.

The classic method of heavy transport by water in ship or barge is much the cheapest when possible, followed at present by rail, road, cross-country tractor train, and fixed-wing aircraft. Some concept

of the financial burden involved is indicated by the rate of \$200.00 per ton for coastal DEW Line station supply from Montreal. Bulk freight may move at five cents or less per ton mile by rail as compared to about ten cents per ton mile by road. General cargo may move cross-country by tractor train or fixed-wing aircraft at forty cents to a dollar per ton mile, cost and choice of such transport being largely controlled by location and nature of the terrain and type of aircraft employable. The adverse effect of logistics on economy is magnified since heavy, rather than light, industry is involved. The cost of mine product shipment alone can easily exceed its market value.

Another difficulty militating against Arctic operations is one which might be termed the "heat balance" in its broad sense. Energy for machine propulsion or endothermic process reaction is, with few exceptions, costly since it usually must be generated locally on a small scale with expensive fossil fuel. In addition, the severe climate necessitates large expenditures for direct heating purposes. The adverse heat balance can amount to a competitive penalty of several dollars per ton mined. Hydro-electric power potential is limited because its transmission is expensive and uneven water flow, ice, and permafrost are complicating factors. The wind is an inexhaustible supply of energy which requires no transportation, but its force fluctuates widely and accumulation of large capacity is uneconomic. Solar energy, although of great magnitude, is extremely variable in delivery, and its density per unit area is low, so that large capacity requires undue investment in collecting surface.

Omnipresent permafrost, the zone in the ground perennially below freezing point, is troublesome in the construction of buildings, utilities, and waste disposal. Costly measures are frequently necessary to avoid disturbing the thermal regime with resulting settlement caused by melting of ice in volume exceeding the void content of the thawed, consolidated soil. Large quantities of gravel, often hard to obtain, are essential for surfacing and foundations. Permafrost does not interfere seriously with underground mining and is basically an aid to road construction. However, its new feet of active top layer and the poor drainage can create virtually impassable conditions for vehicles during the summer months.

Last but not least of the innate impediments of the environment is the problem of manpower. The widely scattered circumpolar aboriginal population, including Eskimos, Lapps, Samoyeds, and Chukchis, totals only 100,000. Thus any major mining enterprise requires importation of labor unaccustomed to the rigorous living conditions and reluctant to settle in the area. It is not only the wind-chill and the lack of urban amenities which the immigrant finds repellent. The long periods in which the sun doesn't rise or is hidden by fog or low overcast and the paucity of fauna and flora exert a depressing effect leading to discontent. This is a problem which does

not lead itself to any ready solution. Compulsion can be employed as in the Soviet Empire, e.g., the penal colonies for useful liquidation of political prisoners which played so prominent a role in the establishment of Vorkuta and Norilsk or the forced transplanting of national groups to Siberia. However, even a political system based on military social discipline and profligate consumption of "human material" has proven inadequate to the task. Currently special financial rewards and vacation privileges are offered to induce voluntary migration of labor to the far north, as practiced in the West.

When all required expenditures are totaled, mine capital investment and operating costs in the Arctic can prove double or more than those in less remote and harsh climes. The reader may now have concluded that the growth prospects of a rational mining industry there in the foreseeable future are cold indeed. This conclusion is not necessarily the case because world population pressure and the meteoric progress of science and engineering can provide capabilities which not long ago would have been considered chimeras.

This discussion avoids flights of fancy such as the recent publicized scheme for damming the Bering Strait which would more likely end in disaster than triumph. It also omits carefully considered but complex projects on the order of the proposed port-creating nuclear blasts on the northwest coast of Alaska. However, tremendous advances have been made which are transforming the present bleak situation in respect to logistics, heat balance, and living conditions in the Arctic. How soon the new potential will become dynamic on a large scale depends in good measure on the wind of change blowing in lands closer to the Equator. The supranational, immutable law of relative energy input per unit of output which made the Czar of old build the epic Trans-Siberian Railroad in the south has made the Czar of today concentrate heavy industry in the same imperial marches. Since the Russians possess more natural resources than any other nation on earth, and the bulk of these are south of the tree line, there is today limited economic incentive for strong industrial development in Arctic Siberia. If the Atlantic Community has adequate access to minerals from areas to the south on the basis of fair and mutually profitable exchange, then intensive Arctic mineral development will be relegated to another generation. The engineer knows that, if political circumstances permit, the enormous reserves of mineral wealth lying between the Tropics of Cancer and Capricorn can economically dominate those lying north of the Arctic Circle. It must nevertheless be understood that man's ability to take rewarding industrial action in the far north will in ten years be very different than it is today.

The cost of transport by air freighter is inverse to the lift capacity and efficiency of the vehicle, and here the jet engine is one of the Arctic's best friends. A projected Lockheed turbofan jet cargo plane will move 40 tons of payload 2500 miles at 500 knots for less than

20 cents per ton mile in Arctic service. VSTOL aircraft (vertical short take-off and landing) will permit aerial truck and bus drivers to take off and land vertically yet travel horizontally with fixed-wing aircraft speed and range, allowing large savings in ground facilities. There is also promise in the hovercraft, a ground effect vehicle which rides a cushion of air separating the craft from land or water a few feet below (or roughly 1/10 of vehicle diameter). It may in due course play a role in freeing light transport from direct contact with the earth where, as in the Arctic, long distances may be traveled over reasonably flat topography. Much improved bulk cargo cross-country locomotion, such as by huge amphibious track-laying vehicles designed for tundra and rock desert use, is already within our grasp. The blue water monopoly exercised by the ice canopy in the High Arctic has now been broken by the submarine, so that traditional heavy transport by water will in time sharply extend its domain.

The advent of nuclear energy has metamorphosed the heat balance problem in the Arctic beyond recognition. Within a decade it will be possible for a major Arctic operation to generate steam and electric power at costs similar to those common in many industrial nations of the temperate zone. Removal of the heat balance handicap can in turn lead, in the case of a number of elements at least, to elimination of the high cost of moving large tonnages of relatively low-grade mine product to market. For instance, raw ore or concentrate could be subjected locally to a choice of pyrometallurgical, hydrometallurgical, or vapometallurgical techniques and thereby allow export of practicable tonnages of high-grade metal.

Insofar as questions of permafrost and personnel are concerned, it is now possible to conduct operations underground and, in the Arctic at least, at lower cost and with greater ease than on the surface. Air-conditioning, television, sun-lamps, hydroponics allow man to build vast, modern subsurface igloos in rock almost independent of the world above. The wind and snow, chilling, sporadically demonic, building concrete-like drifts and sifting through nook and cranny, can be ignored. Selection of employees, good food and private living accommodations, generous public recreation facilities and adequate vacations will minimize the manpower problem.

It is interesting to note that it is the sword which is cutting down the barriers to peaceful pursuits all around the polar Mediterranean. Following in the paths of the Anglo-American military explorers of yesteryear who journeyed into the white solitudes until the Pole was attained, North American defense forces are creating new and favorable circumstances for man living in the Arctic. The list of these military contributions is long and impressive: the long-range jet plane and heavy duty helicopter, the submarine, the icebreaker, special track-laying vehicles, Alaska Railroad, Alcan and other highways, the DEW Line and White Alice, Thule, communications networks, meteorological stations, navigation aids, airfields, harbors, POL, water and sanitation facilities, nuclear power plants, perma-

frost management and use of snow and ice as materials of construction, medical advances, and improvements in cold weather clothing.

Most of the far northern U.S.S.R. is forbidden to foreigners, but there is no doubt as to the outstanding record of achievement there. In war and peace the Russians, from the Cossack conquerors of Siberia to Ivan Papanin and his coworkers, have long and successfully struggled with their cold weather environment. The remarkable efforts expended along the Northern Sea Route have always had a military purpose, quite aside from provision of reliable deepwater transport for economic development. The history of Rozhdestvenski's encounter with Togo might have been different if his route had been less than half as long: via the Taymyr Peninsula rather than the Cape of Good Hope. Ironically, the first warship to complete the Northeast Passage in one navigating season was the German raider "Komet" during the Hitler-Stalin Alliance. The ice-free port of Murmansk and the Pechora coalfields were linked to the interior by railroads built in World War I and World War II, respectively. Since then an immense investment has been made along the entire littoral to aid and control sea-air traffic and to establish an Arctic air-theater; typified by the atomic icebreaker Lenin, hundreds of air strips and radar posts, weather and sea ice forecast stations, and geophysical observatories.

It will be remembered that the superb roads built for the Roman legions became peaceful avenues of commerce for centuries and the same will eventuate at the top of the world. Spectacular achievement in the utilization of the Arctic's natural resources will not be accomplished in the polar summer-long day. The giant efforts involved can only be on a national scale, as exemplified by the intimate association between private enterprise and public interest which is responsible for this continent's magnificent telephone system. The destiny of those countries with horizons in the big sky of the high latitudes is tied to the steadfast North Star, and it must be their guide.

CHAIRMAN WOOD: Our next speaker might well be called "Mr. Arctic Geographer". He is Dr. Trevor Lloyd, Professor of Geography at McGill University. Dr. Lloyd, one of the most distinguished exponents of the field of geography, is so well versed in problems of the Arctic that there is hardly a subject he can't take over. He is basically a human geographer in the very broadest sense, and his topic today is "Human Society in the Arctic Today". Dr. Lloyd.

HUMAN SOCIETY IN THE ARCTIC TODAY

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We have listened during this Conference to a well-merited justification of the importance of research in utilization of the Arctic. We

have discussed the arctic environment with its assets and its disadvantages, and have heard how man may be provided with external and internal protection against its harsher elements through use of the right clothing, shelter and diet. We have learned something of the personal problems faced by men working in isolation under unfamiliar arctic conditions, and have realized that, today, even the ends of the earth are not beyond the long reach of the clinical "head shrinkers."

It has come to be the traditional viewpoint of the public at large that, so severe is the arctic environment, so remote and unfamiliar is it from the experience of ordinary man, that we can consider ourselves little better than transients there. Such limited experience as I have had of bases in the north seems to support this; if only because of the rarity of finding a familiar face at the club bar when returning after an absence of a year or more. So it is encouraging to learn at this Conference that this view is apparently changing—that there is even talk of "conquering the Arctic." (See "Man's Future Conquest of the Arctic" on page 115). Given time and continued scientific effort we may even learn to equal in adaptability and tenacity ~~these admittedly~~ gifted and dogged northerners, the Eskimos. However, unless we surrender, permanently and soon, the view that there is some quite fundamental difference between the Arctic and areas farther south, we shall not colonize any appreciable part of it in the lifetime of those here today—and our descendants may watch "The Northward Course of Empire", in Asia, spilling over the pole to become a southward one in North America!

The task given me is to review the general distribution of human settlement in the Arctic, and to offer appropriate and even provocative comments on it. I shall resist the temptation natural to a geographer, to offer you a menu of maps, complete with great circle courses and innumerable isopleths depicting human, environmental or strategic factors. However, it may be useful to discuss briefly some of the terms to be employed—at least those used in the title.

The title is *Human Society in the Arctic Today*. This suggests, as it is intended to, man living in organized communities. The precise kind of man seems to me to be immaterial—whether one thinks in terms of nations or races. I am not one of those who argues that native peoples should be encouraged—even compelled—to retain their old-time languages, customs, costumes or activities. One rarely hears this desire claimed by the natives themselves. To me it smacks too much of what a Danish friend calls "The Zoological Garden philosophy"—with ourselves on the outside, looking in. If applied to me, for example, the role would require that I address you in the language of my fathers, Welsh—a patent absurdity. A young Russian geographer friend of mine has a Tungus mother and is proud of it, but he writes his scientific papers, also with pride, in Russian from Moscow and not in a Siberian dialect from the banks of the Stony

Tunguska. Just as we permit—even urge—southerners to go to the Arctic to visit or dwell, I very much hope that we shall be no less encouraging when Eskimos wish to settle in the south, and if need be are swallowed up in the proverbial melting pot.

The "Arctic" in my title is, for the present purpose, not to be interpreted literally—or climatically. It is merely that area of the world remote from surface transportation and large settlements and with a particularly brief and inadequate summer.

The term "today" is intended merely to stress the present as contrasted with the past—interesting and important though that be. It is also to be thought of as including the todays that follow this one—so comprehending also the not too distant future.

On considering the many communities that are scattered around the north polar regions, it occurred to me that we can now—as never before—divide them into two main categories. Were it possible to plot both of them on a map, the comparison between the two groups would be instructive, particularly to a geographer. Unfortunately, only one part of the picture can at present be revealed. My two categories are: (1) military settlements; (2) civilian settlements. Something of the extraordinary world in which we live is demonstrated by the fact that we can in any good library look up a map of the distribution of military camps and settlements in Roman Gaul of 2,000 years ago—but not of the arctic regions today.

Of the location, size and morphology of the military settlements I personally know next to nothing; so must leave it to some future historical archaeologist to plot the map I cannot. Suffice to say that military settlements in the Arctic are widespread, some of them are large and many have all the attributes of modern towns, if within a restricted compass. It is understood that most of the problems of carrying on daily life at them have been solved, in the sense that the knowledge exists with which to solve them, and that any local evidence to the contrary such as frozen ears, inadequate water supply, inactive sewers, failure of the regular mail to arrive or inclement weather, is due to local incompetence, or unwillingness to read the instructions and apply them as ordered.

Some of the remarkably extensive knowledge of how to operate complex communities in the Arctic—and the U. S. Army Quartermaster Corps rightly receives a large share of credit for this—does permeate through to the civilian community, if only by the agency of surplus disposal stores and the skills acquired by defence contractors. However, the direct benefits to society as a whole are far fewer than they should be. A simple example will illustrate this point.

At Schefferville, Quebec, about 900 miles north of Boston, is an open-pit iron mine that probably holds a record for the severity of its winter cold. Open air operations continue throughout the year. There is apparently a turnover of skilled personnel because of the severe conditions outdoors in midwinter. The mine management has

proved to be resourceful in dealing with engineering problems due to the cold—cracked booms on electric shovels are now avoided by introducing heating elements; freezing of rocks and ore to the inside of the Euclid trucks is obviated by passing the exhaust gases through their hollow sides. But when the foremen complain of cold feet and frozen limbs—that is their own private trouble. If the winter clothing sold at the local store is inadequate, they alone must take the chilly consequences. I found, when enquiring there last year, not a trace of influence from the long and on the whole successful research programmes of the Quartermaster Corps in precisely this realm.

The feet of a mine foreman are his own personal business—the feet of a soldier on guard duty are a matter of grave public responsibility! So much for the example.

Unfortunately, for the present, the study of human society in the Arctic must exclude the most widespread, technologically advanced and doubtless most costly group of communities there and deal only with what remains, the groups of civilians.

What is the nature and extent of these?

Some of the newest, the smallest and often the most isolated are bases designed for scientific research. They range from groups occupying floating pieces of ice, through isolated weather-reporting stations to more comprehensive and permanent scientific communities where several disciplines are more fully represented. Such scientific stations have in some cases become recognized centres for long-term research, such as those at Point Barrow, Resolute Bay, Godhavn, and at a number of places in the Soviet Union. They provide possibly a prototype for other similar communities, to come when the scientists and the funds are more generally available. Supervision over the programmes of such stations is an appropriate activity for universities and bodies such as the Arctic Institute.

A sharp distinction cannot be drawn between such stations and still larger, multi-purpose communities which may have scientific functions of an incidental character, as for example when the main purpose of the settlement may be commercial, administrative or related to long distance aviation. Such places may include a variety of scientific functions as is the case at Yakutsk, U.S.S.R.; Tromsø, Norway; Godthab, Greenland; or College, Alaska.

The growth in the number of permanent scientific centres in arctic North America in recent years has been commendable. Canada had none at all even fifteen years ago, while the famous station at Godhavn, Greenland was a lonely pioneer for almost forty years after the turn of the century.

Mining provides a justification for new communities, frequently in isolated spots. A few have been founded within the past decade, such as Rankin Inlet on the west coast of Hudson Bay, Mesters Vig on the east coast of Greenland near Scoresby Sund and, somewhat farther south though still in a severe climate, Schefferville, Quebec. A new

town that has grown up on the ashes of an older one may also be mentioned—Kirkenes in northern Norway, a few miles from the Soviet border. The U.S.S.R. is represented by a number of relatively new mining towns. One within sight of Kirkenes is Nikkel', while other mining centres have developed at Kirovsk and Monchegorsk in the same general area. In fact the whole Murmansk region is highly urbanized with 84 per cent of the population living in cities.

Farther east are other Arctic mining cities such as Vorkuta based on coal and Ukhta on oil, and in Siberia the farthest north mining city of the U.S.S.R., Norilsk, in 69° N. latitude producing nickel, platinum, copper, coal, cobalt, gold and smelting most of them. This city has grown to about 110,000 persons since 1940. Still farther east are centres of gold and diamond mining, which though more southerly are still in regions of severe climates.

It may be added in parenthesis that I have discussed at some length with Soviet specialists the factors which determine the exploitation of mineral and other resources in the Soviet Arctic, and conclude that there is in practice little to distinguish between those at work in the U.S.S.R. and those in North America. Capital is, it seems, not expended on economic development of the Soviet far north unless there is reasonable prospect of obtaining products at a competitive price. There, as elsewhere in the world, whether in the Arctic or in the Sahara, communities will be built as a base for exploiting minerals, if the economic prospects are inviting. There is after all it seems, no all-embracing Marxian Santa-Claus.

Mining communities, of course, bear little or no relationship to their immediate surroundings or to the lives of any local population there may be. They are really distant suburbs of some great metropolis. The need to attract highly skilled personnel and, more important, their wives and families, makes it imperative to provide all the comforts of home and others besides. This has, of course, always been so. One of the pioneer arctic mining settlements—founded a century ago—is Ivigtut site of a cryolite mine in Greenland. The contrast between its appearance and standard of living and those of the village of Arsuk a few miles away has always been notable and depressing. So is that between Yellowknife and Fort Rae in northwest Canada, or between Scherfferville and its Indian satellite suburbs. So too in Finnmark, the Norwegian mining town of Kirkenes, complete with paved streets, indoor swimming pool and resort hotel, stands out from the shabby little fishing villages not far away.

In many ways mining towns in the far north are rather like defence communities. They cannot exist unless they are modern and efficient and able to attract some of the elite of the skilled southerly population. So they need to be planned, comfortable, and as well served as possible, in order to carry out the job assigned to them.

Yes, there are extraordinarily few mining communities in the far north—at least in Canada, and there does not appear any likelihood

that many additional ones are on the way. In the 20 or so years that I have been observing economic developments in northern Canada, the rate of advance has not been striking. Today a pioneer settlement, Port Radium, is going out of business, and a recent arrival, Rankin, may soon follow suit. In Greenland, Mesters Vig expects to cease operations, and the life of Ivigtut cannot be extended much longer.

In other words the manner in which mining has been organized in the Arctic down to the present does not suggest that it will provide in the near future a rapid and sure means of settling permanently any appreciable part of the region.

From a consideration of the northern communities that exist today, we can arrange them in a descending order of methodicalness and effectiveness: the defence community, the mining town and finally, the typical general-purpose northern settlement. I have in mind for this last category the villages or small towns of Alaska, northern Canada and Greenland, and I suspect that most of those in the Soviet Arctic are little if any different.

The sites were in most cases chosen by some far off folk as hunting or fishing localities—where seals passed, water remained open, several travel routes converged or some other favourable factor ruled. Traders, missionaries, whalers and eventually administrators were attracted to the little communities for their own diverse purposes, and aided in their growth. No planning went into them, and little elementary forethought. There is nothing unusual in this—it is the way in which most of the great cities arrived on the scene, later to sprawl over the countryside. Boston, Winnipeg, Copenhagen, Cape Town and Moscow evolved thus. The Washingtons, Canberras, Brasílias and Chalk Rivers of this world are the rare exceptions. That most of the northern communities are poorly sited is to be expected from their mode of origin—Aklavik's many deficiencies have for example long been recognized. Godthåb is in the right part of Greenland for a main centre, but in the wrong spot—a small peninsula, without a good water supply, with a poor harbour, no airfield site and little room to expand. Occasionally builders of northern settlements have been granted the opportunity for second thoughts about siting, but rarely have they had the courage to take them. The dead hand of the past has almost always proved too compelling. Those who expanded Godthåb after 1950 could have looked elsewhere for a site but dared not. In north Norway the old settlements were all destroyed by 1945, but even then they were reconstructed sometimes on quite impossible old sites, such as those of Hammerfest and Vardø. These two have been doggedly thrust up again from the ashes, only to prove within a few years hopelessly inadequate as homes for modern commercial or administrative communities.

Occasionally second thoughts came just in time to avoid wrong siting. Churchill on Hudson Bay was very nearly built at the mouth

of the wrong river, as is demonstrated by the hesitating way in which the Hudsons Bay Railway wanders towards it, crossing the Nelson River twice in doing so.

There is less excuse for the poor siting of even more recent northern settlements, such as that at Repulse Bay. This focus of Arctic transportation was selected in the face of advice that it provided one of the worst harbours in the Canadian Arctic. It was in fact used, because a harrassed ice-breaker skipper in a hurry could find nowhere else to dump his load when he failed to reach the assigned site farther west. At that time no preliminary studies had been made to aid in locating this vital northern settlement.

That even defense sites have been chosen with less than Olympian wisdom—in spite of the ample skills and resources that might have been utilized—is perhaps more disturbing. I recall two airfield sites in the Canadian eastern Arctic and two or possibly three in south Greenland that were less well located than they could have been. In fact all three airfields in east Greenland were from an all-round viewpoint poorly selected. Hence the communities that they now serve, or may serve in future, will be less well provided for than they should be.

There is nothing inevitable about this. Some years ago a study was undertaken to locate a commercial harbour site in Greenland. The method followed demonstrated that when the specifications are clearly laid down and all available information is gathered, the job can be done quickly, economically and effectively.

The general picture that emerges from this cursory survey of man living in communities in the Arctic is that he has generally contrived—through ignorance, haste, inefficiency, lack of enterprise or an unwillingness to make use of available knowledge and skills—to build up a pattern of settlement that greatly exaggerates the acknowledged hardships of arctic living. In the case of mining communities there is some excuse in that the ore to be exploited has determined the location—although even then there is usually some room to maneuver. The second time Yellowknife was built, it was a great improvement on the first, though the distance between the two is small. Schefferville contrived to be unnecessarily unattractive, and to exaggerate the hardships of the environment by simple lack of imaginative planning—something that its successor Carrol appears to be avoiding. As is being demonstrated at Thompson in northern Manitoba and at Otonmäki in northern Finland, a mining community does not have to cluster around the mine shaft like a medieval city around its fortress.

Administrative and commercial settlements in the far north have even less excuse to be poorly sited or to remain so as they expand. There is usually a good deal of flexibility about the location as has been shown by the case of the old Aklavik and the new Inuvik. When it was decided to build a new settlement, all the necessary skills were recruited, and adequate time and resources made available, so that the Arctic's first adequately-planned settlement has resulted. This is

today still almost an unique example. In Greenland the very great expenditures on urban development—new harbours, schools, hospitals, fish-processing plants and so on, have been invested in sites hallowed by history but usually blessed in no other way. One exception is Narsaaq in the south, where the need to build a shrimp processing plant has provided an excuse for what is in effect a new village, complete with Denmark's most modern supermarket.

So far I have said little about the location of settlements in the Soviet Arctic—largely because I am all too ignorant of the facts about them. I have twice travelled hopefully to the U.S.S.R., but have so far failed to arrive at any point north of Leningrad. I am however familiar with similar parts of Finland having travelled along much of the border between the two countries.

From searching, if distant, views of "Nikkel" I conclude that there is little to learn from Soviet arctic settlements. Its fire hall and Palace of Culture are not notably different—except in scale—from those at Alma Ata 2,500 miles away, near the Chinese border. Such is that remarkably monotonous nation that there is little likelihood that a burst of originality characterizes Soviet communities in the Arctic, when it does not do so elsewhere. Settlement of the Soviet Arctic is presumably approached in the same manner as that of Karelia, Kazakhstan and Khabarovsk; for the basic principles of the Soviet economy and the political theology that accompanies them know neither latitude nor locale.

We on the other hand, are less inclined to be so simple-minded or so consistent. While the rules that govern the exploitation of resources on this continent require that a reasonable profit be forthcoming or the project cannot be initiated, fortunately there is one major exception; that the rules do not apply in matters of defence. This confronts us with the mildly absurd requirement that a telephone system shall declare a regular profit in latitude 40°N while, if a defence operation, in latitude 70°N it is not expected to do so. Aircraft carrying passengers across North America in latitude 30°N are expected to earn, at least nominally, a surplus. Those flying at 65°N—if they are engaged in defence operations do not even need to publish a balance sheet!

But this recognition that operations in the Arctic may deserve—at least in the initial stages—large subsidies from public funds, applies in general only to defence operations. When it is simply a matter of resource development, and the founding of an economy that may in time provide a sound livelihood for a new population—the building of railways, roads, airfields, mines, harbours, oil wells, shopping centres and so on—we reverse the polarity, and apply a different set of economic and social rules. For these, in our accepted terminology are "civilian" operations. There must be assurance of an operating surplus. And then we wonder why, in spite of a century of activity

there, the underdeveloped areas to the north of us have so little to show to the world.

The reason is not far to seek. With a very few exceptions, no part of the Arctic has ever been successfully developed without aid—whether in direct cash grants, indirect subsidies or by systematic planning—from the secure base of the organized community farther south. In other words, by direct or indirect government intervention.

I am inclined to the view after some contemplation of the circumpolar region, that none of it, including the North American Arctic, will be appreciably developed in the next 25 years—or possibly longer—without greatly increased use of similar techniques.

I have some knowledge of one particular large-scale economic development that stands ready to be launched—but will require hundreds of millions of dollars to float it. There seems no likelihood that the guardians of private capital will round up those millions when they can invest them more securely in nearer, milder and more familiar latitudes. As a Norwegian business man, head of a very successful enterprise a long way north of the Arctic circle, said in a conversation last summer, "Bankers don't lend money north of Trondheim"!

This discouraging assessment does not mean that there is no place for private investment in new northern communities, or that governments will be called upon to plan, build and operate all future industries and enterprises there. But it does mean that what has proved to be good for defence is in this case likely also to be good for the civilian sector: that there is nothing improper in the community as a whole deciding through its governments to underwrite a vast development programme in the far north going far beyond the resources or inclinations of individual investors.

I hazard a guess that arctic settlement of the future will be brought about by greatly increased public expenditure, based upon the results of intensified scientific enquiry on careful, systematic and imaginative planning, and through concentration on selected targets, that offer the best chance of success. In other words, priorities will be set up, and the resources of the community will be brought to bear on those schemes considered most promising. There may still be some place for strictly commercial enterprises in the north, but there is likely to be a careful allocation of tasks between the public and the private sector. The sole criterion will be, "what is in the long-term interest of the whole community"—not forgetting that part of it already living in the far north. If any genuine profit can be made out of Arctic development, and this there is some reason to doubt, it will have to be a secondary consideration. What is urgently needed today in the far north is to devote to non-military development, the kind of imaginative thinking, technical mastery, and sheer hard work that has gone into such enterprises as the DEW line and B.M.E.W.S. (Ballistic Missile Early Warning System). We need to apply to the

expansion of civilian society in the Arctic, for example, the results of the great research programmes of the Quartermaster Corps, dedicated as they have been to the service of the country, without consideration of private gain. Parallel with this must come a greatly expanded programme of research through universities and similar institutions, together with the systematic training of the new generation of personnel needed to work in these still unfamiliar regions. While private contributions may aid in this, the main task of providing the large sums of money needed will, unavoidably, fall on the public treasury.

If only because of the many common problems that exist within the circumpolar lands—not excluding the surrounding seas and the atmosphere—there is an urgent need to improve the international exchange of scientific knowledge, as well as of scientists themselves. This will not happen of itself—for there are many and real obstacles in the way. Leadership will be needed. For example, a Conference of the type we have been attending here would be all the more stimulating if its participants could bring contributions from all points of the Arctic. There is a long and honourable tradition of international scientific collaboration in the polar regions. Little would be lost and much benefit would come from reviving and extending it. Canada is, it is understood, already disposed to encourage this. Through the international, non-governmental contacts maintained by The Arctic Institute of North America, it should not be impossible to set up a programme of scientific exchange visits, to be followed by co-operative arrangements for study and research.

Human society in the Arctic today still faces more than enough natural obstacles to progress. We should at the least be prepared to join forces with other scientists, wherever they may be, who are dedicated to overcoming them.

CHAIRMAN WOOD: Our final speaker has chosen to discuss "The Role of Politics in the Expanding Utilization of the Arctic". He is Dr. George W. Rogers of The Arctic Institute of North America and is now in a transitory stage as Carnegie Visiting Professor of Economics at the University of Alaska and College. Our distinguished speaker has written extensively about Alaska, his most recent publication entitled "Economic Consequences of Alaskan Statehood". Dr. Rogers has also acted as advisor and consultant for the last three Governors of Alaska. It is a pleasure to introduce to you Dr. George W. Rogers.

THE ROLE OF POLITICS IN THE EXPANDING UTILIZATION OF THE ARCTIC

GEORGE W. ROGERS
University of Alaska
College, Alaska

In terms of political organization, the Arctic might be described as the northernmost extensions of an array of governmental types. In addition to various northern territories and districts of Canada, the

USSR, and the Scandinavian nations, it includes the independent republic of Iceland, the former overseas Danish colony of Greenland, and an important part of the newly created "sovereign" state of Alaska. A comparative examination of these political organizations and their administrative problems in the Arctic would be instructive and useful to the purposes of this conference, but the detail required even to provide an outline talk would exceed the time limits. Furthermore, institutional arrangements are not the crucially important political aspects of the Arctic.

My intention is to be both more general and more basic than would be the case if my purpose were to present a political catalog. The choice of title places emphasis where it is intended, upon the role of politics as a motivating, dynamic force in expansion into the Arctic regions. Also as the final speaker, I would like to raise a question: Why should there be a more *popular* interest in the Arctic? The members of this conference have an interest or rather a variety of interests in the top of the world and in terms of your special interests you are somehow "dedicated" to it and its understanding. But to the outsider, to the general public, military activities are seen as a version of armed sentries at our northern gates, and non-military exploration and investigations are looked upon suspiciously as some form of extending Boy Scout or university outing club activities into the later years of our lives and into an outlandish wilderness area. There is something of that element in it, of course, but there is more to it than that.

In getting at this "more" element I must depart from the narrowly scientific and military tone which has dominated this conference and approach my subject from the attitude of the popular mind, i.e., the non-scientific and non-military mind. The title of this conference is given as "Man Living in the Arctic", but with the possible exception of Trevor Lloyd's paper, Man has not emerged from this discussion in any humanly recognizable form. We have been informed on the functions of physical parts of Man under various Arctic conditions. (There is available in the lobby a supply of copies of papers recently presented at a similar symposium on "Protection and Functioning of the Hands in Cold Climates". The title of that conference might have been "The Hand in the Arctic".) The papers given at the present conference have been enlightening. We have considered Man as a piece to be used in the opening plays of the deadly game of international warfare. These papers have been frightening.

As an Alaskan I must confess to be somewhat less than charmed by the role we were assigned in one of the sales points in Colonel Pearson's presentation (see page 35). To paraphrase Lowell Thomas at the close of his High Adventure film on the Arctic. I do hope that the rest of you are able to sleep better at night secure in the thought that tens of thousands of able young Americans are alert to intercept any enemy attack; and if they are not altogether successful, some two

hundred thousand Alaskans stand ready to sop up some of the radioactive blast and fall-out which would otherwise be unloaded on you. Frankly though, I could have done without the map with the neat little red mushrooms scattered about to illustrate how this would be done. The Rogers family happens to live at one of those points.

Speaking seriously, Colonel Pearson and the members of our entire military establishment are hired by the rest of us to think and plan in just such unpleasant terms. If the unthinkable does happen, it is essential that there be an alert and trained group of our citizens prepared to move immediately and with authority along an already predetermined and appropriate line of action. This is the role of the professional soldier in our society. He is our insurance policy, standing by to be drawn upon in the event of an emergency which we hope will not materialize.

To the civilians in the audience, our job is to think in terms of alternatives to war. Such thinking does not mean that we are opposed to the military view of the role of the Arctic which has been featured here, but rather that we must take a broader view in which the military assumes its proper perspective. Without this broader view we fail in a very serious way. This larger picture is what Generals Trudeau and McNamara undoubtedly had in mind when they stressed the dangers inherent in our allowing social science research to lag so behind our other research.

In ending this section, I am acutely aware of the necessity to consider Man in the Arctic as something more than a biological or military concept. Man is essentially and uniquely a political animal. It is in this sense that I wish to draw attention to him in connection with the North. What are the motivations which have directed attention northward, and what are their underlying political nature? Let us review some of the more elementary and basic points already developed in this conference.

Start with the general picture of the Arctic as one of the almost vacant regions of the earth. In view of the world's ever increasing populations we might look northward for the living space man so badly needs and will need even more acutely. But there must be a good reason for these northern regions being virtually uninhabited, and there definitely is one as the earlier papers in the conference have implied. The Arctic is a most uncomfortable place, much too cold for what we consider civilized living. Put into the economist's jargon, this is a general region of "low amenity resources". In order to survive through most of the year, man must become a primitive astronaut somehow creating for himself a new outer body to make up for the shortcomings of the one he possesses naturally and creating indoors the elements which the natural climate does not adequately provide.

In saying this, I speak from personal experience, not as an explorer or scientific investigator, but as a transplanted exurbanite living in the suburbs of Fairbanks, one of the northernmost outposts of

Suburbia, U.S.A. (There may be some purists in the audience who will deny me the privilege of saying that I live in the Arctic. This is a matter of definition, and during the long winter season, at least, it is the Arctic regardless of what they say. When I left home last week, the temperature was down to 38 degrees below zero, and from now on during the next three months all temperature quotations probably will mean "below zero".)

In this Arctic environment we act like the proverbial Englishman dressing for dinner in the depths of the jungle. We attempt to be true to all the detailed rituals of our culture while living in this gigantic deep freeze. Daily we gallantly battle the perils of ice and snow in our non-compact American automobiles with automatic transmission. Nightly we worry and fret over our headbolt heaters which are essential if our beloved monsters are to go on living and dominating our lives. We are kept in a perpetual state of genteel poverty trying to pay the heating and other utility bills for our ranch-type houses. We even have a few worries about our active children suffering frost-bite or freezing their lungs on their way to and from school or their music lessons. Somehow we manage to keep true to our culture and keep up appearances. But it isn't easy, and frequently we ask ourselves why we bother to go on living in such an unnatural place.

With due apologies to Dr. Stefansson, this "friendly Arctic" business can be overdone. During Alaska's statehood battle, our politicians regaled us with comparative temperature data—why, it gets just as cold or colder in Montana and parts of the Dakotas, to say nothing of ever so many parts of Canada—and we were cheerily told that the historical statistics indicate that the North is warming up. There isn't even cold comfort in such talk, for only a little reflection will demonstrate that those other parts of the continent which share our characteristic of extreme cold temperatures are not exactly overcrowded with humanity, and the warming-up process is a long term proposition, much longer than any of us can wait around for.

Attempts to settle the Arctic and sub-Arctic in these terms is indeed a daft notion. At most we could take up seasonal residence during the warm period, take care of our business, and get out before freeze-up. This has been the pattern of the past development of the North. But somehow in Alaska we have been given a public conscience which tells us that this attitude is wrong. In Alaska political aspirations toward full statehood were based upon the idea that, not only was permanent year round settlement desirable, but even possible. It is, but at a cost. Public investment must be diverted to make it possible through costly community facilities. Private investment must pay a subsidy in the form of extra wages and fringe benefits, and the individual pays a heavy cost in inconvenience and added living expenses. Those who believe in the future of the Arctic as a habitable area must realize that the above-mentioned expenditures will be necessary. The satisfaction

of a basically Alaskan political tenet of faith seems to require that this be done.

There are other social motivations causing some of us to continue on in our deep-freeze environment, of course. Whenever I begin to berate myself for continuing this struggle and subjecting my family to its inconveniences and discomforts, it only takes a trip like the present one to bring me back to my senses. The frustrating struggle from congested air terminals into congested cities, the hair-raising drives at top speed along crowded freeways (an ironic label), the polluted air, and the social violence and sudden death screaming from the morning paper does, indeed, make the Arctic and the sub-Arctic seem friendly by contrast. And where else can such a relatively small collection of American citizens, a group which could be lost in one of the neighborhoods of the Boston metropolitan area, enjoy and realize so fully its political destiny?

Paul Queneau's paper has dealt with natural resources as a force for expanded utilization. The natural resources of the Arctic have been exploited in a sporadic and narrowly specialized way in the past. There have been periods of intensive whaling, long-term harvesting of furs, brief sorties in search of gold; and today a growing interest in oil, natural gas, uranium, and other basic minerals. The utilization of natural resources has been hampered by lack of knowledge of how to work and live in cold climates, to say nothing of lack of knowledge of the resources themselves. Such knowledge comes dearly. We have no estimates of the cost of needed basic data programs, but past experience tells us it would run into the hundreds of millions of dollars. Private enterprise has and will provide much of the money, but breaking the back of these problems requires governmental investment in exploration and basic investigation on a large scale.

Mere physical existence of natural resources, however, is not enough to lead to economic development. There must be markets, and the resource must be accessible to meet these demands. In the Arctic this last item is crucial as General McNamara and others have stressed. Development requires massive capital investment in transportation facilities, in community facilities, and in other basic public works. In Alaska alone, basic road requirements and hydroelectric proposals which may trigger further development are estimated to cost not millions but billions of dollars. The magnitude is such that public investment must be resorted to.

The development of the Arctic's natural resources in something other than a selective, specialized way is therefore largely a matter of public investment policy. The decision as to whether sizable sums of public funds will be spent on Arctic development or elsewhere rests with various national political entities represented. Somehow a broader "public will" must be brought to focus upon the Arctic as being worthy of consideration. This decision is essentially a national political problem.

If the Arctic is not a promising place for human settlement, its resources may hold promise for future development. But its past and present importance derives from strategic considerations. From the early searchings for a northwest (or northeast) passage to the present day of ICBM's and atomic powered underseas craft and trans-polar commercial air flights, the strategic significance of the Arctic Basin has been increasingly recognized. Similar considerations applied to the east-west "Great Circle" routes prompted Mr. Lincoln's Secretary of State to engineer the purchase of Alaska and lay plans for a similar attempt to acquire Greenland. Here we are moving into still another level of politics—international politics, geopolitics, power politics or whatever other term you care to use. The motivation is the economic survival of political entities. Depending upon the particular nation or period of history, the Arctic has presented a challenge in the form of a barrier to be overcome or opportunities to be exploited in providing essential intra-national life lines or international routes for commerce and travel in times of peace and for aggression or retaliation in times of war or the threat of war. Whatever the use contemplated, however, the purpose to be served must be a politically recognized and determined one—one arising from an exercise of the apparatus through which the public will is discovered and interpreted.

At this point an Alaskan footnote might be excused to indicate how other unrelated forms of political action in turn meet the strategic considerations in the narrowly military sense. The creation of the state of Alaska was a ceremonial event of the highest political order. In effect, the people of the United States, through their duly elected representatives (the members of the Congress and the President) entered into a compact (so described in the Statehood Act) with the people of Alaska, acting through a popular referendum, by which sovereign powers and responsibilities were to be shared. This purely political act carried out in a never-never land created by 17th and 18th century political philosophers has, we were told in previous papers, modified planning by the Army. Because of its more elevated political order, no part of the state of Alaska now can be considered as a potential buffer zone in the event of enemy attack from over the Pole or as land which might be written off as, at most, so much ground space over which an air struggle would be carried out. Colonel Pearson stressed that the Army still has a job to do to defend American soil from falling into enemy hands, if for no other than international psychological reasons. The political event of statehood, apparently, has heightened these psychological reasons far beyond what they might have been in its absence. Nor can existing defense facilities, the operation of which comprise an important element in the State's basic economy, be freely abandoned in response to a logic arising from technological change—not in the face of a vocal representation of the people of Alaska in the United States Congress.

Clearly, the task set for me by the title of this paper cannot be

accomplished beyond the raising of a few questions. There probably are no political scientists in the audience; but if there were, they should as a result of this conference take a fresh look at the Arctic in relation to human affairs. To the student of international politics and political theory in general, this region is a very fruitful focus for study leading to an understanding of national aspirations, character, and activities. The intensity, purpose, and manner of carrying out activities in the Arctic can serve as an index of these national traits. In his recent popular book *Ghost Ship of the Pole*, Cross presents not merely a lively adventure story of Arctic exploration (the story of the ill-fated Italia, its captain and its crew), but gives an illuminating insight into the basic character and operations of a tawdry dictatorship with political aspirations beyond its spiritual means. A more scholarly study and critical evaluation of other ventures into this region may be equally revealing in providing clues to an understanding of other national groups, including ourselves.

But this is not the note on which to leave my topic. Rather, I shall leave it with a question directed to all of you as citizens of the western nations having a real, but as yet hardly understood, stake in the Arctic. As we each, separately or in organized groups, periodically re-examine and attempt to rediscover a national purpose, let us consider our relation to the North. Then ask ourselves, "In these terms, what should be Man's place in the Arctic?"

Appendix I

DEDICATION OF THE WILKINS ARCTIC TEST CHAMBER

MAJOR GENERAL ANDREW T. MCNAMARA
The Quartermaster General
Department of the Army
Washington, D. C.

We in the Army Quartermaster Corps find it appropriate to dedicate the Arctic Environmental Test Chamber here at our Research and Engineering Center to the memory of our respected colleague and friend, George Hubert Wilkins.

May I say also, Lady Wilkins, that we are truly honored and deeply grateful that you have come to join us today in this tribute to your famous husband.

Before Sir Hubert joined us in 1942, he already had a most impressive record of accomplishments. While many of us who were his friends know something of what he had done in the fields of adventure, exploration, and military service, I think it is fitting on this occasion to recall some of those achievements.

In the Balkan War of 1912-13 Wilkins became the first photographer to obtain motion pictures of actual combat. He was also one of the first to parachute from an aircraft—no mean feat, considering the aircraft and parachutes of that day!

The outbreak of World War I found him second-in-command to Dr. Stefansson—also here with us today to honor Sir Hubert's memory—on an expedition in the Arctic, a place then so remote that not until September 1915 did Sir Hubert learn that a war had engulfed the world.

Eager to get to the battle fronts, he left the expedition in 1916, returned to Australia, and was commissioned in the Australian Flying Corps. After journeying more than 80,000 miles from the Arctic to Australia and then to Europe, he finally reached the Western Front. He took part in every engagement fought by the Australians. He was wounded nine times. He was twice mentioned in dispatches. And he was awarded the Military Cross with Bar for Exceptional Bravery, which is the British equivalent to our Distinguished Service Cross, second only to our Medal of Honor.

Following World War I, Sir Hubert began a series of polar flights that won him international acclaim. His great flight with Eielson from Pt. Barrow, Alaska, across the Arctic Ocean to Spitzbergen in 1928 has been compared to Lindbergh's similar feat of that day in crossing the Atlantic. It was following this flight that he was knighted by King George V, not just for his polar explorations, as was popularly assumed, but also for his wartime record and his contributions to the sciences.

After accompanying Sir Ernest Shackleton on his last voyage, the one on which that great explorer died, Sir Hubert's next expedition was to the other end of the earth and resulted in the first aircraft flights in the Antarctic in November 1923.

In 1931 Sir Hubert came back to his first love, the Arctic. Using the obsolete U. S. Navy Submarine O-12, which he renamed the "Nautilus", he began a research project in which he made the first underwater cruises beneath the Arctic icepack. The final chapter of this adventure was completed in 1958 when two of the Navy's new atomic submarines successfully traversed the entire polar icepack underwater. In honor of Sir Hubert's earlier achievements, the Navy named one of the subs the "Nautilus".

In 1936 Sir Hubert returned to the Antarctic, where he helped organize the first aircraft crossing of that remote continent. The crossing was made by the American explorer Lincoln Ellsworth and Pilot Herbert Hollick-Kenyon.

By 1937 the golden age of polar exploration was drawing to a close, but again Sir Hubert was a participant. His aerial searches in the Arctic for the downed Russian flyer Levanevsky covered some 150,000 square miles of the Arctic basin never before seen by human eyes.

With the advent of World War II, Sir Hubert placed his vast knowledge and experience at the disposal of the United States Army Quartermaster Corps to assist in developing cold-weather clothing and equipment for our own troops and those of our Allies.

Few if any Quartermaster developments can be credited to the work of a single individual, for they all represent team effort by the time the item is issued to troops. Nevertheless, there is scarcely an example of cold-weather clothing or equipment in the U. S. Army supply system today which does not carry the imprint of Sir Hubert's contributions.

General Georges F. Doriot, who was Chief of The Quartermaster General's Military Planning Division during World War II, has said: "One outstanding attribute of Sir Hubert was his willingness to undertake any task, notwithstanding how dangerous or difficult it was, and to always carry it out successfully with great modesty on his part."

He was a man of boundless energy and was never perturbed by his surroundings. He was never demanding and was always ingenious in finding a solution to a problem. If he was unable to induce a tailor to make a design exactly as he conceived it, he would sit down at the sewing machine and make the item himself. He was indefatigable and always wanted to test items himself. He would continue long after younger men became exhausted.

Even in later years he never spared himself in whatever he undertook. He insisted upon going on field maneuvers so that he could personally evaluate developmental items under the most difficult conditions. He was adamant in insisting upon realistic field testing.

Above all he was the champion of the individual soldier in striving to reduce the weight and bulk of what the soldier is expected to carry.

We in the Quartermaster Corps stand in great debt to Sir Hubert. We are deeply proud that he chose to spend his last years working in our midst. In recognition of that debt, out of the fullness of that pride, and on behalf of the entire U. S. Army Quartermaster Corps, I hereby dedicate this facility at the Quartermaster Research and Engineering Center as the Wilkins Arctic Test Chamber.

Appendix II

CONFERENCE DINNER

The Boston Museum of Science was the setting for the banquet Thursday evening (1 December 1960). Dr. Parks opened the program with a general welcome and special recognition for some of the people instrumental in organizing the conference. He then introduced the host, Dr. Washburn, Director of the Museum. Dr. Washburn spoke briefly noting that the great men who pioneered in Arctic exploration laid the foundation upon which present and future knowledge for living in that area can be built and that it is most fitting to turn the clock back briefly to pay tribute to these courageous men. He then turned the program over to the toastmaster, Lowell Thomas.

Mr. Thomas, who knows many of the early Arctic explorers personally, did a superb job of describing some of the first explorations including many humorous anecdotes concerning the people involved. He showed slides and films, and with a little help from Dr. Stefansen, Admiral MacMillan, and Dr. Siple took the audience back to those wonderful days when the Arctic challenged venturesome explorers to seek out her mysteries. Finally he called upon Mrs. MacMillan to say a few words. Having been on nine expeditions herself and with a wonderful wit and ability to tell a good story, Mrs. MacMillan literally brought down the house by relating a number of highly amusing incidents of life with her famous explorer husband. The group left feeling well fed and very well entertained.

NATIONAL ACADEMY OF SCIENCES NATIONAL RESEARCH COUNCIL

The National Academy of Sciences-National Research Council is a private, nonprofit organization of scientists, dedicated to the furtherance of science and to its use for the general welfare. The Academy itself was established in 1863 under a congressional charter signed by President Lincoln. Empowered to provide for all activities appropriate to academies of science, it was also required by its charter to act as an advisor to the Federal Government in scientific matters. This provision accounts for the close ties that have always existed between the Academy and the Government, although the Academy is not a governmental agency.

The National Research Council was established by the Academy in 1916, at the request of President Wilson, to enable scientists generally to associate their efforts with those of the limited membership of the Academy in service to the nation, to society, and to science at home and abroad. Members of the National Research Council receive their appointments from the President of the Academy. They include representatives of the Federal Government, and a number of members at large. In addition, several thousand scientists and engineers take part in the activities of the Research Council through membership on its various boards and committees.

Receiving funds from both public and private sources, by contribution, grant, or contract, the Academy and its Research Council thus work to stimulate research and its applications, to survey the broad possibilities of science, to promote effective utilization of the scientific and technical resources of the country, to serve the Government, and to further the general interests of science.

ADVISORY BOARD ON QUARTERMASTER RESEARCH AND DEVELOPMENT

Recognizing the need for independent scientific advice on his research and development program, the Quartermaster General, in 1943, requested advisory services and for this purpose established a formal contract with the Academy-Research Council. To fulfill the terms of this agreement, the *Committee on Quartermaster Problems* was organized by the Academy-Research Council under the Division of Engineering and Industrial Research. In 1943, the scope of the Quartermaster advisory activity was broadened, and the committee was reorganized as the *Advisory Board on Quartermaster Research and Development*.

The objective of the Advisory Board on Quartermaster Research and Development and its committees, by providing scientific and technical advisory services to the Quartermaster Research and Engineering Command, Natick, Massachusetts, is to aid the Quartermaster Corps in the most efficient achievement of the Corps mission—protecting, feeding, and supplying the combat soldier in any future emergency.