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Article abstract

This article examines the impact of military funding on the career of Dr Alan C. Burton (1904–79), who is widely remembered as a founding father of modern biophysics. Burton performed military research for the Canadian armed services during the earliest decades of the Cold War, securing funding and pursuing opportunities that advanced his career in medical science. Central to his military-sponsored research was a special climatic laboratory at the University of Western Ontario dubbed the Weather Factory, which enabled a long-running experimental research program on cold and the human body. Military sponsorship enabled the research that influenced Burton's professional trajectory from mathematician and physicist to biologist, and thus played an important role in his development as a biophysicist and interdisciplinary health scientist in mid-century Canada.

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Abstract: *This article examines the impact of military funding on the career of Dr Alan C. Burton (1904–79), who is widely remembered as a founding father of modern biophysics. Burton performed military research for the Canadian armed services during the earliest decades of the Cold War, securing funding and pursuing opportunities that advanced his career in medical science. Central to his military-sponsored research was a special climatic laboratory at the University of Western Ontario dubbed the Weather Factory, which enabled a long-running experimental research program on cold and the human body. Military sponsorship enabled the research that influenced Burton's professional trajectory from mathematician and physicist to biologist, and thus played an important role in his development as a biophysicist and interdisciplinary health scientist in mid-century Canada.*

Résumé : *Cet article examine les répercussions du financement militaire sur la carrière d'Alan C. Burton (1904-79), Ph.D., un scientifique de la médecine dont on se souviendra comme un des pères fondateurs de la biophysique moderne. Burton a effectué des recherches militaires pour les services armés canadiens au cours des premières décennies de la Guerre froide, ayant obtenu du financement et saisi des occasions pour faire progresser sa carrière médico-scientifique. Élément central de ses recherches parrainées par l'armée, un laboratoire climatique spécial à l'Université Western Ontario appelé « Weather Factory » (usine de météo) a permis la mise en œuvre d'un programme de recherche expérimentale de longue haleine sur le froid et le corps humain. Le parrainage militaire a façonné la trajectoire professionnelle de Burton, passant de mathématicien et physicien à biologiste, et a ainsi joué un rôle important dans sa formation en tant que biophysicien et scientifique interdisciplinaire de la santé du milieu du siècle dernier au Canada.*

Keywords: Alan Burton, biophysics, University of Western Ontario, Defence Research Board

London, Ontario, September 1953. A volunteer research subject at the University of Western Ontario removes their clothes, enters a small air-conditioned room, and lies down atop a thin layer of metal mesh strung over an uncomfortable plywood bed. Research technicians attach electrical recording devices to the subject's wrists and ankles, set the internal temperature to 40 degrees Fahrenheit (4.4 degrees Celsius), and exit the room. Over the next two hours, they monitor the subject and observe the effects of cold on the unclothed human body. Shivering begins quickly and advances rapidly as the subject's body attempts to generate heat and warm its core. Involuntary chattering of the teeth commences next and the intensity of the physical response produces body vibrations strong enough to shake the entire bed. Experiencing intense cold and unease, the subject chooses to end the experiment early and rewarm outside the cold room while the researchers review the recorded data. Another unclothed volunteer enters the room shortly thereafter and the experiment continues. The purpose of the research: to study heat loss in the human body.[1]

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This experiment took place inside a specially designed laboratory called the "Weather Factory," which included a collection of climate-control rooms that enabled a series of cold-related experiments performed on animals and human research subjects.[2] Biophysicist Dr Alan Chadburn Burton (1904–79) and a small group of colleagues established the laboratory inside a building in Western's Medical School in the early 1950s, using funding from Canada's Department of National Defence (DND), to pay for the equipment, spaces, and resources required to carry out interrelated experiments on cold. The Canadian military was active in northern Canada and the Arctic during the early Cold War, and authorities in the defence department supported experimental research on cold and the human body as part of a wider scientific effort to design and develop improved techniques and clothing for service in cold environments. Burton was one of the first scientists to show that heat dissipates through the head.[3] His biophysics research demonstrated the benefits of wearing a toque to retain body heat in the cold, and he conducted military-sponsored experiments to find related solutions to the heat loss problem in the human body. This article traces Burton's ties to the Canadian armed services, highlighting the story of Western's Weather Factory, to investigate the impact of military sponsorship on his professional career as a biophysicist and interdisciplinary health scientist in Canada during and after the Second World War.

As a sophisticated piece of Cold War research infrastructure, the Weather Factory represents an intriguing and useful subject for historians of medical science. From a historical research perspective, the laboratory's story demonstrates the role of military sponsorship in the promotion and advancement of the interdisciplinary health sciences in mid-century Canada. Burton was an official and actively involved member of the Defence Research Board (DRB), the scientific branch of the Canadian armed services, and military funding motivated and enabled his research on cold and the human body.[4] As a DRB grantee, he performed military-sponsored research on behalf of the defence department and conducted scientific experiments to generate information for the design and development of improved military clothing. He also served DND in an advisory capacity, sitting on quasi-independent DRB committees and providing scientific advice about the military applications of the latest cold-related medical research to senior military and defence officials in the Canadian government.

Under the amended National Defence Act of April 1947, senior DRB scientists gained the authority to distribute funds from the defence budget to support military research projects.[5] The grant approval process was clear and efficient. Along with senior staff, the DRB's chair reviewed grant applications and recommended research projects that had potential military value. The defence minister then forwarded the recommendations to the governor in council for final authorization.[6] Approval was a mere formality, however. Officers in the finance department maintained a DRB trust fund and there is little evidence to suggest that government officials ever rejected a research project submitted for budgetary approval. The recommendations of senior DRB scientists held considerable weight, and officials in the federal government seldom questioned the value or purpose of distributing defence monies and supporting academic scientists who conducted military research.

University archives, written and oral testimony, and DRB records opened as recently as 2020 illustrate Burton's long involvement in military research and the impact of defence funding on his experimental work at Western.[7] Tracing the history of the Weather Factory is particularly useful for understanding and contextualizing the role of military sponsorship in shaping Burton's research as an interdisciplinary medical scientist, with a focus on biophysics, in post-war Canada. Senior scientists and military officials in the defence department prioritized Arctic-related research during the early Cold War, and DRB grant funding provided to Burton and his colleagues at Western paid for the construction and experimental research program of the climatic laboratory. In return, Burton and his peers used military funding to perform experimental research, write secret reports, publish vetted results, and advance in their professional careers as medical scientists.

The links forged between the military and professional medical science research community in Canada were not new or unique to the Cold War; the National Research Council (NRC) funded academic science during the Second World War to support the research needs of the Canadian armed services and help to expedite Allied victory. Nevertheless, the creation of the DRB in April 1947, coupled with the increased prominence of scientists and the exceptional challenges of military preparedness during the early Cold War, enabled and sustained long-standing professional associations between academic scientists and the Canadian armed services. Military sponsorship thus represents an intriguing and useful subject for studying Burton's career in biophysics, and the story of Western's Weather Factory demonstrates the increasingly close entanglements between military priorities and academic science in post-war Canada.

Over a professional career that spanned four decades, Burton gained widespread recognition for interdisciplinary health research.[8] He founded and led Western's Department of Biophysics (now Medical Biophysics) and made lasting contributions to the health sciences that earned him an induction into the Canadian Medical Hall of Fame in 2010.[9] Remembered as a founding father of modern biophysics and a pioneer of interdisciplinary approaches to medical science, few people outside Burton's close circle of former colleagues and friends are aware of his deep ties to the Canadian military. He studied the physiological and psychological effects of cold for the Canadian armed services between 1948 and 1970, performing open and classified research of medical importance to the soldiers, sailors, and aviators called upon to perform military service in northern Canada, the Arctic, and other dangerously cold and wet environmental regions and conditions.

Burton studied the design and development of protective military clothing for soldiers under the auspices of the NRC during the Second World War, and his wartime research grabbed the attention of the DRB's founding chair, Dr Omond Solandt, himself a medical scientist who trained under Charles Best at the University of Toronto.[10] Upon Solandt's invitation, Burton joined the DRB in an official capacity in 1948 and expanded his wartime research. He spent the next two decades conducting military-sponsored research, some of it classified, for the Canadian armed services, leading laboratory and field experiments into the effects of cold on the human body. His military-sponsored research contributed to the DRB's Environmental Protection Program, which focused heavily on the physical, psychological, and gendered aspects of military service in northern Canada and the Arctic.[11] Ottawa had neither the money nor the resources to place standing forces in the North during or after the war, but science and engineering played an important role in military preparedness for the vast geographical area considered increasingly important to Canadian security and national defence.

In the context of the early Cold War period, environmental protection had nothing to do with the science of protecting the environment of northern Canada. To DRB scientists, the term environmental protection was a reference for studies involving "the protection of the serviceman and his equipment against the adverse physical effects of his [operational] environment."[12] Burton and a relatively small but notable group of Canadian scientists received DRB funds to study the impact of cold and extreme conditions on predominantly white male service personnel. Although specific to the DRB, this definition aligned closely with non-military-funded government approaches to environmental science in northern Canada. In fact, the NRC, the Department of Agriculture, and other government agencies contributed financially to the Environmental Protection Program. Nonetheless, authorities in the Environmental Protection Section of DRB Headquarters, with the advice of senior DRB scientists, coordinated all research activities carried out under the program.

During the early years of the Cold War, between 1947 and 1955, when the idea and institutional support for Western's Weather Factory first emerged, environmental protection research funded under the DRB's program focused on supporting the development of service equipment and improving operations for the defence of Canada in both sub-Arctic and Arctic regions. Military-funded scientists were particularly keen to develop equipment and techniques for protecting male service personnel from harsh and challenging conditions, such as sentry duty on the snowy barrens of northern Canada, deep submariner dives in the frigid waters of the North Atlantic, and long and cold oxygen-restricting reconnaissance flights over the ice islands of the Canadian Arctic Archipelago. Theoretically, science was a tool for mitigating and overcoming the many challenges of northern geography: weather, climate, terrain, darkness, and isolation—or so was the belief and intent of the Canadian scientists and engineers who undertook Arctic research for the DRB, helping to generate new knowledge and prepare the armed services for northern and cold-weather operations in peacetime.

Burton's professional affiliation with the DRB is important for medical historians and historians of science because it demonstrates the entangled histories of military funding and medical science during a critical period in world affairs. His medical research experiments conformed to a military agenda that was unrelated to the civilian applications of the work, but the decision to conduct research for the Canadian armed services was his alone. He accepted military research funding to pursue scientific curiosities and further his professional career. Burton also made the decision to observe the effects of cold on his research subjects. He envisioned an experimental research program and convinced senior military officials to champion his work. The personal desire to support his country and make a lasting research contribution to the interdisciplinary health sciences were strong motivating factors, as were the availability and access to steady research funds through the scientific research branch of Canada's defence department.

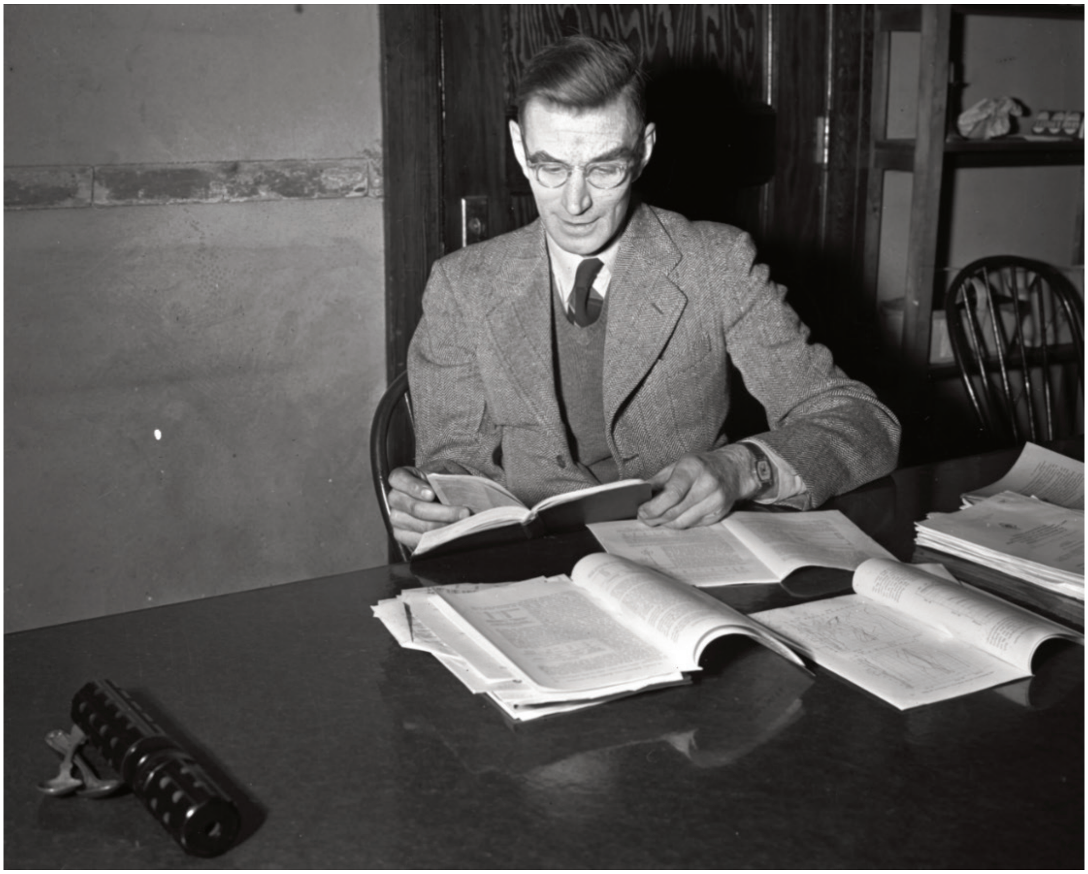

Figure 1. *"Dr Alan Burton, assistant professor of Medical Research, UWO." Credit: Archives and Special Collections, Western University, AFC-177-S3-SS11-F63, London Free Press Collection of Photographic Negatives (LFP), January 25, 1946, London, Ontario.*

Indeed, military sponsorship enabled the research that influenced Burton's professional trajectory from mathematician and physicist to biologist, and thus played an important role in his development as a biophysicist and interdisciplinary health scientist in mid-century Canada.

Burton's Wartime Research

Burton's ties to the Canadian military predate the Cold War. The outbreak of global hostilities in September 1939 gave him the opportunity to perform military research of significant importance to the national war effort. Appointed to the Department of Medical Research at the Banting Institute, University of Toronto, on a Rockefeller fellowship grant, he carried out aviation medical research for the NRC.[13] As an agency of the federal government, the NRC funded Burton's research, but he was not a federal employee. Many academic scientists across the country received federal research funding in the form of grant monies during the war to augment the professional capacities, expertise, and research capabilities of federally employed scientists and engineers who worked in research facilities owned and operated by the Canadian government.

Before the DRB emerged in April 1947, the defence department did not have a branch devoted to science and technology. During the war, the NRC held the responsibility for funding and facilitating research and development projects to support the military. As an NRC grantee housed at an advanced academic research centre, Burton received federal research funding to study the design, development, and testing of protective clothing and equipment for the armed services. He submitted more than 60 classified reports to the NRC between 1940 and 1945, including 51 on aviation medicine, 12 on protective clothing, and several others on ad hoc problems of medical importance to the army, navy, and air force. Only three papers based on Burton's NRC-funded military research appeared in the open scientific literature, one of which outlined a new method for calculating the insulation and metabolic energy properties of clothing: the Clo and Met units.[14] Labelled and protected at various levels of classification under strict security measures imposed by government authorities and senior scientists in the NRC, the balance of Burton's wartime research amounted to several secret and highly restricted military reports.

Canadian scientists working in aviation medicine made pioneering contributions to applied science during the war. British scientists were preoccupied with the design and development of radar and air defence technology during the Battle of Britain, and the United States did not enter the war until applied science had been developed for military purposes, leaving the bulk of Allied research performed early in the war to Canadian scientists affiliated with the NRC.[15] Under the auspices of the Canadian government, Burton and his colleagues in aviation medicine conducted biophysical investigations into the comfort and welfare of service personnel. The field of clothing and heat exchange was particularly important for soldiers, sailors, and aviators who required protection from the elements during year-round warfare conducted on land, at sea, and in the air.

One of Canada's pioneering contributions made during the war was the design and development of protective survival suits. In fact, stimulated by Sir Frederick Banting and G. Edward Hall, Canadian scientists created the first artificial person for use in place of human research subjects, which proved useful for various cold-related experiments.[16] Equipped with wires, a condenser, and a thermostat, scientists placed the artificial test subject inside a cold chamber overnight and used automatic recording devices to determine the level of "body heat" required to keep the subject warm. From these experiments, Burton and his colleagues learned that the effectiveness of clothing insulation depends on thickness rather than fibre. Shivering is an involuntary activity of the body for the sole purpose of producing heat to warm the body's core temperature, they determined, ultimately using the experiments to develop a survival suit for Allied pilots and aircrews forced to ditch their aircraft over the English Channel or elsewhere and survive search-and-rescue in frigid cold waters. The newly developed rubber-plastic suit fit over standard military kit, preventing water penetration and aiding personal floatation. By war's end, the British, Canadian, and US air forces had procured the protective suit for widespread use around the globe.

Despite the availability and use of artificial research subjects, Burton and his wartime colleagues used human research subjects in several cold-related experiments. They cut holes in the ice in the Toronto harbour and dunked research subjects in the cold water to test and improve flight suits, for instance.[17] They also exposed male service personnel to varying winds and temperatures inside the Royal Canadian Air Force (RCAF) cold chambers in Toronto, observing and measuring heat loss from the body of naked and clothed subjects to test wind-chill impact and clothing efficacy.[18] The researchers treated their human subjects with caution and care, only carrying out experiments with humans when necessary and taking precautions to ensure the safety and wellbeing of the participants. Coupled with experiments performed using artificial research subjects, wartime experiments involving human research subjects allowed Burton and his colleagues to make key recommendations for the improvement of military clothing. "Anything which makes a man uncomfortable immediately causes his [overall experiment test] score to deteriorate, so we were justified in telling military authorities that they must make the men comfortable [and] not just pamper them," Burton told a news reporter in June 1946.[19] He argued for functional clothing design over ascetic and commercial considerations, pointing out that improved clothing could have reduced the discomfort for service personnel and improved Allied operations in Italy, the Aleutian Islands, and other locations during the war.

Burton's wartime experience had a drastic impact on his professional development as a scientist. Tragically, he lost a younger brother to a flying accident that occurred during training for the Royal Air Force over New Forest in southern England, and surviving correspondence illustrates the war's lasting toll on him and his family.[20] Science offered Burton an intellectual outlet, however. He learned of his fascination for applied physiology, the value of objective data, and the importance of applying physical and mathematical analysis to interdisciplinary health research. "I enjoyed a chance to develop a 'science of protective clothing' (which did not really exist before the war)," he later wrote, recalling his work on the design of life jackets with flashing lights and the investigation of which colours were best suited for air- and sea-rescue life rafts.[21] Burton was a practical but unique thinker who used theory, research, and simple reasoning to narrow the traditional disciplinary gaps between physics and biology, physiology and medicine—an effective methodology that underpinned his professional career in the interdisciplinary health sciences.[22]

Edward Hall became Western's Dean of Medicine in 1945 and invited Burton to join the university as a biophysicist. Appointed Assistant Professor of Medical Research, Burton moved to London and began his career as a permanent faculty member. He departed for Germany only a few days after receiving his appointment, however, postponing his start date by two months to represent the NRC overseas, attempting to glean the secrets of the German war and industrial machine.[23] He spent the summer of 1945 in Germany as a member of the Enemy Science Technical Intelligence Team, assessing German capabilities and resources in science and engineering for the Canadian government. Later that December, the NRC held a press conference in Ottawa, where twenty-five members of the Intelligence Team shared publicly their unanimous determination that German science as whole was behind the rest of the world. "Science cannot flourish without freedom. It cannot work in a totalitarian state," Burton declared, providing the underlying reason for the Team's conclusion.[24]

These comments played into a specific political and cultural rhetoric of the period, and particularly a heightened confidence in the political orthodoxy of social democratic capitalism. Burton had assessed German research capabilities purely as a scientist, but his condemnation of the enemy, though void of direction from government public relations, reflected the pride of a victorious country and the belief that many Canadians held about the superiority of Western culture. Burton proudly served his country during the war and he believed firmly in the value and necessity of scientific autonomy, sharing with one graduate student "how profoundly affected he was by the utter destruction and inhumanity of war – reinforced by his participation on the allied science team visiting Germany in the summer of 1945."[25] He also understood that science occupied a larger and increasingly prominent cultural place in the immediate post-war period, and he used his platform to advocate for the values that he held as a both a British Canadian and a scientist.

Western embraced the interdisciplinary health sciences after the war and Burton advanced quickly in his academic career. University officials created the first biophysics department in a Canadian medical school in 1946, promoting Burton to Associate Professor and Chair. He received a subsequent promotion to full Professor in 1948 and continued to chair the department for more than two decades, until his retirement, in 1970. In the interim years, he received several invitations to accept prestigious faculty and research positions in the United States. He turned down all invitations he received, opting to remain in Canada and continue his research and teaching at Western. "I'm a Canadian," he expressed in his own words. "I love my American friends but I love my Country, and I want to stay here."[26] True to his word, Burton worked at Western for the balance of his professional career, developing the discipline of biophysics and mentoring a strong group of graduate students, many of whom went on to establish national and international reputations in scientific research and attain distinguished positions in Canada and the United States.

Military Medicine and Arctic Research in Cold War Canada

Burton belonged to a relatively small but notable group of academic scientists who conducted Arctic research for the Canadian military during the early Cold War. Upon establishing the DRB, senior defence and military officials in Ottawa sought the assistance of academic scientists to help prepare the armed services in peacetime.[27] Having lived through the dramatic horrors and startling death toll of the Second World War, the protection of soldiers was top of mind for many scientists in Canada and around the world. Northern Canada and the Arctic represented a central research focus for government officials after the war, and the medical aspects of military service in cold environments received special attention as a top priority for several Canadian scientists and engineers who received grant funding from the DRB.

In 1948, DRB authorities organized a conference about the effects of cold on the human body. Scientists selected from Canada, Britain, and the United States convened in Toronto for the meeting, where they discussed the latest military and civilian research on acclimatization, tolerance, hypothermia, frostbite, and other cold-related medical problems. Concerned that much of the wartime work on the medical aspects of cold and the prevention of cold injury would remain buried in classified military reports and unpublished in the open literature, the Canadian representatives at the meeting agreed to produce a standard reference text on the topic. Subsequently, a DRB advisory panel including Burton recommended the publication of a book reviewing the wartime work and current research in the field.[28] First published in 1955 by Burton and his co-author Otto Edholm, *Man in a Cold Environment: Physiological and Psychological Effects of Exposure to Low Temperatures*, served as a detailed yet accessible scientific text on the principles of thermal insulation, vascular and metabolic reactions to cold, acclimatization, hypothermia and resuscitation, and local cold injury. The book discussed experiments performed on animals and human research subjects, in both military and civilian settings, and included a brief concluding section about medical problems for future research.

A comprehensive discussion of *Man in a Cold Environment* is beyond the scope of this article, but the conference on cold that led to the book solidified Burton's ties to the DRB and laid the theoretical groundwork for Western's Weather Factory. He accepted the chair duties of the DRB's newly formed advisory committee on Clothing and General Stores that year, assuming an official leadership position in the DRB and becoming highly integrated with the scientific research branch of the Canadian armed services.[29] In his role, he communicated with high-ranking military officials and guided clothing research performed by scientists and engineers associated with the defence department. He also served on the DRB's Arctic Medical Research Panel, sharing ideas and collaborating with other medical scientists who performed cold-related experiments for the Canadian military.[30] Furthermore, despite the restricted character of DRB-funded research, Burton showed a desire to bridge the gap between classified military research and the wider scientific community. He respected and honoured the security restrictions governing his military-sponsored work, but regularly advocated for the involvement of graduate students and sought permission to discuss or publish his DRB experiments in open venues.

Military-sponsored science in northern Canada and the Canadian Arctic expanded significantly during the earliest decades of the Cold War, with leading academic and government scientists receiving DRB funds and support to study the effects of Canada's high latitude climate on soldiers, sailors, aviators, and military equipment and hardware. As historical geographer Matthew Farish has demonstrated, northern Canada served as a "natural laboratory" for cold-weather experimentation involving military personnel, and DRB grant funding enabled selected scientists to travel north and conduct research on behalf of the armed services.[31] Between 1947 and 1954, for instance, Malcolm Brown of Queen's University conducted a race-based experimental study of cold-weather acclimatization in human subjects.[32] Funded in part by DRB grants, Brown made an annual research trip to the Arctic and gathered samples of skin, blood, and urine from Inuit men, women, and children who represented the acclimatized "control group" for a comparative study of cold tolerance with a group of so-called unacclimatized white medical students. He hypothesized that cold tolerance in Inuit was biological, and his team of researchers aimed to generate medical knowledge about climatic adaptation for Canadian military personnel called upon to serve in cold regions. The results were inconclusive and the experiment ultimately showed no distinct biological trait for cold acclimatization in Inuit.

Burton's scientific interest in the effects of cold on the human body was distinct from Brown's research. Theories about Inuit biology did not underpin Burton's experimental work, nor did his research extend to racial characteristics of Indigenous peoples or people of colour. Instead, Burton was curious about how the human body responds to the physical stresses produced by exposure to severe cold. Whereas Brown explored cold tolerance from a racial perspective, Burton questioned biological theories of acclimatization to cold and applied his knowledge of environmental physiology to study methods for mitigating the effects of severe cold on predominantly white male service personnel.[33] He investigated heat loss in the human body, combining physiological observation with quantitative data analysis to study thermal insulation and make science-based recommendations for the design and development of cold-weather military clothing and equipment – experimental research enabled by Western's Weather Factory.

The Weather Factory and Military Research at Western

The precise origins of the Weather Factory date to March 29, 1951, when the Medical Committee of Western's Board of Governors convened for a semi-annual meeting.[34] According to the recorded minutes, military research was a priority for the men involved:

> Dean [of Medicine James] Collip stated that if there is a full scale war, organizations will have to be set up to carry out the various research projects. Dr. M.G. Whillans, whose position is equivalent to Director of Medical Research in the Defence Research [Board] set-up, has indicated his interest in getting our group here together and going on with research. It was brought to our attention that we simply could not do things here unless we had more room, and more room meant revamping the present Medical School building … We have learned unofficially that $50,000 on an annual basis for two years has been voted; some of this money would be for grants-in-aid, and some for changes in the building.[35]

Spurred by Whillans' incentive and the inducement of federal funding, the attendees established a "University of Western Ontario Medical Committee on D.R.B. Research" that included Burton and a group of his academic colleagues who also had professional ties to the scientific branch of the Canadian defence department.[36]

The organization of a DRB medical committee at Western and the federal research funding that followed enabled a long-running series of cold-related experiments performed on behalf of the Canadian armed services. Some of the details even appeared in local newspapers. As the *London Free Press* reported in March 1953, DRB authorities had made a significant investment in the construction and operation of a new and innovative medical research laboratory:

> University of Western Ontario medical scientists are fighting a 'cold war' of their own. The battleground for this struggle is a new $100,000 'weather factory' at the Medical School built by the Defence Research Board of Canada. Here the scientists have launched an attack in the battle against one of man's oldest enemies: Stress. The research is being financed by $50,000 in DRB grants. Outcome of this war may have far-reaching results in the form of increased survival from shock, and greater comfort for men under trying conditions.[37]

To clarify any ambiguity contained in the news report, it is worth noting that DRB funds covered the whole $100,000 investment. Half of the monies paid for the construction and renovation costs to build the laboratory inside Western's Medical School, while the other half covered grants paid to participating scientists and their graduate assistants and research technicians.

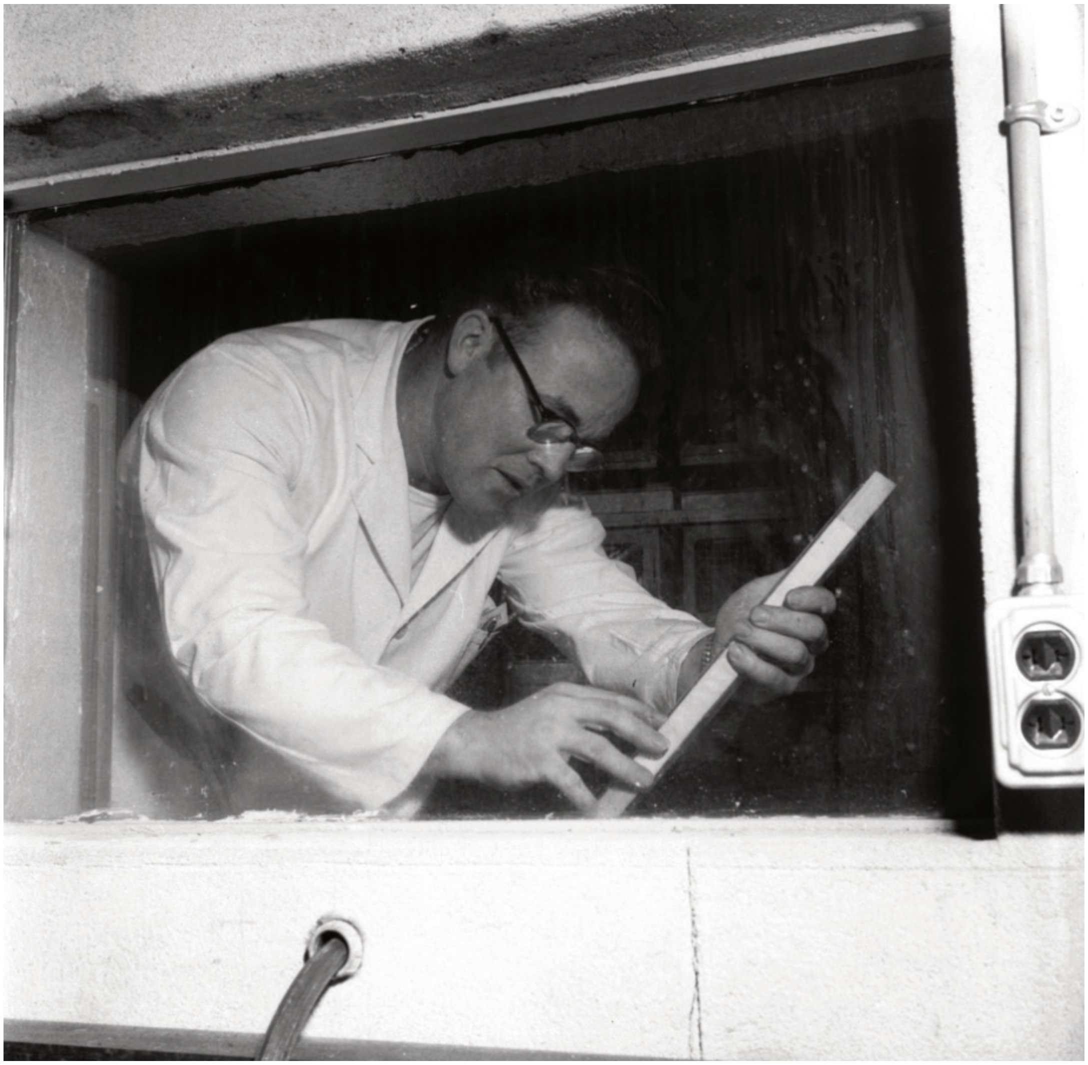

Figure 2. *"New cold lab work at medical school [performed by unnamed scientist]." Credit: Archives and Special Collections, Western University, AFC 177-S1-SS2-F1334, LFP, March 17, 1953, London, Ontario.*

Indeed, military sponsorship vis-à-vis DRB financing was absolutely crucial to the entire experimental research project, which illustrates a strong degree of continuity in the history of federal research support for medical science in mid-century Canada. Although the unique circumstances of the early Cold War introduced new challenges for military preparedness, and arguably new opportunities for the professional scientific community, the extremely close entanglements created between military needs and academic research represented a continuation of a pre-existing relationship that emerged in Canada during the Second World War. Senior military and defence officials modelled the DRB's extramural research program on the NRC's grants-in-aid funding structure, continuing and expanding upon wartime policies, practices, and networks to enable and promote military research on university campuses in Canada after the war. The Cold War only exacerbated the total amount of military research performed across the country, as hundreds of academics applied for and accepted grant monies from the newly created DRB.

The scientists at Western were particularly interested in understanding how the human body adjusts to extreme heat and cold. Human beings represented an ideal research subject for studying the science of climate-induced stress, the news report about financing explained, because the body is constantly subjected to temperature changes, injuries, burns, fatigue, blood loss, starvation, and a host of other dangerous factors.[38] With the goal of developing precautionary medical techniques to recognize and ward off dangerously severe climate stresses that might otherwise result in irreparable damages or death, they devised and carried out a series of interrelated experiments involving animals and human research subjects. While this article concentrates exclusively on the human experiments performed at Western, experimental research on animals often occurred first, enabling scientists to test physiological and psychological responses to cold in rats, for instance, before adapting the research for human trials.

Western's special laboratory – dubbed the Weather Factory by the scientists involved – was a collection of ten climate-control rooms located on the Medical School premises opposite London's Victoria Hospital.[39] Three of the units were cold rooms designed specifically for experiments on animals, while a fourth cold room was for human experiments alone.[40] Images of the human experiments, if they existed, do not seem to have survived.[41] Nevertheless, the surviving documents are rich in details about the experimental research and the character of the laboratory itself. While military scientists performed cold-weather research at the DRB's Defence Research Northern Laboratory (DRNL), near Churchill, Manitoba, the availability and efficiency of construction materials and public utilities in southern Canada led to the creation of climate-simulation laboratories in such larger urban centres as Montreal, Ottawa, and Toronto.[42] The facilities constructed at Western enabled accurate and consistent control of temperature and humidity, which represented the two variables scientists deemed necessary to simulate the conditions of a natural cold climate. Temperatures reached as low as -40 degrees Celsius or as a high as 43 degrees Celsius, with fluctuating humidity levels to suit the specific needs of each experiment. The absence of wind, water, darkness, and other impeding elements was beneficial to the research, and the scientists involved had the advantage of a clean, dry, accessible, and reliable workspace and experimental laboratory.

Western's Medical School shared the facilities and several faculty members engaged in the expansive climate research project kick-started with DRB funds. A five-person committee of Alan Burton, biochemist Roger Rossiter, physiologist James Stevenson, and medical researchers Russell Waud and Murray Barr oversaw and directed the entire Weather Factory research program.[43] The people involved remained tight-lipped about the results of the research, only sharing basic details with the press and generally avoiding open discussion in public. This is unsurprising given the nature of the DRB's extramural grants program, because scientists and engineers who received federal funding to conduct research for the armed services signed an oath of secrecy and agreed to protect the results of any work as a matter of national security.[44] Small parcels of information about the experiments appeared in select medical journals, but the DRB's public relations staff vetted all papers and research reports prior to publication in the open literature.

Figure 3. *"New cold lab work at medical school [performed by unnamed scientist]." Credit: Archives and Special Collections, Western University, AFC 177-S1-SS2-F1334, LFP, March 17, 1953, London, Ontario.*

By in large, the Weather Factory represented a gendered space. A select group of male professionals with connections to the Canadian defence department facilitated the financial and institutional support required to construct and operate the research facility. While women scientists worked in the laboratory, as the surviving records demonstrate, most of the users were men and they produced research to serve the specific military needs of predominantly white male service personnel. This fit a wider pattern of DRB-funded research in post-war Canada. Institutionally, senior scientists in the DRB employed or funded relatively few women scientists and engineers during the early Cold War.[45] The government branch did not discriminate against women's professional work, but the DRB's institutional mandate prioritized service needs and adopted the male-dominated cultural practices of DND and the armed services.

Under Burton's direction, medical scientists in Western's biophysics department conducted experimental research at the Weather Factory to find out why damp cold seems worse to humans than dry cold. They narrowed the search to clothing, theorizing that humidity damages the insulating qualities of textiles. As a test of this theory, they devised a series of experiments that exposed lightly clothed and unclothed research subjects to various conditions. Burton also expressed an interest in theories of acclimatization to cold. "Why can a fisherman handle his nets in ice cold water without discomfort, when you and I would scream with pain?" he asked when interviewed about his research.[46] Studying blood circulation in the extremities of the body could provide an answer, he suggested.[47]

The Weather Factory enabled research experiments under controlled conditions, combining theory and practice to improve laboratory research. From Burton's perspective, laboratory experiments and field-testing were equally important to the successful design and manufacture of adequate clothing and equipment for military personnel.[48] Neither approach to medical research was sufficient on its own. More precisely, Burton argued that rigorous scientific research could yield practical methods, techniques, and materials to improve the safety and operational effectiveness of the Canadian armed services. This strong belief in the practical value of laboratory and field research informed how he perceived and approached the medical problems that he addressed in his military-sponsored research, thus further contextualizing his experimental work at Western and pedagogical views toward training graduate students in the interdisciplinary health sciences.

According to a newly opened progress report submitted for DRB Grant 341, "Reaction of Man and Animals to Cold and Damp," Burton and his research team commenced "routine experiments on medical students" in September 1953.[49] The first experiment involving human research subjects saw nine people lie unclothed in an air-conditioned room; each individually exposed for two hours to temperatures of 48 and 58 degrees Fahrenheit. "We found that 40 F. [4.4 degrees Celsius] was so drastically cold that only a few experiments were done at this temperature," Burton wrote in a progress report.[50] The experiment produced intense shivering in the research subjects, who had their reactions to the varying degrees of cold observed and recorded by participating scientists and research technicians. As the subjects shivered on the bed, the researchers recorded skin and rectal temperature, thermal conductivity, oxygen consumption, and related physiological responses.[51] They also made mechanical readings of the bed itself, tracing the rate and intensity of the shivering induced in the experimental subjects. "The results were unexpected," explained an official press release issued by DND in mid-April 1955. "The subjects felt colder when the humidity was low than when it was high, and their bodies responded more by shivering and by other physiological changes."[52] The results indicated greater heat loss and shivering in conditions of dry cold and low humidity, which led Burton to theorize that the sensation of damp cold results from the uptake of air moisture in the temperature receptors of the skin. He further extrapolated that human skin has behavioural qualities similar to textile fabrics—an idea that reinforced the value of biophysical research for studying the insulating deficiencies of military clothing and equipment.

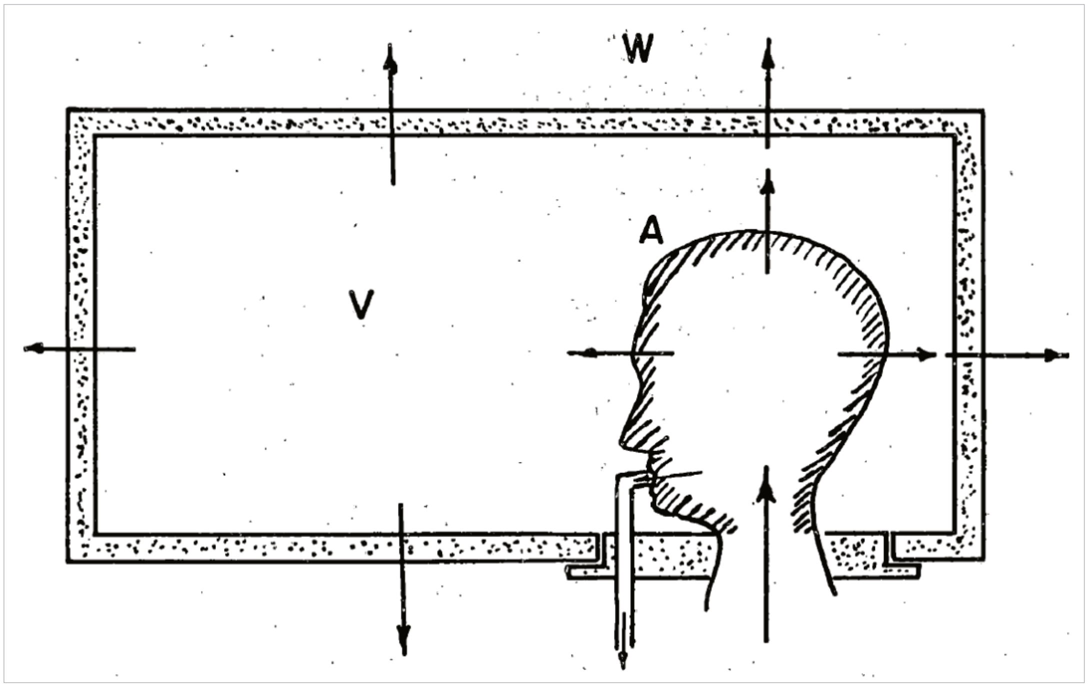

Figure 4. *"Diagram illustrating the flow of heat in the calorimeter. Arrows, flow of heat; W, wall of calorimeter; A, surface area of the head; V, volume of the calorimeter." Credit: Alan C. Burton and Gerd Froese, The Heat Losses of the Unprotected Human Head in Cold Conditions (Ottawa: Environmental Protection Section, DRB, 1957), file DRBC 9310-37 Pt. 3, acc. 1983-84 167 GAD, vol. 7553, RG24-F-1, LAC. After having their work vetted by authorities in the DRB, the researchers proceeded to publish this illustration in the open medical literature. See Gerd Froese and Alan C. Burton, "Heat Losses from the Human Head," Journal of Applied Physiology 10, no. 2 (1957): 236.*

In a follow-up study carried out for the DRB, Burton and a graduate student, Gerd Froese, subjected three people to varying room temperatures and oxygen levels during a series of experiments designed to investigate heat loss from the human head. Froese graduated with an honours degree in physics from the University of Saskatchewan in May 1954 and relocated to London, joining Burton's research team at Western. The experiment measured heat loss from the heads of the three research subjects at nine different room temperatures between -20 degrees Celsius and 28 degrees Celsius.[53] Each person sat fully clothed on a chair positioned at the centre of the temperature- and humidity-controlled room with their head enclosed inside a device called a gradient calorimeter. As illustrated in Fig. 4, Burton and Froese designed the calorimeter specifically for this experiment. Constructed of Styrofoam and nickel alloy wire, the device enclosed the subject's head inside a relatively small space calibrated to prevent condensation. The scientists used an electrical heater to calibrate the calorimeter, and installed a small fan inside the device to reduce the internal air insulation and decrease the time necessary to reach the temperature consistency required for the experiment. The research subjects sat with their heads inside the calorimeter for 30 to 45 minutes while the scientists observed the effects and recorded measurements of non-evaporative heat loss.

After completing several cold-related research experiments in the Weather Factory, Burton concluded that calorimeters were particularly useful in the design and development of military clothing and equipment because they could measure the insulating properties of heat storage in particular materials.[54] The laboratory research at

Western had indicated that calorimeters were also useful for understanding changes in heat balance, and especially the physiological aspects of cold-weather acclimatization. Moving forward, Burton recommended the construction of a larger whole-body calorimeter for expanded experiments at the DRB's cold chambers in Toronto.[55] Experiments of heat loss from fully clothed subjects, including thermal buffering and moisture equilibrium in various textile fibres, he suggested, would be a relatively expensive but worthwhile investment for the defence department. Whether his recommendation became a reality is unclear in the surviving records, but Burton conducted follow-up experiments at Western and advised senior officials in the defence department through the 1950s and 1960s.[56]

Burton and Medical Research Ethics

Information about the human subjects of the experimental research conducted inside Western's Weather Factory is virtually non-existent. Burton's research reports described the theory, observations, and preliminary conclusions of the experimental work. He also discussed his plans for expanding the research in collaboration with scientists and technicians at the DRB's Toronto facility, proposing a series of additional laboratory tests to measure heat loss from clothed and unclothed humans. The military applications of his research were clear, Burton argued, inasmuch as understanding the biophysics of thermal insulation and heat loss was crucial for developing new and improved clothing, sleeping bags, and related equipment for regular military service in cold environments. His research reports did not explain the recruitment methods or procedures, however. Other archival records indicate that medical students and faculty members volunteered to participate in the experimental research, but the conditions of their involvement are largely unclear.[57] The surviving records make little mention of ethical considerations and the practices or guidelines governing the consent process went unrecorded.

Nevertheless, oral and written testimony provides some important insights into the origins, purpose, and experimental procedures of the human research studies conducted at Western. Long-time University of New Brunswick physicist Merrill Edwards, who studied biophysics in the mid-1950s, once recalled his experience researching blood vessels and the body's reaction to cold under Burton's direction:

> It was a given that all of us [graduate students] were to serve as each other's research subjects, or guinea pigs, and as such were intimately involved in everybody's research … Much of the research was funded by grants from the Defence Research Board, in particular for projects on reaction to and protection from cold, for the Canadian military in the Arctic. I worked on measuring and managing heat loss from the head. Subjects sat in a cold room, and a box lined with instruments was put over the head to measure the heat loss. This was useful in designing head gear, and for the prevention of frost bite in sensitive areas – tips of the ears, nose and chin. It was not an experiment for subjects who were claustrophobic![58]

Merrill was not alone in his assessment. Medical doctor and scientist Margot Roach, who succeeded Burton as chair of Western's biophysics department, came to a similar conclusion when she reflected on her long-time colleague, mentor, and friend: Burton "got very excited about whether beards grown in a contest by Labatt's Brewery workers decreased heat loss from the head in cold as he had shown a hat did," she wrote. "Unlike a hat, however, there was only a slight benefit (conclusion of the MSc project of Gerd Froese)."[59]

Regarded as a gifted professor by his students and peers, Burton's teaching style was energetic, interactive, and highly inventive. "He had a striking presence – impressive height, angular face with very busy eyebrows, red hair and a booming voice that would capture the attention of students or discussants at a scientific meeting," wrote medical biophysicist Peter Canham, a former student and colleague of Burton, in a collection that documents and explores Burton's storied career.[60] Theory and experimental research formed the foundation of Burton's methodological philosophy as a scientist and educator, as neurosurgeon Gary Ferguson, one of Burton's former physiology students, reflected in 2009:

> An example of this was the famous lab session on 'cold' physiology, on a day that Burton gleefully hoped would be the coldest one in January. Students in groups of four, identified a group 'volunteer' who stripped down to underclothing and lay on a lab bench. Windows were opened widely and for the next two to three hours, the other three students in the lab group measured the serial responses of the volunteer (skin temperature, core temperature, shivering, piloerection, psychological response etc.). None of us has ever forgotten the 'experience' of that lab session.[61]

A large portion of the core courses in the undergraduate biophysics program at Western derived from the ideas and research behind Burton's two published books: *Man in a Cold Environment*, the DRB-sponsored publication identified earlier in this article, and *Physiology and Biophysics of the Circulation*.[62] "He had an outstanding ability to make the application of physics to biology understandable to both physicists and biologists, as well as to experts and new students alike," scientist Diane Finegood wrote in a nomination letter endorsing Burton for the Canadian Medical Hall of Fame.[63]

Although indirectly related to Burton's experimental work at Western, the wider history of medical research ethics in Canada provides some additional context for the circumstances encountered by the volunteer subjects. Authorities in the DRB first considered instituting formal policies governing research ethics for military-sponsored experiments performed on animals and human subjects in December 1967, during a joint meeting of three research panels in Toronto, where Burton and his colleagues in Arctic medicine and climatic physiology resolved to put the suggestion before senior leadership in the defence department.[64] Before then, however, scientists who performed research on behalf of the Canadian armed services followed international standards and used their own discretion when formulating and following protocols for medical research involving human subjects.[65] Voluntary consent formed the basis of ethical clinical research, meaning all persons involved in experimental work understood the risks involved in the research and participated without coercion. Sources indicate that Burton and his research team used volunteer research subjects only, and there is no evidence to suggest that involvement in experiments at the Weather Factory resulted in short- or long-term health effects to any of the participants. While the history documented in this article uncovers a series of interrelated research experiments involving human subjects, the experimental work performed at Western conformed to contemporary ethical standards and research practices, and Burton's experimental work fit a wider pattern of military-sponsored research in Canada.

Conclusion

The story of Western's Weather Factory offers a useful and intriguing glimpse into the history of medical research in mid-century Canada that illustrates the foundational importance of military funding for academic research. The surviving records demonstrate, in particular, the role of military sponsorship in the promotion and advancement of the interdisciplinary health sciences. Experimental research in environmental physiology advanced Alan Burton's professional career and his military-sponsored research at Western generated knowledge deemed useful for the Canadian armed services, and by extension, the security and national defence of Canada. Burton received deep financial support, performed experimental research in a newly constructed state-of-the-art laboratory, and recorded findings in secret military reports and vetted publications. In return, military and defence officials learned about the physiological effects of cold on human beings. The research findings generated through the climatic experiments at Western also contributed to a wider body of scientific knowledge about predominantly white male service personnel responses to cold, and scientists in the DRB considered Burton's experimental work valuable for preparing the Canadian military for service in northern Canada and other cold environments.

Burton's experimental work for the scientific branch of the Canadian armed services is also significant for what it indicates about the influence of military funding on the progression of medical science in Canada. Burton was the longest-serving member of the DRB's Arctic Medical Research Panel, but medical historians and historians of science know little about the military applications of his research. His wartime work on protective clothing laid the foundation for the development of environmental physiology, which represented a burgeoning field that gained popularity among a notable collection of like-minded interdisciplinary health scientists who worked in Canada. If not for government sponsorship through research initiatives directed by authorities in the DRB, however, it is unlikely that Burton and his colleagues would have obtained the resources and support required to conduct laboratory research and grow the interdisciplinary health sciences in the capacity they achieved.

Activities at the Weather Factory, although unique in terms of the actual experiments that occurred, typified military-sponsored medical research performed in Canada during the early-to-mid Cold War. The mechanisms of the military-academic science relationship that first emerged under the NRC during the Second World War continued and expanded under the DRB after 1947, and several research establishments across the country embraced military research and obtained defence funding to pursue novel findings in the interdisciplinary health sciences. From this perspective, medical science was not immune to the heightened importance of national defence and military preparedness in the early Cold War. On the contrary, as demonstrated in the history of Burton's experimental research and the story of Western's Weather Factory, the interdisciplinary health sciences in Canada are deeply rooted in the country's military past.

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Endnotes

1 A.C. Burton, Progress Report of Project D 40-93-10-37, DRB Grant 341, Reaction of Men and Animals to Cold and Damp, August 6, 1953, file DRBC 9310-37 pt. 1, vol. 7553, RG 24-F-1, Library and Archives Canada (LAC).

2 "UWO Weather Factory Works on Heat, Cold," *Globe and Mail*, April 10, 1953, file November 20/[19]52 to August 27/[19]53 Clippings (Vol. 2), vol. 10341, RG 24, LAC.

3 Morris Kaplan, "Wear Hat in Cold Scientists Advise: Tests by 2 Show Body Heat Dissipates through Head—Beard's Insulation Doubted," *The New York Times*, April 21, 1956, 36.

4 On the official history of the DRB, see D.J. Goodspeed, *A History of the Defence Research Board of Canada* (Ottawa: Queen's Printer, 1958). See also Jonathan Turner, "The Defence Research Board of Canada, 1947 to 1977" (PhD diss., University of Toronto, 2012).

5 *Canada's Defence: Information on Canada's Defence Achievements and Organization* (Ottawa: Department of National Defence, 1947), 47–8.

6 Brooke Claxton to His Excellency, April 12, 1949, file DRBS 2-1-87 pt. 1, vol. 4230, RG 24, LAC.

7 LAC holds documents about Burton's DRB-sponsored research, including details about his experimental work and correspondence with other medical scientists who conducted Arctic research for the Canadian armed services. I obtained the LAC records (RG24-F-1, vol. 7553, acc. 1983-84 167 GAD) through a formal Access to Information request. The university archives at Toronto and Western also hold relevant records. University of Toronto Archives and Records Management Services maintains the Omond Solandt papers, which contain correspondence between Burton and other DRB members, while Archives and Special Collections at Western University keep institutional documents, faculty minutes, letters, and newspaper clippings about Burton's career and professional contributions to medical biophysics and interdisciplinary health research. Aside from archival material, the richest collection of documents, correspondence, and written testimony about Burton (although not focused on his military research) is Peter B. Canham and Alfred W.L. Jay, eds. *Alan C. Burton: Pioneer in Biophysics*, 2nd Edition (London: Department of Medical Biophysics, University of Western Ontario, 2020).

8 For detailed biographical information about Burton, see Canham and Jay, eds. *Alan C. Burton*. See also P.B. Canham, "Alan Chadburn Burton (1904-1979)," *Biorheology* 17, no. 4 (1980): 297–300; A.C. Groom, "In memoriam: Alan Chadburn Burton (1904–1979)," *Physiologist* 23, no. 1 (1980): 17–18; A.C. Groom, "29th APS President: Alan Chadburn Burton," *Physiologist* 28, no. 2 (1985): 66–68.

9 "2010 Inductee: Alan C. Burton, PhD," *Canadian Medical Hall of Fame*, https://www.cdnmedhall.org/inductees/alanburton, accessed January 25, 2021.

10 For biographical information about Solandt, see Jason Sean Ridler, *Maestro of Science: Omond McKillop Solandt and Government Science in War and Hostile Peace, 1939-1956* (Toronto: University of Toronto Press, 2015).

11 See *Annual Report on the Progress of Environmental Protection Research, December 1953: Report No. DR 80* (Ottawa: DRB, 1954), file 1009-2[5], vol. 299, RG 85, LAC.

12 Ibid., 1. See also Goodspeed, *History of the Defence Research Board of Canada*, 229–231; "Human Problems in War Studied by New Division," *Globe and Mail*, June 12, 1952, 2.

13 "Biochemist at University Royal Society Appointee," in Canham and Jay, eds., *Alan C. Burton*, 130.

14 A clo unit indicates the basic measurement for the thermal properties of clothing, where one clo unit is the thermal insulation required to keep a resting person comfortable at 21 degrees Celsius. See Gerd Froese and Alan C. Burton, "Heat Losses from the Human Head," *Journal of Applied Physiology* 10, no. 2 (1957): 241; A.P. Gagge, A.C. Burton, and H.C. Bazett, "A practical system of units for the description of the heat exchange of man with his environment," *Science* 94, no. 2445 (1941): 428–430.

15 "Canada had Pioneer Role in Applied Science during War, Dr. Burton Declares," in Canham and Jay, eds., *Alan C. Burton*, 131.

16 Ibid.

17 Mike Plyley, "Dr. Alan C. Burton – Biophysicist Extraordinaire," in Canham and Jay, eds., *Alan C. Burton*, 165.

18 Alan C. Burton and Otto G. Edholm, *Man in a Cold Environment: Physiological and Psychological Effects of Exposure to Low Temperatures* (London: Edward Arnold Ltd., 1955), 111–112.

19 Burton, quoted in, "Canada had Pioneer Role in Applied Science during War, Dr. Burton Declares".

20 Canham and Jay, eds. *Alan C. Burton*, 7–8.

21 Alan C. Burton, "Variety—The Spice of Science As well As of Life: The Disadvantages of Specialization," *Annual Review of Physiology* 37 (1975): 2.

22 J. Battista, "Epilogue," in Canham and Jay, eds., *Alan C. Burton*, 172.

23 "Two Londoners Join German Survey Group," in Canham and Jay, eds., *Alan C. Burton*, 132.

24 Burton, quoted in Groom, "29th APS President," 67.

25 Peter Canham, "Foreword," in *Alan C. Burton*, eds. Canham and Jay, 7.

26 Burton, quoted in Groom, "29th APS President," 67.

27 Goodspeed, *History of the Defence Research Board of Canada*, 100.

28 Burton and Edholm, *Man in a Cold Environment*, xi.

29 See National Archives and Records Administration (NARA), College Park, Maryland, RG 319 (Records of the Army Staff), box 857, Annual Report of the Defence Research Board, 1 April 1949 – 31 March 1950 (Ottawa: DRB, 1950), 20; 41.

30 Ibid., 29. At the time, the DRB's Arctic Medical Research Panel also included G. Malcom Brown (Queen's University), L.P. Dougal (Laval University), O.G. Edholm (National Institute of Medical Research, London), D.R.E. McLeod (School of Hygiene, University of Toronto), D.Y. Solandt (Banting and Best Institute, University of Toronto), M.G. Whillans (Medical Research Laboratories, DRB), and L.W. Billingsley (DRB).

31 Matthew Farish, *The Contours of America's Cold War* (Minneapolis: University of Minnesota Press, 2010), 178–180; Matthew Farish, "Making 'Man in the Arctic': Academic and Military Entanglements, 1944–49," in *Cold Science: Environmental Knowledge in the North American Arctic during the Cold War,* Stephen Bocking and Daniel Heidt, eds. (New York: Routledge, 2019), 96–98.

32 Matthew S. Wiseman, "Unlocking the 'Eskimo Secret': Defence Science in the Cold War Canadian Arctic, 1947–1954," *Journal of the Canadian Historical Association* 26, no. 1 (2015): 192–194. See also Farish, "Making 'Man in the Arctic'," 96–98.

33 Wiseman, "Unlocking the 'Eskimo Secret'," 209; Alan C. Burton, "Abstract of Discussion on Acclimatization to Cold," file Acclimatization, vol. 237, RG 128, LAC.

34 Lieutenant-Colonel Gordon Ingram chaired the committee, which also included President G. Edward Hall, Dean Collip, and Ross Willis.

35 Archives and Special Collections, Western University, AFC 54-S6, box AFC 54-11, Medical School Committee Minutes 1926-1966, "Meeting Minutes, Medical School, March 29, 1951," in *Medical Committee of the Board of Governors, 1926-1966*, 4.

36 Roger Rossiter chaired Western's newly formed DRB medical committee. The other members included Alan Burton, James Collip, James Stevenson, Murray Barr, Russell Waud, and G. Edgar Hobbs.

37 "Western Scientists Seek Answer to Man's Survival in Extreme Heat or Cold," *London Free Press*, March 25, 1953, file November 20/[19]52 to August 27/[19]53 Clippings (Vol. 2), vol. 10341, RG 24, LAC.

38 "Western Scientists Seek Answer to Man's Survival in Extreme Heat or Cold."

39 On the history of Western's Medical School, see John R.W. Gwynne-Timothy, *Western's First Century* (London, ON: University of Western Ontario, 1978), 380–398; Ross Baxter Willis, *Western 1939-1970: Odds and Ends* (London, ON: University of Western Ontario, 1980), 75–79.

40 "Western Scientists Seek Answer to Man's Survival in Extreme Heat or Cold". See also A.C. Jones, memo re: Aero Section, Royal Aeronautical Society Lecture, June 13, 1955, file DRBC 9310-37 pt. 2, vol. 7553, RG 24-F-1, LAC.

41 As demonstrated in the illustrations reproduced in this article, some photographs of Western's Weather Factory survived, but I was unable to find images of the human experiments.

42 DRNL was a year-round scientific research facility located on the premises of Fort Churchill, a northern military base adjacent to the town of Churchill in Manitoba's northeast corner. The DRB also operated the Defence Research Medical Laboratories (DRML), a research facility with a cold room, at Downsview in Toronto's north end. See A.M. Pennie, *Defence Research Northern Laboratory, 1947–1965* (Ottawa: Department of National Defence, 1966); M.G. Whillans, "The Defence Research Medical Laboratories: Their Character and Opportunities," *Canadian Medical Association Journal* 68 (March 1953): 265–268.

43 Rossiter studied the effect of hormones and shock on the body's chemical composition. Stevenson examined food and diet in relation to cold tolerance, as well as the use of drugs as a means of warding off the effects of severe cold. Waud studied the effect of blood substitutes in counteracting shock and used radioactive tracers prepared in Western's isotope laboratory to investigate chemical changes in the body, as well as the uptake of chemicals in human tissues. See "Western Scientists Seek Answer to Man's Survival in Extreme Heat or Cold"; "UWO Weather Factory Works on Heat, Cold".

44 Matthew S. Wiseman, "Canadian Scientists and Military Research in the Cold War, 1947–60," *Canadian Historical Review* 100, no. 3 (September 2019): 453.

45 One obvious and important exception is geographer Moira Dunbar, who made pioneering contributions to Arctic glaciology while working as a DRB scientist during the earliest decades of the Cold War.

46 "Western Scientists Seek Answer to Man's Survival in Extreme Heat or Cold".

47 "UWO Weather Factory Works on Heat, Cold".

48 Alan C. Burton, *On the Science of Field Testing as Applied to Clothing and Personal Equipment* (Ottawa: Defence Research Board, 1948).

49 The research team included graduate students R.A. Snyder and Charles Eagan, as well as Flight Lieutenant Wilson Leach of the RCAF Institute of Aviation Medicine. See Burton, Progress Report of Project D 40-93-10-37.

50 A.C. Burton, Progress Report of Project D.R.B. 341, Effects of Cold and Damp, file DRBC 9310-37 pt. 1, vol. 7553, RG 24-F-1, LAC.

51 Progress Report on Project D 341, 1954, file DRBC 9310-37 pt. 2, vol. 7553, RG 24-F-1, LAC.

52 Directorate of Public Relations (National Defence), *Armed Forces News*, April 13, 1955, file DRBC 9310-37 pt. 2, vol. 7553, RG 24-F-1, LAC.

53 Froese and Burton, "Heat Losses from the Human Head," 237.

54 A.C. Burton, Annual Progress Report, DRB Grant 9310-37: "Reactions of Man and Animals to Cold and Damp," September 1962, file DRBC 9310-37 Pt. 4, vol. 7553, acc. 1983-84 167 GAD, RG 24-F-1, LAC.

55 Alan C. Burton, DRB Application for a Grant for Research: Grant No. 9310-37, October 27, 1959, file DRBC 9310-37 Pt. 3, vol. 7553, acc. 1983-84 167 GAD, RG 24-F-1, LAC. On the DRB's Climatic Suite at the DRML in Toronto, see "DRML to Create its Own Weather Conditions," in *Defence Research Board Newsletter* 3, no. 4 (Ottawa: DRB, April 1957), Hartland Molson Library, Military History Research Centre, Canadian War Museum.

56 Burton's DRB records held at LAC end in 1962, but other sources indicate that he continued to receive grant funding afterward and maintained a professional affiliation with the DRB until his retirement in 1970.

57 Alan C. Burton to A.C. Jones, February 10, 1954, file DRBC 9310-37 pt. 1, vol. 7553, RG 24-F-1, LAC; A.C. Burton, Annual Report on Project D.R.B. 9310-37, 31 October 1956, file DRBC 9310-37 pt. 2, vol. 7553, RG 24-F-1, LAC.

58 Merrill Edwards, "My time in the Biophysics Lab with Alan Burton," in Canham and Jay, eds., *Alan C. Burton*, 151–152.

59 Margot Roach, "Memories of Burton," in Canham and Jay, eds., *Alan C. Burton*, 167. For details on "the cooperation of the 'Hairy Apes Club' of John Labatt's Limited" in Burton's research, see A.C. Burton, Annual Report on Project D.R.B. 9310-37, September 30, 1955, file DRBC 9310-37 pt. 2, vol. 7553, RG24-F-1, LAC.

60 Canham, "Foreword," in *Alan C. Burton*, eds. Canham and Jay, 7.

61 Gary G. Ferguson, "Re: Dr. Alan C. Burton," in Canham and Jay, eds., *Alan C. Burton*, 25.

62 Ian MacDonald, "Recollections of Alan Burton," in Canham and Jay, eds., *Alan C. Burton*, 159. See also Burton and Edholm, *Man in a Cold Environment*; Alan C. Burton, *Physiology and Biophysics of the Circulation: An Introductory Text* (Chicago: Year Book Medical Publishers, 1965).

63 Diane T. Finegood to Dr. Alain Beaudet, in Canham and Jay, eds., *Alan C. Burton*, 18.

64 Joint Meeting: Panel on Arctic Medicine and Climatic Physiology, Panel on Aviation Underwater Physiology, Panel on Nutrition and Metabolism, Defence Research Establishment Toronto, December 8, 1967, file 84-11-4C vol. 3, vol. 955, RG 22-A-1-A, LAC.

65 The 1947 Nuremberg Code set a base international standard for medical research ethics, but the Canadian government formally implemented ethical guidelines for medical research in 1980. On the Nuremberg Code, see Laura Stark, *Behind Closed Doors: IRBs and the Making of Ethical Research* (Chicago: University of Chicago Press, 2012), 7; 104.