CHAPTER 5

Well-being: From Neurosciences to Sustainable Housing

Sentinel North

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In the context of accelerating climate change and socioeconomic development in the Arctic and Subarctic, the Sentinel North research program at Université Laval helps generate the knowledge needed to improve our understanding of the changing northern environment and its impact on humans and their health. The program fosters the convergence of expertise in the engineering, natural, social and health sciences to catalyze scientific discovery and technological innovation in support of sustainable health and development in the North.

This compendium presents a selection of results from the Sentinel North research program, from its beginning in 2017 through to the end of its first phase in 2022. The results are highlights from innovative research projects and original peer-reviewed publications, which have been integrated into five interdisciplinary chapters addressing major northern issues. Notwithstanding the scale and complexity of these issues, each chapter of the compendium aims to provide new insights through the process of integration, and fill fundamental gaps in our knowledge of the changing North.

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From Stress Neurobiology to Sustainable Housing: Advancing Knowledge on Health and Well-being for the North

Introduction

Mental health and well-being are the critical basis by which humans can flourish, fulfil their potential, contribute to their communities, and remain resilient in the face of stress and adversity. However, according to the World Health Organization, about 970 million people were living with a mental disorder in 2019, making it one of the leading causes of disability worldwide (GBD 2019 Mental Disorders Collaborators, 2022; Lopez and Murray, 1998). In Canada, mental illness was estimated to affect more than 6.7 million people in 2011, or one in five Canadians (Smetanin et al., 2011). Mental health challenges are particularly pressing in Arctic and Subarctic regions, where rapid social and cultural changes impact the well-being of Indigenous populations (Young et al., 2012; Lehti et al., 2009). The National Representational Organization Inuit Tapiriit Kanatami has identified mental wellness as the number one health priority (Alianait Inuit-specific Mental Wellness Task Group, 2007), which was also reflected in the *Qanuilirpitaa?* 2017 health survey in Nunavik. Four out of ten Nunavimmiut reported experiencing clinically significant depressive symptoms (Muckle et al., 2020a), a level more than twice as high as the general Canadian population (Statistics Canada, 2020). Tackling this situation requires a holistic and culturally appropriate approach to mental health, recognizing that socio-economic factors such as housing play a role in determining health, including mental health and well-being (Alianait Inuit-specific Mental Wellness Task Group, 2007). Improving our capacity for diagnosis and treatment in multiple populations is also part of this approach, which brings together knowledge from diverse disciplines to provide new understanding of the biological roots of mental health problems, new early-detection methods, and new environmental and biological mechanisms that can be targeted for intervention (Patel et al., 2018).

Gradually, we are expanding our understanding of factors that underlie depression, including chronic stress (van Praag, 2004) and sex-based differences with respect to the prevalence, symptoms, and treatment of depression. For example, women are twice as likely to be diagnosed with major depressive disorder (MDD) compared to men (Dudek et al., 2021), a trend that was also observed within the Inuit Nunavik population where women reported distress more frequently than men (Muckle et al., 2020a; Kirmayer and Paul, 2007). Currently approved anti-depressant treatments have been estimated to be ineffective for 30 to 50% of patients from the general population (C. Ménard, personal communication). However, recent findings on the molecular mechanisms underlying mood disorders (Bittar et al., 2021; Mena and Labonté, 2019) and the interactions of the neurovascular and neuroimmune systems (Dudek et al., 2020; Dion-Albert et al., 2022a) may point toward innovative treatments and earlier diagnosis. Fundamental research in brain structure (Allard and Serrano, 2020; Zheng et al., 2020), new optogenetic technology using animal models (Gagnon-Turcotte et al., 2020), and biomarker identification (Gagné et al., 2020; Arsenault et al., 2021) are expanding our knowledge, and translating results into potential diagnosis and therapeutic advances. Developing biomarkers capable of diagnosing diseases in the early stages would be of paramount importance to tackle mental health issues.

The complex web of environmental, sociocultural, and physiological factors that determine mental health requires an "ecosystem approach" that involves multiple community stakeholders in fostering mental wellness (Paquin et al., 2020). Within this holistic understanding of mental wellness, access to housing plays a major role. In 2016, over half of Inuit living in the north were in crowded housing (ITK, 2019), an issue that seems to be linked with mental distress in northern communities (Pepin et al., 2018; Perreault et al., 2022). Not only do northern communities lack housing stock, but what is available may be of lower quality. Since this housing crisis is unfolding within a unique northern context, solutions will require designing and building culturally and environmentally appropriate housing (Bayle, 2020; Vachon, 2020). Collaboration between architects and community stakeholders has led to the development of tools for sustainable planning of northern villages. "Biophilic design," which seeks to integrate the human-built environment into the natural environment (Kellert et al., 2011), appears to be a promising approach to address the biological and psychological need for natural light in high latitude environments (Parsaee et al., 2019, 2020, 2021).

The links between housing and public health are multifaceted, and intersect not only with mental health, but also respiratory illnesses and their risk factors. Inuit children are disproportionately affected by respiratory infections. Causes for the high rates of infections include poverty, overcrowding, and housing in need of major repairs and a better ventilation (Kovesi, 2012). Tobacco use compounds these ill effects on respiratory health and is particularly significant for northerners, for whom rates of smoking are higher than the national average (Bélanger et al., 2020).

This chapter gathers Sentinel North research results from a broad range of disciplines. Together, these results contribute to addressing mental health issues and well-being in northern communities. From neuroscience to architecture, these interdisciplinary insights aim to improve our understanding of mental health problems, identify new biomarkers for early diagnosis and treatment, encourage an ecosystem approach to mental health, and prevent health problems through culturally sensitive interventions that address key health determinants, such as housing.

KEYWORDS:

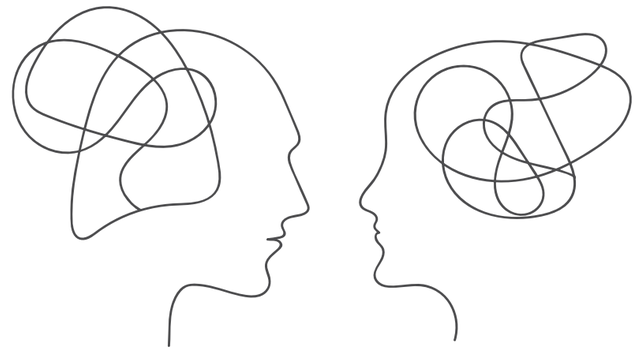
Well-being, Mental Health, Neuroscience, Stress, Resilience, Housing Planning, Air Quality, Health Determinants, Action-Research, Nordic Architecture, Biophilia

1. The Effects of Stress on Mental Health

Selected research highlights

The *Qanuilirpitaa*? 2017 health survey reveals that most Nunavimmiut have experienced stressful social and historical events with a potentially negative impact on their lives (Muckle et al., 2020b). These events may be associated with chronic stress, that is a prolonged and repeated exposure to stress, which can lead to the appearance or progression of mental health issues. To enhance the efficacity of proposed treatments, it is essential to gain a comprehensive understanding of the effects of chronic stress, as well as of the molecular and functional mechanisms underlying its impact, on both men and women.

1.1 Sexual dimorphism observed in major depressive disorder appears to come from sex-specific molecular alterations affecting the functional pathways that allow us to cope with daily life stress. Transcriptional changes associated with epigenetic alterations have been observed in the brains of men and women suffering from depression. Similar changes have been reported in animal models of depressive-like behaviours induced by stress (Mena and Labonté, 2019).



1.2 In mice, prolonged exposure to stress leads to changes in the mesocortical and mesolimbic dopaminergic pathways, which play an important role in the expression of depressive-like behaviors. In addition, differences in the molecular and morphological alterations have been noted between animals of the opposite sexes, which would explain the differences observed in clinical manifestations of mood disorders within men and women (Quessy et al., 2021).

1.3 The medial prefrontal cortex is a region of the brain that is involved in responses to stress. Depressive behaviours induced by chronic exposure to stress in male and female mice result from specific changes in the pathways that control morphological and synaptic properties of transcriptional activity in the prefrontal cortex. The nature of the changes differs between males and females (Bittar et al., 2021).

1.4 Some mechanisms linked to inflammation could promote the loss of blood-brain barrier integrity involved in different mental disorders, especially in major depressive disorder, bipolar disorder, and schizophrenia. Furthermore, sex hormones modulate neurovascular integrity by regulating neuroinflammation and directly affecting astrocyte and endothelial cell functions. Alterations to cerebral blood flow and sex-specific transcriptional pathways may be the key to discovering new markers for mental illnesses as well as promising diagnostic tools (Dion-Albert et al., 2022a).

2. Understanding Resilience to Stress

Selected research highlights

Following the experience of chronic stress or a traumatic event, certain individuals do not develop any physical, psychological, or behavioural changes; they remain resilient to adversity. Resilience is thus defined as the capacity to resist or recover quickly when faced with difficult conditions (Smith et al., 2008).

2.1 The blood-brain barrier (BBB) constitutes the last border between the brain and harmful toxins or inflammatory signals circulating in the blood. Chronic stress alters this barrier's integrity, which can lead to depressive behaviours. Molecular changes in the BBB associated with resilience to stress have been identified and may play a protective role for the neurovascular system (Figure 2.1). These results highlight the importance of studying neurovascular pathologies brought on by stress in order to identify new therapeutic targets so as to treat mood disorders and foster resilience (Dudek et al., 2020).

2.2 Epigenetic changes, such as histone acetylation/methylation and DNA methylation, take part in stress response. Epigenetic modification of the genes involved in synaptic plasticity and the endocrine, immune, and vascular systems are linked to resilience. Identifying central and peripheral epigenetic changes that foster resilience to stress represent promising novel targets in the development of preventive and personalized medicine (Dudek et al., 2021).

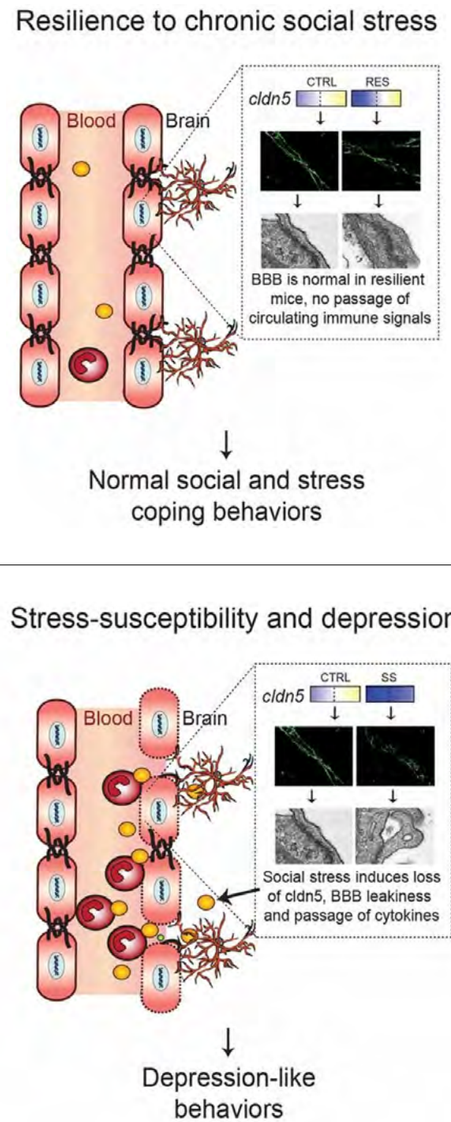


Figure 2.1
Claudin5 (cldn5) is a protein responsible for tight junctions of the blood-brain barrier (BBB). Claudin5 permissive epigenetic regulation is associated with maintenance of BBB integrity and stress resilience while lack of endothelial molecular adaptations and inflammation leads to cldn5 loss, BBB leakiness and depression-like behaviors. Figure taken from Dudek et al., 2020, licensed under CC BY 4.0.

Selected research highlights

3. Toward Early Diagnosis of the Main Psychiatric Disorders

Major depressive disorder is the most common consequence of chronic stress and a major cause of disability in the world (Vos et al., 2020). However, depression is diagnosed solely on the basis of self-reported symptoms. It is important to develop reliable biomarkers in order to identify individuals at risk of developing the illness and to ensure more rapid, effective, and appropriate management.

3.1 Chronic stress alters the blood-brain barrier (BBB) at different places depending on sex. In the female mouse, stress alters the BBB of the prefrontal cortex (Figure 3.1), which causes anxiety- and depressive-like behaviours. In the event of chronic stress, these females presented changes in soluble E-selectin levels. In humans, the same changes in circulating soluble E-selectin, BBB gene expression, and morphology were observed in blood serum and postmortem brain samples from women diagnosed with major depressive disorder (MDD). Soluble E-selectin in circulation may therefore be a biomarker of interest in diagnosing MDD in women (Dion-Albert et al., 2022b).

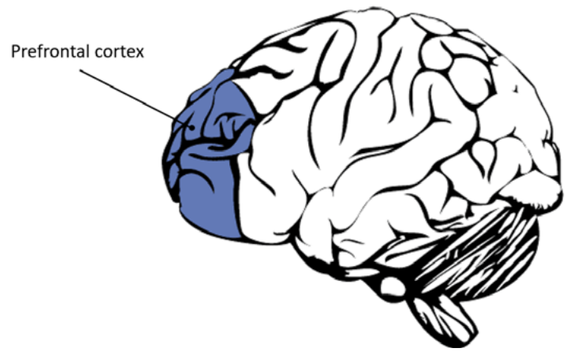


Figure 3.1
Prefrontal cortex of the brain. Figure modified from Erik Lundström, licensed under CC BY-SA 3.0.

3.2 The retina can be used to detect psychiatric disorders since it is part of the central nervous system, and both share the same embryonic origin. The electroretinogram (ERG) is a signal generated by the retina in response to a flash of light and represents a non-invasive and reliable approach. In mouse models, the ERG was shown to predict the expression of susceptibility and resilience before stress exposition in males and females with up to 71% efficacy (Figure 3.2; Arsenault et al., 2021).

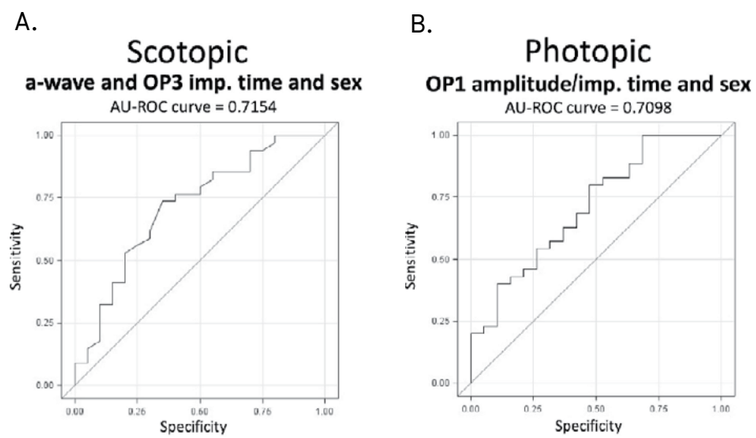


Figure 3.2
Electroretinogram can predict the expression of stress susceptibility and resilience in mice. (A) The scotopic model (associated to rods) has an area under the receiver operating characteristic (AU-ROC) curve of 0.7154 ($p < 0.05$) and (B) the photopic model (associated with cones) has an AU-ROC curve of 0.7098 ($p < 0.05$). Figure taken from Arsenault et al., 2021, licensed under CC BY 4.0.

3.3 Children with a high genetic risk of developing schizophrenia, bipolar disorder, or major depressive disorder presented an abnormal response in their cones and rods during the electroretinogram (ERG) test, similar to what has been reported in adult patients with these conditions. These results suggest that some features of the ERG as a risk endophenotype could be used in defining a childhood risk syndrome (Gagné et al., 2020).

3.4 Preliminary data have revealed that children at risk of developing one of the major psychiatric disorders show some difficulties with regard to intermodal transfer, that is, the transfer of sensory information from one sense to another. In these same children, difficulties in multisensory integration and emotional body processing have also been observed. Further work is needed to determine whether these results can lead to the identification of new risk biomarkers or endophenotypes (P. Marquet, personal communication).

3.5 Close analysis of fibroblasts from patients with bipolar disorder has led to the identification of a promising cell-specific biomarker that could serve as an aid in early diagnosis. These observations were made using quantitative phase microscopy based on digital holographic microscopy, a non-invasive technique. Validation studies of a companion diagnostic test with a view to making it available commercially are underway (P. Marquet, personal communication).

4. Some Tools for a Better Understanding of the Brain

Selected research highlights

To better understand how the brain works, several approaches have been developed. Whether it be through the optimization of the zebrafish animal model or the use of optogenetics or network science, knowledge is evolving to allow for possible new therapeutic approaches.

4.1 To understand how some exposures that individuals experience during embryonic development affect mental health, research teams have used the zebrafish animal model. Its transparency in the larval stage makes it possible to observe, with the help of advanced neurophotonic and optogenetic technology, the activity of all the neurons in the fish's brain. This model will thus allow researchers to study the effects of environmental factors on fundamental processes of brain function, such as sensory integration, behaviour, and learning (P. De Koninck, personal communication).

4.2 A multichannel optogenetic system capable of operating in a closed loop was designed to monitor neural activity in mice. This system works with optogenetics, a technology that uses light to selectively activate neurons in genetically modified animals to observe the effect on large biological networks. This work speeds up the development of new therapeutic approaches to brain diseases (Gagnon-Turcotte et al., 2020).

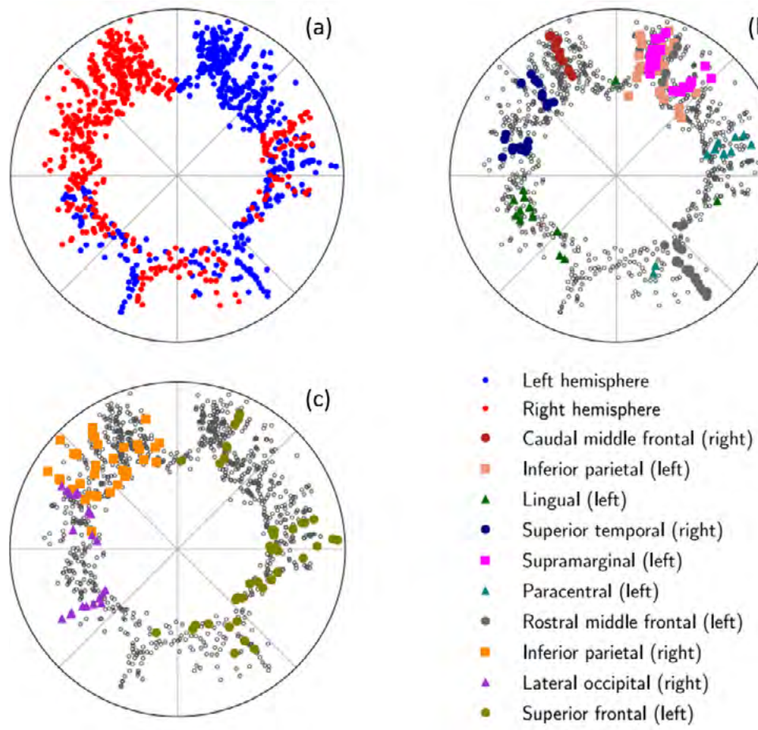


Figure 4.3
(a) Hyperbolic map obtained for the Human5 connectome. Nodes belonging to the two different hemispheres are shown in blue and red. (b) and (c) A sample of representative neuroanatomical regions are superimposed over the inferred positions of nodes shown on (a). Most neuroanatomical regions of Human5 are localized in narrow regions of the similarity space in the hyperbolic maps. Figure modified from Allard and Serrano, 2020, licensed under CC BY 4.0.

4.3 Models of networks immersed in hyperbolic spaces have made it possible to represent the structure of the connectome, the set of neuronal connections, almost perfectly (Figure 4.3). Thus, human connectomes, as well as those of various species, have been represented. This work offers a new perspective to map the organization of various regions of the brain (Allard and Serrano, 2020).

4.4 A renormalization semi-group defined based on networks immersed in a hyperbolic space was used to reproduce the multiscale properties of human connectomes. The results support that the same principles govern brain connectivity at different scales and lead to efficient decentralization. The impact of this work enables the development of advanced tools to simplify digital reconstruction and simulation of the brain (Zheng et al., 2020).

5. Developing an Ecosystemic Approach to Mental Health

Selected research highlights

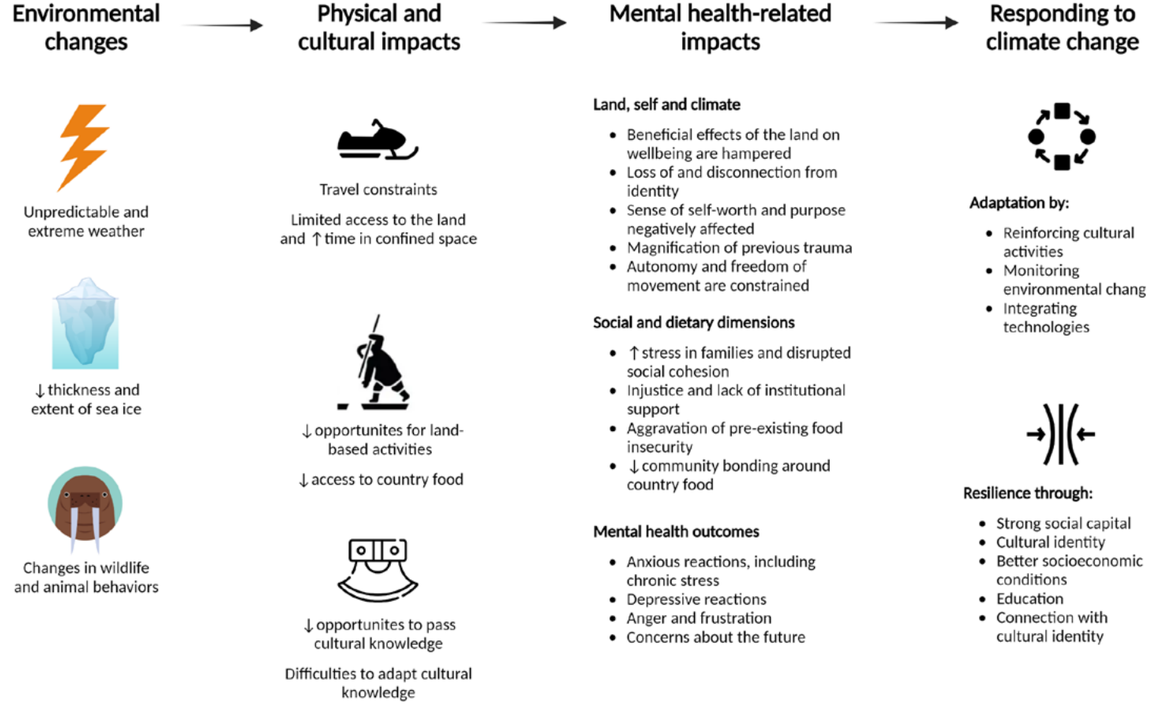
Mental health and well-being require a holistic view and a comprehensive approach, whereby communities and organizations work together to address these issues. Many determinants of health, including sociocultural and environmental factors, influence mental health and need to be considered in this approach, particularly in northern communities.

5.1 An ecosystemic approach allows for the interactions between sociocultural, ecological, and biological factors of health to be considered. Since the risks of developing schizophrenia are multi-factorial and interdependent, an ecosystemic approach is needed; an approach that integrates different bodies of knowledge and involves the communities concerned (Paquin et al., 2020).

5.2 A research team analyzed the associations between different sociocultural factors and mental health among the Inuit of Nunavik. The results showed that stronger family cohesion and a regular practice of hunting and fishing were associated with lower depression scores. These sociocultural factors therefore deserve more attention in the areas of prevention and mental health promotion programs for Inuit (Poliakova et al., 2022).

5.3 The well-being and mental health of northern Indigenous communities are closely linked to a connection to the land. The extent of climate change in Arctic and subarctic regions is limiting access to the land and affecting livelihoods. Changes related to loss of identity and culture, food insecurity, interpersonal stress and conflicts, and housing problems also have an impact on mental health (Figure 5.3). Health clinicians can play a role in recognizing and offering support to those affected by these disruptions (Lebel et al., 2022).

Figure 5.3
The mental health-related impacts of environmental changes in the circumpolar North. Figure modified from Lebel et al., 2022, licensed under CC BY 4.0. Figure created with BioRender.



5.4 A new model combining genetic and socioeconomic risk factors improves the capacity to predict the development of psychiatric disorders, such as schizophrenia and bipolar disorder. In particular, the results indicate that an increase in the Blishen index (a rating scale that measures socioeconomic status) of one unit is associated with a reduced risk of developing these same disorders (Bahda, 2022).

A more inclusive approach to brain research

Sentinel North neuroscience researchers have embarked on a multicultural approach with Indigenous communities as part of the Canadian Brain Research Strategy. The goal of this initiative is to further research on the central nervous system in a way that better reflects the diversity of the Canadian population. The research will be able to incorporate Indigenous knowledge and thus better meet the needs of these populations (Perreault et al., 2023).

6. Revisiting the Planning and Design of Housing for the Well-Being of Northern Populations

Selected research highlights

Access to sustainable and culturally appropriate housing promotes better physical and mental health. There is a need to work with and build the capacity of local communities to develop and facilitate access to such housing.

6.1 A decision-making support tool has been developed to support sustainable and resilient planning in Nunavik's villages. Using a multidisciplinary approach and in collaboration with the community of Kangiqsualujjuaq, the project identified planning principles tailored to local Inuit aspirations. One of the principles is to contribute to the community's well-being, notably by ensuring that the architecture of houses and community buildings supports physical and psychological health. The tool is available online: Pinasuqatigiitsuta.org.

6.2 The complexity of the processes related to producing housing in Nunavik encourages a logic based on "building" and a technical rationale rather than on a perspective considering the "dwelling" of the North, including social, cultural, and symbolic considerations. Linking and integrating the ways of building and residing in buildings by working together with local stakeholders could allow for the creation of housing that is better rooted in the realities and aspirations of Inuit communities and Inuit ways of living (Vachon, 2020).

Figure 6.3
The definition of home is presented according to three main themes that are most present in the literature studied: 1) the home-land (harmony between place and home); 2) the home-subject (a body that protects gestures and bodies); and 3) the home-family (the social space and the space to talk). © Myrtille Bayle

6.3 A review of the literature has allowed us to better understand the Inuit perspective of the home. The symbolic Inuit home is defined as a protective body, a space of refuge, and a supportive place for transmitting culture (Figure 6.3). In order for the built environment to reflect the concerns and vision of the Inuit world, it is important to encourage the integration of the Inuit inhabitant in the production of his dwelling (Bayle, 2020).

A much-needed evaluation of practices in partnership research projects in an Indigenous context

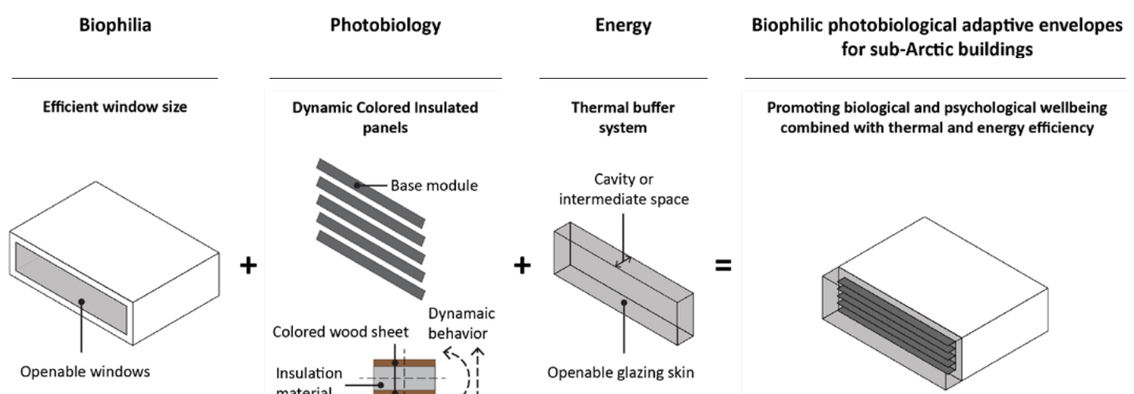
A conceptual modelling of collaborative research revealed the stakeholders involved and identified the factors that determine the authenticity of research partnerships between universities and Indigenous communities. Factors include the quality of the relationship between the partners, the level of trust in stakeholders and the organizations they represent, the duration of the partnership, and a suitable mediation process to establish shared goals and objectives. This model provides a better understanding of the processes that determine the success of research with Indigenous communities (Gouin, 2020).

Selected research highlights

7. A Nature-Based Architectural Approach for the Well-Being of Inhabitants

With limited availability of natural light and a unique photoperiod, Arctic and subarctic regions present challenges for architectural design. One of the goals of the biophilic approach is to integrate natural light into architectural design strategies to improve the quality and habitability of interior spaces while increasing their relationship with the outdoors. This approach, culturally adapted to local populations, can thus contribute to the health and well-being of inhabitants.

7.1 A digital tool was designed to visualize the qualitative and quantitative aspects of light using HDR (High Dynamic Range) images. These images create luminance maps, accurately render human perception, and generate photopic/melanopic dominance maps. The resulting spatial representations allow for improved communication between architects and other building stakeholders and promote better integration of daylight into future architectural projects (Lalande et al., 2020).



7.2 For people living in northern territories, biophilic design must be adapted to extremely cold climates in order to meet their needs. A fundamental multi-skin adaptive envelope model (Figure 7.2) based on key biophilic and photobiological indicators for subarctic buildings was developed to enable efficient indoor-outdoor connections (Parsaee et al., 2019; Parsaee et al., 2020; Parsaee et al., 2021).

7.3 An action-research project led by professors in architecture, and carried out in partnership with the community of Ikaluktutiak, Nunavut, integrated bioclimatic concepts aimed at food self-sufficiency and health of occupants, while taking into account traditional knowledge. The objective was to design low-energy buildings that could withstand the harsh climate conditions of the region. As part of this research, several projects by professional master's students were awarded prizes in *the American Institute of Architects Committee on the Environment competition* (C. Demers, personal communication).

Figure 7.2
The biophilic-photobiological adaptive envelope model for subarctic buildings including essential components and configurations.
Figure taken from Parsaee, 2021.

8. The Role of Ventilation in Indoor Air Quality

Selected research highlights

Between 2007 and 2012, hospitalization rate related to respiratory system diseases in children under one year of age was nearly 7 times higher in Nunavik than for the whole province of Quebec (NRHBSS and INSPQ, 2015). Several factors influence respiratory health, including indoor air quality and home ventilation systems.

8.1 In Nunavik, interventions performed on ventilation systems led to a decrease in respiratory infections and an improvement in indoor air quality. These results suggest that proper use and maintenance of residential ventilation systems may contribute to a reduction in respiratory infections among Nunavimmiut children. That said, children's respiratory health is the result of a combination of multiple factors. Thus, collaborative work between local health and housing authorities is essential to reduce the health inequities affecting northern communities (Poulin et al., 2022).

8.2 The effects of three different ventilation systems and their optimization on microbial communities in bioaerosols and dusts were studied in 54 newly constructed or renovated dwellings in Nunavik. The type of ventilation and its optimization had no effect on microbial communities, which were probably more affected by human activities, the main source of biological particles in the study (Degois et al., 2021).

9. A Smoke-Free Indoor Environment for the Health of Residents

Selected research highlights

Smoking and exposure to second-hand smoke are prevalent in Nunavik. The *Qanuilirpitaa*? 2017 health survey revealed that a significant proportion of Nunavimmiut aged 16 years and older are smokers (Bélanger et al., 2020). It is important to deal with this public health issue.

9.1 Levels of benzene, toluene, and polycyclic aromatic hydrocarbons (PAHs) were significantly higher in Inuit adults than in adults in Canada or the United States. The results suggest that the high prevalence of smoking in Nunavik is an important source of exposure to benzene and PAHs. This reinforces the importance of regional efforts to reduce smoking and encourage a smoke-free indoor environment in Nunavik homes. Inquiries should also be conducted to determine other possible sources of exposure (Caron-Beaudoin et al., 2022).

9.2 Work has shown that during exposure to cigarette smoke, inflammation is marked by a rapid and sustained infiltration of IL-1 neutrophils and the release of pulmonary surfactant and the alteration of its homeostasis. In mice, results have shown that neutrophils play a crucial role in maintaining lung homeostasis during acute exposure to cigarette smoke (Milad et al., 2021).

9.3 Electronic cigarette vapours, without nicotine or flavour, can be harmful and influence the lungs' response to tobacco cigarette smoke exposure in mice model who use both, potentially altering the pathological course of smoking. This dual exposure leads to an increase in airway resistance (Lechasseur et al., 2020).

Research Projects Cited in this Chapter

The knowledge and technological advances referenced in this chapter were generated by several Sentinel North interdisciplinary research teams. These scientific contributions were gathered from the projects listed below, which involved, in addition to the principal investigators, numerous researchers, graduate students, postdoctoral fellows, research professionals, collaborators, partners from northern organizations and national and international partners from the public and private sectors.

- Biological signatures of stress responses and potentiality of a diet enriched in n-3 fatty acids to promote positive mental health status despite adversity

  Principal Investigator: Caroline Ménard (Dept. of Psychiatry and Neurosciences)

- Development, implementation and use of miniature portable technologies for the prevention, assessment and treatment of chronic diseases in northern areas

  Principal Investigator: Laurent Bouyer (Dept. of Rehabilitation)

- Doing things differently: An atlas of best practices and opportunities for culturally acceptable and sustainable living environments in Nunavik

  Principal Investigators: Geneviève Vachon (School of Architecture), Michel Allard (Dept. of Geography)

- Impact of environmental conditions on airway microbiota and respiratory health in the North

  Principal Investigators: François Maltais (Dept. of Medicine), Marc Ouellette (Dept. of Microbiology, Infectious Disease and Immunology)

- Optimizing biophilia in extreme climates through architecture

  Principal Investigators: Claude Demers (School of Architecture), Marc Hébert (Dept. of Ophtalmology and ORL-Head and Neck Surgery)

- The use of diatom microalgae for improving the treatment of the light-driven dysfunctions of the biological clock in Arctic human populations

  Principal Investigator: Johann Lavaud (Dept. of Biology)

- Sentinel North partnership research chair in economics and brain health

  Chairholder: Maripier Isabelle (Dept. of Economics)

- Sentinel North partnership research chair in molecular neurobiology of mood disorders

  Chairholder: Benoît Labonté (Dept. of Psychiatry and Neurosciences)

- Sentinel North research chair in the neurobiology of stress and resilience

  Chairholder: Caroline Ménard (Dept. of Psychiatry and Neurosciences)

- Sentinel North partnership research chair on ecosystemic approaches to health

  Chairholder: Mélanie Lemire (Dept. of Social and Preventive Medicine)

- Sentinel North research chair on the applications and theory of network analysis

  Chairholder: Antoine Allard (Dept. of Physics, Physical Engineering, and Optics)

- Sentinel North research chair on the relations with Inuit societies

  Chairholder: Caroline Hervé (Dept. of Anthropology)

Research projects cited in this chapter

Some results presented in this chapter are also drawn from research projects conducted by recipients of Sentinel North Excellence scholarship and postdoctoral fellowship awards.

- Repenser le rôle de l'habitant dans le logement social au Nunavik: vers une intégration des valeurs Inuit
  Myrtille Bayle (M. Sc. Scholarship)
- Effets d'une exposition prénatale et postnatale aux contaminants et nutriments issues d'une alimentation traditionnelle Inuit sur le développement cognitif d'enfant d'âge scolaire
  Mireille Desrochers-Couture (Ph.D. Scholarship)
- Les processus de réalisation des projets d'habitations au Nunavik: vers une conception inclusive des acteurs locaux
  Marika Vachon (Ph.D. Scholarship)
- Recherche partenariale en aménagement dans les milieux nordiques: évaluation des processus participatifs en contexte innu
  Élisa Gouin (Ph.D. Scholarship)
- Role of the endocannabinoid system in stress resilience and depression: A master regulator of neurovascular and gut health
  Katarzyna Anna Dudek (Ph.D. Scholarship)
- Amélioration de la qualité de l'air intérieur dans les habitations du Nunavik: projet d'optimisation de la ventilation
  Jodelle Degois (Postdoctoral Fellowship)
- Role of blood-brain barrier transport in depression
  Fernanda Neutzling-Kaufmann (Postdoctoral Fellowship)

Sentinel North has developed partnerships with leading international institutions to conduct innovative and interdisciplinary research projects. The following joint collaborative project has contributed to the results of this chapter.

- Joint International Research Unit in child neural development and psychiatry
  Director: Pierre Marquet (Dept. of Psychiatry and Neurosciences)
  University of Lausanne, Switzerland
  Associated with the CERC in Neurophotonics

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Ongoing Sentinel North Research Projects

Several research projects supported by Sentinel North and through joint funding initiatives are ongoing as part of the second phase of the program (2021-2025). These projects, listed hereunder, continue to fill fundamental gaps in our scientific knowledge of the changing North.

- Biological signatures of stress responses and potentiality of a diet enriched in n-3 fatty acids to promote positive mental health status despite adversity

  Principal Investigator: Caroline Ménard (Dept. of Psychiatry and Neurosciences)

- Biophilic design in the Arctic: Immersive community co-creation to reconcile well-being and energy performance in Ikaluktutiak architecture

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- Extreme zooming on intestinal permeability and the western-style diet: Unravelling the role of dietary antigens on the prevalence of cardiometabolic and mental health diseases in the North

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- Housing and energy transition in Nunavik: A better understanding of human, technical and environmental issues

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- Technical-social solutions to expand the use of renewable energy from Whapmagoostui-Kuujjuarapik to other regions of Nunavik

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- The exposome-microbiota-brain axis under the microscope to tackle environment-health interactions in the North

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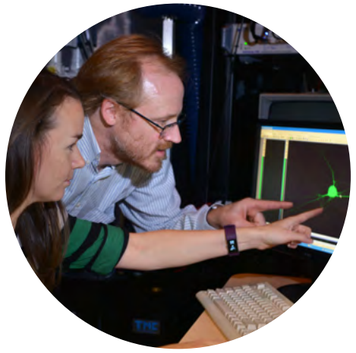

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References

Publications from Sentinel North

Allard, A., & Serrano, M. Á. (2020). Navigable maps of structural brain networks across species. *PLoS Computational Biology, 16*(2), e1007584. https://doi.org/10.1371/journal.pcbi.1007584

Arsenault, E., Lavigne, A.-A., Mansouri, S., Gagné, A.-M., Francis, K., Bittar, T. P., Quessy, F., Abdallah, K., Barbeau, A., Hébert, M., & Labonté, B. (2021). Sex-specific retinal anomalies induced by chronic social defeat stress in mice. *Frontiers in Behavioral Neuroscience, 15*(183), 714810. https://doi.org/10.3389/fnbeh.2021.714810

Bahda, M. (2022). Modèle prédictif des troubles psychiatriques en combinant scores de risque génétique et variables socio-économiques. [M. Sc. thesis, Université Laval]. Corpus UL. http://hdl.handle.net/20.500.11794/73372

Bayle, M. (2020). Réflexions pour une architecture significative: Univers symbolique et matériel de la maison chez les Inuit du Nunavik (Note de recherche). *Études Inuit Studies, 44*(1-2), 161-182. https://doi.org/10.7202/1081801ar

Bittar, T. P., Pelaez, M. C., Hernandez Silva, J. C., Quessy, F., Lavigne A.-A., Morency D., Blanchette L.-J., Arsenault, E., Cherasse, Y., Seigneur J., Timofeev, I., Sephton, C. F., Proulx, C. D., & Labonté, B. (2021). Chronic stress induces sex-specific functional and morphological alterations in corticoaccumbal and corticotegmental pathways. *Biological Psychiatry, 90*(3), 194-205. https://doi.org/10.1016/j.biopsych.2021.02.014

Caron-Beaudoin, É., Ayotte, P., Aker, A., Blanchette, C., Ricard, S., Gilbert, V., Avard, E., & Lemire, M. (2022). Exposure to benzene, toluene and polycyclic aromatic hydrocarbons in Nunavimmiut aged 16 years and over (Nunavik, Canada) - Qanuilirpitaa 2017 survey. *Environmental Research, 206*, 112586. https://doi.org/10.1016/j.envres.2021.112586

Degois, J., Veillette, M., Poulin, P., Lévesque, B., Aubin, D., Ouazia, B., Brisson, M., Maltais, F., & Duchaine, C. (2021). Indoor air quality assessment in dwellings with different ventilation strategies in Nunavik and impacts on bacterial and fungal microbiota. *Indoor Air, 31*(6), 2213–2225. https://doi.org/10.1111/ina.12857

Dion-Albert, L., Bandeira Binder, L., Daigle, B., Hong-Minh, A., Lebel, M., & Menard, C. (2022a). Sex differences in the blood-brain barrier: Implications for mental health. *Frontiers in Neuroendocrinology, 65*, 100989. https://doi.org/10.1016/j.yfrne.2022.100989

Publications from Sentinel North

Dion-Albert, L., Cadoret, A., Doney, E., Kaufmann, F. N., Dudek, K. A., Daigle, B., Parise, L. F., Cathomas, F., Samba, N., Hudson, N., Lebel, M., Campbell, M., Turecki, G., Mechawar, N., & Menard, C. (2022b). Vascular and blood-brain barrier-related changes underlie stress responses and resilience in female mice and depression in human tissue. *Nature Communications, 13*(1), 164. https://doi.org/10.1038/s41467-021-27604-x

Dudek, K. A., Dion-Albert, L., Lebel, M., LeClair, K., Labrecque, S., Tuck, E., Ferrer Perez, C., Golden, S. A., Tamminga, C., Turecki, G., Mechawar, N., Russo, S. J., & Menard, C. (2020). Molecular adaptations of the blood-brain barrier promote stress resilience vs. depression. *Proceedings of the National Academy of Sciences, 117*(6), 3326. https://doi.org/10.1073/pnas.1914655117

Dudek, K. A., Neutzling Kaufmann, F., Lavoie, O., & Menard, C. (2021). Central and peripheral stress-induced epigenetic mechanisms of resilience. *Current Opinion in Psychiatry, 34*(1), 1-9. https://doi.org/10.1097/yco.0000000000000664

Gagné, A.-M., Moreau, I., St-Amour, I., Marquet, P., & Maziade, M. (2020). Retinal function anomalies in young offspring at genetic risk of schizophrenia and mood disorder: The meaning for the illness pathophysiology. *Schizophrenia Research, 219*, 19-24. https://doi.org/10.1016/j.schres.2019.06.021

Gagnon-Turcotte, G., Bilodeau, G., Tsiakaka, O., & Gosselin, B. (2020). Smart autonomous electro-optic platforms enabling innovative brain therapies. *IEEE Circuits and Systems Magazine, 20*(4), 28-46. https://doi.org/10.1109/MCAS.2020.3027220

Gouin, E. (2021). Research partnerships in planning and architecture in Indigenous contexts: Theoretical premises for a necessary evaluation. *Journal of Community Practice, 29*(2), 133–152. https://doi.org/10.1080/10705422.2021.1938769

Lalande, P., Demers, C. M. H., Lalonde, J.-F., Potvin, A., & Hébert, M. (2021). Spatial representations of melanopic light in architecture. *Architectural Science Review, 64*(6), 522–533. https://doi.org/10.1080/00038628.2020.1785383

Lebel, L., Paquin, V., Kenny, T.-A., Fletcher, C., Nadeau, L., Chachamovich, E., & Lemire, M. (2022). Climate change and Indigenous mental health in the Circumpolar North: A systematic review to inform clinical practice. *Transcultural Psychiatry, 59*(3), 312–336. https://doi.org/10.1177/13634615211066698

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Publications from Sentinel North

Lechasseur, A., Huppé, C.-A., Talbot, M., Routhier, J., Aubin, S., Beaulieu, M.-J., Duchaine, C., Marsolais, D., & Morissette, M. C. (2020). Exposure to nicotine-free and flavor-free e-cigarette vapors modifies the pulmonary response to tobacco cigarette smoke in female mice. *American Journal of Physiology. Lung Cellular and Molecular Physiology*, *319*(4), 727. https://doi.org/10.1152/ajplung.00037.2020

Mena, F., & Labonté, B. (2019). Molecular programs underlying differences in the expression of mood disorders in males and females. *Brain Research*, *1719*, 89-103. https://doi.org/10.1016/j.brainres.2019.05.016

Milad, N., Pineault, M., Lechasseur, A., Routhier, J., Beaulieu, M.-J., Aubin, S., & Morissette, M. C. (2021). Neutrophils and il-1α regulate surfactant homeostasis during cigarette smoking. *Journal of Immunology*, *206*(8), 1923–1931. https://doi.org/10.4049/jimmunol.2001182

Paquin, V., Lemire, M., & King, S. (2020). Ecosystem approaches to the risk for schizophrenia. *Schizophrenia Research*, *220*, 278–280. https://doi.org/10.1016/j.schres.2020.03.057

Parsaee, M., Demers, C. M. H., Hébert, M., Lalonde, J.-F., & Potvin, A. (2019). A photobiological approach to biophilic design in extreme climates. *Building and Environment*, *154*, 211-226. https://doi.org/10.1016/j.buildenv.2019.03.027

Parsaee, M., Demers, C. M. H., Hébert, M., Lalonde, J.-F., & Potvin, A. (2020). Biophilic, photobiological and energy-efficient design framework of adaptive building facades for Northern Canada. *Indoor and Built Environment*, *30*(5), 665–691. https://doi.org/10.1177/1420326X20903082

Parsaee, M., Demers, C. M. H., Potvin, A., Lalonde, J.-F., Inanici, M., & Hébert, M. (2021). Biophilic photobiological adaptive envelopes for sub-Arctic buildings: Exploring impacts of window sizes and shading panels' color, reflectance, and configuration. *Solar Energy*, *220*, 802-827. https://doi.org/10.1016/j.solener.2021.03.065

Publications from Sentinel North

Parsaee, M. (2021). Biophilic and photobiological developments of adaptive high-performance building envelopes for Northern Canada. [Doctoral thesis, Université Laval]. Corpus UL. http://hdl.handle.net/20.500.11794/68405

Perreault, M. L., King, M., Gabel, C., Mushquash, C. J., De Koninck, Y., Lawson, A., Marra, C., Ménard, C., Young, J. Z., & Illes, J. (2023). An Indigenous lens on priorities for the Canadian Brain Research Strategy. *Canadian Journal of Neurological Sciences*, *50*(1), 96–98. https://doi.org/10.1017/cjn.2021.501

Poliakova, N., Riva, M., Fletcher, C., Desrochers-Couture, M., Courtemanche, Y., Moisan, C., Fraser, S., Pépin, C., Bélanger, R. E., & Muckle, G. (2022). Sociocultural factors in relation to mental health within the Inuit population of Nunavik. *Canadian Journal Public Health*. https://doi.org/10.17269/s41997-022-00705-w

Poulin, P., Marchand, A., Lévesque, B., Dubé, M., Aubin, D., Ouazia, B., Duchaine, C., & Brisson, M. (2022). Impact of improved indoor air quality in Nunavik homes on children's respiratory health. *Indoor Air*, *32*(2), 13009. https://doi.org/10.1111/ina.13009

Quessy, F., Bittar, T., Blanchette, L. J., Lévesque, M., & Labonté, B. (2021). Stress-induced alterations of mesocortical and mesolimbic dopaminergic pathways. *Scientific Reports*, *11*(1), 11000. https://doi.org/10.1038/s41598-021-90521-y

Vachon, M. (2020). Habiter le Nunavik: considérer le système de production du logement en envisageant la complexité. *Études Inuit Studies*, *44*(1-2), 301-321. https://doi.org/10.7202/1081807ar

Zheng, M., Allard, A., Hagmann, P., Alemán-Gómez, Y., & Serrano, M. Á. (2020). Geometric renormalization unravels self-similarity of the multiscale human connectome. *Proceedings of the National Academy of Sciences*, *117*(33), 20244-20253. https://doi.org/10.1073/pnas.1922248117

External references

Alianait Inuit-specific Mental Wellness Task Group. (2007). *Alianait Inuit Mental Wellness – Action Plan*. ITK, Ontario, Canada. https://www.itk.ca/wp-content/uploads/2009/12/Alianait-Inuit-Mental-Wellness-Action-Plan-2009.pdf

Bélanger, R., Muckle, G., Courtemanche, Y., & Poliakova, N. (2020). *Substance Use*. Nunavik Inuit Health Survey 2017 Qanuilirpitaa? How are we now? Quebec: Nunavik Regional Board of Health and Social Services (NRBHSS) et Institut national de santé publique du Québec (INSPQ). https://nrbhss.ca/sites/default/files/health_surveys/A12332_RESI_Substance_Use_EP5.pdf

GBD 2019 Mental Disorders Collaborators. (2022). Global, regional, and national burden of 12 mental disorders in 204 countries and territories, 1990–2019: A systematic analysis for the Global Burden of Disease Study 2019. *The Lancet, 9*(2), 137-150. https://doi.org/10.1016/S2215-0366(21)00395-3

Inuit Tapiriit Kanatami. (2014). *Social determinants of Inuit health in Canada*. ITK, Ontario, Canada. https://www.itk.ca/wp-content/uploads/2016/07/ITK_Social_Determinants_Report.pdf

Inuit Tapiriit Kanatami. (2016). *National Inuit Suicide Prevention Strategy*. ITK, Ontario, Canada. https://www.itk.ca/wp-content/uploads/2016/07/ITK-National-Inuit-Suicide-Prevention-Strategy-2016.pdf

Inuit Tapiriit Kanatami. (2019). *Inuit Nunangat Housing Strategy*. ITK, Ontario, Canada. https://www.itk.ca/wp-content/uploads/2019/04/2019-Inuit-Nunangat-Housing-Strategy-English.pdf

Kellert, S. R., Heerwagen, J., & Mador, M. (2011). *Biophilic Design: The Theory, Science and Practice of Bringing Buildings to Life*. John Wiley & Sons, New Jersey, USA.

Kirmayer, L. J., & Paul, K. (2007). *Qanuippitaa? How are We? Mental health, social support and community wellness*. Institut national de santé publique du Québec et Nunavik Regional Board of Health and Social Services. Québec, Canada. https://collections.banq.qc.ca/ark:/52327/46571

Kovesi, T. (2012). Respiratory disease in Canadian First Nations and Inuit children. *Paediatrics Child Health, 17*(7), 376–380. https://doi.org/10.1093/pch/17.7.376

External references

Lehti, V., Niemelä, S., Hoven, C., Mandell, D., & Sourander, A. (2009). Mental health, substance use and suicidal behaviour among young Indigenous people in the Arctic: A systematic review. *Social Science & Medecine, 69*(8), 1194-1203. https://doi.org/10.1016/j.socscimed.2009.07.045

Lopez, A., & Murray, C. (1998). The global burden of disease, 1990–2020. *Nature Medecine, 4*, 1241–1243. https://doi.org/10.1038/3218

Muckle, G., Fraser, S., Desrochers-Couture, M., Pépin, C., Bélanger, R., Fletcher, C., Poliakova, N., & Moisan, C. (2020a). *Mental Health and Wellness*. Nunavik Inuit Health Survey 2017 Qanuilirpitaa? How are we now? Quebec: Nunavik Regional Board of Health and Social Services (NRBHSS) et Institut national de santé publique du Québec (INSPQ). https://nrbhss.ca/sites/default/files/health_surveys/A12528_RESI_Mental_Health_and_Wellness_EP5.pdf

Muckle, G., Fletcher, C., Riva, M., Desrochers-Couture, M., Pépin, C., Poliakova, N., Moisan, C., Bélanger, R., & Fraser, S. (2020b). *Sociocultural determinants of health and wellness*. Nunavik Inuit Health Survey 2017 Qanuilirpitaa? How are we now? Quebec: Nunavik Regional Board of Health and Social Services (NRBHSS) & Institut national de santé publique du Québec (INSPQ). https://nrbhss.ca/sites/default/files/health_surveys/A12343_RESI_Sociocultural_Determinant_EP5.pdf

Nunavik Regional Board of Health and Social Services (NRBHSS), in collaboration with Institut national de santé publique du Québec (INSPQ). (2015). *Nunavik Health Profile 2014: Young Children and Their Families*. Government of Québec. https://nrbhss.ca/sites/default/files/Profile_Enfants_Famille_EN.pdf

Patel, V., Saxena, S., Lund, C., Thornicroft, G., Baingana, F., Bolton, P., Chisholm, D., Collins, P. Y., Cooper, J. L., Eaton, J., Herrman, H., Herzallah, M. M., Huang, Y., Jordans, M. J. D., Kleinman, A., Medina-Mora, M. E., Morgan, E., Niaz, U., Omigbodun, O., Prince, M.,Rahman, A., Saraceno, B., Sarkar, B. K., De Silva, M., Singh, I., Stein, D. J., Sunkel, C., & UnÜtzer, J. (2018). The Lancet Commission on global mental health and sustainable development. *The Lancet Commissions, 392*(10157), 1553-1298. https://doi.org/10.1016/S0140-6736(18)31612-X

External references

Pepin, C., Muckle, G., Moisan, C., Forget-Dubois, N., & Riva, M. (2018). Household overcrowding and psychological distress among Nunavik Inuit adolescents: A longitudinal study. *International Journal of Circumpolar Health, 77*, 1. https://doi.org/10.1080/22423982.2018.1541395

Perreault, K., Dufresne, P., Potvin, L., & Riva, M. (2022). Housing as a determinant of Inuit mental health: Associations between improved housing measures and decline in psychological distress after rehousing in Nunavut and Nunavik. *Canadian Journal of Public Health, 114*, 241–253. https://doi.org/10.17269/s41997-022-00701-0

Smetanin, P., Stiff, D., Briante, C., Adair, C.E., Ahmad, S. & Khan, M. (2011). *The life and economic impact of major mental illnesses in Canada: 2011 to 2041.* RiskAnalytica, on behalf of the Mental Health Commission of Canada. https://www.mentalhealthcommission.ca/wp-content/uploads/drupal/MHCC_Report_Base_Case_FINAL_ENG_0_0.pdf

Smith, B. W., Dalen, J., Wiggins, K., Tooley, E., Christopher, P., & Bernard, J. (2008). The brief resilience scale: Assessing the ability to bounce back. *International Journal of Behavioral Medicine, 15*(3), 194–200. https://doi.org/10.1080/10705500802222972

Statistics Canada. (2020). *Canadian Community Health Survey, 2019.* https://www150.statcan.gc.ca/n1/en/daily-quotidien/200806/dq200806a-eng.pdf?st=09juPkhD

Van Praag, H. M. (2004). Can stress cause depression? *Progress in Neuro-Psychopharmacology and Biological Psychiatry, 28*(5), 891-907. https://doi.org/10.1016/j.pnpbp.2004.05.031

Vos, T., Lim, S. S., Abbafati, C., Abbas, K. M., Abbasi, M., Abbasifard, M., Abbasi-Kangevari, M., Abbastabar, H., Abd-Allah, F., Abdelalim, A., Abdollahi, M., Abdollahpour, I., Abolhassani, H., Aboyans, V., Abrams, E. M., Abreu, L. G., Abrigo, M. R. M., Abu-Raddad, L. J., Abushouk, A. I., ... Alanzi, T. M. (2020). Global burden of 369 diseases and injuries in 204 countries and territories, 1990–2019: A systematic analysis for the Global Burden of Disease Study 2019. *The Lancet, 396*, 1204-1222. https://doi.org/10.1016/S0140-6736(20)30925-9

Young, T. K., Rawat, R., Dallman, W., Chatwood, S., & Bjerregaard, P. (2012). *Circumpolar Health Atlas*. The University of Toronto Press, Ontario, Canada.