CASE 11

Crypto Climate Creep: The Movement of Tropical Infectious Disease to the Arctic

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The Inuvik Sunrise Festival is an annual festival that takes place in early January and is a time when everyone participates in feasts and festivals to celebrate the return of the sun after many weeks of complete darkness. Dr. Jacob Sanders, an epidemiologist and public health physician, was excited to attend the event and see many of his old friends.

Jacob was eager to have his favourite traditional foods at the feast, especially Muktuk (beluga blubber), beaver, caribou, bearded seal, and blue mussels. Just like the old days, Jacob felt back at home after eating these traditional foods. During the festival, there was a severe snowstorm and the feast was cut short.

The next morning, Jacob does not feel well. He has a bad case of diarrhea and assumes the Muktuk, beaver, caribou, bearded seal, or the blue mussels is the reason for his ill health. Celina, Jacob's wife and an environmentalist and Indigenous public health expert, is worried about Jacob's condition and has him admitted to Inuvik Regional Hospital. They take stool, urine, and blood samples. While they are waiting, friends from the feast are arriving at the hospital with the same symptoms. A lack of laboratory equipment for diagnosing the cause of the illness means the stool samples are sent to Nunavik, Quebec, where the public health unit has onsite molecular testing capabilities and specialized equipment to determine the problem. After a few days, the diagnosis is revealed—Jacob has contracted a parasite known as *Cryptosporidium*. This is a surprise, since there have never been any cases of cryptosporidiosis reported in Inuvik and it is a tropical parasite that is not native to the Arctic.

Through collaboration with the National Enteric Surveillance Program at the Public Health Agency of Canada (PHAC), and the provincial/territorial governments of Quebec and the Northwest Territories, Jacob is notified that the last outbreak of cryptosporidiosis was in 10 communities in Nunavik in 2013. How did cryptosporidiosis spread to Inuvik? What is the host(s)? How can a tropical parasite survive in the cold Arctic environment?

BACKGROUND

Jacob and Celina

Dr. Jacob Sanders and Dr. Celina Roy live in Inuvik in the Northwest Territories. This community is a special place for both Jacob and Celina. They met here 10 years earlier when Jacob was completing his residency training and Celina was finishing her thesis on a zoonotic infectious disease called toxoplasmosis. Jacob is an Inuvialuit epidemiologist and public health physician working for the Infectious Disease Prevention and Control Branch at the PHAC. He is married to Celina, a Gwich'in senior environmentalist and Indigenous public health expert at the First Nations and Inuit Health Branch (FNIHB) of Indigenous Services Canada.

After living in Canada's capital city for 10 years, Jacob and Celina moved to Inuvik, where Jacob works at the Inuvik Regional Hospital and Celina works at the Inuvik public health unit. As part of her work, Celina wanted to expand the surveillance systems for infectious diseases and coordinate these systems with climate monitoring. The beginning of Celina's new job could not have been more timely because surveillance reports generated by the Centre for Food-Borne, Environmental and Zoonotic Infectious Diseases (CFEZID) at the PHAC showed a rise in zoonotic and water-borne infectious diseases in the Arctic. Social and ecological determinants of health play a major role in the livelihood of the Indigenous peoples living in the Arctic as a result of historical trauma, colonization, and the residential school system (Inuit Tapiriit Kanatami, 2014). The negative effects these determinants of health have on Indigenous communities have amplified the negative impacts of *Cryptosporidium* in this population.

Jacob and Celina wanted to work with the Indigenous nurses at the public health unit in Inuvik to investigate the prevalence and incidence of certain zoonotic infectious diseases. They want to see whether the rates have decreased, increased, or remained relatively the same over the past 10 years.

The Canadian Arctic

The Canadian Arctic comprises the regions north of approximately 55 degrees latitude. It includes the Yukon, the Northwest Territories, Nunavut, Northern Quebec, and Northern Labrador, making up around 40% of Canada's landmass (Government of Canada, 2017). A majority of the approximately 100,000 people living in the Canadian Arctic are Indigenous peoples from different groups such as First Nations people and the Inuit (Government of Canada, 2013). The winters are long and cold, lasting for most of the year, with a few warmer summer months. Permafrost covers most of the region with little year-round vegetation (Exhibit 1).

Inuvik, Northwest Territories

The town of Inuvik is situated 200 km above the Arctic Circle and 80 km below the Arctic Ocean. Located in the Beaufort Sea region, Inuvik is next to the Mackenzie River and is home to more than 3,000 people. The population breakdown is as follows: 38.9% Inuvialuit, 18.4% Gwich'in, 4.7% Métis, 1.2% other Aboriginal, and 36.7% nonnative (Statistics Canada, 2017). Inuvik has the Inuvik public health unit and one hospital, Inuvik Regional Hospital.

Nunavik, Quebec

Nunavik is located in the northern region of Quebec and is considered to be a part of the Canadian Arctic. It has about 12,000 people, 90% of whom are Inuit. Nunavik is also home to many dog sledding races, with teams attending from all over the world to compete (Nunavik Tourism Association, 2010). While most people now travel by snowmobile, dogs were essential to the survival of the Inuit in the Arctic in the past.

ZOONOTIC INFECTIOUS DISEASES

An increase in population, diminishing resources, and increased exposure to the virosphere results in a higher chance of people becoming exposed to infectious diseases. The coexistence of humans with animals can be a potential passageway for the spread of disease that can impact the physical, social, and economic well-being of a population (Centers for Disease Control and Prevention, 2017a). The transmission of disease from animals to humans is known as zoonosis, and can occur through direct or indirect contact. Direct contact involves contact with the saliva, blood, urine, or feces of an infected animal. Indirect contact includes the spread of zoonoses via water, food, or the environment. Zoonotic diseases can be caused by viruses, bacteria, parasites, or fungi. Depending on the severity, they can lead to many types of illnesses in animals and humans, ranging from mild sickness to death (World Health Organization, 2009).

Approximately 60% of infections in humans have a zoonotic component (Centers for Disease Control and Prevention, 2017a). Three of every four new or emerging infectious diseases are zoonotic. Some common zoonotic infectious diseases are Trichinosis, Toxoplasmosis, Botulism, Brucellosis, and Cryptosporidiosis.

CRYPTOSPORIDIOSIS

Cryptosporidium is a microscopic parasite that lives in the intestines of vertebrates and can cause cryptosporidiosis infection in humans or other animals. Cryptosporidiosis is transmitted by *Cryptosporidium* oocysts that contaminate food or water sources. There are many different species of *Cryptosporidium* that can infect humans and animals, although *C. parvum* and *C. hominis* are the most common (Safe Drinking Water Foundation, n.d.; Thivierge et al., 2016, Exhibits 2 and 3). See Appendix A for more information.

Outbreaks

The first case of cryptosporidiosis in humans was reported in 1976 (Thivierge et al., 2016). Since then, it has become one of the most common causes of water-borne disease, found in 95 countries around the world. Through contact tracing, many outbreaks in humans have been linked to contaminated drinking water, recreational water use, and food products. While it is more commonly found in tropical countries and developing countries in Africa and South America, there have been large outbreaks of cryptosporidiosis in the United States and Canada. In 1993, 50% of the people in Milwaukee, Wisconsin were infected with *C. parvum* because of a contaminated water supply (MacKenzie et al., 1995). In 2001, the Saskatchewan Health Authority reported 1,200 cases of cryptosporidiosis in North Battleford as a result of water supply contamination (Wallis et al., 2003). In 2010, there were 86 cases of the *Cryptosporidium* transmitted from animals to humans in Nunavut (Goldfarb et al., 2013). This was the first case reported as far north as the Arctic. In 2013, there was a *C. hominis* outbreak in Nunavik, Quebec, with 69 cases resulting from human-to-human transmission. This was 250 times higher than the expected number of outbreaks of the parasite in southern Canada (Murphy, 2016; Thivierge et al., 2016). In 2015, there were 872 reported cases of cryptosporidiosis across Canada because of poor-quality rural water sources and ineffective water treatment (Safe Drinking Water Foundation, n.d.).

Diagnosis

It is difficult to identify cryptosporidiosis in the Canadian Arctic because equipment and testing facilities are limited. After the outbreak in Nunavik, Quebec, onsite molecular testing equipment was set up to test for *Cryptosporidium* along with other zoonotic infectious diseases. This site reduced the testing wait time from two weeks to same day diagnosis, helping to minimize transmission of *Cryptosporidium* at home and in schools (Thivierge et al., 2016).

CLIMATE CHANGE IN THE ARCTIC

The Canadian Arctic is particularly susceptible to anthropogenic climate change because of the sensitivity of the cryosphere, which is made up of sea ice, snow, iced-over rivers and lakes, and permafrost. The Arctic has experienced warming increases of about 2°C to 3°C over the past 30 years (Furgal & Seguin, 2006). By the end of the 21st century, there will be an estimated 30% increase in precipitation levels in the Arctic region (Furgal & Seguin, 2006). Warmer temperatures in some areas of the Arctic will limit snow accumulation on the ground, which will negatively impact a wide range of ecological processes. If temperatures continue to rise, rivers and lakes may not remain frozen as long as they have in previous ice seasons, and the average thickness of the ice will decrease (Johannessen et al., 2004). Warming temperatures will also have significant effects on the melting of permafrost, which will subsequently lead to the release of trapped methane and carbon dioxide (Johannessen et al., 2004). Disruptions to the environmental balance will change the Arctic environment into a land foreign to its inhabitants.

Effects of Climate Change on the Emergence of Infectious Diseases

The spread, frequency, and intensity of infectious diseases across Canada could be influenced by climate change in the upcoming years and decades. Increased precipitation will result in increased water turbidity from high water velocity. Rapid snowmelt also contributes to an increase in cases of gastrointestinal illness. Both the increased precipitation and rapid snowmelt will mix and transport more pathogens into water sources and increase the risk of water-borne infectious disease transmission (Lindgren, 2015). Rising temperatures will increase food-borne illnesses and result in food spoilage and proliferation of disease organisms. In the Arctic specifically, melting permafrost will disrupt traditional food storage methods that involve canning, fermentation, and outdoor food storage. Air-drying of meat will increase the risk of exposure to pathogens as a result of climate change and increased temperatures (Parkinson & Evengård, 2009). This can increase the incidence of botulism, salmonella, campylobacteriosis, and other food-borne diseases (Parkinson & Evengård, 2009). Climate change warming will also expand the range of habitats for animal hosts migrating farther north. This will cause animal hosts to proliferate and will increase the transmission of zoonotic infections.

Effects of Climate Change on the Livelihood of Indigenous Peoples

Indigenous peoples living in the Canadian Arctic face many health disparities due to community remoteness, reduced access to health care, inadequate infrastructure, food insecurity, decreased mental wellness, and environmental pollution. These effects are already exacerbated by climate change. Many communities face drinking water problems from water contamination and, as a result, have sporadic boil water advisories. With warmer temperatures reducing the thickness of the sea ice, delaying the formation of the ice, and melting the permafrost, people in the Arctic will have a limited ability to sustain themselves using traditional food practices. Food scarcity affects 24% to 46% of households in the Canadian Arctic (Thivierge et al., 2016). Climate change will result in less food to eat because animal migratory patterns will change and the contaminated water will make it unsafe to eat marine animals. Hunting will become challenging, if not impossible, since depleted sea ice will make it difficult to commute on land (Furgal & Seguin, 2006). These changes will also threaten Indigenous traditions and culture. These conditions make Indigenous populations in the Arctic especially vulnerable to the effects of emerging infectious diseases as a consequence of climate change.

PUBLIC HEALTH RESPONSE AND STAKEHOLDERS

There are various stakeholders involved in public health responses to zoonotic infectious diseases. The PHAC was created in 2004 to respond to public health emergencies and to protect the health of all Canadians (PHAC, 2013). To facilitate a multijurisdictional response, the PHAC works alongside Health Canada, the Canadian Food Inspection Agency, and various other stakeholders by following the steps laid out in Canada's Foodborne Illness Outbreak Response Protocol (FIORP) (PHAC, 2013). The FIORP was developed to enhance multijurisdictional collaboration and streamline roles and actions during food-borne illness outbreaks (Canadian Food Inspection Agency, 2018). The FIORP seeks to minimize the impacts of food-borne illnesses/morbidity, mortality, increased health care burden, economic losses, and lost productivity in the event of an outbreak. In addition to working with FIORP, the PHAC has an Infectious Diseases and Climate Change Program that includes a climate change infectious disease toolkit, and a public health and water-borne illness research tool to assess the burden of gastrointestinal illness and adaptation to climate change in the Canadian North (PHAC, 2013). Another important stakeholder is the FNIHB. The FNIHB is a branch within the newly created Indigenous Services Canada (Government of Canada, 2018a). It works with a nationwide organization known as the Inuit Tapiriit Kanatami (ITK).The organization represents more than 60,000 Inuit living in the Northwest Territories, Northern Quebec, and Northern Labrador in an effort to highlight environmental, social, cultural, and political issues facing the

Inuit peoples of Canada (ITK, 2018). See Appendix B for more information on the specific stakeholders.

BACK TO THE PROBLEM

C. hominis was identified for the first time in the Canadian Arctic in Nunavik, Quebec in 2013. Now, with another outbreak of cryptosporidiosis in Inuvik, public health professionals need to act fast to mitigate this problem. The recognition of widespread human cryptosporidiosis in this region is a public health concern because of the possible long-term effects on growth and development of children in Inuit communities who already face many other challenges. Cryptosporidiosis may be one of the first tropical diseases discovered in the Arctic, but it will not be the last. It is up to all circumpolar countries to look at this outbreak as a sign of the Arctic's future, where pathogens will proliferate and spread diseases from animals to humans. Steps need to be taken today so that the Arctic does not become the new danger zone for zoonotic infectious diseases.

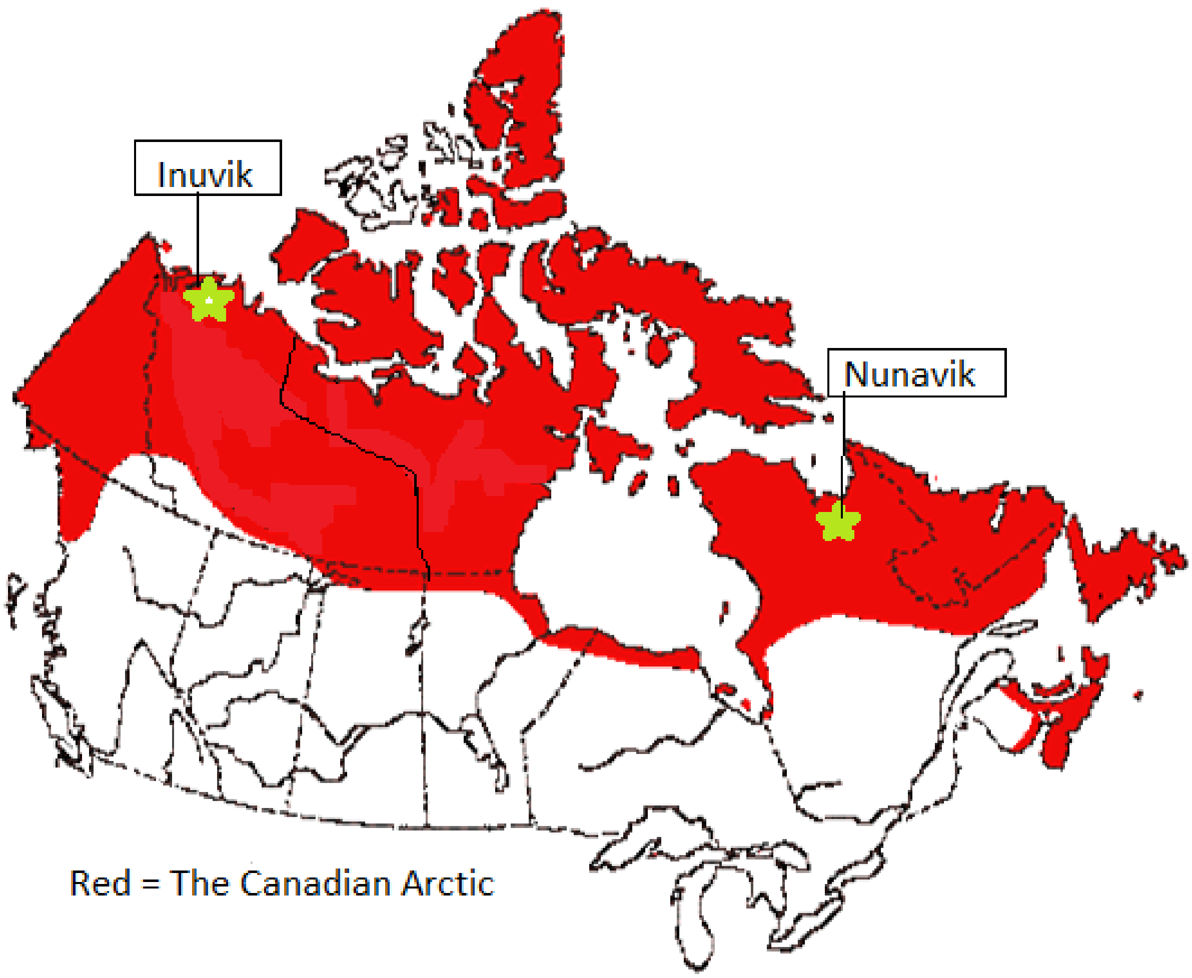
CONCLUSION

From West Nile virus and Lyme disease in Canada's south to cryptosporidiosis in the north, the geographical spread of infectious diseases is creating new public health challenges. It is also exacerbating the existing socioeconomic determinants of health affecting Indigenous peoples in the Arctic. Northern communities already deal with food scarcity, mental health issues, antiquated infrastructure, trauma from colonization and residential schools, and environmental changes. The emerging health threats of zoonotic infectious diseases will only worsen health outcomes in the generations to come. Surveillance of climate-sensitive infectious diseases should be strengthened. With consultation from Indigenous peoples, culturally appropriate adaptation and mitigation strategies to tackle new emerging infectious diseases in the Canadian Arctic and in the global context can be identified.

WHAT'S NEXT?

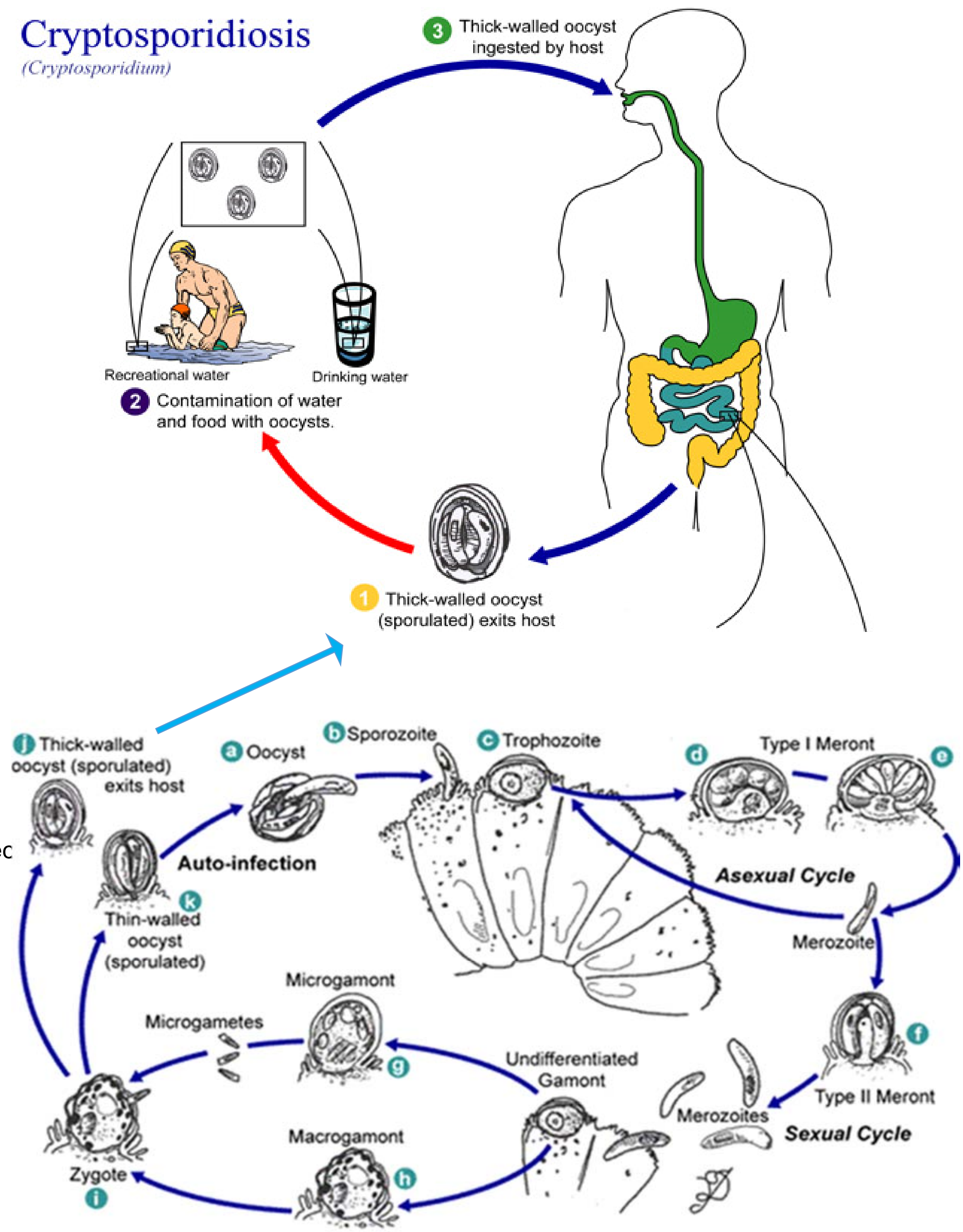
Using a systems-thinking approach, Celina wants this problem viewed using the One Health Model—a transdisciplinary model incorporating animal, human, and ecosystem health. This model will allow for an integrated and holistic approach to solving the problem. There is a dynamic interplay between infectious disease incidence and climate change, and the close connection of Indigenous peoples with their land in the Canadian Arctic. Celina is now looking to conduct contact tracing to identify how the tropical parasite *Cryptosporidium* is present in the Arctic. As a public health professional, it is important for her to disseminate the information to various audiences in a time-sensitive manner. Depending on the type of audience, whether it is the general public, technical experts, or governmental officials, the risk communication and public health messaging will have to be tailored accordingly.

EXHIBIT 1
Map of the Canadian Arctic



Source: Adapted from the Government of Canada, 2017.

EXHIBIT 2
Life Cycle of *Cryptosporidium*



Spec

Source: Adapted from Centers for Disease Control and Prevention, 2017b and Safe Drinking Water Foundation, n.d.

EXHIBIT 3
***Cryptosporidium* Species**

Number	Species of *Cryptosporidium*	Major Hosts	Zoonotic Status
1	*C. andersoni*	Cattle	Yes
2	*C. baileyi*	Birds	No
3	*C. bovis*	Cattle	Yes
4	*C. canis*	Dogs	Yes
5	*C. cuniculus*	Rabbits	Yes
6	*C. erinacei*	Hedgehogs and horses	Yes
7	*C. fayeri*	Marsupials	Yes
8	*C. felis*	Cats	Yes
9	*C. fragile*	Toads	No
10	*C. galli*	Birds	No
11	*C. hominis*	Humans	Most common species in humans
12	*C. macropodum*	Marsupials	No
13	*C. meleagridis*	Humans and birds	Yes
14	*C. molnari*	Fish	No
15	*C. muris*	Rodents	Yes
16	*C. parvum*	Ruminants	Yes
17	*C. ryanae*	Cattle	No
18	*C. scrofarum*	Pigs	Yes
19	*C. serpentis*	Snakes and lizards	No
20	*C. suis*	Pigs	Yes
21	*C. tyzzeri*	Rodents	Yes
22	*C. ubiquitum*	Primates, ruminants	Yes
23	*C. varanii*	Lizards	No
24	*C. viatorum*	Humans	Least common species in humans
25	*C. wrairi*	Guinea pigs	No
26	*C. xiaoi*	Sheep and goats	Yes

Source: Adapted from Zahedi et al., 2016.

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APPENDIX A

CRYPTOSPORIDIOSIS

Life Cycle

Cryptosporidium starts as an oocyst, which consists of a tough shell containing four parasites. Once the oocyst is swallowed by the host, the shell opens and releases the parasites into the small intestine. The parasites can then develop and reproduce in the same host or start another cycle of infection by being excreted via feces and infecting other hosts. The infection is usually limited to the intestinal tract; however, in immunocompromised individuals and animals, it can spread to other areas of the body (Exhibit 2, Safe Drinking Water Foundation, n.d., Thivierge et al., 2016).

Spread of Infection

Cryptosporidium has a low infectious dose: a host needs to be in contact with only 10 to 30 oocysts to acquire the infection (Putignani & Menichella, 2010). After four days of infection, oocysts are shed into the feces at a rate of 1 to 10 billion per day (Putignani & Menichella, 2010). On average, this shedding lasts three to 12 days in animals and 18 days in humans. *C. parvum* oocysts can live up to 18 months in an environment that is cool and damp/wet (Safe Drinking Water Foundation, n.d.). They can be found in soil, food, or water contaminated with feces from infected humans or animals. The feces can contaminate nearby water sources when rainfall causes runoff. Vegetation can also become infected if the fertilizer is contaminated or if the water used to wash the vegetation is contaminated.

Symptoms

The most common symptom of cryptosporidiosis is watery diarrhea. This is in part because the body's immune system tries to fight the infection by sending immune cells into the intestine, which end up destroying the intestinal cells. In addition to diarrhea, an individual can also have stomach cramps, nausea, vomiting, dehydration, fever, fatigue, and weight loss depending on the severity of the infection. These symptoms can last from two to 10 days after infection in normally healthy individuals. However, for people who are immunocompromised (e.g., have HIV), the infection can last for several weeks and may require hospitalization. In some cases, the infection can become chronic and an individual can shed oocysts for months after not showing any symptoms. The symptoms are also more severe in young children, and this can lead to long-term negative impacts on a child's cognitive development (Murphy, 2016; Thivierge et al., 2016).

Treatment and Prevention

C. parvum has a thick-walled oocyst that allows it to survive outside the body for a long time and makes it resistant to chlorine. Thus, treatment of water contaminated with *Cryptosporidium* becomes difficult (Lindgren, 2015). Because of its contagious nature, hand washing before preparing food and after going to the washroom is highly recommended. An infected person should not swim in recreational water and should avoid exposing other people to their fecal matter. While there are no current treatments for cryptosporidiosis, the best method of control is prevention. Supportive treatments include hydration therapy and antidiarrheal drugs. For immunocompromised people who have cryptosporidiosis, antiretroviral therapy can reduce oocyst excretion and diarrhea (Lindgren, 2015; Safe Drinking Water Foundation, n.d.). To purify water, filters with a pore size of one to two micrometres should be used so they can block the four micrometre *C. parvum* from entering the water supply. Boiling water for at least one-minute can also decrease the number of oocysts present (Lindgren, 2015).

APPENDIX B

PUBLIC HEALTH RESPONSE AND STAKEHOLDERS

The Public Health Agency of Canada

The PHAC was created in 2004 to respond to public health emergencies and to protect the health of all Canadians (PHAC, 2013). One of the four branches of PHAC is the Infectious Diseases Prevention and Control Branch, which investigates the risks of infectious diseases in Canada and how they can be mitigated. Within the Infectious Diseases Prevention and Control Branch is a department known as CFEZID. The CFEZID analyzes data on emerging zoonotic, enteric, food-borne, and water-borne diseases in Canada in order to assess the associated risks and reduce their impact on the Canadian population (Public Health Agency of Canada, 2013). The CFEZID also helps the various levels of government develop policies about infectious diseases by providing evidence-based recommendations. The PHAC is not the only level of government involved in outbreak investigation; local, provincial/territorial governments, and other sectors are also involved in the process. In order to facilitate a multijurisdictional response, the PHAC works alongside Health Canada, the Canadian Food Inspection Agency, and various levels of stakeholders by following the steps laid out in Canada's FIORP (PHAC, 2013).

Canada's Foodborne Illness Outbreak Response Protocol (FIORP)

The FIORP was created by the PHAC, Health Canada, and the Canadian Food Inspection Agency in partnership with provincial and territorial sectors. Stakeholders developed this response protocol to enhance multijurisdictional collaboration and streamline roles and actions during food-borne illness outbreaks (Canadian Food Inspection Agency, 2018). The protocol is important in helping minimize the negative impacts that may result from food-borne illness outbreaks, including the morbidity and mortality, increased health care burden, economic losses, and lost productivity. Because Indigenous populations rely heavily on hunting animals and fish, they are especially susceptible to food-borne illness outbreaks arising from raw meat. The FIORP uses enhanced enteric illness surveillance networks to regulate all stakeholders responsible for human health in relation to food safety. Scientists working for the FIORP conduct molecular subtyping in order to initiate outbreak investigation by detecting case linkages. Because of the potential severity of food-borne illnesses, the FIORP provides ongoing public awareness about food safety measures in a timely manner to prevent further illness. It improves the efficacy and effectiveness of the response to food-borne outbreaks from the local, provincial/territorial, and federal governments and other relevant organizations (Canadian Food Inspection Agency, 2018).

National Enteric Surveillance Program (NESP)

The NESP is a Canada-wide surveillance system administered by the CFEZID and the National Microbiology Laboratory. It looks at the national incidence of food-borne pathogens to help identify any potential enteric disease outbreaks. A software program known as PulseNet Canada helps to link the databases of public health laboratories across Canada together for streamlined analysis of trends in emerging infectious diseases (Government of Canada, 2018b). The NESP system is important for creating policies and programs that are supported by evidence.

Preventative Public Health Systems and Adaptation to a Changing Climate Program

The PHAC has implemented an Infectious Diseases and Climate Change Program to inform decision-making and adaptation strategies to mitigate infectious diseases in order to protect the health of Canadians. The projects associated with this program include a climate change infectious disease toolkit, a public health and water-borne illness research tool, and an assessment of the burden of gastrointestinal illness and adaptation to climate change in the Canadian North (PHAC of Canada, 2013). However, there is still a lack of syndromic and disease surveillance data that is coupled with climate observations. This makes it difficult to identify any epidemiological changes and infectious diseases trends in the Arctic.

First Nations and Inuit Health Branch (FNIHB)
The FNIHB is a branch under the newly created Indigenous Services Canada (Government of Canada, 2018a). Previously a part of Health Canada, the FNIHB has been committed to First Nations and Inuit health since 2012. It works with a nationwide organization known as the Inuit Tapiriit Kanatami (ITK). The organization represents more than 60,000 Inuit living in the Northwest Territories, Northern Quebec, and Northern Labrador to highlight the environmental, social, cultural, and political issues facing Inuit peoples of Canada (ITK, 2018). The ITK has five priorities: (1) community education and mobilization; (2) intersectoral partnership to address social determinants of Inuit health; (3) evidence-based Inuit-appropriate programs; (4) improved surveillance and research; and (5) better evaluation and reporting (Indigenous Services Canada, 2013; ITK, 2018). The FNIHB also works with the local and territorial/provincial governments to identify their needs and address them at the federal level (Government of Canada, 2018a).

INSTRUCTOR GUIDANCE

Crypto Climate Creep: The Movement of Tropical Infectious Disease to the Arctic

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BACKGROUND

Dr. Jacob Sanders was excited to attend the Inuvik Sunrise Festival and see friends, old and new. The evening was cut short due to the snowstorm, but the next morning, Jacob was very ill. Not knowing the cause, he assumed it was the food: Muktuk (beluga blubber), beaver, caribou, bearded seal, or blue mussels. Severely dehydrated from diarrhea, he was admitted to Inuvik Regional Hospital. Insufficient lab equipment at the hospital meant the stool samples had to be sent far away to Nunavik, Quebec where the public health unit had an onsite molecular test to diagnose the problem. When the diagnosis was finally revealed, he was shocked to learn it was a disease unknown to the Inuvik region, and nearly unseen for the past decade—cryptosporidiosis.

Cryptosporidiosis is a zoonotic infectious disease transmitted by a microscopic parasite known as *Cryptosporidium.* This transmission occurs via oocysts that can contaminate food or water sources. Symptoms of cryptosporidiosis include diarrhea, stomach cramps, nausea, vomiting, dehydration, fever, fatigue, and weight loss. Although it is typically a tropical disease, it was first discovered in 2013 in the Canadian Arctic in Nunavik, Quebec. The recognition of widespread human cryptosporidiosis in the Canadian Arctic is a public health concern because of its possible long-term effects on the growth and development of children in Inuit communities who already face many other challenges.

Climate change has been linked to the emergence of new infectious diseases in Northern Canada. Increased precipitation from climate change will result in increased water turbidity from high water velocity. As a result, this will mix and transport more pathogens into water sources and increase the risk of water-borne infectious disease transmission. The warmer temperatures associated with climate change will also expand the range of habitats for animal hosts and allow them to migrate further north. Consequently, this will cause animal hosts to proliferate and will increase the transmission of zoonotic infections. The Centre for Food-borne, Environmental and Zoonotic Infectious Diseases at the Public Health Agency of Canada is looking to inform decision-making and adaptation strategies to mitigate infectious diseases to protect the health of Canadians, especially for those living in the Arctic Circle.

OBJECTIVES

1. Demonstrate knowledge about the effects of environmental factors that affect a population's health.
2. Assess the links between the quality of the environment and population health and exposure to infectious diseases, with an emphasis on systems thinking.

3. Demonstrate knowledge about the One Health Model, which encompasses animals, humans, and the environment.
4. Learn about the public health response and the various levels of government involved in containing an infectious disease outbreak.
5. Evaluate the impact of changes in the environment on the biology, behaviour, and psychology of populations at risk.
6. Explain how globalization affects global burdens of disease.

DISCUSSION QUESTIONS

1. Create a CASE and DPSEEA model for *Cryptosporidium*. Be prepared to discuss this briefly in class.
    a. List the potential indirect health impacts from climate change issues (such as an increase in temperature, change in snow composition, or change in the range and activity of infective agents) on Indigenous peoples living in the Arctic.
2. Discuss the One Health Model and how this approach could be valuable in this case.
3. Create an influence diagram to show your understanding of a systems thinking approach to this problem.
4. Discuss the effects of the following issues and brainstorm coping/adaptation strategies to address them:
    a. Warmer temperatures in summer and year-around
    b. Increased precipitation
    c. Contaminated food and water sources
    d. Changing animal migration routes
5. In collaboration with Indigenous Services Canada, discuss what actions the Public Health Agency of Canada can take to limit the exposure of Indigenous communities in Northern Canada to zoonotic infectious diseases such as *Cryptosporidium*? Students should look at the strategic plan of the Infectious Disease Prevention and Control Branch at the agency in order to facilitate the discussion.
6. Discuss the steps that can be taken to avoid a future outbreak of cryptosporidiosis in the Canadian Arctic.

KEYWORDS

Climate change; *Cryptosporidium*; One Health Model; systems thinking; zoonotic infectious diseases; Arctic Region; Indigenous peoples