Principles of Planetary Health

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WILLIAM MONTELPARE AND LAURIE MCDUFFEE

Contents

The Plan for the Sub-committee of Planetary Health

Together members of our sub-committee will examine the fundamental principles of planetary health to establish the body of knowledge that introduces the concepts of one health and the effects of climate change on human health.

This approach to studying planetary health is based on the soon-to-be ratified Declaration of the Association of Faculties of Medicine Canada (Academic Health Institutions Declaration on Planetary Health). Members of the working group preparing the Declaration for the AFMC include the Planetary Health Alliance along with the Association of Faculties of Medicine Canada, the Canadian Association of Physicians for the Environment (CAPE), and the Canadian Federation of Medical Students (CFMS), and experts from medical schools around the world.

Academic Health Institutions Declaration On Planetary Health

In brief this Declaration originates from the Association of Faculties of Medicine of Canada (AFMC)'s International Declaration Development Committee which comprises international leaders in planetary health and academic medicine. The AFMC recognizes that Faculties of medicine have a Social Accountability mandate: to educate health professionals and conduct research that will improve the health of the populations they serve.

This Declaration endorses the definition of planetary health as defined by the Planetary Health Alliance: planetary health is a solutions-oriented, transdisciplinary field and social movement focused on analyzing and addressing the impacts of human disruptions to Earth's natural systems on human health and all life on Earth.

The declaration states: We recognize that Academic health institutions must promote interdisciplinary and transdisciplinary research and education in three important tracks: Climate change and health education, education for sustainable healthcare, and planetary health education including One Health. Further, we must bridge our research and teaching between human health sciences, veterinary medicine, and environmental sciences.

The concept of using a principles approach is that the principles become the most important take-away points from the chapter and can also be used as the basis of the exam questions. Moreover, the principles that are identified in Year 1, become the basis for the threads that weave through the curriculum in the upper years.

Important background notes for the creation of each chapter.

- Each chapter provides the essential background information for two, 50-minute lectures in the Planetary Health course.
- Each chapter should begin with the *Learner Objectives* in a list format as shown in the sample chapter.
- Each chapter should include a definition and description of important terminology.

Overview and Mission of the Planetary Health Program

The curriculum of Planetary Health is designed for medical students and will be offered in the Faculty of Medicine at UPEI as part of the Professional Undergraduate Medical Education program across Phases 1 through 4.

The proposed starting date for this program is August 1, 2024.

The term Planetary Health is defined here as: "*a solutions-oriented, transdisciplinary field and social movement focused on analyzing and addressing the impacts of human disruptions to Earth's natural systems on human health and all life on Earth*."

Our mission is to:

- develop graduates who can work collaboratively with a planetary health lens to operationalize the enhancement of health in all its meanings and complexities, and especially to extend the concepts of planetary health to ensure the maintenance of physical, mental, and social well-being among patients.
- The planetary health program will graduate students that can contribute to solving complex problems that affect planetary health. Graduates will recognize the need to practice sustainable medicine that will lead to better planetary health outcomes.

PROGRAM FOCUS AND OBJECTIVES
The Planetary Health Program is a solutions-focused transdisciplinary program.

The curriculum focuses on developing essential knowledge based on theory and evidence from real world planetary health issues.

The program is informed by the Planetary Health Alliance along with the Association of Faculties of Medicine Canada, the Canadian Association of Physicians for the Environment (CAPE), and the Canadian Federation of Medical Students (CFMS), all of whom have identified the need to incorporate greater awareness of planetary health into the medical school curriculum.

The Planetary Health Program represents a new approach to training medical learners, healthcare providers, and the public about issues that influence planetary health.

Individuals who complete the Planetary Health program will be ready to build strong collaborative networks with other health professionals and thereby make meaningful contributions to solving real-world challenges and promoting policies that will lead to positive effects on planetary health.

To this end, the planetary health program focuses on developing individuals with the competencies required to bridge gaps between health systems, health researchers, health practitioners, and decision/policymakers in a manner that breaks down silos and enables professionals to work toward common goals to reverse the negative effects of humans on planetary health.

PROGRAM DESCRIPTION

The program begins with the introductory course on Planetary Health in year 1. This is a regular semester offering in Year 1 of the UGME. The course is designed to provide the essential background information on climate change, one health, and planetary science.

In this course, students will be introduced to the rapidly changing global environment and how these changes impact the health of the population, the loss of biodiversity, the influence of emerging infectious diseases, and the threats to food and water security.

In year 2 the student will be introduced to problem-based learning approaches that deal with planetary health problems. In this transdisciplinary course, the medical learner will interact directly with students from other academic disciplines to share, discuss, collaborate, and resolve real-world problems in planetary health.

In Year 3, an implementation science approach will be used to introduce students to the methods that lead to the resolution of problems in planetary health. This approach will incorporate live actors to simulate real-world scenarios that require the student to contrive interventions and problem-solving strategies.

In Year 4, students will have the opportunity to pursue research questions in planetary health as part of their research course or as a choice during “Selective and Elective” courses.

Proposed Table of Contents

- What is food security
- What is food safety (what is the role of anti-microbial resistance)
- What is the relationship to human health? (acute and chronic)
    - Physical, mental, and social implications

Chapter 6: Planetary Health and Infectious diseases

- What are Emerging Infectious Diseases (EIDs)?
    - What is zoonosis?
- What are the epidemiological considerations?
- What is the relationship to human health? (acute and chronic)
    - Physical, mental, and social implications

Chapter 7: Understanding the interface between humans and animals

- Human Interaction with wildlife
    - Loss of Biodiversity
- Human Interaction with companion animals
- Human Interaction with Food production
    - Anti-microbial resistance
- What is the relationship to human health? (acute and chronic)
    - Physical, mental, and social implications

Part 3: Sustainability Issues in Climate Change

Part 4: Planetary Health Impacts on Humans

Chapter 14: Human development and health from a planetary health perspective

- Defining human development and its impact on planetary health
- The negative consequences of planetary health on non-infectious diseases
- The importance of practicing conscientious and sustainable healthcare delivery
- Working toward inter-professional problem solving and being an advocate for community development (the built environment)

Planetary Health Committee Members

Committee Members

The following individuals are members of the Planetary Health Sub-Committee for the UPEI-MUN Medical School Curriculum Development Program

- Faculty of Medicine Representatives
    - Dr. Cathy Vardy, cvardy@mun.ca, Executive Director, Medical Program Development for UPEI
    - Gerona McGrath, gerona.mcgrath@med.mun.ca, Project Manager
    - Joan Fillier, joan.fillier@med.mun.ca, Assistant to the Executive Director, Medical Program Development for UPEI
    - Dr. Atanu Sarkar, atanu.sarkar@med.mun.ca, Community Health & Humanities
    - Dr. Delphine Grynszpan, dgrynszpan@mun.ca, Assistant Professor in Public Health, CHH
    - Dr. Ken Kao, kkao@mun.ca, Professor of Oncology

- UPEI Representatives
    - Dr. Laurie McDuffee, Co-Chair, lmcduffee@upei.ca, Professor of Large Animal Surgery, Director of Human and Animal Health Collaborations
    - Dr. William Montelpare, Co-Chair, wmontelpare@upei.ca, Professor & Research Chair in Human Development and Health
    - Dr. Aitazaz A. Farooque, afarooque@upei.ca, Interim Associate Dean, School of Climate Change and Adaptation
    - **, Assistant Professor, Pathology & Microbiology
    - Dr. John Vanleeuwen, jvanleeuwen@upei.ca, Interim Dean, Faculty of Veterinary Medicine
    - Dr. Alyson Campbell, alycampbell@upei.ca, Assistant Professor, Nursing

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- Ex Officio
    - Dr. Margaret Steele, deanofmedicine@med.mun.ca, Dean of Medicine – (dean.executiveassistant@med.mun.ca)

Individuals from this committee are contributing authors and co-authors for the text in this Pressbook presentation.

Planetary Healthcare Pressbook Status Table

The following table outlines the status of the Planetary Health Pressbook as of the date indicated at the bottom of the document. Presenting the table in this way will enable authors to remain current with the developmental process.

Status of the Planetary Health Pressbook
History: July 29, 2022

Chapter	Name	Section	Status	Editorial Comments
1. Understanding Planetary Health — Sharing Space in the Biosphere	Grynszpan, D., & Montelpare, W.	All Sections	Penultimate Draft	Referencing format to be updated. Images and videos along with supplemental materials to be added.
2. One Health: i) What is One Health? ii) Animal models in Human Disease and Medical research	Ojha, S. & Kao, K.		Penultimate Draft rec'd July 29, 2022	Referencing format to be updated. Final edits to be completed. Images and videos along with supplemental materials to be added.Working draft. PPT slides rec'd July 29, 2022. Power point text to be converted to prose format
3. Defining ECO-Health	Sarkar, A., & Atkinson, S.,		Penultimate Draft rec'd July 29,2022	Final edits to be completed. Update and edit figures for main body of text. Images and videos along with supplemental materials to be added.
4. Climate Change	Wang, X., Kinay, P., Farooque, A.		All sections Penultimate Draft rec'd July 29,2022	Final edits to be completed. Update and edit figures for main body of text. Images and videos along with supplemental materials to be added.
5. Food and Water Security and Climate Change: I) AMR and Food Safety ii) Calamities iii) Food Security iv) Water Security	Daley, P., Sarkar, A., & Wahl, M.			Update and edit figures for main body of text. Final edits to be completed. Images and videos along with supplemental materials to be added.
6. Planetary Health and Infectious diseases	Grynszpan, D., & Russell, R.,	All sections		Awaiting draft of work completed to date. Final edits to be completed. Images and videos along with supplemental materials to be added.

7. Understanding the interface between humans and animals- i) Human interaction with wildlife ii) Loss of Biodiversity iii) Human interaction with companion animals iv) Human interaction with food production animals v)Anti-microbial resistance)	Cusack, L., Hurnik, D., Kao, K., & McDuffee, L.	
8.		
9.		
10.		
11.		

6. Planetary Health and Infectious diseases Grynszpan, D., & Russell, R., All sections I) No draft or material rec'd July 29, 2022

Comments: Awaiting draft of work completed to date.
Final edits to be completed.
Images and videos along with supplemental materials to be added.
7. Understanding the interface between humans and animals Cusack, L., Hurnik, D., Kao, K., & McDuffee, L. -Human interaction with wildlife
–Loss of Biodiversity
-Human interaction with companion animals
-Human interaction with food production animals –Anti-microbial resistance
*Waiting for information on wildlife
-ppts rec'd for loss of biodiversity
***Human interaction with companion animals is penultimate draft
****awaiting feedback from food production author July 29, 2022

Comments: Power point text to be converted to prose format.
Recently recruited author and expecting to receive sections from Wildlife by end of the year.
Recently recruited author, expecting to receive sections for food animal production during the Fall term.
Images and videos along with supplemental materials to be added.
8. Human development and health from a planetary health perspective Grynszpan, D., Kao, K., & Montelpare, W.
Introduction section added. Section on the Exposomes to be expanded Wm to edit and connect with co-authors July 29, 2022

Comments: Power point text to be converted to prose format.
Authors need to meet to discuss the content of this chapter.
Images and videos along with supplemental materials to be added.
9. Sustainable Healthcare Delivery Campbell, A., & Reshef-Kalogirou, M., All sections google doc received Converting to Pressbook (WJM) July 29, 2022
Please add the practical aspects – for example how does one set up a green clinic?
Comment: Alyson and Maya to provide title for columns in Table 1.
Update and edit figures for the main body of the text.
Final edits to be completed.
Images and videos along with supplemental materials to be added
10. Climate Change and mental health Netten, A., & Fenech, A., July 29, 2022

Comments: Anticipating receiving learner outcomes and keywords by September 1.
Recently recruited author and expecting to receive sections by the end of the year

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PART 1: INTRODUCTORY CONCEPTS IN PLANETARY HEALTH

Chapters in This Section

In this first section, information will be presented that introduces the basic principles of Planetary Health and includes the following topics

- Chapter 1: Introduction to Planetary Health
- Chapter 2: Introduction to One Health
- Chapter 3: Introduction to Eco-Health
    - What is ECO-Health
    - Core Values of the ECO-Health Approach
    - Nature as therapy – what is the importance of biophilia to human health
    - What is the relationship to human health? (acute and chronic)
- Chapter 4: Introduction to Climate Change
    - Fundamentals of climate change
    - Direct and indirect impacts of climate change
    - Climate change mitigation and adaptation
    - Climate change and human health (acute and chronic impacts and physical, mental, and social implications)

What is Planetary Health?

In short, **Planetary Health** is described as the intersection between human civilization and the natural world. Planetary Health accepts that human health and the ability to achieve well-being in societies are fundamentally impacted by interactions between human civilization and the natural world. Moreover, Planetary Health recognizes that human activities in and upon the natural world dictate the status of human health both directly and indirectly.

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://pressbooks.library.upei.ca/planetaryhealth/?p=3#oembed-1

What is the purpose of this text?

We are in a state of crisis with regard to the health of our planet and its constituents. We face tremendous urgency to act in ways that can change the trajectory of the outcomes associated with our actions. The purpose of this text is to provide a body of background knowledge about Planetary Health for medical students over the four years of their undergraduate medical education experience.

The Planetary Health Program represents a new approach to training medical learners, healthcare providers, and the public about issues that influence Planetary Health

The text will help to establish the essential information upon which the curriculum in Planetary Health can be based. In so doing, the text will recognize the solutions-focused transdisciplinary elements of Planetary Health so that the student is introduced to the multiple elements of Planetary Health from a cross-cutting perspective. By establishing this background information, we intend to provide a curriculum that focuses on essential knowledge based on theory and evidence from real-world Planetary Health issues. The program is informed by many sources and organizations, including but not limited to the Planetary Health Alliance along with the Association of Faculties of Medicine Canada, the Canadian Association of Physicians for the Environment (CAPE), and the Canadian Federation of Medical Students (CFMS), all of whom have identified the need to incorporate greater awareness of Planetary Health into the medical school curriculum.

Individuals who complete the Planetary Health program will be better prepared to build strong collaborative networks with other health professionals and thereby make meaningful contributions to solving real-world challenges and promote policies that will lead to positive effects on Planetary Health and positive effects on human health. To this end, the Planetary Health program focuses on developing individuals with the competencies required to bridge gaps between health systems, health researchers, health practitioners, and decision/policymakers in a manner that breaks down silos and enables professionals to work toward common goals to reverse the negative effects of humans on Planetary Health and ultimately negative effects on themselves.

In December 2021, the Geneva Charter for Well-being was created at the 10th Global Conference on Health Promotion by some 5000 delegates representing 149 countries. The aim of this Charter was to bring attention to the multiple issues that challenge the planet and its constituents. The charter points

out the essential changes that we as citizens of the planet must make to ensure a sustainable world in which current and future societies can achieve a state of positive well-being. The charter is important to enforce the point that there cannot be healthy humans without a healthy planet.

Most notably, the Geneva Charter identified 5 specific actions that can help us to achieve well-being societies "for all members of current and future generations to thrive on a healthy planet, no matter where they live."

The Geneva Charter for Well-being

The five charter actions from the Geneva meeting for Well-Being (2021) are described in detail at: (The Geneva Charter for Well-being (who.int)) and should be shared. The five recommended actions are shown here:

1. To value, respect and nurture planet earth and its ecosystems
2. To design an equitable economy that serves human development within planetary and local ecological boundaries
3. To develop health public policy for the common good
4. To achieve universal health coverage
5. To address the impacts of digital transformation

Taken together, these five recommendations are fundamental to an implementation science plan that can move us from a know-to-do approach that can help direct our societies to achieve well-being from a Planetary Health perspective. That is, to fundamentally change the interactions between human civilization and the natural world so that no society is disadvantaged by the activities of others and so that no society is ignored.

1
Understanding Planetary Health -- Sharing Space in the Biosphere

Authors: Grynszpan, D., & Montelpare, W.

Learning Objectives

This chapter sets the stage for the textbook. At the end of this section the student should be able to:

- Define planetary health
- Describe the effects of human civilization on the current state of our ecosystems
- Define the biosphere
- Describe the elements within the biosphere
- Define the Anthropocene
- Describe the value of measuring change using a geological time clock
- Describe the relationship of planetary health to human health

Key Words

The important keywords for this chapter are:

- Planetary Health, biodiversity, the biosphere, the Anthropocene, ecosystems, human health

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Setting the Stage – defining the biosphere

To understand planetary health, we begin by considering the place in which planetary health is established – the biosphere.

Planet earth is protected from the external universe by five thin layers of gases and particulate matter, beginning at sea level and extending four hundred kilometers outward. The five layers, starting with the layer closest to the earth's surface are: the troposphere (from sea level to ~18 km), the stratosphere (~18 – 75 km), the mesosphere (~75 – 250 km), the thermosphere (~250 – 400 km) and the exosphere (> 400 km) (1). While each of these layers is essential to maintaining the balance of life on earth, the troposphere is the layer in which we live.

In 1543, Nicolaus Copernicus broke with the traditional beliefs of the Holy Roman Catholic Church to declare his radical belief that the sun rather than the earth was the center of the universe. Although we often act as if we as humans are the center of the universe, and all we do is condoned because we are that center point, we must realize that we are not alone here!

We exist in the troposphere as part of the community of ecosystems known as the biosphere. Here we define the biosphere as the entire earth in which living organisms exist (Gillard, 1969), while the term ecosystem is best explained by Blew (1996) as being organism centric and localized within a defined environment.

Folke (2011) referred to the biosphere as, "the global ecological system" which accounts for the implicit links between all living entities, consisting of flora and fauna, and the interaction and impact of these constituents on the environment.

Just as are we, the constituents of the biosphere are alive, and our actions have consequences on life within the biosphere for all of our neighbors and the elements upon which the biosphere exists and depends (i.e., the land, sea, and air). Taking responsibility for our actions is essential to our existence and the existence of the constituents with whom we share this space. Ignoring this existential call to action will lead to a devastating future in which extremes of negative consequences will be the norm.

An unhealthy ecosystem within the biosphere

Downloaded from: https://www.esdaw.eu/environmental-degradation.html Sept. 29, 2022

A healthy ecosystem within the biosphere

Image Source: WJ Montelpare, 2022

Defining our time – entering the Anthropocene

Steffan, Crutzen, and McNeill (2007) suggested that we are currently in the midst of a new geological time period which we refer to as the Anthropocene. That is, considering Earth's geological time record beginning with the Paleozoic era, and moving forward past the age of dinosaurs in the Mesozoic era and into the Cenozoic Era, the Anthropocene represents the most recent epoch (e.g., a period) within the Cenozoic era. According to Steffan and colleagues, the Anthropocene period began around the mid-1800s with the introduction of the industrial revolution and has continued to the present day. The period of the Anthropocene is derived from the term anthropo – as in human and cene which is used in describing a period within an era of geologic time. Hence these researchers refer to the Anthropocene

as the “age of mankind”.

The Anthropocene is marked as a period of tremendous flux during an age of development (Whitmee, et al., 2015). The Anthropocene accounts for the migration of humans away from agrarian economies and subsistence farming to widescale production of commodities but with little regard for the impact of such activities on the biosphere. The Anthropocene denotes the accelerated impact of the human quest for development across a broad spectrum of measurable outcomes, some of which led to positive advancements in the civilization of humans and especially in the enhancement of human health (Whitmee, et al., 2015).

During the Anthropocene, we accomplished advances in the production of mechanisms to make our work and everyday life tasks easier (Zalasiewicz, Williams, Haywood, and Ellis, 2011). We created new strategies to genetically modify foodstuff so that we could increase product yield and reduce crop failure. We improved travel on land, sea, in the air, and even into space beyond the biosphere. We built economies that are based on fuel sources which are not limited to fossil fuel resources but may include natural sources such as the sun, wind, water, and tidal flows. We also developed methods by which we can harness the power of the atom by producing electricity from nuclear resources via fusion and fission reactions (Horvath and Rachlew, 2016).

In the life sciences, we discovered ways to reduce the risks of disease through advances in medicine, and biomedical engineering, along with illness prevention and health promotion including various new and emerging treatments, strategies for harm reduction, and the use of widespread and regularly scheduled immunization strategies; and we improved the quality of life through rehabilitation and the replacement of body parts that are either worn out or non-functional (Hansson, 2021; Jiang et al., 2022).

These are but a few examples of the many human civilization accomplishments during the Anthropocene that have enhanced the quality of life for our current existence on earth. However, much of what we have done has been without consideration of the collateral damage to the other constituents and natural elements in the biosphere (Baumann, 2021). Increased concentrations of human populations, leading to increased urbanization and encroachment on natural habitats, tied with the direct effects of climate change, and both economic shocks and ecological disruption are among the direct causal mechanisms of negative impacts on the biosphere which are leading to negative health consequences.

Emblematic of the Anthropocene age has been the impact of increased population density on the biosphere. The rapid growth of human populations and the uncontrolled infringement of these populations on the natural environment has led to an unprecedented mixing and removal of habitats and the subsequent reduction in biodiversity.

Image from the UN Report: Nature's Dangerous Decline 'Unprecedented'; Species Extinction Rates 'Accelerating' — Image Source: https://www.un.org/sustainabledevelopment/blog/2019/05/nature-decline-unprecedented-report/

As habitats give way to human development and species become extinct at rates that range from 100 to 1000 times higher than that which occurred in the past 1 billion years (May, 2011) the normal flow of life in the biosphere is in peril. However, since many of us have not yet recognized the impacts of the loss of biodiversity, we do not view these events as part of the wicked problem that mankind has created during the age of the Anthropocene (Sukhdev, Whitmer, Schröter-Schlaack, Nesshöver, et al., 2010).

Image Source:https://foecanada.org/wp-content/uploads/2019/10/2019_strike-photo-feat_climate-change_foe-canada.jpg

Planetary Health

The term planetary health is based on the understanding of the interconnectedness of all living elements (Whitmee, Haines, Beyrer, Boltz, et al., 2015) and the acknowledgment that our sustained existence depends on a drastic human behavioral change across all aspects of life. At every level of society, humans must realize and act on the threats to our existence. The research evidence is clear. We are messing up the balance of life in the biosphere to a point from which we may never return.

We are negatively influencing Planetary Health.
Our influences on climate ultimately influences the health of all flora, fauna, and humans.

Image Source:https://www.king5.com/article/news/nation-world/biodiversity-crisis/507-1ee8ac98-8382-4293-9426-7ad6fb36ac76
Image Caption:
FILE – Volunteers help clean up a heavily polluted river in the Tembisa Township, north of Johannesburg, March 25, 2021. One out of five people in the world depends on wild species for food and income, according to a new UN-backed report. Climate change, pollution and overexploitation, however, have put a million species of plants and animals at risk of extinction. (AP Photo/Denis Farrell, File)

There is growing momentum to reverse our destabilizing influence on our environment. No longer can we ignore the loss of biodiversity on the constituents of the hierarchy that comprise the food chain, the continued disposal of particulate matter and toxic gases into the air that we breathe, or the wasteful exploitation of potable water resources, in addition to the detrimental effects on our oceans through the careless management of our rubbish. We have moved well beyond the ability to ignore our impact on the non-living physical environment as our current exploitive actions perpetuate the cataclysmic degradation of the essential infrastructure that maintains the balance needed to sustain life on earth.

The term planetary health is based on the understanding of the interconnectedness of all living elements (Whitmee, Haines, Beyrer, Boltz, et al, 2015) and the acknowledgment that our sustained existence depends on a drastic human behavioral change across all aspects of life.

For example, knowing the importance of sea ice as a naturally occurring solar radiation reflection mechanism should be enough to realize that without this “white shield” the earth has no mechanism to reflect solar radiation. As we transition from our frozen tunic to a fluid state, we increase solar heat absorption of oceans and large bodies of water (Trenberth, Chang, Jacobs, Zhang, and Fasullo, 2018). Losing the ability to cool our oceans not only leads to a reduction in the ability of the oceans to absorb

carbon dioxide from the atmosphere, but the increased environmental heat sequestration also changes the habitat on which billions of organisms depend.

Consider also the effects of increased environmental temperatures as a stimulus for increased frequency and intensity of hurricane-force storms in regions that have never experienced such tropical weather-related events. As Trenberth and co-workers explained, the ocean heat content (OHC) increase is a direct outcome of increased radiant heat resulting from greenhouse effects, leading to an overall increase in sea surface temperatures (SSTs). This increase is associated with a change in the normal pattern of more frequent smaller storms in tropical ocean environments to less frequent but more severe storms of greater size and more severe intensity, which can then travel into areas that maintain higher sea surface temperatures.

In more recent days (September 2022), we witnessed the effects of Fiona, a sub-tropical storm that traveled north from the Caribbean Ocean to devastate parts of Atlantic Canada with the force of a Category 2 hurricane *(a Category 2 Hurricane has wind speeds of 154-177 km/hr (96-110 mph), NASA, 2014*). In the images below we observe the wrath of Fiona on the landscape at Brackley Beach, Prince Edward Island, Canada. While this may seem like an incidental change to the beachscape, the sub-tropical storm Fiona completely destroyed the dunes which were the nesting place for piping plovers, thereby negatively hampering recovery efforts for this endangered bird (Thomas and Laheunesse, 2004). Knowing that climate change can lead to species extinction (Thomas, Cameron, Green, *et al.*, 2004), we must ponder the question, will the wrath of sub-tropical storm Fiona be a sufficient causal mechanism in the subsequent extinction of the endangered piping plover?

The images below show the destruction by Sub-Tropical Storm Fiona (September 2022) to the beachscape of Brackley Beach, Prince Edward Island, Canada (source: Twitter feed for Mary Lynn Futers @gathertonourish, downloaded October 1, 2022).

Images of Brackley Beach prior to Sub-Tropical Storm Fiona (September 2022).

Images of Brackley Beach following Sub-Tropical Storm Fiona (September 2022).

Earth exists as a biosphere in which homo sapiens (aka the wise human) are an integral part. Our existence as a species requires us to maintain the dynamic integration between the living and non-living components of the system, which together acts as a functional unit. Humans need to demonstrate their wisdom and maintain the health of this ecosystem – to be the stewards of our planet and maintain the positive state of all parts of the biosphere.

We cannot overstate the importance that a healthy biosphere is fundamental to human health and hence the sustainability of civilization. As Whitmee and colleagues reported, ecosystems within the biosphere provide multiple services, such as the availability of food and water, structural materials such as wood and fiber, as well as medicines and fuels. Ecosystems regulate life on the planet; they regulate climate, erosion, disease, and the replenishment of flora through processes such as pollination. Healthy

ecosystems provide an aesthetic in which culture, recreation, and spirituality flourish.

Degrading or severely altering the biosphere within earth's ecosystems not only impacts the individual constituent parts that comprise the ecosystems but will also lead to a direct negative impact on the health of humans. Degrade the ecosystem that enables global food production and observe increases in malnutrition and diseases associated with food insecurity. Degrade the ecosystem that ensures appropriate access to potable water and observe the increase in drought-related crop failures, dehydration, and pestilence associated with the lack of quality drinking water. Degrade the environment to the extent that severely reduces pollinators and observe the starvation of millions of inhabitants across the biosphere.

Here we show a video of the drought in Spain reported by Reuters Press Aug 10, 2022

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://pressbooks.library.upei.ca/planetaryhealth/?p=5#h5p-7

The UN Secretary-General António Guterres said the [IPCC, 2021] Working Group's report was nothing less than "a code red for humanity. The alarm bells are deafening, and the evidence is irrefutable". (IPCC report: 'Code red' for human-driven global heating, warns UN chief | | 1UN News).

Our planet is in a code red situation regarding planetary health. As a first step to mitigating the condition, we need to first increase awareness and understanding of planetary health. Next, we need to provide achievable actions so that every level of society can pursue meaningful and sustainable behavior change. This means moving away from dependency on fossil fuels and moving toward renewable energy sources. This also means increasing carbon capture and storage through innovative mechanisms, a warning that has been stated many times but largely ignored.

The months of July through October 2022, were filled with a series of cataclysmic climate-related global events. Examples include but are not limited to the wrath of hurricanes Fiona in Atlantic Canada, and Ian in Florida and the Carolinas, along with extreme flooding throughout Pakistan in which at least one-third of the country was directly affected by flood waters, and in contrast, the severe droughts in China and in Spain that have impacted essential food production.

Here we show a video of the drought in China reported by the BBC News Aug 23, 2022— China faces severe drought amid a record-breaking heatwave –

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://pressbooks.library.upei.ca/planetaryhealth/?p=5#h5p-6

From a positive perspective, one might think that changing the behaviors of society by taking full advantage of a***transformative utopian impulse for planetary health*** – that point at which society is inclined to take action that will transform society positively (Basso and Krpan, 2022) – is now more likely than ever before.

As a society, we need to reduce consumption, reduce waste, and reduce unnecessary development of the environment, especially when such development is based on inappropriate policies and poor planning. Societies need to seek better ways to mitigate coastal erosion through the development of wetlands and salt marshes and continue to invest in the production of alternative energy sources such as wind, solar, and geothermal energy production.

Changing the behaviors of society by taking full advantage of a transformative utopian impulse for planetary health – that point at which individuals in a society are inclined to take action that will transform their society positively (Basso and Krpan, 2022) – is now more likely than ever before. Recent reports by the International Panel on Climate Change suggest that human activity got us into this mess and so human activity can get us out. Our challenge is to spread the word, translate the knowledge, and continue developing strategies that eliminate the degradation of the biosphere.

Planetary Health influences on Human Health

The consequence of human activity throughout the Anthropocene on planetary health has led to problems that are intractable and without comprehensive solutions. Horst Rittel first described such problems of extreme complexity as wicked problems (Churchman, 1967). That is, problems with no stopping rules and which can only be tamed or for which elements of the problem can be resolved but which there is no complete solution (Rittel and Weber, 1973).

As humanity continues to strive for economic growth and the pursuit of prosperity in all aspects of life, we continue to create situations with complex outcomes that impact the entire biosphere and ultimately give rise to wicked problems for planetary health. Cimate change by itself is a wicked problem. Climate change, defined by the Australian Academy of Science (2022) refers to changes in patterns of weather that are related to changes in ocean activity, land surfaces, and ice sheets, which occurs over decades. This builds on the definition of Werndl (2016), which added that climate change requires “a finite distribution” of events related to climates over time that result as a consequence of “varying external conditions”.

Lazarus (2009) called climate change a super wicked problem because the relationship between human health and the effects of climate change on planetary health is extremely complex and it is disproportionately different across the planet. The complex problems associated with climate change are dependent on the multiplicity of factors that are a function of the physical and social determinants of health (Patz, Frumkin, Holloway, Vimont, and Haines (2014). As Dr. Margaret Chan, the former Director-General of the World Health Organization stated in 2008, "The warming of the planet will be gradual, but the effects of extreme weather events – more storms, floods, droughts, and heatwaves – will be abrupt and acutely felt. Such events will affect some of the most fundamental determinants of health: air, water, food, shelter, and freedom from disease." Further, as Al-Lamki (2008) suggested, the learned among us are expected to provide the important message to the general public that the negative consequences of climate change will have a direct effect on the health of all civilizations, as borne out by the data.

Despite the gradual pace of planetary health, the people most at risk will be those that are most disadvantaged. Marginalized and poor populations — the intentionally ignored, will suffer more devastating effects of negative planetary health, more often, and at a greater cost to their health than those who are well situated in developed environments, and who can afford to act sooner to recognize and mitigate potential effects. Food and water insecurity leading to higher costs and more frequent shortages of essential commodities will be among the early bellwether events followed by loss of income and opportunities to maintain livelihood through work or government support. The consequences of climate change on place – as in loss of land through coastal erosion, wildfires, floods, and landslides will lead to population displacement and in some instances forced migration.

Understanding the importance of the geographic area is essential to understanding the impact of negative planetary health and the ensuing environmental conditions that will have a direct effect on human health. The degradation of planetary health may appear to be a relatively slow process because the effects are measured on a geological clock, especially when one considers the age of the earth. A common euphemism for slow progress is to move at a glacial pace, as the creeping movements of glaciers was thought to be so slow. However, the speed of changing environments, which includes melting of the continental glaciers leading to increased sea level volumes, loss of biodiversity, increased concentrations of atmospheric carbon dioxide, and the permafrost melting which is leading to an overall increased load of methane gas, are each happening at a pace that has not been observed previously in the time record of the planet.

Recognizing the direct effects of human activity within local and regional locations is an important first step in identifying causal mechanisms for the rapidity of climate change — mechanisms that we can change. For example, Kovats and Akhtar (2008) describe the role of urban centers as heat repositories because of the built environment. At a local level, cities become "urban heat islands" resulting from daytime storage of heat caused by increased human activities with a concomitant loss of the necessary vegetation to mitigate the heat sequestering effect. As stated by Kovats and Akhtar, while urbanization can lead to urban heat islands that cause temperatures in both daytime and nighttime to increase,

urbanization can also contribute to the intensity of rainfall, the formation of hail, and the severity of thunderstorms. The size of urban area and design of the built environment can have a measurable effect on local weather, and depending on proximity to coastal water and rivers, can contribute to the likelihood of flooding (Kovats and Akhtar, 2008). Yet, in addition to the heat load from urban areas, cities are a major source of greenhouse gas emissions and thereby contribute to environmental impacts at a global level.

Illnesses caused by undernutrition because of reductions in both the quality and security of food will increase in prevalence as well as the increase in both morbidity and mortality associated with vector-borne diseases like Zika, Lyme disease, West Nile Virus, and malaria. While these diseases were previously localized to specific geographic regions of the world, many are not only emerging in areas that were unscathed previously, but more importantly, the spread of such illnesses is occurring at a more rapid rate. For example, while Lyme Disease was once thought to be localized to the Northeast region of the United States, originating from the town of Lyme, Connecticut, it is reported to be the most common type of vector-borne disease in North America (Ginsberg et al., 2021). Lyme disease is caused by the spirochete bacteria from the Genus: Borrelia. The bacteria are carried by the black-legged tick (Ixodes scapularis) and are passed on to humans when the individual is bitten by the tick. As Ginsberg and colleagues suggested, the spread of the disease may be dependent on the tick-host relationship and can involve more than one host. Having more than one host to spread the disease increases not only the risk of infection to humans but the spread of the disease into areas that are frequented by any of the various hosts.

Here we see one of the MANY individuals that doubted that climate change is real. This is unfortunate when scientific evidence is trumped by populus politics.

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https://pressbooks.library.upei.ca/planetaryhealth/?p=5#h5p-2

The negative consequences of poor planetary health on human health are not events that might happen in the distant future. The negative consequences of poor planetary health are happening now, and we can both observe and measure the outcomes on human health. For example, research by Ahmad, Scholz, Al-Faraj, and Niaz (2016) support that among the human health consequences attributed to the negative consequences on planetary health are the effects of extreme weather events leading to loss of freshwater resources which in turn will have a direct effect on food supplies and subsequently human health.

Similarly, Guirguis and coworkers (2013) reported that heatwaves, resulting from extreme weather events are linked directly to increased prevalence of heat-related illness. Seasonal mortality rate increases can be attributed to the increasing frequency, duration, and severity of heat wave conditions

in both urban and rural areas. Similarly, as heat waves increase air quality is decreased and this relationship affects those with respiratory illness more severely since many will have difficulty finding necessary relief from heat-related air quality degradation. Portier et al (2010) referred to air quality because of the complex characteristics of atmospheric chemistry, which we know can increase risks for asthma and asthma like symptoms, respiratory-related morbidity, and cardiovascular disease. Air quality is determined by the interactions of heat and humidity with the various concentrations of atmospheric elements such as smog (fog and smoke comprised of gases that include but are not limited to carbon monoxide, carbon dioxide, and sulfur dioxide), which is especially prevalent in urban areas, along with molds, fungi, air borne bacteria and viruses, as well as particulate matter as that which occurs with greater abundance in areas with wildfires. Similarly, Kinney (2018) indicated that agricultural emissions like methane and ammonia are added to the toxic soup we are breathing.

Recognizing Planetary Health Through Zoonosis, Pandemics, and the Emergence of Infectious Diseases

As noted by Rizzardini, Saporito, and Visconti (2018), infectious diseases cause approximately 19% of all deaths worldwide per year. While many would think that vaccination regimens will make infectious diseases obsolete, there is growing concern that we cannot rest in our efforts to recognize and manage the continued rise of infectious diseases, especially related to planetary health. The WHO has addressed this potential lack of recognition for emerging infectious diseases by including the term Disease X in its blueprint of prioritized diseases (WHO R&D Blueprint Team, 2022).

An easy start to spread the word and the conversation on planetary health and infectious disease is by addressing the issues of the COVID-19 pandemic (SARS-CoV-2), and the ways in which humans have disrupted the natural systems of life on earth. The transmission of emerging infectious diseases (EIDs), many of which arise through zoonosis –the transmission of pathogens from animal to human (Jones et al 2008, Han et al, 2015) is well studied as a plausible vector of transmission for human contagion. According to Han, Schimdt, Bowden, and Drake (2015), more than 1 billion illnesses are attributed to zoonotic infections worldwide, each year. The emergence of the COVID-19 global pandemic is one such zoonotic infection that was not without forewarning (Jones et al, 2008). Research by Jones and coworkers included a review of some 335 EIDs identified between 1940 and 2004. The researchers found that the presence of EIDs was not a function of random occurrence but could be linked directly to increases in population density and population growth.

Moreover, Jones and coworkers reported that EIDs were linked not only to zoonosis in a general sense, as may be anticipated with domesticated animals, but directly to unconventional pathogens arising from wildlife. In their comprehensive review, the authors reported that while more than 60% of EIDs were associated with zoonosis, more than 71% of EIDs were associated with pathogens from wildlife, specifically listing Nipah virus (NiV), and SARS-CoV-1, as examples.

The work of Jones et al in 2008 was extremely important to public health awareness of global pandemic risk as it was the first analytical support for the suggestion that the “threat of EIDs to global health was

increasing!" Likewise, noting that more than half of the zoonotic pathogens could be linked to wildlife, the authors explicitly stated that identifying the relationship between factors that increase contact between wildlife and humans is essential to developing not only predictive approaches to identify disease emergence, but to establishing strategies to prevent localized outbreaks and widespread contagion.

Later research by O'Callaghan-Gordo and Antó (2020) supported the presence of a transmission route for wildlife to human zoonosis by noting that the cause of the COVID-19 pandemic was attributed directly to open-air markets in Wuhan China where some 120 animals of 75 different species were sold. This plausible pathway for disease transmission was also affirmed in a separate investigation by the WHO which reported its findings in February 2021. According to O'Callaghan-Gordo and Antó some of the animals sold at the Wuhan open-air market were alive and included puppies of wolves, salamanders, crocodiles, scorpions, rats, squirrels, foxes, civets, and turtles; all of which could be considered active vectors for transmission of emerging infectious diseases. However, the most important overlooked issue related to the transmission of pathogens from wildlife to humans is that not only were the market traders among the earliest cases in Wuhan to be treated or to die as a result of contracting COVID-19 but that the risk of producing a virus-like COVID-19 (aka SARS-CoV-2) was predictable given the environment and what we had learned previously from the events which led to SARS-CoV-1 in Guangdong Province, China, more than 17 years earlier.

In the earlier development of SARS-CoV-1, it was believed that live bats were exposed to Civets (a cat-like mammal) which created an optimal pathway for disease progression between animal species. As O'Callaghan-Gordo and Antó suggested, despite having previous knowledge of routes for disease transmission scientists alerted officials that the current environment of live meat markets (not only in Wuhan but throughout China) was primed for another outbreak of widespread zoonotic infection as a function of exposures, the authorities chose not to act (O'Callaghan-Gordo and Antó, 2020).

Summary

Without question, the negative consequences of planetary health represent a real and present danger as an existential threat to humanity (Ramadan and Ataallah, 2021). Moreover, the relationship between the negative consequences of planetary health and human health is demonstrated continuously by both direct and indirect effects on rates of morbidity and mortality. The pace at which the degradation of our planetary health is occurring is not monotonic but is accelerating at a rate unprecedented in the chronological record of the planet. Now is the time to recognize and act on the direct and indirect effects of planetary health so that we can thwart the specific negative health outcomes that include chronic diseases (e.g., cardiovascular and respiratory), injuries, and fatalities from severe weather events (e.g., floods, landslides, heat waves, ice storms), emerging infections and vector-borne diseases (e.g., malaria, Zika, Covid-19, West Nile Virus), mental health outcomes (e.g., stress, and financial hardship resulting from disasters to the natural environment), food insecurity and loss of freshwater resources, to name but a few of the observable and measurable outcomes. The negative consequences of planetary health and climate change are not only affecting the existence of humans, but planetary

health and climate change, are also having a negative effect on all our neighbors in the biosphere.

It's time to take action — it's time to make your voice heard! You may not be a celebrity but you are going to be impacted by planetary health!

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REFERENCES are included in Section 5: Bibliographies

Sample of adding H5P content — here I incorporated a true/false question which is a feature of the H5P interactivity module.

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We can continue to add all sorts of elements to each chapter to create a dynamic learning environment.

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*all referencing in this text will follow the Vancouver Style: Format (Print) 1. Author Last Name Author First Initial Author Middle Initial. Article Title. Journal Title. Published Date;Volume(Issue):Pages. (Digital) 1. Author Last Name Author First Initial Author Middle Initial. Article Title. Journal Title [Internet]. Date Published [cited Date Accessed]; Volume(Issue):Pages. Available from: URL

Introduction to One Health

Authors: Ojha, S., and Kao, K.

What's in this chapter?

- What is One Health?
    - Animal, Humans, and The Environment
- What is the relationship to human health? (acute and chronic)
    - Animal models in Human Disease and Medical research

Learner Outcomes

After reading this chapter students should be able to:

- Understand the concept of One Health
- Know the factors that affect One Health
- Recognize environment as a common ground for existence of all life forms
- Appreciate the common health challenges shared between humans and animals
- Identify the roles of human and veterinary medicine in application of One health in controlling infectious diseases
- Understand the domino effect in planetary health
- Develop a thought process of One health action plan

Key Words

Important key words for this chapter include:

- One health, urbanization, anthropogenic factors, environment, domino effect, biosphere, Sentinel, antimicrobial resistance, zoonotic disease

What is One Health?

The One Health Commission has defined One Health as 'an integrated, unifying approach that aims to sustainably balance and optimize the health of people, animals and the environment (ecosystems). In other words, 'One Health' is the 'Health of Many', which utilizes a pluralistic approach for the well-being of its constituents.

What are the constituents of One Health? The humans, animals (domestic, wild, terrestrial, aquatic), plants, and the larger biosphere which sustains life are closely linked and inter-dependent, constitute One Health. Broadly speaking, One Health is geared into the triad of human health, animal health, and the environment health, which are the pillars of One Health (Figure 1).

Since there are many peripheral factors that influence One Health, there is no single, internationally agreed upon definition of it. The most commonly used definition accepted by the US Centers for Disease Control and Prevention and the One Health Commission is: 'One Health is defined as a collaborative, multisectoral, and transdisciplinary approach—working at the local, regional, national, and global levels—with the goal of achieving optimal health outcomes recognizing the interconnection between people, animals, plants, and their shared environment'. It forms the basis of the tripartite alliance of World Health Organization (WHO), the Food and Agriculture Organization of the United Nations, and the International Organization for Animal Health (FAO et al. 2008).

In order to increase global awareness of the One Health concept, particularly among students, November 3rd is marked as the 'One Health Day'. It was initiated in 2016 by the One Health Commission (www.onehealthcommission.org), the One Health Platform Foundation (www.onehealthplatform.com), and the One Health Initiative (http://www.onehealthinitiative.com) to raise awareness through educational events organized around the world.

One Health concept is inherently flexible providing liberty to work across perspectives, species, disciplines, thus appropriating to the Planetary Health. The term 'One Health' was in fact conceived by the Wildlife Conservative Society in 2004 when the 'Manhattan principles' were laid out to endorse an integrated holistic approach to tackle diseases at the human-animal-environment interface (Cook et al. 2004). The 'One Health' approach was first used in 2003–2004 to address the emergence of severe acute respiratory disease (SARS) in early 2003 and subsequently in the spread of highly pathogenic avian influenza H5N1 (FAO et al. 2008). The resilience of the concept is vital to its action to diffuse into several inter-related sub-disciplines of science, sociology, economics in adopting a collaborative action plan for the efficient use of resources and productive outcomes (See Box 1).

The Planetary health was seeded in us through elementary science chapters of ecosystems, food web and predator-prey relationships. However, when zooming out of the elementary level, One Health may appear very complex. Through this chapter, we will try to understand the health from a biological perspective.

Figure 1. One health is 'Health of Many'. It is composed of health of the humans, animals and the environment. Health is influenced by several peripheral factors.

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Humans, Animals, and The Environment

Health co-exist in the same space, at the same time

Environment is the most dynamic one, and therefore is the most impactful constituent of the One Health triad. Fundamentally, the environment affects how organisms live, thrive and interact, and thus must be duly considered to achieve optimal health for people and animals (Maller, 2008; Christensen, 2012). The environment can be defined as the amalgamation of 'the physical, chemical and biological factors' that determine the growth and survival of all life forms." (Christensen, 2012). This definition incorporates many different contexts ranging from a local environment, to social environments and the climate in which we exist. As such, the environment can be defined by both the man-made environment, such as urban systems, and the unmodified, natural ecosystems. An ecosystem is composed of all the species, their physical and chemical environment within a specific geographic area (Chu, 1994; Christensen, 2012). The diverse animal and plant species are the 'eco-stabilizers' of the planet, which directly and indirectly influence the human health.

Animals are inherent entity of our planet. Diverse species of vertebrates and invertebrates promote healthy and sustainable ecosystems. Animals are enrolled in food, income in remote communities, mental health, agriculture, soil fertility, defense services, and scientific research. Animals tend to maintain the homeostasis of ecosystem through intricate web of a 'prey-predator' relationship. An example of service of bats to health and economy is by consuming insect pests, which not only saves pesticides cost, but also the health of humans and environment in curbing the use of chemicals (Benjamin, 2021).

Biologically, humans are one of the species among the mammoth catalog of various species on the planet Earth. However, humans created Anthropocene beginning in the 20th century, which is the

geological age of the people, by the people and for the people with utmost influence on the whole biosphere (Stephen, 2020). An increase in human population, consumption, faster global movements of biota and abiota, carbon pollution, extinction of animal species and more, created new landscapes to generate new, unforeseen health risks of the planet.

The health systems have conventionally focused on the disease surveillance in humans, rather than the source of pathogens. Yet, the majority of human pathogens have originated from animals ("zoonotic" diseases) (Taylor et al. 2001), with 70% of emerging infectious diseases coming from wildlife (Jones et al. 2008). Thus, humans and animals share infectious organisms. The industrial revolution of 20th century soon observed anthropogenic effects in the emergence of several microbial infections, of which Ebola, influenza and Severe Acute Respiratory Syndrome (SARS) viral epidemics in the Urban dwellings have been the wake up calls. Several of such outbreaks have been linked to human practices that lead to the biodiversity loss. Analyses of recently emerging infectious diseases show that anthropogenic factors including, land use change (e.g. deforestation, mining, oil extraction, etc.), food production changes, intensive livestock production, and global trade and travel are among the leading causes of disease emergence (Karesh et al. 2012). Besides, massive prophylactic antimicrobial use in livestock industry for growth promotion, in plant agriculture, as well as inadequate prescribing in companion animal medicine (Kakkar et al., 2017; Laura Kahn, 2017) have driven another set of epidemic in the 21st century, 'an epidemic of antimicrobial resistant (AMR) organisms' (O'Neill, 2016; Kakkar et al., 2017).

These practices have caused fundamental changes in the environment, such as (1) change in the basal temperature of the planet Earth, (2) the loss and disruptions of wildlife habitats, and (3) the chemical contamination at the micro-environment level with the spills of antibiotics and industrial sewage. The burden of antibiotic resistance has been ignored and not understood in the environment. Environmental bacteria are the most abundant bacteria, which serve as reservoirs of resistance genes that can become incorporated into human and animal pathogens over time (Kozak et al. 2009; Larsen et al. 2015; Essack, 2018). Such disturbances facilitated emergence and re-emergence of diseases and antimicrobial resistance among pathogens.

Environment is a vacillating factor that has gained greatest attention in terms of climate change. The breach in the environmental integrity has affected ecosystems of pathogens, lifecycle changes in vectors and reservoirs (Essack, 2018 Lancet). Globally, more than 1 billion infections and 1 million deaths annually are attributable to zoonoses, and vector-borne diseases that result in health and socioeconomic burdens (Karesh 2012). Strong evidence suggests that in many vector-borne disease systems, presence of more diverse species helps to reduce the risk of infection (Keesing et al. 2010; LoGiudice et al. 2003). This is due to 'the dilution effect', which works through incompetent reservoir hosts that act as barriers by "diluting" the possibility of disease transmission among vectors and competent hosts (Schmidt et al. 2001; Johnson et al. 2008; Keesing et al. 2006; Begon, 2008). In the classic example of Lyme disease, *Borrelia* pathogen would circulate among a greater proportion of poor reservoirs species of forest mammals with higher levels of biodiversity, thus curbing the infection risk to humans and dogs (Barrett and Osofsky, 2013). Such pattern has also been seen in other vector-borne

disease transmissions, e.g., West Nile Virus (WNV), leishmaniasis, and Rocky Mountain spotted fever (Chivian, 2004). The changes in climate and ecosystem has permitted species to expand their range and/or become established in new areas when introduced, as observed with the introduction and establishment of WNV in the United States in 1999, followed by its presence in all of the continental states (Hadler et al. 2015). Similarly, while most cases of Chagas disease documented in USA have been thought to be imported; however, recent detection of *Trypanosoma cruzi* infections in Texas suggests that endemic transmission within Southern states may be underdiagnosed (Garcia et al. 2015). Similarly, the first detection of rodent-borne Hantavirus pulmonary syndrome in 1993 in United States sustained. The disease re-surfaced in large number of human cases in 2017, of which, 36% were fatal (CDC). Cases of hantavirus pulmonary syndrome have also occurred in Canada, mostly in the western provinces, and in South Americas with large outbreaks typically being linked to changes in environmental factors (Drebot et al., 2015; CDC). Tick-borne diseases are an increasing public health threat in the North America, with a quadrupling incidence of tick-borne ehrlichiosis since 2000 and a steady expansion in the rates of Lyme disease (Heitman et al. 2016; Kugeler et al. 2015).

Despite both endemic and emerging disease risks, actions to mitigate the same remain limited. While animals are the sentinels for environmental contamination, sentinel surveillance is generally underused, and when it does occur, it is poorly utilized due to inter-agency incoordination (Rabinowitz and Conti 2010). In a potential infection of *Borrelia* in a pet dog, a critical role of veterinary clinician comes into play, since this one case becomes the 'Sentinel case' to blow the whistle of an increased wildlife activity in a particular geographic region. The 'caution' of potential risk of arising human cases of Lyme disease needs to be communicated promptly across the human medicine interface (Rabinowitz and Conti 2010). At the same time, public health agency should be able to accept the information to attune the clinicians.

Disturbance in ecosystem

To understand the consequences of disturbing interfaces of One Health, here we take an example of the SARS-CoV-2 (COVID-19, begins in December 2019) pandemic. The disturbance of one entity can conduit a ripple effect or a domino effect of disturbances to another (Figure 2). The WHO report suggests that an intermediate animal, possibly the one sold at markets in Wuhan, China passed SARS-CoV-2 to humans after becoming infected with a predecessor coronavirus in bats (Maxmen, 2021). Extensive industrialization and urbanization led to deforestation, thus disturbing the bats dwellings in the wild. The bat population, which is the reservoir of many zoonotic pathogens encroach urban areas, come in contact with animals and infect them; thus passively infecting humans through live and/or dead animal markets leading to an epidemic. The epidemic briskly molts into a pandemic, not giving enough time to even assimilate the chronology of events! Once the outbreak is in full swing, it leads to anthropozoonosis in companion animals (Klaus, 2021) and more so importantly in mink that leads to mass culling of the furry animals, eventually shutting down the mink farming industry in Europe and North America causing severe economic losses (Fenollar, 2021).

What kind of health are we talking about? These events lead to the loss of physical health, socio-

economic health, emotional health…the list is on. That's how One Health is so dynamic, it is affected at the both macro and micro level.

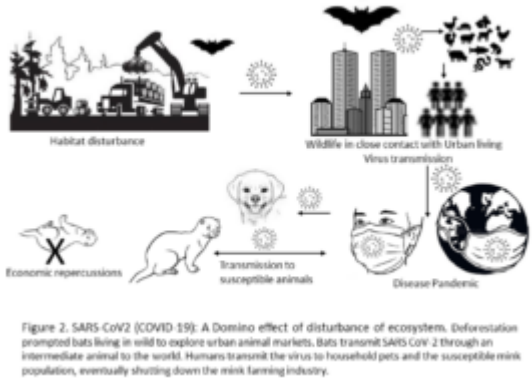

Figure 2. SARS-CoV2 (COVID-19): A Domino effect of disturbance of ecosystem. Deforestation prompted bats living in wild to explore urban animal markets. Bats transmit SARS CoV-2 through an intermediate animal to the world. Humans transmit the virus to household pets and the susceptible mink population, eventually shutting down the mink farming industry.

What is the relationship to human health? (acute and chronic)

In general, a veterinary clinician is fairly attuned to the intertwined health of the three pillars of One Health. A veterinarian could identify a zoonotic risk and will counsel the client on the risk of contacting *Salmonella* from a reptile pet. A human physician will treat *Salmonella* infection as an acute risk to the human health, but could miss the source. There are several ubiquitous zoonotic pathogens that survive for prolong period in the environment to cause acute and chronic diseases in humans. To name a few here are, *Mycobacterium tuberculosis*, non-tubercle *Mycobacterium* species, *Coxiella burnetii*, *Bacillus anthracis* and *Brucella* species that are carried and amplified in animals, and contaminate the environment. Many of these are occupational hazards for people in livestock agriculture, such as veterinarians and the farmers. Some of these, such as *Mycobacterium* spp, *Coxiella burnetii* and *Brucella* spp. are excreted in milk, which discourages consumption of raw milk and highlights food safety. However, this very clause of food safety might not align with many nutritionists and people who benefit from raw milk (Lucey, 2015). Thus, One Health is dynamic across perspectives.

To understand the 'acute and chronic' relationship of One Health to human health, a robust example of the largest ever Q fever outbreak in the Netherlands over three years period (2007 to 2009) is described (Figure 3, Table 2). In the period from March to June 2007, six patients were hospitalized with atypical pneumonia, high fever, headache and dizziness in the province of Noord-Brabant (NB). In May, 2007, family physicians in a rural village of Herpen in the NB province alerted the regional public health service due to an unusually high number of atypical pneumonia in adult patients. These cases were initialy attributed to *Mycoplama pneumoniae*, but additional serological tests rapidly identified an outbreak of acute Q fever. This notifiable disease was until then very rare in the Netherlands. Despite the implementation of measures aiming at identifying and controlling the source of infection, the number of acute Q fever cases increased enormously to overwhelm the Dutch healthcare. The seasonality of cases followed that of small ruminant (goats and sheep) birth period, however the Human- Veterinary interface remained unseen (Roest et al. 2011). Q fever (or query fever) is caused by a gram negative intracellular bacterium, *Coxiella burnetii*. The organism is carried asymptomatically by

ruminant animals, especially goats and sheep. It is excreted in large numbers in the birthing tissues of placenta and fluids during parturition and abortions to contaminate soil and the environment. *C. burnetii* is considered an infection risk to the agriculture personnel and potential risk in urban settings as well, since its sporulated form can survive for more than an year in the environment and can be carried for miles with wind (Roest et al. 2011).

Back to the small village of Herpen where a large and protracted human Q fever epidemic started. In 2007, a total of 168 cases were notified, followed by 1,000 notified cases in 2008, mainly in residents of the province of Noord-Brabant. In 2009, a total of 2,354 cases were notified as the epidemic further expanded in neighboring provinces. The clue to the source of infection was nowhere since the communication between the two health sectors could not be interfaced. However, based on the history of visiting goat farms and the proximity of nearby dairy goat farms to the residential addresses of cases indicated the source of infection. During the period, abortion waves due to *C. burnetii* were confirmed on several dairy goat farms and few dairy sheep farms. The Dutch Q fever epidemic emerged as an important nationwide human and veterinary public health challenge and gained worldwide attention due to its size, disease burden and high societal costs.

The most important lesson learnt from the Dutch Q fever epidemic is that a close cooperation between the human and veterinary fields is essential for responding to outbreaks of zoonotic diseases. The involvement of two different ministries in this Q fever epidemic demonstrated key organizational differences in response structures, with a highly centralized veterinary domain and a strongly decentralized operational public health response. The prerequisite of a 'One Health' approach was one of the conclusions made by the official Q fever outbreak evaluation committee in 2010 that evaluated the process and actions of the Dutch government with respect to the Q fever crisis (Roest et al. 2011).

The chronic consequences were examined over the next 14 months post the Q fever outbreak. During the epidemic, over 4,000 cases of acute Q fever were reported, while 215 chronic cases were catalogued (Kampascher, 2014). Vascular focus and endocarditis were the chronic sequalae in 75% of acute Q fever infections. Mortality rate of 9.3% was reported among endocarditis patients and 18.0% in vascular chronic Q fever cases.

In context of Q fever in Atlantic Canada, a characteristic community acquired *C. burnetii* infection in humans from companion animals is notable. Q fever is endemic in the Atlantic provinces where dogs and cats are the reservoirs of the pathogen, which is shed at the time of parturition. Cases of acute and chronic Q fever in humans with history of contact with parturient cats have been emphasized during 1980's, and later in a study on the seroprevalence of *C. burnetii* antibodies in patients during a period of 2004 to 2007 (Marrie et al. 2008).

Figure 3. Q fever:- Human:Animal:Environment - Interface

Cross-talks to Co-exist

It is needed to emphasize here that the stage of Cross-talks and relationships among the constituents of One Health was set during the primordial times when the planet Earth began upholding life. Humans tamed animals to develop civilizations with them, explored and inhabited deserted parts of the Earth. The socio-cultural habits influenced the gearing of the triad. For example, in some culture practices, several animals and plants are considered as sacred. This very notion pulls away the dominion of human over Earth's resources, thus aid in saving medicinal plants and directs the attitude towards health and wellness of all (Barrett and Osofsky, 2013; Stephen, 2020). When we began to equate water to H2O, the very significance and naturalism of water element deteriorated leading to anthropocentric water managements, the consequences of which are the adverse effects on the ecosystems which the naturalists and philosophers argue (Blackstock, 2001). The gaps in the triad began in the past two centuries due to anthropogenic pressures, thereby ignoring the big picture, 'the Circle of Life'. Humans are in fact realizing it in the 21st century as the disturbances of the ecosystem are reciprocating upfront to face the 'shared risk'. The common denominator here is the Earth's biosphere, which is adversely affected due to over-exploitation of resources. Thus, in the last two decades, the way forward paved is the coming together of people of diverse disciplines and programs to embrace the fact that the 'health is the interactions and inter-dependence among animals, humans and the environments' (Box 2). The programs and policies at the international level and Government levels are bringing in new collaborations and thought process to refrain from limiting health to a 'mathematical data point'; instead, understand health as a 'positive socio-ecological' phenomenon.

Implementation of One Health is inadequate on the ground. It faces ongoing barriers of professional segregation and data sharing in the animal and human health communities, which downsize relevant evidences to blank a clear understanding of the significance of animal and environmental health indicators to human health, which in-turn leads to limited acceptance of sentinel surveillance approaches. The constant efforts toward systematic and sustained holistic action is the key to achieve the goal of One Health and Earth stewardship. You may be at various places at a given time and space, such as, in your residential neighborhood with pets, at the beach, hiking along the marshy areas, visiting a hospital or an animal farm; being the health care providers, from now onwards, think of 'One

Health’ around you.

Table 2. Dynamics of One Health: Q-fever epidemic	
Lesson: Close cooperation between the human and veterinary fields: Clinicians and the Government Ministries	
Human • Within 5 km radius of farm • Contact with goat, sheep • Susceptible population	Dairy goats • Density, 38. 1 goats/km2 • Hot, dry weather • No biosecurity • Circulation of highly virulent strains
One Health: In Action: Harm reduction, Health promotion	
Human Response: Follow-up chronic Q fever Sero-surveillance	Animal, Environment Response: 1. Culling of pregnant goats 2. Vaccination of herds 3. Bulk tank milk PCR monitoring 4. Notifications 5. Stringent protocols for soil and environment decontamination • vermin control • manure handling • rendering of aborted fetuses and placentas • aborted tissues submission for pathology • preventing dust, aerosols formation • farm hygiene • biosecurity

Box 1. Focus of One Health

Consequences, responses, and actions at the animal–human–environment interfaces

Aim: Healthy biosphere of sustainable development with Zero impact

- Emerging and endemic zoonoses
- Antimicrobial resistance (AMR)
- Health of food animals
- Food safety
- Risks and benefits of companion animals
- Wildlife health
- Environment conservation
- Socioeconomic impact
- Resources: efficient use, devoid of exploitation
- Education, communication

Box 2. Notes for Clinician

- The majority of human infectious diseases originated from animals
- Nearly ¾ of recently-emerging diseases originating from wildlife
- Emerging diseases pose threats to public health, food security and endangered species
- Growing global human population, and anthropogenic factors are drivers of biodiversity loss
- Loss of 60% of the essential ecosystem services of the planet
- Most public health systems lack integrated mechanisms to adequately detect and respond to infectious threats
- Knowledge of pathogens in wildlife can guide risk prioritization and prognostic modeling of outbreaks
- Think and Act One Health

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3
Defining ECO-Health

Authors: Sarkar, A., & Atkinson, S.

Learner Outcomes

After reading this chapter you should be able to:

- Describe the relevance of Eco-health to clinical practice
- To learn the application of eco-health perspectives in disease prevention and promotion of health and wellness

- To understand nature as therapy in an evidence-based context

Keywords

Key words associated with this chapter include:

- ecosystem health
- ecological determinants
- social prescribing
- nature prescribing

Introduction

The significant developmental challenges for the 21st century have been improving people's health while promoting thriving, resilient communities and environmental sustainability. Globalization, overexploitation of the earth's resources, climate change, and extreme weather conditions, widespread pollution have all contributed to our awareness of the interdependency of the fate of human societies and the well-being of our planet. Overall carrying capacity of the earth is being exceeded, and preventing us from living healthy and productive lives now, and threatening similar conditions for future generations. An ecosystem approach distinguishes that health and well-being result from complex and dynamic interactions among various determinants, such as people, social and economic conditions, and ecosystems. It is worth noting that an ecosystem approach to health focuses on improving human health by going beyond existing biomedical or epidemiological methods to health policy. Thus the ecosystem approaches to health (or Ecohealth) focus on the interactions between the ecological and socioeconomic dimensions of a given situation and their influence on human health, as well as how people use or impact ecosystems, their implications for the quality of ecosystems, the provision of ecosystem services, and sustainability. While improving livelihoods and economic conditions with inadequate attention to the environment and inequities can endanger health and become unsustainable over time, ignoring the existing environmental and social needs when trying to improve health can be ineffective.

Ecohealth awareness influences investigators and their students to engage in ecohealth-related research projects, partnering with multiple stakeholders, including the affected communities. Indeed

the ongoing planetary health crises affect the poor the most, and most of the existing ecohealth approaches focus on the global south. But, it is undeniable that the problems are escalating in scale and are increasingly co-occurring in every corner of the plant. Severe drought, flood, heat waves, forest fire, and the spread of vector-borne infectious diseases have become routine phenomena in Europe and North America. In this regard, people from low socioeconomic status, Indigenous backgrounds and people of colors, and people living in remote and rural areas are more disadvantaged. The cocktails of endocrine disrupting chemicals in human blood resulting in a steady decline in sperm counts and rising infertility and the recent discovery of nano-plastics in the blood of the European population are examples of putting commercial interest before public health and eventually exerting enormous financial burden on the health system. The study shows that the member countries of the European Union spend an additional 50 billion Euros on health care for the additional burden of illnesses due to endocrine-disrupting chemicals. The Millennium Ecosystem Assessment (MEA) represents a landmark attempt to link human health and well-being with conservation and more sustainable use of ecosystems. The MEA conceptual framework articulates the relationships between human health and well-being in our ecosystems. However, WHO's International Health Regulations (WHO 2005) and Commission on the Social Determinants of Health (CSDH 2008) only peripherally addressed the contributions of ecosystems to health, despite their inclusion as part of the Millennium Development Goals (MDGs) and the links made in the MEA. Understanding how people and their health are related to ecosystems is very complex. However, involving medical communities in ecohealth is still very insufficient. Therefore, awareness of the transdisciplinary approach among medical learners has become a top priority in leading medical schools across the continent. The following section will briefly overview various methods to enhance the knowledge and skills about ecohealth.

1. System approach to assessing health risks and actions

Systems thinking considers the relationships among ecological, social-cultural, economic, and governance dimensions and helps apply some order to the complex reality of health in the context of social-ecological systems. For health professionals, systems thinking can lead to a better understanding of the limits of the problem, its scale, and its dynamics. The behavior of individuals in a household, and their interactions within groups in a community, may be determined by gender, ethnicity and culture, residence, and socioeconomic status. For example, the rapidly spreading urban sprawl to rural and forest areas may result in more exposure to ticks and disease-causing mosquitoes. These exposures might also be determined by socioeconomic, ethnicity, and cultural factors, such as preference and affordability to spend more time in outdoor activities, dress codes, and complexion. Thus systems thinking can lead to changes in policies and practices and health promotion activities. The health officials can team up with local veterinarians, town and park officials, family physicians, microbiologists, public health officials, local school district officials, tour operators, media, and prominent community members. The collective efforts will include regular entomological (tick) surveillance, case surveillance,

identification of high-risk areas, notification to the public in parks and trails, and public awareness via media, schools, clinics, and tour operators.

1. A transdisciplinary approach to designing health care

A transdisciplinary approach integrates different scientific perspectives, community representatives, and other stakeholders' knowledge about the health problem and ecosystem perspectives based on their experiences. A transdisciplinary approach while addressing ecohealth perspectives of any diseases will enhance innovations and design strategies to improve health care and environmental conditions in a sustainable, contextually appropriate way. The transdisciplinary approach also provides more opportunities to establish an acceptable process for discussion and negotiation among stakeholders pursuing a new understanding of a given health problem or situation. To achieve a practical transdisciplinary approach, health professionals must draw on a wide range of skill sets that are not usually part of their academic training, including consensus building, negotiation, communication, facilitation, and strategic planning. To lead a multi-stakeholder process, the health professional can develop a framework for group dialogue, social inquiry for development, multi-criteria evaluation for conflict management, and outcome mapping. For instance, endocrine disrupting chemicals wreak havoc worldwide, causing infertility, hypothyroidism, cancer, and poor immune responses – need the active involvement of family physicians, endocrinologists, obstetricians, and public health professionals, laboratory medicine, environmental toxicologists, and analytical chemists. While routine testing of EDCs for infertility and hypothyroidism patients, pregnant women, and infants can generate more substantial evidence of causal relations, eco-toxicological and epidemiological studies will give clear evidence of sources and existing risk factors. Eventually, the transdisciplinary team can play a decisive advocacy role in developing the right developmental policy, including case management protocol, antenatal care, banning or restricting the use of high-risk products, etc.

1. Ensuring sustainability in ecohealth approach

Any ecohealth approach will aim to make it ethical and positive, and its sustainability should be given priority. By sustainability, the initiative implies that these changes be environmentally sound, socially and culturally responsible and appropriate, and economically less burdensome. There may be the possibility of the initiative slipping back into previous negative patterns or relationships; any forms of setbacks or any new forms of problems may arise. The policymakers may face ethical quandaries when people's short-term needs and priorities are inconsistent with a longer-term process for improving health and the environment. Therefore, ecohealth proponents should anticipate these dynamics and be prepared to learn from them. It is important to note that seeking sustainability is fundamentally

challenging and maybe a very lofty goal, mainly when the health issues are complex, multi-sectoral, and multi-generational. For example, addressing food insecurity issues in the Indigenous communities cannot be solved by improving the supply chain and price control due to external factors that cannot be controlled at the local levels (such as global gas prices, poor yields in traditional food production areas). On the other hand, local food production can be a promising solution if scientifically sound. Still, it can only be sustainable if the initiative is participatory, provides economic incentives, and is based on equity and justice.

1. Gender and social equity as a foundation for an ecosystem approach

Any ecosystem approach to health should explicitly address gender and social equity and mainly focus on vulnerable groups in the society based on gender, age, race, ethnicity, socioeconomic conditions, occupation, habitat, and so on. Considerable evidence shows that the differences between members of different socioeconomic classes, ages, and ethnic or gender groups in all societies are reflected in their relationships with ecosystems, exposure to different health risks, health status, and well-being goals. Therefore, the health professionals who lead the ecohealth approach will not only address the existing social inequity affecting the health status of the vulnerable population but should make sure to reduce the gap in the process. Otherwise, any health promotion or disease prevention initiative can be ineffective or counterproductive. For example, imposing a sugar tax on packaged sweet beverages can be a novel approach to reducing obesity and chronic diseases. However, it can be financially challenging for the Indigenous communities living in remote locations without a clean drinking water supply. Perhaps, these communities are compelled to spend on sweetened beverages for drinking since bottled water is more expensive. Therefore, the sugar tax will put an additional financial burden on vulnerable communities.

Ecohealth action may generate unintended consequences (either favorable or unfavorable), which can influence the future course of action. Gathering knowledge from ecohealth activities and translating it for further follow-up actions is essential. Knowledge translation is paramount for operational research and developing and assessing interventions' effectiveness.

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Nature as therapy; What is the importance of biophilia to human health?

Understanding the evolution of our relationship with nature.

Biophilia is proposed by Edward Wilson as the innate human tendency to focus on and seek connection with other life and life-like processes (1986). This may be evolutionary and born out of human ancestors' need to identify food, shelter, and threat for survival. The ever presence of the human desire to form a relationship with the natural world can be seen in historical artifacts, writings, and art from cultures all over the world. In the last millennia, as humans came indoors and many cultures evolved through technology, the industrial revolution, and the modernization of medical practice, many of the most important aspects of the relationship faded from view. There are, of course, exceptions to that; indigenous cultures in Canada and around the world have continued to foster beautiful reciprocal relationships with nature that have flourished despite the threat of cultural loss under the guise of modernization (I think it would be a good idea to have an excerpt here from an indigenous perspective). That said, polls carried out by numerous organizations indicate that Canadians, like their counterparts in the USA, UK, and Europe, are spending little time in nature. A company specializing in indoor living environments polled more than 16,000 adults living in 15 countries and found that we are spending up to 90% of our time indoors with 52% of respondents stating that in the preceding month they had spent less than one hour per day outdoors (Velux, 2019). Similarly in 2017 the Coleman Canada Outdoor Report revealed that among the 1500 Canadians surveyed, 30% of Canadians were spending less than 30 minutes outdoors per week.

Despite spending such little time outdoors, Institut Publique de Sondage d'Opinion Secteur (Ipsos) conducted a poll in 2018 on behalf of Nature Conservancy Canada that found more than 85% of Canadians polled agreed that they are happier when spending time in nature. In fact, the majority who answered the poll indicated that when spending time in nature they noticed improvement in their creativity, focus at work, and sleep (IPSOS, 2018). In fact these reported benefits are just the tip of the iceberg. An expanding body of evidence is just beginning to uncover the vast and significant health

benefits nature can provide to humans across the lifespan. Physicians are, therefore, beginning to prescribe time in nature as a therapeutic intervention supporting mental and physical health.

Supporting mental health through nature prescribing

The Ipsos report touches on the mental health benefits afforded by nature; people feel better, perform better, and sleep better. Beyond the vastly important subjective reports of individuals reporting feeling better in nature, science has begun to report more objective measurements of the benefit of nature on stress. Cortisol, a glucocorticoid hormone produced by adrenal gland, is released in abundance during times of stress. Persistently high levels of cortisol can result in sustained hyperglycemia, dulled immune response, and disrupted sleep leading to the numerous health conditions associated with chronic stress. A study measuring salivary cortisol has shown that it decreases in subjects having nature experiences of ten minutes or more (Hunter, Gillespie, Chen, 2019). This decrease was measured at 21.3% per hour and was noted to be most significant between 20-30 minutes in nature (Hunter, Gillespie, Chen, 2019). A similarly objective and compelling measurement of the mental health benefits afforded by nature is heart rate variability (HRV). HRV is a way of measuring balance between sympathetic and parasympathetic nervous system activation; when a subject is in a state of rest, growth, and digestion their parasympathetic nervous system is activated and sending signals to decrease heart rate. Conversely, in a state of stress or exercise their sympathetic nervous system is activated and sending signals to increase the heart rate. HRV is the resulting variation in heart rate from these two autonomic competitors among other influences. Increases in a subject's HRV are suggestive of increased parasympathetic effect and less sympathetic activation due to stress. Time in nature has been found to result in just that; an increased HRV among healthy subjects viewing a forest landscape when compared to those viewing an urban landscape (Kobayashi et. al., 2015)!

Beyond decreasing stress and the ensuing negative affects it has on human health, physicians and health care providers should be aware of its numerous other impacts on mental health and wellbeing. Among children who have ADHD, 85% indicated that it improved their day (Barfield and Driessnack, 2018). Furthermore, a 20 minute walk in the park was found to elevate attention performance for children with ADHD in a manner that rivalled some stimulant medication (Taylor and Kuo, 2009). Time in nature has been shown to improve memory (Koselka et. al. 2019), reduce prefrontal cortex activation and rumination Bratman et. al, 2015), and, among elder adults, connecting with the natural world through gardening decreases their risk of dementia by more than 30% (Simons et. al, 2006).

Supporting physical health through nature prescribing.

The mental health benefits of nature are bountiful but there are countless other representations of how spending time in nature positively influences health. For example, we know that trees have an enormous role to play in the livability of our environments; they play a direct role in the degradation and removal of pollutants from the air and their overstory reduces air temperature. These functions of trees within our ecosystem and particularly in urban areas provides cleaner and cooler air to breath (Nowak, Crane & Stephens, 2006). It is unsurprising then that living in an area with more trees is associated with a decreased risk of respiratory illness and associated morbidity and mortality (Twohig-Bennett & Joneas, 2018; Donovan et. al., 2013). The benefits of spending time in nature are farther reaching in that it cuts patients' risk of cardiovascular disease, diabetes, stroke(Twohig-Bennett & Joneas, 2018); it helps manage hypertension, hyperglycemia, and promotes meeting physical activity goals(Ochiai et. al, 2015; Ohtsuka, Yabunaka and Takayama, 1998;

Faka et. al, 2019). Some of the positive outcomes seen from spending time in nature may be from increasing physical activity, however it is even shown that adults who exercise outdoors reduce their stress levels and improve their energy and mood more than adults who exercise indoors (Coon et. al, 2011).

Physician advocacy.

When it comes to primary prevention, disease management, or overall health maintenance advocating for urban green spaces and promoting time in nature is well within the purview of health providers. In fact, in the interest of practicing evidence based medicine, as the breadth and strength of evidence mounts it appears remiss to negate the powerful potential health benefits nature affords our patients at little to no cost. In fact promoting nature as therapy stands to improve individual health but also potentially decreasing the cost of health care to the system while giving the planet and society the gift of a stronger relationship between humans and the rest of the planet. People who feel connected with nature are more likely to protect it and, for children in particular, participate in environmentalism later in life (Wells and Lekies, 2006). Promoting nature as therapy, therefore, is a step toward improved planetary health and toward ensuring nature is available as therapy for generations to come.

Foundations of nature as therapy in clinical practice.

So how is this being incorporated into clinical practice? What recommendations should we be making? There are aspects of this that are somewhat dependant on specialty, practice, location, and patient population but the foundations can be the same. We know the endless benefits of green spaces; advocating for conservation of existing natural spaces and forests while incorporating more rewilding and planting of trees in urban living areas are valuable recommendations from a population health perspective. From an individual health perspective, research supports the recommendation that 120 minutes in nature per week promotes health and wellbeing (White et.al., 2019). There is also evidence supporting the greatest reduction in cortisol level between 20 and 30 minutes (Hunter, Gillespie and Chen, 2019). These can be the foundations of nature prescribing in clinical practice that can be further tailored to meet the needs of individual patient populations.

In fact, nature is being prescribed across the world already and in some places for many years; In New Zealand physicians have been prescribing nature since the 'green prescriptions' program began in 1998 (How the Green Prescription Works, 2017)! In the United Kingdom after a pilot program in 2017 physicians have been providing Nature Prescriptions across all regions of Scotland (Nature Prescriptions RSPB Scotland, 2017). In the United States physicians are prescribing nature in 35 states through multiple programs including Park Rx, a national nature prescribing program that inspired a similar program here in Canada (Murdoch, 2022; James, Christiana and Battista, 2019). The PaRx (https://www.parkprescriptions.ca) program here in Canada began as a trial in British Colombia and has now expanded across the country.

As the evidence supporting nature based social prescribing is expanding so too do the burden of disease affecting humans and the threats to planetary health. As members of the health care community, knowledge of how vast nature's health benefits are can and should inform our advocacy work and clinical practice and help us to make choices with our patients that will benefit us all.

4

Climate Change

Climate Change

Authors: Wang, X., Kinay, P., Farooque, A.

Learner Outcomes

After reading this chapter, you should be able to:

- Understand the main causes of climate change;
- List the direct and indirect impacts of climate change on human societies and ecosystems;
- List the potential solutions for climate change mitigation and adaptation;
- Describe the relationship between climate change and human health.

Keywords:

Climate change, impacts, mitigation, adaptation, human health.

Environmental and Health Impacts of Climate Change

This chapter will introduce the topic of climate change and provide information on some key terms. The first section of the chapter will give a general overview of climate change, such as definitions and certain cause-and-effect relationships. The impacts, both direct and indirect, will then be discussed. There will also be an introduction to and some examples of adaptive and mitigating measures for climate change. Most importantly, the links between human health and climate change will be discussed.

4.1. Fundamentals of Climate Change

Concepts, Definitions & General Explanations

Climate change refers to any significant change in climate measures, such as temperature, precipitation, or wind, lasting for an extended period (decades or longer) [1]. Climate change may result from:

• natural factors, such as changes in the sun’s intensity or slow changes in the Earth’s orbit around the sun.

• natural processes within the climate system, such as changes in ocean circulation.

• human activities, such as burning fossil fuels, can change the atmosphere’s composition and the land surface, such as deforestation, urbanization, and desertification [2].

Although the terms “climate change” and “global warming” are frequently used interchangeably, “climate change” covers that there are more changes besides temperature increases. These modifications could be caused by natural processes, such as variations in the solar cycle. But since the 1800s, human activities have been the main driver of climate change, primarily due to the burning of fossil fuels like coal, oil, and gas, according to the Intergovernmental Panel on Climate Change (IPCC) [3]. The influence of humans on the climate now far outweighs the effects of known changes in natural processes, such as solar variations and volcanic eruptions.

The Difference Between Weather, Climate, Climate Variability, And Climate Change

Weather is the temperature, humidity, precipitation, cloudiness, and wind we experience in the atmosphere at a given time in a specific location. Climate is the average weather over a long period (30–50 years). A systematic change in the atmosphere’s long-term state over several decades or longer is referred as climate change. In the same way that clinical trials employ statistical tests to examine if a favourable reaction to therapy is likely to have happened by chance, scientists use statistical tests to determine the likelihood that climatic changes fall within the range of natural variability. For example, there is a less than 1% chance that the warming of the atmosphere since 1950 could be the result of natural climate variability. Before explaining the causes and effects in depth, there are two important terms to look at. Following sections will introduce two essential terms: climate prediction and projection, and the differences in between.

Climate Prediction

A climate prediction or forecast is a statement about how the climate system will evolve in the future, considering both internal variability and changes caused by GHG emissions [4]. Climate predictions do not seek to predict the system’s fundamental day-to-day changes. Rather, they attempt to forecast whether seasonal, yearly, or decadal averages or extremes will be higher, lower, or equal to climatological averages. While seasonal forecasts are frequently produced in many places, longer-term (decadal) climate predictions are now more of a research endeavor, however, operational systems are being advanced, for example within the CMIP6 (Coupled Model Intercomparison Program 6) climate modeling community [5, 6].

Climate Projection (Scenario)

In contrast to predictions, projections are not started with current-situation observations. They usually begin their simulations in the past, from pre-industrial to 1950, or even more recently [7]. The forecasts are derived by forcing the climate models with scenarios for future GHG emissions or concentrations. At the same time, the historical simulations are driven (or forced) by estimates of past human-induced and natural climate forcing agents (concentrations of GHGs). A climate projection simulates the climate system’s response to various greenhouse gas scenarios, frequently based on climate model simulations [7, 8]. Climate projections are distinguished from climate predictions to emphasize that climate projections are dependent on the emission/concentration/radiative forcing scenario used, which is based

on assumptions that may or may not be realized, and thus is subject to substantial uncertainty unrelated to the climate system [9]. Climate scenario and climate projection are often used interchangeably. Climate projections often simulate the future climate until 2100 or even beyond (Figure 1).
Figure 1. Time-horizon of climate predictions and projections.
Difference Between Predictions and ProjectionsThe most likely future occurrences in a specific location or area are foreseen through forecasts or predictions. Depending on the site, the validity of model-based weather forecasts may be restricted beyond a week due to the atmosphere's intrinsic dynamic nature. Because the environment is so dynamic, even little adjustments to the observed beginning conditions, which are continuously fed into the model, might give radically different weather predictions for the coming week.Climate variables are generated for each day in a climate projection, but the output for a given day cannot be trusted to be accurate so far in the future. Instead, it is indeed critical to determine whether long-term data is reliable for a particular location and/or season. This is independent of the simulation's initial conditions; it is dependent on the model's parameters as well as the provided forcings, such as GHGs.

Causes of Climate Change

Climate change has many consequences for the physical environment, ecosystems, and human societies [10]. How countries reduce greenhouse gas emissions and adapt to climate change will determine the future impact of climate change [11]. The loss of sea ice, rapid sea-level rise, and longer, more extreme heat waves that scientists anticipated in the past are already happening [12]. Climate change is projected to be unevenly distributed across the globe. Land areas change faster than oceans, and high northern latitudes change faster than tropics. Melting glaciers, modifying the hydrological cycle (evaporation and precipitation), and changing currents in the sea are three primary ways global warming may alter regional climate [13].

Extreme weather, glacier retreat, sea-level rise, Arctic sea ice decreases, and changes in the timing of seasonal occurrences are all physical changes [14]. Climate change has harmed the environment by boosting temperatures, drying soils, and increasing the risk of wildfires. The latest IPCC report highlights different climate futures and emphasizes the warming impact (1.5 degree Celsius temperature rise) [10]. Recent warming has had a significant impact on natural biological systems. Species are migrating poleward to colder climates around the world. On land, species migrate to higher elevations, whereas marine species migrate to deeper depths to find colder water. Climate change has been estimated to put between 1% and 50% of land-based species at risk of extinction [15]. The causes of climate change can be increased energy use, agricultural practices, deforestation, mass production, increasing pollution, changes in land use, and solar radiation (Figure 2). In the following sections, these causes will be introduced briefly.

Figure 2 Goes here
Figure 2. Cause-effect relationship of climate change.
Energy Use

Energy use is by far the main source of greenhouse gas emissions from human activities on a global scale [16, 17]. Burning fossil fuels for energy for heating, power, transportation, and industry accounts for almost two-thirds of worldwide greenhouse gas emissions [18]. Our energy use and production have a significant impact on the climate[19]. Climate change could modify our energy generation capacity as well as our energy requirements [20]. Changes in the water cycle, for example, have an impact on hydropower; warmer temperatures increase the energy demand for cooling in the summer while decreasing the need in the winter.

Agricultural Practices

Agriculture both causes and is affected by climate change [21, 22]. To combat climate change, nations must reduce agricultural greenhouse gas emissions and modify their food production methods [23]. However, there are many other factors besides climate change that have an impact on agriculture. To fulfill the growing global demand and maintain resource competitiveness, food production and consumption must be considered in a broader context that integrates agriculture, energy, and food security [24, 25]. The food supply releases greenhouse gases at every level into the atmosphere [26]. Farming produces significant amounts of the potent greenhouse gases methane and nitrous oxide. Belching is the method that allows livestock to release methane after digestion due to enteric fermentation [27, 28]. It can also escape from landfills where organic waste and manure are dumped, causing more agricultural GHGs.

Deforestation

Tropical forest trees employ photosynthesis, like other green plants, to absorb carbon dioxide from the atmosphere and release oxygen [29]. But as forests expand, photosynthesis outpaces respiration, and the extra carbon is stored in the soil, tree roots, and tree trunks. They also do the opposite process known as respiration. When trees are cut down, a significant amount of the carbon they have stored is released as CO2 back into the atmosphere [30]. This is how climate change and global warming are impacted by deforestation and forest degradation. Deforestation is one of the primary human drivers of climate change. Removing trees reduces a vital carbon “sink” that absorbs CO2 from the atmosphere. Large-scale deforestation also causes extreme warming [31]. It is evident that greener areas can foster cooling impact [32, 33]

Changes in the Land Use

Changes in land use are responsible for an increase in human population, deforestation, food types, and the demand for energy and fiber [24]. While deforestation and rapid population increase are two factors that affect the environment, unpredictable heavy rainfall and warming temperatures are two factors that affect land usage [34, 35]. Changes in land usage and strategies for efficient land management are indicators of how climate change is affecting land use. For instance, the climatic change affects crop output, which alters how land is used. The two driving force adjustments are different in time and space. Land-use change (LUC) is a crucial element of global adjustment that directly impacts climate

change [36-38].

Solar Radiation

The primary source of energy for life on Earth is the Sun, which also greatly influences the climatic conditions of our habitats. The amount of solar energy that reaches the surface is an important factor in the surface energy balance [39]. It controls a wide range of surface processes, including evaporation and related hydrological components, snow and glacier melt, plant photosynthesis and associated terrestrial carbon uptake, as well as the diurnal and seasonal patterns of surface temperatures [40]. Major practical ramifications include those for solar energy technologies and agricultural productivity, for instance. Therefore, changes in the amount of solar radiation reaching the Earth's surface may significantly affect the environment, society, and the economy. Over the course of the next century, the Earth keep warming due to the imbalance between thermal radiation from the sun and that from the sun's atmosphere [41]. This warming will hasten the melting of the polar ice caps, raise sea levels, and increase the likelihood of more extreme weather patterns exacerbated by climate change [42].

Page Break

4.2. Direct and Indirect Impacts of Climate Change

Climate change impacts can manifest in various ways [21, 43-45]. In recent years, heatwaves and other extreme events such as wildfires and flooding have been evident around the globe [46, 47]. There is, however an explanation for all these events happening and why and how they are exacerbated by climate change. This section will explain the links between climate change indicators and provide some examples (Figure 3).
Figure 3. Goes Here
Figure 3. Direct and indirect impacts of climate change.

Direct Impacts of Climate Change

Heatwaves

An extended stretch of unseasonably high temperatures and oppressive humidity is referred as a heatwave. Climate change is increasing the amount of heat that people experience [48]. On a worldwide scale, extreme temperature occurrences appear to get more often, longer, and more severe [46, 47, 49]. The ground loses more moisture on warm days, which dries out the vegetation. The consequences include damage to agriculture, larger, more intense wildfires, and a longer fire season. Heatwaves have an impact on human health and are the leading cause of fatal natural disasters [46]. Heat waves also impact our environment, agriculture, infrastructure, and services [21, 26]. Increases in heat and humidity would undoubtedly reduce worker output since they put a burden on people's tolerance levels and make it difficult for outdoor workers to stay cool, and healthy. Continuous heat waves have more disastrous effects than severe temperatures on a single day. There is no doubt that sustained extreme temperatures are linked to excessive human morbidity and mortality rates and as climate change

manifests these links are becoming more evident [49, 50].

Flooding

Water accumulation over typically dry land causes flooding [51]. It results from inland waters (rivers and streams) overflowing, tidal waters, or an extraordinary water buildup from sources like torrential rains, dams, or levee failures [51, 52]. Floods are one of the most frequent and deadly natural disasters worldwide [53, 54]. In almost every county, they have caused destruction, and in many places, they are getting worse. A variety of sources can cause a flood. River flooding, inland flooding, and coastal flooding are a few examples of flooding types [55]. A flood can be brought on by weather-related factors (heavy or protracted rainfall, storm surges, abrupt snowmelt). Still, there are also human-driven factors, such as the way we manage our waterways (via dams, levees, and reservoirs), as well as the changes we make to the land [56]. For instance, increased urbanization results in more paving and other impermeable surfaces, changes to natural drainage systems, and frequently more housing construction on floodplains [57, 58]. Urban flooding can result from poorly maintained infrastructure in cities [59]. Flooding-related concerns are increasingly being connected to climate change. Numerous weather- and human-related factors influence whether a flood occurs, and the lack of data on historical floods makes it challenging to compare them to current flood trends that are affected by climate change [60]. However, it is becoming more evident that climate change "has detectably altered" numerous of the water-related factors that cause floods, such as rainfall and snowmelt, as the IPCC (Intergovernmental Panel on Climate Change) stated in its special report on extremes [61].

Drought

A lack of precipitation over a lengthy period (often a season or more), resulting in a water deficit, is referred as a drought [62, 63]. Precipitation, temperature, streamflow, ground and reservoir water levels, soil moisture, and snowpack are all drought indicators [64]. The likelihood of droughts worsening in many places of the world rises with climate change [65]. Droughts are becoming more likely in many parts of the world because of climate change [61]. Evaporation is accelerated by warmer temperatures, which decrease surface water and dry out soils and vegetation. Because of this, dry spells last longer than they would in the past decades [66]. The timing of when water is available is also changing due to climate change [63]. Snowmelt, which provides cold water for organisms like salmon, is essential to some ecosystems [67]. Snowmelt, which provides cold water for organisms like salmon, is vital to some ecosystems [68, 69]. Reduced snow cover raises surface temperatures because snow acts as a reflective surface, worsening drought conditions [70]. According to some climate models, warming increases precipitation variability, so more spells of excessive precipitation and drought will occur [71]. In drought years, this necessitates additional water storage, and during periods of exceptionally heavy precipitation, it increases the risk of flooding and dam failure.

Wildfires

Wildfire risk and size have increased in some areas because of climate change [72]. Temperature, soil

moisture, and the availability of trees, bushes, and other possible fuel sources are some variables that affect the danger of wildfires [73]. These elements are strongly related to climatic variability and climate change, either directly or indirectly. The likelihood of hot, dry weather, prone to start wildfires, is increasing due to climate change [74]. Numerous research showed that climate change results in warmer and drier situations [75, 76]. These increases in wildfire risk are fueled by increased drought and a more extended fire season. The growth of dangerous insects that can weaken or destroy trees, adding to the fuels in a forest, is another effect of warmer, drier weather [77]. Wildfire risk is also influenced by land use and forest management [36]. As a result of climate change, extreme fire weather conditions, such as increased lightning and strong winds, are now occurring more frequently. In addition to these causes, climate change is predicted to continue to expand the region affected by wildfires [74].

Coastal Erosions

Climate change threatens coastal areas, which are already stressed by human activity, pollution, invasive species, and storms [78]. Sea level rise could erode and inundate coastal ecosystems and eliminate wetlands [79, 80]. Warmer and more acidic oceans are likely to disrupt coastal and marine ecosystems [81]. As cliffs regress or beaches and dunes "migrate," coastal erosion causes the shoreline to shift landward (change location) [82]. Dunes and salt marshes may completely vanish in some areas, while new depositional features (such as beaches and spits) may develop in other areas [80]. Along with other elements, including variations in sea level, input from rivers, and tectonic activity (movements beneath the earth's surface), both processes have long formed the shoreline. However, the shoreline's tendency to shift inland frequently creates issues for human endeavours because it puts the roads, structures, and other coastal infrastructure at risk that support transit, agriculture, and the fishing industries [83]. Additionally, it might cause a change in habitat (e.g., through the loss of areas of marsh, lagoons, or sand dunes) [84].

Indirect Impacts of Climate Change

An increase in food and water insecurity, particularly in developing nations, is one of the indirect effects of climate change that directly affects us humans and our environment [85]. Forest fires and floods pose a hazard to people's lives, health hazards brought on by a rise in the frequency and severity of heatwaves or economic effects of dealing with climate change-related secondary damage and related migration could also be counted among the indirect impacts of climate change [86, 87]. Also, the loss of biodiversity as a result of poor adaptation to the rapidity of flora and fauna, ocean acidification brought on by rising bicarbonate (HCO_3) levels in the water as a result of rising CO_2 levels and the necessity of adaptation in every context (e.g., agriculture, forestry, energy, infrastructure, tourism, etc.) could be considered as indirect impacts of climate change [88-90].

4.3. Climate Change Mitigation and Adaptation

Anticipating the adverse effects of climate change and acting appropriately to prevent or minimize the

harm they can bring, or seizing opportunities that may present themselves, is what adaptation means [91]. Examples of adaptation strategies include extensive infrastructure modifications, such as the construction of sea-level rise fortifications, and behavioural changes, such as people cutting back on food waste [92]. Adjusting to the present and future effects of climate change can be viewed as the essence of adaptation [92]. By preventing or limiting the production of greenhouse gases (GHG) into the atmosphere, mitigation refers to lessening the severity of the effects of climate change [93, 94]. Mitigation can be accomplished by either reducing the sources of these gases, such as by increasing the proportion of renewable energies or implementing a cleaner transportation system or by improving the storage of these gases, such as by expanding forests [95]. In a nutshell, mitigation is human action that lowers GHG emission sources and improves sinks. Mitigating climate change entails preventing and reducing emissions of heat-trapping greenhouse gases into the atmosphere to prevent the planet from experiencing increasingly harsh temperatures [96]. While neither adaptation nor mitigation measures can completely halt the effects of climate change, they can greatly lower risks when implemented together. While adaptation is crucial to lowering such losses, mitigation is essential to reducing the irreversible losses brought on by climate change.

Adaptation and mitigation can be addressed with a single set of policies and procedures [97]. For instance, the likelihood of localized flooding in metropolitan areas may increase due to the expected increasing frequency and intensity of rainstorms due to climate change [98]. Governments can take the step of planting street trees to lessen stormwater runoff (adaptation) and boost carbon storage (mitigation) [99]. In other situations, there can be a contradiction between the goals of adaptation and mitigation that can only be resolved within a larger framework of community priorities and risk tolerance.

Mitigating Strategies

Mitigation strategies include retrofitting buildings to make them more energy efficient; adopting renewable energy sources like solar, wind, and small hydro; helping cities develop more sustainable transport such as bus rapid transit, electric vehicles, and biofuels; and promoting more sustainable uses of land and forests [21, 100]. The mitigation strategies can include:

enhancing energy efficiency and choosing renewable energy sources over fossil fuels [101, 102],

encouraging the use of public transportation and sustainable mobility by increasing the number of bicycle trips inside cities, decreasing the number of flights, and increasing the use of trains and shared vehicles [103, 104],

promoting the 3Rs rule, sustainable food production, ecological industry, agriculture, fishing, and animal farming (reduce, reuse, recycle) [105],

through levying fees on carbon markets and the consumption of fossil fuels [106].

Adaptive Strategies

To adapt means to modify the current or predicted future environment. The objective is to lessen our susceptibility to the negative impacts of climate change (like sea-level encroachment, more intense extreme weather events or food insecurity) [107, 108]. Adaptation strategies can include:

developing more sustainable and secure structures and infrastructure [109],

planting new trees and mending ecosystems [110, 111],

crop diversification will improve their ability to respond to climate change [112, 113],

investigating and creating novel ways to control and avert natural disasters [114],

creating plans of action for climate emergencies [115].

Figure 4 Goes Here

Figure 4. Mitigative and adaptive strategies.

4.4. Climate Change and Human Health

As mentioned in the above sections, the impacts of climate change include warming temperatures, changes in precipitation, increases in the frequency or intensity of extreme weather events, and rising sea levels [116, 117]. These impacts threaten our health by affecting the food we eat, the water we drink, the air we breathe, and the weather we experience [118, 119]. The disruption of food systems, rise in zoonoses and food-, water-, and vector-borne diseases, as well as mental health problems are all already effects of climate change on health. Extreme weather events like heatwaves, storms, and floods are among the many ways that climate change is already having an impact on health [61, 120]. Human health consequences of climate change include:

respiratory diseases [121-123],

cancer [124-126],

cardiovascular disease and stroke [127, 128],

mortality and morbidity affected by weather [129, 130],

nutritional issues and foodborne illnesses [131, 132],

heat-related morbidity and mortality [133],

mental health and stress-related disorders [134-136],

vectorborne and zoonotic diseases [137],

waterborne diseases [43, 133, 138].

Respiratory Diseases

Increased human exposure to pollen (due to altered growing seasons), mold (due to extreme or more frequent precipitation), air pollution, and aerosolized marine toxins (due to increased temperature, coastal runoff, and humidity), as well as dust, may lead to an increase in respiratory allergies and diseases (from droughts) [86, 139]. Adaptation and mitigation strategies may significantly reduce these hazards. It is clear that there is a connection between the composition of air pollutant mixes and climate change (e.g., how changed pollen counts and other climate change effects affect the severity of asthma) [140, 141]. Such methods help scientists evaluate illness risks, and as a result, they are a crucial part of creating effective risk communication and directing the messaging to at-risk groups.

Cardiovascular Diseases and Stroke

Climate change may exacerbate already existing cardiovascular disease by increasing heat stress, raising the body load of airborne particles, and altering the distribution of zoonotic vectors that transmit infectious diseases associated with cardiovascular disease [142, 143]. This new knowledge should be applied to developing health risk assessment models, early warning systems, health communication strategies aimed at vulnerable populations, land-use decisions, and strategies to meet air quality goals related to climate change [12, 142]. The science that addresses the cardiovascular effects of higher temperatures, heat waves, extreme weather, and changes in air quality on health is required. In some regions, the risks of cardiovascular disease and stroke brought on by climate change may be lessened by the air pollution decreases brought on by climate change mitigation [21].

Weather-Related Morbidity and Mortality

Increases in the frequency and severity of extreme weather events like hurricanes, floods, droughts, and wildfires could negatively impact people’s health during and after the events [49]. To make sure that risks are understood, and that ideal measures are created, communicated, and executed, research is required to enhance the capacity of healthcare and emergency services to address disaster planning and management [144, 145]. Climate change is projected to increase heat and cold-related illnesses and fatalities. However, proactive public health measures like heat wave response plans and health alert warning systems can reduce morbidity and mortality [144, 146]. By defining environmental risk factors, identifying susceptible people, and creating efficient risk communication and prevention measures, other science should concentrate on developing and expanding these tools in various geographic regions [49, 147-149]. Heat exposure can aggravate a variety of medical issues in addition to causing heat exhaustion and heat stroke [150]. Extreme heat increases morbidity and death in vulnerable groups, including the elderly, children, outdoor workers, some racial and ethnic groupings, those with chronic illnesses, and those who are socially or physically isolated. In addition to the outside temperature, air pollution, high humidity, and a lack of air conditioning all contribute to the health risks associated with the heat [151].

Cancer

The environmental effects of carbon emissions and climate change may result in a rise in cancer

mortality rates, disturbances in cancer treatment, and an increase in cancer risk [152]. Although there are many known direct consequences of climate change on cancer risks, such as increased ultraviolet (UV) radiation duration and intensity, future research is needed to determine whether there may also be indirect effects on chemical and toxin exposure pathways [124-126, 153]. Advanced health and environmental research are required advantages of alternative fuels, new battery and voltaic cell technologies, and other technologies, as well as potential negative risks from exposure to their components and wastes. This will allow the best strategies to be developed and implemented [154].

Food-borne Disease and Nutrition

Malnutrition, food contamination, and shortages of staple foods may all be correlated with climate change [155]. There is a need for scientific study in this area to identify and map complex food webs and sentinel species that may be vulnerable to climate change, as well as to understand better how changes in agriculture and fisheries may affect food supply and nutrition [62]. This investigation could be utilized to design more efficient outreach to impacted areas and prepare the public health and healthcare sectors for new diseases, evolving monitoring requirements, rising disease incidence, and more [156]. Undernutrition during pregnancy and the early years of life brought on by scarcities in food supplies and exposure to harmful pollutants and biotoxins as a result of severe weather events, increased use of pesticides in agricultural production, and an increase in toxic algal blooms in public areas are all possible effects of climate change that would have an impact on how humans usually develop [157]. Future health research should examine the relationship between human development and climate change adaptations, including changes to agriculture and fisheries that may affect food availability, increased pesticide use to combat spreading disease vector ranges, and prevention of toxic waste sites leaching into floodwaters during extreme weather events, to avoid adverse developmental effects [158, 159].

Mental Health and Stress Disorders

Climate change may cause or contribute to extreme weather events, leading to population displacement (migration, relocation), property damage, loss of loved ones, and chronic stress, all of which can be detrimental to mental health (Figure 5) [135, 160]. To help assure the provision of proper health care support, research is needed to identify significant mental health consequences, vulnerable groups, and migration monitoring networks [161-163]. The prevalence of neurological problems and diseases in humans may arise due to climate change, as well as mitigation and adaptation measures [32, 163]. Acknowledging the processes and effects of human exposure to neurological hazards such as metals (found in new battery technologies and compact fluorescent lights), pesticides (used in response to changes in agriculture), harmful algal blooms, and biotoxins (from harmful algal blooms), as well as the potential exacerbating effects of malnutrition and stress, is crucial [164]. Vulnerable populations to mental health burdens include Indigenous peoples, women, children, and older adults [165].

Vectorborne and Zoonotic Diseases

Warmer temperatures, up to an optimal temperature over which transmission decreases, accelerate the transmission of vector-borne diseases [166]. Varying mosquitoes have different temperature tolerances, much as they do in terms of the diseases they transmit [167]. For example, dengue fever and the Zika virus danger will arise when global temperatures and weather patterns change as a result of climate change [168]. Due to linked expansions in vector ranges, shortened incubation times for pathogens, and disruption and movement of sizable human populations, disease risk may rise due to climate change [137]. Improving the infrastructure for controlling pathogens and their vectors, including the identification of vectors and hosts, the integration of human and other terrestrial and aquatic animal health surveillance systems, the use of ecological studies to improve predictive models, and the strategies for risk communication and prevention must be prioritized by environmental and health researchers [169].

Waterborne Diseases

Water-borne infections will probably increase in frequency as climate change continues. This is due to an increase in precipitation, storm surges, and sea temperatures brought on by climate change [170]. These environmental variables can cause runoff and flooding, which spreads disease agents, pollutants, and sewage. The likelihood of water contamination with dangerous pathogens and chemicals, leading to greater human exposure, could increase as a result of increases in water temperature, precipitation frequency and intensity, evaporation-transpiration rates, and changes in the health of coastal ecosystems [44, 171]. What food sources may become contaminated, where changes in water flow will occur, how water will interact with sewage in surface and underground water supplies as well as drinking water distribution systems, where changes in water flow will happen, and how to better predict and prevent human exposure to waterborne and ocean-related pathogens and biotoxins should all be the focus of future research [138, 172].waterborne and ocean-related pathogens and biotoxins should all be the focus of future research [138, 172].
Figure 5. Goes Here
Figure 5. Health impacts of climate change.

In addition to the research needs identified in the individual research categories, there are cross-cutting issues relevant to preventing or avoiding many of the potential health impacts of climate change, including identifying susceptible, vulnerable, underrepresented, and displaced populations [173]; enhancing public health and health care infrastructure; developing capacities and skills in modeling and prediction; and improving risk communication and public health education [164, 174]. Such research will lead to more effective early warning systems and greater public awareness of an individual’s or community’s health risk from climate change, which should translate into more successful mitigation and adaptation strategies [175-177]. For example, health communications research is needed to properly implement health alert warning systems for extreme heat events and air pollution that primarily affect people with existing conditions such as cardiovascular disease [178-181]. Such risk communication pilot project might demonstrate effective communication practices in multiple areas and contribute to a comprehensive strategy for addressing various health risks simultaneously with different

populations and in different regions. For example, health communications research is needed to properly implement health alert warning systems for extreme heat events and air pollution that primarily affect people with existing conditions such as cardiovascular disease [178-181]. Such risk communication pilot project might demonstrate effective communication practices in multiple areas and contribute to a comprehensive strategy for addressing various health risks simultaneously with different populations and in different regions.

Page Break

Conclusion

This chapter briefly introduced the concept of climate change, how it is brought about, and its consequences. In addition, the chapter discussed contexts for mitigation and adaptation and provided examples of mitigation and adaptation approaches. The primary focus of this chapter was on the relationship between climate change and human health because these links are evident. The risks associated with climate change to the population's mental and physical health should be further investigated. Although climate change has an influence on human health, it is still difficult to predict the scope and severity of many climate-sensitive health hazards. But as science progresses, we can increasingly link an uptick in sickness and mortality to human-caused global warming and assess the severity of these health problems more precisely. The sensitivity of individuals, their resilience to the current rate of climate change, and the breadth and pace of adaptation will all significantly impact the health implications of climate change. The environmental impacts of climate change will become more severe, frequent, and intense in the future. The long-term outcomes will have a more significant impact on how far-reaching action is taken now to decrease emissions and stop the breaching of dangerous temperature thresholds and possibly irreversible tipping points. Interdisciplinary research should be conducted in these areas, emphasizing how government policy is implemented to lessen the danger of climate change.

References included in Back Matter

II

PART 2: UNDERSTANDING THE INTERFACE BETWEEN HUMANS AND ANIMALS

Chapters in This Section

In this second section, information will be presented that discusses the principles of Planetary Health with regard to relationships between humans and animals

- Chapter 5: Human interaction with wildlife
- Chapter 6: Human interaction with food production animals
- Chapter 7: Loss of Biodiversity
  - ??
- Chapter 8: Human interaction with companion animals
  - ??

Human – Animal Relationships

The relationship between humans and animals has a long history that has evolved over time. There is evidence that humans interacted with animals in the form of hunting and fishing approximately 400,000 years ago (Encyclopedia.com). Domestication of animals is thought to have occurred between 13000 and 2500 BC. Animals have played a significant role in the evolution of human societies, cultures, and religions (Beckoff, Encyclopedia HA bond).

Animals are principal constituents in the health of the planet. Invertebrate animals contribute extensively to ecosystem health through pollination, aeration of the soil, and as a source of food for other animals to name a few. Vertebrate animals such as bats, rodents, and birds can be essential pollinators as well. While we may have interactions with such animals, we do not often have relationships with them like we do with domesticated mammals (even though I had worms as pets when I was little). Our interactions with animals are diverse and depend on the culture. “We eat them, wear them, live with them, work them, experiment on them, try to save them, spoil them, abuse them, fight

them, hunt them, buy, sell, and trade them, and love, fear, or hate them." (Urbanik, Placing Animals, Geography)

Anthrozoology is the field of research that focuses on human-animal relationships and includes studies on the interactions of humans with animals in a variety of venues worldwide. These venues include educational and research settings, animal shelters, farms and ranches, zoos, rodeos, houses of worship, and even slaughterhouses. Relationships within various contexts can be complex and challenging (Beckoff Ency HA bond).

5
Understanding the interface between humans and animals

Authors: Cusack, L., Hurnik, D., Kao, K., & McDuffee, L.

What's in this chapter?

- Human interaction with wildlife
    - Loss of Biodiversity
- Human interaction with companion animals
- Human interaction with food production animals
    - Anti-microbial resistance

Learner Outcomes

After reading this chapter you should be aware of:

- Wildlife stuff GOES HERE
- Human Interaction with Food production STUFF GOES HERE
- List the benefits of biodiversity to human health
- Explain how local and planetary biodiversity are sustained
- Describe how human activity contributes to loss of biodiversity
- Provide examples on how loss of biodiversity impacts negatively on human health

Human interaction with companion animals

- List the potential benefits of companion animals to human health: cardiovascular, exercise, mental health, social capital, service, and therapy
- Explain possible negative health aspects of living with companion animals: zoonosis, parasites, the burden of care; grief
- Explain negative effects of pets on the environment/planet: CO2 emissions from the production of pet food, feces, plastic bags of feces, loss of biodiversity, competition for food
- Disadvantages to human health – feces, methane and carbon dioxide, predation leading to loss of biodiversity.

Keywords

- Keywords for human interaction with wildlife:
    - blah
- Keywords for loss of biodiversity:
- Keywords for human interaction with companion animals:
    - Human animal bond, human animal interactions, human animal relationship, companion animals, pets, biodiversity, zoonosis, animal feces; social capital, social network; social support; biophilia, service animals, animal-assisted therapy, anthrozoology

Loss of Biodiversity

1. Ecological niche
2. Habitat destruction
3. Reproductive fitness
4. biodiversity
5. Healthy environments

Preface

The relationship between humans and animals has a long history that has evolved over time. There is evidence that humans interacted with animals in the form of hunting and fishing approximately 400,000 years ago (Encyclopedia.com). Domestication of animals is thought to have occurred between 13000

and 2500 BC. Animals have played a significant role in the evolution of human societies, cultures, and religions (Beckoff, Encyclopedia HA bond).

Animals are principal constituents in the health of the planet. Invertebrate animals contribute extensively to ecosystem health through pollination, aeration of the soil, and as a source of food for other animals to name a few. Vertebrate animals such as bats, rodents, and birds can be essential pollinators as well. While we may have interactions with such animals, we do not often have relationships with them like we do with domesticated mammals (even though I had worms as pets when I was little). Our interactions with animals are diverse and depend on the culture. “We eat them, wear them, live with them, work them, experiment on them, try to save them, spoil them, abuse them, fight them, hunt them, buy, sell, and trade them, and love, fear, or hate them.” (Urbanik, Placing Animals, Geography)

Anthrozoology is the field of research that focuses on human-animal relationships and includes studies on the interactions of humans with animals in a variety of venues worldwide. These venues include educational and research settings, animal shelters, farms and ranches, zoos, rodeos, houses of worship, and even slaughterhouses. Relationships within various contexts can be complex and challenging (Beckoff Ency HA bond).

Human Interaction With Wildlife

blah blah blah

Loss of Biodiversity

Loss of Biodiversity

What is biodiversity?

Biodiversity means the variety of different living species living within a particular habitat. The concept can range from the bacterial flora in the gut to small ecosystems such as a treetop canopy, to large habitats such as an entire continent. Biodiversity also applies to the planet earth, defining all of the

living organisms living in the atmosphere, the land, bodies of water and beneath the surface as well.

Regardless of the size of the habitat, it is important to know that each living individual exists in a relationship with all of the other individuals in its surroundings. How an individual interacts with its neighbours is in part deterministic, based on genetics inherited through the species, but only in a probabilistic manner, depending on many factors, both physical and biological. Likewise, each individual must play a role in the ecological niche that it inhabits – environmental changes can alter the niche, which can either benefit or be detrimental to the individual.

In a balanced ecosystem, multiple species compete or complement each other such that they are able to successfully reproduce. The conditions for successful reproduction can be intricate and highly demanding from an energy perspective. The challenge for a species to survive lies in the ability of its individuals to find or modify their environment and themselves in order to maximize their chances of reproducing successfully. Thus, the term "Reproductive fitness" is a concept that means the ability for a species to pass down their genes to the next generation. Ensuring that all species have the opportunity to be reproductively fit is a requirement to maintain life on the planet.

In this section, there are 4 objectives:

1. **List the benefits of biodiversity to human healt**h – Every species on earth relies on other species for a balanced co-existence. As biological organisms, humans also inhabit a place on Earth that benefits from, and contributes to biodiversity
2. **Explain how local and planetary biodiversity are sustained**– The range of living organisms on the planet is sustained by ensuring their reproductive fitness. Both living and non-living features of the planet are essential to create the conditions that optimize the ability for all species to pass down their genes to subsequent generations
3. **Describe how human activity has contributed to loss of biodiversity** – Since their existence on Earth, humans have exploited the resources of the planet in their favour to ensure an unfair advantage in reproductive fitness over that of other species. Humans shape the planet in ways that protect them from harmful physical elements but also modify themselves with medicines that protect against harmful biological elements, with little or no regard to collateral damage inflicted on other species.
4. **Provide examples on how loss of biodiversity impacts negatively on human health –** As members of the planetary biosphere, humans benefit from their natural relationship with non-human species. The loss of those relationships can lead to consequences impacting health.

Reproductive fitness

Biodiversity, which reflects the vast range of living organisms on earth, has arisen through a process of natural selection, so that only the fittest individuals get to pass down their genes to their offspring. The fitness of a species is defined by their traits – phenotypes that allow them to survive in a defined ecological niche. Individuals within and between species compete to acquire, or maintain their habitat, within the niche. This competitive strategy is the basis for continuation of life to exist as the environment changes. The greater the variability or diversity of phenotypes, the greater the chances of life to continue as the environment shifts.

In that regard, humans can be thought as the ”winners”, hands down, because rather than evolving naturally to adapt to environmental changes, humans engineer the environment to remain evolutionarily static, or at least stable. But over-engineering the Earth has caused uncontrollable shifts in the physical environment that have jeopardized swaths of species –humans seemingly seek to destroy the biological environment that they depend on.

Keywords

1. Ecological niche
2. Habitat destruction
3. Reproductive fitness
4. biodiversity
5. Healthy environments

Benefits of biodiversity to human health

Biodiversity is required for the living, natural infrastructure, the softscaping of living organisms that provide shelter, such coral reefs, forests, dune vegetation and soil. The natural infrastructure provides essentials for human life including clean water, shade, wind protection and retention of symbiotic microorganisms for vegetation required for consumption.

Humans create physical infrastructure for protection but which is still subject to deterioration and destruction by large changes in the physical environment including natural disasters. Living infrastructure is at a much larger scale than anything humans can produce and can adapt to a changing physical environment. On its own, the living infrastructure is much better suited to large changes in the physical environment. However human intervention has threatened to reduce biodiversity, and in so doing threaten their own existence.

The term Symbiosis is used to describe mutually beneficial relationships between species that allow them to thrive independently. The loss of biodiversity has taught us that symbiotic relationships are not only beneficial, but essential to good health. While we may perceive our bodies as a collection of billions of cells all with the same, or closely similar genetic identity, our bodies actually are living spaces for a greater number of microorganisms, several trillion, in fact. These microbes constitute the body's microbiome, which is essential for a healthy life. The gut microbiome produces feces that become recycled into soil to support vegetation which provides food for consumption.

The body's microbiome is perhaps a microcosm for the importance of planetary biodiversity. In fact the existence of a physiological microbiome clearly defines our bodies as part of, or integral to planetary biodiversity. An obvious benefit of biodiversity is of course food, including animal and plant protein, but in our quest to feed as many mouths as possible, too much of a good thing by over-development of agricultural spaces and over exploitation of animal species is a threat to biodiversity.

In our discussion of the importance of inter-species relationships, one of the areas for which biodiversity is important is in the role of certain species which serve as a reservoir for parasitic infections. These species serve as a Buffer zone of sorts, which provide a defense against interspecific transmission to

humans, a concept known as zoonosis.

Biodiversity is not only important for physical health. Natural environments have always provided a respite for humans, as an aesthetic retreat for recreation and mental health.

Not all microorganisms are living symbiotically within us, with some parasitic, which can cause infection and for which we have immune systems and medicines to combat. On that note, most beneficial pharmaceuticals have been derived from natural sources. Aboriginal medicine and traditional healing methods, for example are perhaps the earliest form of healing therapy that were derived from natural sources. Chemical technology has refined and concentrated the beneficial elements and include drugs such as digoxin, from the foxglove and anticancer agents from, for example the periwinkle (vinblastine) and the yew tree (taxanes).

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Anticancer drugs derived from plants

Here is an example of how plants have been used to create some of the most important pharmaceuticals used to treat cancer. Drug companies are on the constant search for novel therapies to treat human disease in this approach.

https://www.cell.com/trends/cancer/fulltext/S2405-8033(20)30063-7

What aspects of human activity affect biodiversity?

Unlike the majority of species, humans, in their own way and through evolution of a unique nervous system, seek to create or drastically modify existing physical spaces for protection and optimal growth and development, to allow them to have a selective survival advantage over other species. A single human can easily modify its surroundings to displace or remove species that may immediately and in the long term reduce their chances of reproducing.

Multiply that effect by several billion and you can see why humans in general have become a significant threat to biodiversity. This process of niche destruction, the loss of species and the knock-on effect of loss of interspecies relationships serves only to “burn down the entire house” leading to our own extinction.

In recent decades, there has been an alarming rate of species loss. The threat to reproductive fitness of entire ecosystems and entire classes of living organisms has resulted from predatory extinction through excessive hunting and harvesting. Domestication of single favoured species has out competed the existence of closely related species. As well, genetically isolated species may serve as reservoirs to

increase vector borne infection in wild species.

We need to accept that Humans have a shared responsibility with all of the species of the planet, as caretakers of the biosphere.

- Alarming rate of species loss
- Threat to reproductive fitness of entire ecosystems and entire classes of living organisms
- Predatory extinction
- Hunting
- harvesting
- Domestication
- Genetically isolated species may serve as reservoirs to increase vector borne infection in wild species – fish farming
- Habitat destruction
- Loss of niches leading to extinction or incursion into other habitats including human living spaces
- Niche destruction – species no longer able to interact
- Climate change
- Need to accept that Humans have a shared responsibility as caretakers of the biosphere

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Humans (and indirectly all species) are stewards of the environment

- **Human activity that disregards the health of other living organisms affects human health**
- **Altering physical habitats can threaten reproductive fitness of species living in those natural spaces**
- **human populations have grown disproportionately**
- **consume disproportionate amounts energy and produce a disproportionate amount of waste**
- **There is a need to engineer human spaces that minimize impact on other species**

There are 5 ways that humans have threatened biodiversity. In order to make our environment suitable to enjoy a long life, we have shaped the planet to our liking, causing loss of habitat of significant numbers of species.

To generate a lifestyle to satisfy a hunger for power and self image, we have created chemical and petroleum based products that pollute our air and water and have lead to climate change, affecting species migration patterns by elimination of existing habitats.

The explosion of human populations worldwide has resulted in more mouths to feed, causing exploitation of habitats for agriculture and harvesting natural species. In addition, the global movement of large masses of produce, products and people has resulted in the formation of new species relationships, some newly parasitic ones that result in elimination of indigenous ones, thereby upsetting pre-existing extended relationships, many of which can be intricately complex

Examples of how loss of biodiversity affects human and animal health

“Fish Farms a Viral Hotspot for Infection of B.C.’s Wild Salmon, New Study Finds”

Here is a good example of how human activity has directly impacted on biodiversity and subsequent negative consequences to human health and well-being. The thriving salmon farming industry in Canada is a lucrative industry with $1.6 billion in 2019 in British Columbia alone. Evidence has demonstrated that there is a high risk of viral and other parasitic infection in physically isolated fish populations raised using the preferable, open ocean-based farming methods. These infections are lethal and can spread to wild fish populations upon which First Nations communities rely.

- https://thenarwhal.ca/fish-farms-viral-hotspot-infection-b-c-s-wild-salmon-new-study-finds/
- https://thefishsite.com/articles/study-suggests-farmed-salmon-spread-prv-to-wild-fish
- https://www.science.org/doi/10.1126/sciadv.abe2592
- Effect on First Nations Health (https://www.nationalobserver.com/2020/10/05/news/salmon-lifeblood-many-bc-first-nations-communities)

Another example of how loss of biodiversity affects human health is in the ability for some non-passerine species to act as a vectorial “buffer” for West Nile virus infections. These birds include ducks, geese and other waterfowl, which act as less competent hosts as compared to passerines and have been

linked to lower rates of infection in Humans. Loss of wetland habitats may lead to reduction in non-passerine birds.

Ezenwa VO, Godsey MS, King RJ, Guptill SC (2006) Avian diversity and West Nile virus: testing associations betweenvbiodiversity and infectious disease risk. Proceedings of the Royal

Society Biological Sciences 273:109–117

Pongsiri, MJ and Roman, J (2007). Examining the Links between Biodiversity and Human Health:An Interdisciplinary Research Initiative at the U.S. Environmental Protection Agency, EcoHealth 4, 82–85.

Another modeling Study showed that biodiversity loss would lead to increased tick infections in humans

LoGuidice K, Ostfeld RS, Schmidt KA, Keesing F (2003) The ecology of infectious disease: effects of host diversity and community composition on Lyme disease risk. Proceedings of the National Academy of Sciences of the United States of America 100:567–571

Finally, here is a very clear demonstration of how deforestation and human settlement displaces species and increases malarial and other parasitic infection risk.

“Deforestation and the incidence of malaria.

Schematic diagram showing how the risk or incidence of malaria first increases and then decreases as deforestation proceeds. Before deforestation (bottom left) the forest is largely pristine, with a low population density and activities that do not cause deforestation. Malaria can be epidemic (1) and mostly driven by environmental/climatic conditions. As deforestation proceeds (bottom middle), humans

start to colonize the area, roads (shown in grey) are built, and agricultural (yellow) and urban areas (white) follow. Malaria risk is enhanced (2) at this modified boundary between human settlements and the forest. Once deforestation is widespread, and after some time that depends on the region and alteration of the landscape (bottom right), the area can sustain only low but endemic malaria transmission (3); however, the risk of infection increases for other diseases transmitted by mosquitoes that thrive in this domesticated environment, such as dengue and Zika.

MacDonald J, and Mordecai, EA (2019) Amazon deforestation drives malaria transmission, and

malaria burden reduces forest clearing 22212–22218 | PNAS | October 29, 2019 | vol. 116 | no. 44 “

We are the champions?

I want to end by circling back to our conceptual understanding of the role of biodiversity and how its precipitous loss is a detriment to planetary health.The late Stephen Jay Gould was one of the most prominent evolutionary biologists of our time. As The Agassiz Professor of Zoology at Harvard University, he was a prolific writer of books on the origin and evolution of life, questioning many of the traditional views of our place on Earth. Gould challenged the anthropocentric view of humans at the top of biological complexity in which the human body represents the epitome of life’s success on Earth.

The basis for his argument is that the largest biomass from the origin of life until now, belongs to the unicellular prokaryotic organisms, the bacteria and blue-green algae. Vertebrates, and in particular humans, are relatively late developments; but their existence depends on the vast diversity of preceeding life organisms. In fact, one could go so far as to say that humans evolved as habitats for the microbiome that inhabits the digestive systems of every person. In todays context, Gould’s book, “Full House”, published in 1996, could not have greater significance and impact to planetary and human health.

In the concluding chapter entitled “The power of the modal Bacter, or why the tail can’t wag the dog” he puts forward his main argument that symbiosis with our single-celled “masters” found in soil, in the air and in the water, is essential for existence of all life on the planet. They form the largest proportion of biomass, which supports all of the more complex organisms including humans These microbes are necessary to recycle the basic nutrients required for all life; altering the physical world jeopardizes planetary biodiversity and extinction of species, including ultimately our own.

Gould’s prophetic work provides the scientific basis for the reasons why biodiversity is essential for the

continuation of life on Earth. Humans and complex species are simply the twigs of a massive foundation consisting of a massive trunk of microorganisms and single celled beings – ignoring them and their relationship to our well-being in the process of an ever changing physical planet threatens our very existence as a species.

WHAT IS BIODIVERSITY?

Sample video on Biodiversity from:

Nature-based solutions in the fight against climate change | Thomas Crowther | TEDxLausanne from (Nature-based solutions in the fight against climate change | Thomas Crowther | TEDxLausanne – YouTube)

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://pressbooks.library.upei.ca/planetaryhealth/?p=167#h5p-3

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individual must play a role in the the ecological niche that it inhabits – environmental changes can alter the niche, which can either benefit or be detrimental to the individual.

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Take a few minutes to enjoy this video by Sir David Attenborough on Biodiversity.

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://pressbooks.library.upei.ca/planetaryhealth/?p=167#h5p-4

Human Interaction with Companion Animals

In the Anthropocene, most vertebrate animals live in captivity as livestock or companion animals (Bovenkirk). North America is the world’s leading country in pet-keeping, having over 300 million pets, which is four times the number of children. Approximately 58 % of Canadian households own at least one cat or dog, and in 2020 the dog population was estimated at 7.7 million while the cat population was estimated at 8.1 million. (CAHI). In many households dogs and cats are considered important companions for family members and indeed may be referred to as “a member of the family”(Silcox; AVMA 2012). Other animals can be beloved pets and have similar importance in the lives of humans; however, most of the literature focuses on the most common pets which are cats and dogs.

There are numerous positive health effects reported for pet owners. The COVID-19 pandemic has

highlighted the importance of pets promoting social capital in our lives improving our quality of life and mental health (from CAHI)., Wood:Social capital and pet ownership?).

Healthy pets may lead to healthy humans in other ways as well. In terms of physical activity, adults with dogs take 25% more steps per day than adults without dogs, and children with dogs are significantly more active than children without them (Owen et al. 2010). There is evidence that dog and cat owners were less likely to be obese and more likely to report excellent health (Utz 2014), and dog owners got more exercise, were fitter, and were seen less often by doctors than non-owners (Heady, Na, & Zheng, 2008).

Cardiovascular benefits have been reported for pet owners (Beck and Katcher). In a benchmark study in the 80s pet owners discharged from a coronary care unit had better outcomes compared to nonowners and this was attributed to the social support provided by pets (Freidman, E 1980). Subsequently, other similar studies reported that a prospective study found that dog ownership was associated with an increased likelihood of 1-year survival after a myocardial infarction, and dog ownership could be considered an independent predictor of survival (Friedmann &Thomas, 1995). Further evidence has shown that that pet owners had slightly lower systolic blood pressures, plasma cholesterol, and triglyceride values than non–pet owners (Anderson, Reid, and Jennings (1992).

Health research into chronic pain suggests that dogs may indirectly improve their owners' ability to cope with, manage, and live with chronic pain by providing emotional, social, and mental health benefits. (Carr). However, the benefits may only occur specifically with people who actively use human–animal interactions as a pain-coping mechanism, and care should be taken before recommending companion-animal ownership to all persons suffering from chronic pain (Bradley & Bennet)

Aside from COVID 19 isolation promoting the ownership of pets, previous reports showed that companion animals provided psychological benefits to pet owners with particular benefits to those in one-person households (Antonacopoulos & Pychyl 2010). Female university students were less likely to report being lonely and depressed as a benefit of animals in their room. Psychological effects of pets include a feeling of being needed, and a feeling of well being which were in part a result of increased social interactions between people with dogs such as meeting at a dog park and positive social effects from positive comments and attention by people who are drawn to pets in the community (Wells, 2009).

Other impacts that pets have on wellbeing of humans include alleviation of highly stressful life occurrences such as divorce and death in the family, alleviation of depression and anxiety, and these effects were shown to extend to all members in the household (Lewis, Krägeloh, & Shepherd, 2009). Other studies have shown positive effects of pets on childhood development and healthy aging ((Beck & Katcher). (See SIlcox and add silcox as ref in above statements)

These studies show evidence of the positive impact that pets have on wellbeing. In fact, in several countries pet ownership has been shown to result in savings to the national health program. (in Fine:

Understanding Our Kinship with Animals: Input for Health Care Professionals Interested in the Human–Animal Bond Aubrey H.Fine,Alan M.Beck?)

Domestic animals also provide benefits to human health when trained as service and therapy animals. Service animals are trained to provide specific medical care or support to a person with physical, mental or emotional disabilities and reside with that person, while Therapy animals work with more than one person and reside with a handler or at the facility where they work. The best known example of assistance animals is the Guide dog which is highly trained to guide humans with impaired vision. The success of Guide dogs as "adaptive technology" led to the training of dogs to provide other services including hearing, mobility, medical alert needs and many others; and the success with dogs led to training of other species as service animals such as guide ponies and service monkeys (Beckoff encyclopedia).

Therapy animals are not service animals. In animal assisted therapy a person trained in that therapy incorporates an animal into a prescribed therapeutic plan (Beckofff bk 1). Well known examples of therapy animals include horses used in therapeutic riding programs or equine facilitated psychotherapy and dogs providing affection and comfort to people in hospitals, retirement homes, nursing homes, schools, hospices, disaster areas, and to people with learning difficulties.

Although there are amazing stories of the benefits from the human animal bond and from loyal service and therapy animals, it is important to be aware that the human animal bond (HAB) and its relationship with human mental health is complex (Hill), and the HAB may interfere with self care and contribute to noncompliance of health/medical recommendations. For instance, if there is a contradiction between pet care and self care the owner may choose to put the animal's needs first resulting in noncompliance toward their own therapy. One example is a patient being referred to a rehabilitation facility that does not allow animals. This may not be a viable option to that owner due to lack of pet care and may lead to non compliance by the patient. This could have a critical effect on patient outcome (McNicholas; silcox?). There is also evidence that pets can have no effect or be associated with decreased health and morale in some human animal interactions (Scoresby, K.J, 2021; (Beck and Katcher). Therefore, it is essential to investigate the human animal interactions in the daily life of each patient. This will help the physician make recommendations for the patient which work for the entire family including the pet members.

It is also important to recognize that companion animals interacting and living with humans need to be healthy to provide health benefits. The appropriate veterinary care is important to promote a strong human animal bond. The HAB is defined by the American Veterinary Medical Association as "a mutually beneficial and dynamic relationship between people and animals that is influenced by behaviors essential to the health and wellbeing of both" (AVMA). Unhealthy pets con be a source of zoonotic diseases (Tarazona et al) transmitting infectious diseases to humans when they are not healthy themselves. More on health disadvantages… burden of care??

Moreover, it is also important to acknowledge that pets contribute to poor planetary health. The pet

animal population accounts for 25 to 30 per cent of the environmental impact of meat consumption in the United States and are responsible for creating approximately 64 million tons of carbon dioxide each year. They also produce millions of tonnes of feces every year, much of it individually wrapped before being sent to landfills. Whereas feces left in the environment contaminate waterways with bacteria, viruses and parasites. (Suzuki report; Voith)

Cats can have an additional negative effect on the planetary health due to their agency as predators. Many owned cats are allowed to be free ranging, and there are many free ranging feral cats in most communities. Free-ranging domestic cats impact biodiversity through predation, fear effects, competition, disease and hybridization. Prey items include a wide range of animals, including birds, mammals, reptiles, amphibians, fish, and invertebrates like butterflies and dragonflies. (Trowburst) Another indirect impact on the planet is competition with wild animals for food. For example, every mouse eaten by a cat cannot be eaten by a hawk. Domestic cats can also impact wildlife through cat-transmitted diseases like toxoplasmosis, rabies or feline leukemia (Voith).

Overall, there is much evidence of mental and physical health benefits from humans interacting with domestic animals; however, this is unique to each individual, including patients, and their circumstances. Questions about pets and interactions with animals should be a routine part of history taking for the medical record. (see See Silcox- recommendations for clinicians. supplemental) This information may be pertinent for both mental and physical health aspects of patients. Conscientious and responsible pet ownership should be promoted to optimize health benefits from pets and to protect the planet. Patient-Centered Medical Homes should consider including a veterinarian as one of the health professionals on the team.

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February 15, 2021

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Exploring the differences between pet and non-pet owners: Implications for humananimal interaction research and policy Jessica Saunders1 , Layla Parast1 *, Susan H. Babey2 , Jeremy V. Miles

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History of Animal Agriculture

Life on the surface of the earth depends on energy from the sun. The first life forms, once established, began to grow exponentially and so inevitably overshadowed each other in the quest for light. Thus began a fight for sunlight and survival. Competition for resources remains a common theme that drives all animal life and human civilization to this day.

The initial competition for sunlight caused early life forms to form solid structures like cellulose and lignin so that they can grow up over each other to reach sunlight sun. New innovative life forms began consuming plant material instead depending on photosynthesis. To optimally access many plants, these herbivores needed to be mobile, and so animals evolved to move to their food source. The variety of herbivores that swim, fly and walk today are a consequence of the intense competition for food. Other animals rather than continually searching for leaves just found it easier to eat the herbivores. Carnivores are part an ecological balance where the sun's energy is captured and shared in a food chain where every life form is looking to survive and reproduce. *Homo Sapiens* arose in this distributive energy ecosystem

Humans have become the most widespread competitor for resources and have settled almost everywhere in the world from the arctic where no plants grow, to tropical jungles to deserts. The advantage that humans have over other species is the ability to communicate and work together. The evolution of language, initially spoken, then pictorial, and now written, requires a large brain and a more intensive nutritional demand. Humans evolved to survive on a variety of foods and ecosystems. We can exist on an all-animal diet[1] or primarily on plants when living in lush vegetation. We evolved an ability to run distances and outlast prey and a metabolism to endure periods of hunger when prey wasn't found.

As humans started to work together, we taught each other how to hunt animals much more efficiently. Examples still exist of these early hunting techniques [figure 1], and we became the most effective carnivore on earth. As our population grew humans fought over optimal land and learned to trade resources, all activities in which we still engage.

When prey was scarce, early hunter gather societies found a way to corral and confine animals [figure 2], and so livestock farming began. All our livestock species had their origin in wildlife. Canadian cattle began as wild European aurochs[2] (Bos primigenius) pigs as wild eurasian pigs[3] (*Sus Scrofa*), and chickens as wild birds traded from Asia[4]. Through natural selection we have domesticated these species to improve their temperament – so they are less likely to kill us – and to better meet our nutritional needs. Historically we have increased their fat content [Figure 3] to be a better source of energy and enlarged their muscles for a source of protein. This continual refinement of our livestock's genetic base continues to this day[5].

We found nutrition could come from animals without having to killing them Milk designed to grow offspring is nutritionally dense, and even if we were lactose intolerant, the benefits outweighed the discomfort.[6] Similarly eggs became a favoured nutritionally dense food giving a survival advantage to societies that found ways to domesticate poultry and keep them laying.

Humans also found a myriad of ways to preserve animal-based foods to carry over times of famine. Early nomads carried meat under the saddle of their horses where both drying and the salt from the sweating horse would preserve the meat[7]. Heavy salt can prevent bacterial growth and with natural fermentation we can create the dry cured meat products that we still eat today[8]. Pickling in low pH, fermenting, smoking, cooking, drying and freezing techniques were discovered to preserve animal based foods for consumption later. These techniques form the basis of our culinary and charcuterie skills we take pride in.

The value of animal-based foods goes is deeper than the nutrition it provides. Humans still enjoy hunting and fishing, and we pay particular attention to food preparation to impress others. Bonding around food experiences whether it's the raising, obtaining or preparation of foods is an emotionally satisfying activity that creates friendships and harmony. A lack of food and inequitable distribution leads to strife.

Economics

The production of food from animals is not separated from the human's competition for resources and survival. Animals, once slaughtered, are sold as meat products, and once packaged, meat is generally

considered a commodity. Just like coal, metals, and wood products, meat is traded on an open market Butchers buy animals to process and farmers compete to supply them. The producer with the lowest cost is the most profitable. It is difficult for butchers to raise prices of their meat if another can supply it for a lower price. Humans retain a universal and fundamental motivation to never pay more than we need to.

This market approach forms the basis of modern agriculture and farmers struggling to survive are continually looking for efficiency and cost savings. The net effect to society is an ever-present supply of food ingredients at the lowest cost possible. This food production system has made our human population to grow exponentially and reduce starvation episodes. Our civilization less has food production crises[9], but we do retain a distribution problem.

The most expensive cost of raising a farm animal is feed. In pig and poultry production 70-80% of the production cost is feed[10] and the conversion of feed to meat is the metric most closely monitored by livestock producers. Chasing a better feed conversion ratio is the greatest driver of the change we see in modern livestock today. Fat is more energy dense than muscle and and so fatter animals needs more feed. In the pursuit of feed efficiency, we are selecting our farm animal to be leaner. If at the same time an animal grows faster, the producer can sell more animals annually and animals reaching market age sooner use less feed for maintenance (metabolism and mobility) and again require less feed. Consequently, modern agriculture has been selecting faster growing and leaner animals[11].

Starting from a traditional multi species mixed farm, producers found it more efficient to specialize and become exceptionally good at raising their preferred species. Most commercial farms today focus one livestock species and can negotiate supplies at better prices and gain economy of scale through increasing farm size. The competition for farm survival resulted in fewer, larger increasingly specialized farms which raise livestock indoors[12].

Farm animals are brought under a roof for several reasons starting with shelter from cold. Cold animals will eat more feed to stay warm and raising them in their thermoneutral zone minimizes feed cost. Animals indoors are at less risk of predation and disease coming from wildlife. Some zoonotic diseases such a trichinosis can be controlled when animals are indoors as are diseases such as influenza, leptospirosis and tuberculosis which can spread from wildlife.

Disease

Further feed efficiency can be found in eliminating endemic diseases. Most pig and poultry production use principles of Specific Pathogen Free (SPF) production where pathogens are eliminated where possible. Starting with the breeding stock down to commercial farms if pathogens are removed, disease loss can be eliminated. Some diseases resist elimination and so vaccination and parasite control is another foundational strategy on most farms. Some countries have eliminated severe animal diseases such as Foot and Mouth Disease which can affect many livestock species, however in some regions it remains endemic[13]. Animal diseases are still spreading internationally, particularly African Swine Fever, which survives months in meat products and has spread worldwide save the continental Americas and Oceania. This disparity of health status results in severe restrictions on trading of animals or meats between regions. Our cultural differences and emotional attachments to food products drives people to smuggle meats over borders[14] and requires intensive border protection and inspection.

Early in the intensification of animal production the use of antibiotics was found to be particularly valuable because controlling subclinical disease and changing on enteric flora improved growth rate and feed efficiency[15]. Other pharmaceuticals were found that could increase growth rates and muscling to bring economic advantages. Anabolics such as zeranol[16] and Beta agonists such as Ractopamine[17] have been approved for food animal use in North America. For consumers looking for the lowest price for meat, antimicrobial drugs and pharmaceuticals are powerful economic tools.

Globalization

The same economy of scale that producers used to reduce their cost applies to slaughter and meat processing companies as well. Larger processors in animal dense areas have significant cost advantages, and with refrigeration can transport meat in large volumes to consumers in large cities and countries with high populations. This evolution coinciding with industrialization profoundly shaped North American society and is well described[18]. Large processing plants can invest in technology that can utilize every part of the animal and package it for sale anywhere in the world that will give the best price. The modern pig in Canada is sold in worldwide and is processed into a myriad of cuts[19]. [figure 4 – cut chart] Again, competition for profitability has led to small number of high volume processing plants. The intense competition survival by producers and processors to stay in business gives *Homo sapiens* globally a lower real cost of food.

There are disadvantages of open market economics for food production, and other systems have been tried. In centrally planned economies where technocrats set price and production targets, political influence controlled access to food. The resulting corruption and inefficiency eventually returned

market economics. Governments worldwide do try to soften the rough edges of market economics. In Canada we have a supply managed system production for poultry and dairy foods which supports local producers, but they require border restrictions to keep cheaper imports out.

Challenges of Animal Agriculture

Despite the abundance our food production system, there are always drawbacks and opportunities to improve food production .

Nutrition and Health

Animal based protein may that they negatively impact our health. When we were cold, starving, and depended on manual labour, animal proteins and particularly fats were highly valued because of their nutrient density. As we mechanized, both obesity and heart disease became a concern. Low fat and increased polyunsaturated intake nutritional recommendations urged people away animal based foods. Animal agriculture responded by reducing the fat content of livestock-based foods. Leaner cuts of meat were marketed, which coincided well with the search for feed efficiency. A consequence of leaner cuts with less fat is reduced tenderness and flavour. We can now find moisture enhanced meat cuts in the super market[20],[21], along recommendations not overcook meats as attempt to improve the eating experience. Niche marketing of flavourful "heritage breeds" such as Berkshire hogs or Wagu raised cattle which carry more intra muscular fat are marketed for their superior taste.

As our understanding of heart disease has become more sophisticated, role of animal-based fats is not as clear and some authors tout the benefits of animal fats and recommend the nutrient density of animals based foods.[22]

There are more recent concerns around the carcinogenicity of meats, particularly processed meat products preserved with nitrites and other compounds Preserving meats with wood smoke reduces bacterial growth, but smoke (like campfires and wood stoves) has creosotes and nitrites convert to nitrosamines during the cooking process[23].

The health risk of animal-based foods remains intensely debated with varied motivations.[24].

Zoonoses

Animal diseases can spread to people via animals and their food products. Some bacteria such as salmonella strains cause enteric disease in both animal and human hosts. One of the first diseases that animal agriculture eliminated from domestic animal populations were ones causing significant human disease. Brucellosis and tuberculosis were eliminated from domestic livestock populations in North America in the previous century through veterinary public health initiatives. Coupled with milk pasteurization, both diseases have been well controlled. The infectious organisms still exist in wildlife. Similarly, *Trichinella spiralis* infections in pigs were historically a risk when eating pork; today moving production indoors and away from wildlife has controlled the risk in commercial pork production. Consequently, pork cooking recommendations have relaxed, recommending leaving an "hint of pink" to enhance the eating experience[25].

Gut pathogens such as salmonella strains, O157 E. coli, and Campylobacter species can contaminate animal carcasses at slaughter and if the resultant animal food products are not cooked throughly, can result in human disease. The risk is mitigated by food safety plans at slaughter that minimize cross contamination of meat. One consequence of larger processing plants is that contamination in one plant can have a large impact[26]. Food inspection processes provided by the federal Canadian Food Inspection Agency (CFIA) use prevention principles centred around Hazard Analysis and Critical Control Points (HAACP) to evaluate food safety plans in federally inspected meat processing plants[27]. These plans these require significant investment in refrigeration, sanitation, and traceability of food products. Federally inspected meat products will have federal markings and certificates of inspection (figure 5). Smaller scale processing plants may be licensed provincially, and those products can only marketed within the province. Provincial requirements may differ from federal, and any associated outbreak will be limited to that province. If animals are slaughtered directly on a farm the meat may be consumed by that household, but if it is sold or traded with others it must be inspected either provincially or federally.

Some zoonotic hazards can arise from improper storage or preservation. If meat products are insufficiently refrigerated, bacteria from any source can grow to quantities posing a health threat. Federal inspection standards require cold chain verification prior to sale and modern food transportation have temperatures monitoring processes. Food safety training and awareness at the consumer level can further mitigate hazards, but humans make mistakes and food-based problems will

always pose potential risk to our health.

Antimicrobial resistance

Antimicrobial compounds in food production do bring an economic benefit; however, based on an understanding of antimicrobial resistance (AMR), there is a growing concern that widespread use of antimicrobial drugs may create a drug resistance problem for both human and veterinary medicine. Data shows that AMR carrying bacteria can be present on meat products, shed in animal manure and dust exiting animal facilities[28]. As response both industry and public health authorities have initiatives to mitigate this AMR risk to the Canadian public. The Veterinary Drugs Directorate branch of Health Canada, which approves the use of veterinary drugs has recently (2018) removed all claims for antimicrobial drugs licensed for growth promotion and made all antimicrobial use in livestock directed by veterinary prescription[29]. Veterinarians have guidelines for prescribing antimicrobials to food animals and some veterinary regulatory bodies have mandated AMR training as part their continuing education requirements. Nationally the veterinary profession has developed prudent use guidelines to reduce the risk AMR in livestock and have classified veterinary drugs based on their importance for human use[30], and the Canadian integrated program antimicrobial resistance surveillance (cipars) project continues to monitor AMR in Canadian food[31]

All antimicrobial and pharmaceutical use in food animals also has a requirement time passes from treatment until slaughter. This withdrawal time is to ensure any remaining residues of veterinary drugs fall below federal safety limits. The maximum residual limits (MRLs) approved by Health Canada, are publicly available, and form the basis for the dosing, label claims and withdrawal times for veterinary drugs in Canada.[32]

Livestock producers similarly recognize concerns around antimicrobial use and have put into place quality assurance programs to ensure withdrawal times are met and that there is veterinary oversight of antimicrobial use.

AMR remains a major concern to some consumers and a further response by industry has been the growth of an 'antibiotic free' (ABF) animal production systems. To meet labelling requirements[33], participating producers do use not routine use of antimicrobial drugs when growing their animals. If individual animals become infected, they can be treated, but they need to be identified and marketed as conventional animals. ABF farms will use disease elimination and vaccination strategies to mitigate the need to routine prophylactic or metaphylactic antimicrobial use. ABF farms consequently do have a higher cost of production and processors and consumers pay a premium price for these meat products. What started as a niche market has become a regular choice alongside commodity meat products at retail.

Some consumers also have concerns about anabolic and other pharmaceuticals in the food chain. While these are also generally covered in most ABF claims, additional consumer concerns around herbicides and chemicals used in agriculture lead them to source organic or biodynamic meat products. Organic certification[34] limits all chemical use which leads to a drop in crop productivity. Organic livestock feeds are generally 2 to 3 times more expensive than conventional feeds. Since feed is 70% or more the cost of raising livestock, organic meats tend to be more significantly more expensive. Organic meats are a niche choice for motivated consumers.

Animal Welfare

The efficient production of livestock has been challenged by people who state that the animal's needs are not considered. Initial welfare recommendations were that animals we raise for food be given key freedoms, specifically: freedom from hunger, pain, fear, disease, given shelter and comfort and that they be allowed to express their natural behaviour.[35] Moving animals inside has been successful in providing protection from the elements, predators, with the provision of ample feed animals aren't hungry and they can grow efficiently. The stocking density of animals in a pen or barn is generally optimized to provide maximum livestock throughput. Like humans, farm animals will compete for feed and sleeping space, and in some cases such as poultry egg layers, gestating sows, or stanchioned dairy cattle are confined to small areas and their movement is restricted. Animal welfare advocates argue that such confinement doesn't allow animals to express their natural behaviour resulting frustrated or bored animals and ask for less confinement and an elimination of procedures such as tail docking, castration, dehorning and beak trimming.

The livestock Industry has responded by implementing welfare recommendations through national codes of practice[36]. Ongoing research looks for methods of implementation of welfare

recommendation that do not reduce productivity and profitability. For consumers who feel that is not moving fast enough, there are certified welfare programs that limit confinement or animal procedures[37]. These programs do have a higher cost of production and are so the meat and food products are sold to consumers for a premium.

Animal welfare concerns extend to transport and slaughter processes. The Canadian Food Inspection agency oversees transportation and slaughter of livestock. Slaughter requires the animal are stunned and unconscious prior to exsanguination which is required for food safety and aesthetic reasons. Some religious slaughter prohibits stunning leading to some contention between religious and animal welfare principles[38].

There are consumers that avoid all animal food products not wanting to kill or exploit sentient life. All food production though requires extensive rodent and pest control[39] with some methods such as poisons causing pain and slow death of targeted animals. Just by our existence, regardless of what were eat, humans create negative welfare experience for other animal species and ecosystems.

Climate Change

Calculations on the impact of animal agriculture suggest that animals do contribute to greenhouse gas production, particularly methane. Methane is generated from the decay and digestion of plant matter, and so ruminants such as cattle, sheep and goats who are herbivores release methane as they digest cellulose and plant matter. Mono-gastric livestock, poultry and pigs generate less methane [figure 6]. The degree and amount of the contribution of livestock to climate change is under dispute.[40]

Livestock, particularly monogastrics (chickens and pigs) primarily eat foods that would normally not be used to feed people. Soybeans are widely grown with most beans processed for oil, leaving the protein component, which humans generally do not consume, Pigs and poultry will efficiently convert that waste stream into foods we do consume. Similarly, corn and grains are grown and further processed into subcomponents for human use. Flour, corn starch, beer, fructose and more recently ethanol are derived from these crops. Components not used for humans are fed to animals: wheat middlings, Distiller’s grains, as well as whole grains that don’t meet human quality standards are converted to meat through livestock. If we remove livestock from the equation, these plant byproducts would be wasted. Livestock are a valuable part of reducing food waste and efficient use of energy.

Future of Animal Agriculture

As a society we will continue to evolve our relationship with animal-based foods. Niche markets featuring antibiotic free production, organic meats and welfare enhanced systems all exist and are competing for their place on the plate.

All livestock production methods have advantages and disadvantages. Moving animal production back to extensive outdoor production gives animals more freedom but places them in contact with wildlife. Pastured animals have a higher risk of contracting *trichinella* parasites, toxoplasmosis[41]. Regenerative agriculture where multiple animal species are raised together in harmony with the soil has advantages[42], but requires motivated agricultural entrepreneurs willing to invest years building their farms. Currently agriculture has worker shortages and to find enough farmers to supply food through smaller scale agriculture to feed 8 billion people may be difficult. Efforts to force organic principles on a food production system has led to financial and political difficulties[43] Wholesale change in food production needs to be done carefully.

Perhaps the most radical change to animal agriculture is the trend to grow meat in cell culture as opposed to living animals. This technology would solve the welfare issues of raising sentient animals, but so far exists as an investment opportunity. Whether it will prove to be as energy efficient as livestock converting 2kg of grain to 1 kg of meat and what proportion of consumers will chose cultured meats will remain to be seen.

Animal based foods have been with humans throughout our history, and they remain a significant source of nutrients and emotional comfort. There currently is such variety of food choices that each person can chose based on their preferences. The diversity of preferences will continue to drive innovation and evolution of food products.

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Climate Change and Wildlife

Authors: Cusack, L.

After reading this chapter you should be aware of:

- Wildlife stuff GOES HERE

7

Planetary Health and Food Animal Production

Authors: Hurnik, D.

After reading this chapter you should be aware of:

- Human Interaction with Food Production STUFF GOES HERE

History of Animal Agriculture

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The value of animal-based foods goes is deeper than the nutrition it provides. Humans still enjoy hunting and fishing, and we pay particular attention to food preparation to impress others. Bonding around food experiences whether it's the raising, obtaining or preparation of foods is an emotionally satisfying activity that creates friendships and harmony. A lack of food and inequitable distribution leads to strife.

Economics

The production of food from animals is not separated from the human's competition for resources and survival. Animals, once slaughtered, are sold as meat products, and once packaged, meat is generally considered a commodity. Just like coal, metals, and wood products, meat is traded on an open market Butchers buy animals to process and farmers compete to supply them. The producer with the lowest cost is the most profitable. It is difficult for butchers to raise prices of their meat if another can supply it for a lower price. Humans retain a universal and fundamental motivation to never pay more than we need to.

This market approach forms the basis of modern agriculture and farmers struggling to survive are continually looking for efficiency and cost savings. The net effect to society is an ever-present supply of food ingredients at the lowest cost possible. This food production system has made our human

population to grow exponentially and reduce starvation episodes. Our civilization less has food production crises[9], but we do retain a distribution problem.

The most expensive cost of raising a farm animal is feed. In pig and poultry production 70-80% of the production cost is feed[10] and the conversion of feed to meat is the metric most closely monitored by livestock producers. Chasing a better feed conversion ratio is the greatest driver of the change we see in modern livestock today. Fat is more energy dense than muscle and and so fatter animals needs more feed. In the pursuit of feed efficiency, we are selecting our farm animal to be leaner. If at the same time an animal grows faster, the producer can sell more animals annually and animals reaching market age sooner use less feed for maintenance (metabolism and mobility) and again require less feed. Consequently, modern agriculture has been selecting faster growing and leaner animals[11].

Starting from a traditional multi species mixed farm, producers found it more efficient to specialize and become exceptionally good at raising their preferred species. Most commercial farms today focus one livestock species and can negotiate supplies at better prices and gain economy of scale through increasing farm size. The competition for farm survival resulted in fewer, larger increasingly specialized farms which raise livestock indoors[12].

Farm animals are brought under a roof for several reasons starting with shelter from cold. Cold animals will eat more feed to stay warm and raising them in their thermoneutral zone minimizes feed cost. Animals indoors are at less risk of predation and disease coming from wildlife. Some zoonotic diseases such a trichinosis can be controlled when animals are indoors as are diseases such as influenza, leptospirosis and tuberculosis which can spread from wildlife.

Disease

Further feed efficiency can be found in eliminating endemic diseases. Most pig and poultry production use principles of Specific Pathogen Free (SPF) production where pathogens are eliminated where possible. Starting with the breeding stock down to commercial farms if pathogens are removed, disease loss can be eliminated. Some diseases resist elimination and so vaccination and parasite control is another foundational strategy on most farms. Some countries have eliminated severe animal diseases such as Foot and Mouth Disease which can affect many livestock species, however in some regions it remains endemic[13]. Animal diseases are still spreading internationally, particularly African Swine Fever, which survives months in meat products and has spread worldwide save the continental Americas and Oceania. This disparity of health status results in severe restrictions on trading of animals

or meats between regions. Our cultural differences and emotional attachments to food products drives people to smuggle meats over borders[14] and requires intensive border protection and inspection.

Early in the intensification of animal production the use of antibiotics was found to be particularly valuable because controlling subclinical disease and changing on enteric flora improved growth rate and feed efficiency[15]. Other pharmaceuticals were found that could increase growth rates and muscling to bring economic advantages. Anabolics such as zeranol[16] and Beta agonists such as Ractopamine[17] have been approved for food animal use in North America. For consumers looking for the lowest price for meat, antimicrobial drugs and pharmaceuticals are powerful economic tools.

Globalization

The same economy of scale that producers used to reduce their cost applies to slaughter and meat processing companies as well. Larger processors in animal dense areas have significant cost advantages, and with refrigeration can transport meat in large volumes to consumers in large cities and countries with high populations. This evolution coinciding with industrialization profoundly shaped North American society and is well described[18]. Large processing plants can invest in technology that can utilize every part of the animal and package it for sale anywhere in the world that will give the best price. The modern pig in Canada is sold in worldwide and is processed into a myriad of cuts[19]. [figure 4 – cut chart] Again, competition for profitability has led to small number of high volume processing plants. The intense competition survival by producers and processors to stay in business gives *Homo sapiens* globally a lower real cost of food.

There are disadvantages of open market economics for food production, and other systems have been tried. In centrally planned economies where technocrats set price and production targets, political influence controlled access to food. The resulting corruption and inefficiency eventually returned market economics. Governments worldwide do try to soften the rough edges of market economics. In Canada we have a supply managed system production for poultry and dairy foods which supports local producers, but they require border restrictions to keep cheaper imports out.

Challenges of Animal Agriculture

Despite the abundance our food production system, there are always drawbacks and opportunities to improve food production .

Nutrition and Health

Animal based protein may that they negatively impact our health. When we were cold, starving, and depended on manual labour, animal proteins and particularly fats were highly valued because of their nutrient density. As we mechanized, both obesity and heart disease became a concern. Low fat and increased polyunsaturated intake nutritional recommendations urged people away animal based foods. Animal agriculture responded by reducing the fat content of livestock-based foods. Leaner cuts of meat were marketed, which coincided well with the search for feed efficiency. A consequence of leaner cuts with less fat is reduced tenderness and flavour. We can now find moisture enhanced meat cuts in the super market[20],[21], along recommendations not overcook meats as attempt to improve the eating experience. Niche marketing of flavourful "heritage breeds" such as Berkshire hogs or Wagu raised cattle which carry more intra muscular fat are marketed for their superior taste.

As our understanding of heart disease has become more sophisticated, role of animal-based fats is not as clear and some authors tout the benefits of animal fats and recommend the nutrient density of animals based foods.[22]

There are more recent concerns around the carcinogenicity of meats, particularly processed meat products preserved with nitrites and other compounds Preserving meats with wood smoke reduces bacterial growth, but smoke (like campfires and wood stoves) has creosotes and nitrites convert to nitrosamines during the cooking process[23].

The health risk of animal-based foods remains intensely debated with varied motivations.[24].

Zoonoses

Animal diseases can spread to people via animals and their food products. Some bacteria such as salmonella strains cause enteric disease in both animal and human hosts. One of the first diseases that animal agriculture eliminated from domestic animal populations were ones causing significant human

disease. Brucellosis and tuberculosis were eliminated from domestic livestock populations in North America in the previous century through veterinary public health initiatives. Coupled with milk pasteurization, both diseases have been well controlled. The infectious organisms still exist in wildlife. Similarly, *Trichinella spiralis* infections in pigs were historically a risk when eating pork; today moving production indoors and away from wildlife has controlled the risk in commercial pork production. Consequently, pork cooking recommendations have relaxed, recommending leaving an "hint of pink" to enhance the eating experience[25].

Gut pathogens such as salmonella strains, O157 E. coli, and Campylobacter species can contaminate animal carcasses at slaughter and if the resultant animal food products are not cooked throughly, can result in human disease. The risk is mitigated by food safety plans at slaughter that minimize cross contamination of meat. One consequence of larger processing plants is that contamination in one plant can have a large impact[26]. Food inspection processes provided by the federal Canadian Food Inspection Agency (CFIA) use prevention principles centred around Hazard Analysis and Critical Control Points (HAACP) to evaluate food safety plans in federally inspected meat processing plants[27]. These plans these require significant investment in refrigeration, sanitation, and traceability of food products. Federally inspected meat products will have federal markings and certificates of inspection (figure 5). Smaller scale processing plants may be licensed provincially, and those products can only marketed within the province. Provincial requirements may differ from federal, and any associated outbreak will be limited to that province. If animals are slaughtered directly on a farm the meat may be consumed by that household, but if it is sold or traded with others it must be inspected either provincially or federally.

Some zoonotic hazards can arise from improper storage or preservation. If meat products are insufficiently refrigerated, bacteria from any source can grow to quantities posing a health threat. Federal inspection standards require cold chain verification prior to sale and modern food transportation have temperatures monitoring processes. Food safety training and awareness at the consumer level can further mitigate hazards, but humans make mistakes and food-based problems will always pose potential risk to our health.

Antimicrobial resistance

Antimicrobial compounds in food production do bring an economic benefit; however, based on an understanding of antimicrobial resistance (AMR), there is a growing concern that widespread use of antimicrobial drugs may create a drug resistance problem for both human and veterinary medicine. Data shows that AMR carrying bacteria can be present on meat products, shed in animal manure and dust exiting animal facilities[28]. As response both industry and public health authorities have initiatives to mitigate this AMR risk to the Canadian public. The Veterinary Drugs Directorate branch of Health Canada, which approves the use of veterinary drugs has recently (2018) removed all claims for antimicrobial drugs licensed for growth promotion and made all antimicrobial use in livestock directed by veterinary prescription[29]. Veterinarians have guidelines for prescribing antimicrobials to food animals and some veterinary regulatory bodies have mandated AMR training as part their continuing education requirements. Nationally the veterinary profession has developed prudent use guidelines to reduce the risk AMR in livestock and have classified veterinary drugs based on their importance for human use[30], and the Canadian integrated program antimicrobial resistance surveillance (cipars) project continues to monitor AMR in Canadian food[31]

All antimicrobial and pharmaceutical use in food animals also has a requirement time passes from treatment until slaughter. This withdrawal time is to ensure any remaining residues of veterinary drugs fall below federal safety limits. The maximum residual limits (MRLs) approved by Health Canada, are publicly available, and form the basis for the dosing, label claims and withdrawal times for veterinary drugs in Canada.[32]

Livestock producers similarly recognize concerns around antimicrobial use and have put into place quality assurance programs to ensure withdrawal times are met and that there is veterinary oversight of antimicrobial use.

AMR remains a major concern to some consumers and a further response by industry has been the growth of an ‘antibiotic free’ (ABF) animal production systems. To meet labelling requirements[33], participating producers do use not routine use of antimicrobial drugs when growing their animals. If individual animals become infected, they can be treated, but they need to be identified and marketed as conventional animals. ABF farms will use disease elimination and vaccination strategies to mitigate the need to routine prophylactic or metaphylactic antimicrobial use. ABF farms consequently do have a higher cost of production and processors and consumers pay a premium price for these meat products. What started as a niche market has become a regular choice alongside commodity meat products at retail.

Some consumers also have concerns about anabolic and other pharmaceuticals in the food chain. While these are also generally covered in most ABF claims, additional consumer concerns around herbicides and chemicals used in agriculture lead them to source organic or biodynamic meat products. Organic certification[34] limits all chemical use which leads to a drop in crop productivity. Organic livestock feeds are generally 2 to 3 times more expensive than conventional feeds. Since feed is 70% or more the cost of raising livestock, organic meats tend to be more significantly more expensive. Organic meats are a niche choice for motivated consumers.

Animal Welfare

The efficient production of livestock has been challenged by people who state that the animal's needs are not considered. Initial welfare recommendations were that animals we raise for food be given key freedoms, specifically: freedom from hunger, pain, fear, disease, given shelter and comfort and that they be allowed to express their natural behaviour.[35] Moving animals inside has been successful in providing protection from the elements, predators, with the provision of ample feed animals aren't hungry and they can grow efficiently. The stocking density of animals in a pen or barn is generally optimized to provide maximum livestock throughput. Like humans, farm animals will compete for feed and sleeping space, and in some cases such as poultry egg layers, gestating sows, or stanchioned dairy cattle are confined to small areas and their movement is restricted. Animal welfare advocates argue that such confinement doesn't allow animals to express their natural behaviour resulting frustrated or bored animals and ask for less confinement and an elimination of procedures such as tail docking, castration, dehorning and beak trimming.

The livestock Industry has responded by implementing welfare recommendations through national codes of practice[36]. Ongoing research looks for methods of implementation of welfare recommendation that do not reduce productivity and profitability. For consumers who feel that is not moving fast enough, there are certified welfare programs that limit confinement or animal procedures[37]. These programs do have a higher cost of production and are so the meat and food products are sold to consumers for a premium.

Animal welfare concerns extend to transport and slaughter processes. The Canadian Food Inspection agency oversees transportation and slaughter of livestock. Slaughter requires the animal are stunned and unconscious prior to exsanguination which is required for food safety and aesthetic reasons. Some

religious slaughter prohibits stunning leading to some contention between religious and animal welfare principles[38].

There are consumers that avoid all animal food products not wanting to kill or exploit sentient life. All food production though requires extensive rodent and pest control[39] with some methods such as poisons causing pain and slow death of targeted animals. Just by our existence, regardless of what were eat, humans create negative welfare experience for other animal species and ecosystems.

Climate Change

Calculations on the impact of animal agriculture suggest that animals do contribute to greenhouse gas production, particularly methane. Methane is generated from the decay and digestion of plant matter, and so ruminants such as cattle, sheep and goats who are herbivores release methane as they digest cellulose and plant matter. Mono-gastric livestock, poultry and pigs generate less methane [figure 6]. The degree and amount of the contribution of livestock to climate change is under dispute.[40]

Livestock, particularly monogastrics (chickens and pigs) primarily eat foods that would normally not be used to feed people. Soybeans are widely grown with most beans processed for oil, leaving the protein component, which humans generally do not consume, Pigs and poultry will efficiently convert that waste stream into foods we do consume. Similarly, corn and grains are grown and further processed into subcomponents for human use. Flour, corn starch, beer, fructose and more recently ethanol are derived from these crops. Components not used for humans are fed to animals: wheat middlings, Distiller's grains, as well as whole grains that don't meet human quality standards are converted to meat through livestock. If we remove livestock from the equation, these plant byproducts would be wasted. Livestock are a valuable part of reducing food waste and efficient use of energy.

Future of Animal Agriculture

As a society we will continue to evolve our relationship with animal-based foods. Niche markets featuring antibiotic free production, organic meats and welfare enhanced systems all exist and are

competing for their place on the plate.

All livestock production methods have advantages and disadvantages. Moving animal production back to extensive outdoor production gives animals more freedom but places them in contact with wildlife. Pastured animals have a higher risk of contracting *trichinella* parasites, toxoplasmosis[41]. Regenerative agriculture where multiple animal species are raised together in harmony with the soil has advantages[42], but requires motivated agricultural entrepreneurs willing to invest years building their farms. Currently agriculture has worker shortages and to find enough farmers to supply food through smaller scale agriculture to feed 8 billion people may be difficult. Efforts to force organic principles on a food production system has led to financial and political difficulties[43] Wholesale change in food production needs to be done carefully.

Perhaps the most radical change to animal agriculture is the trend to grow meat in cell culture as opposed to living animals. This technology would solve the welfare issues of raising sentient animals, but so far exists as an investment opportunity. Whether it will prove to be as energy efficient as livestock converting 2kg of grain to 1 kg of meat and what proportion of consumers will chose cultured meats will remain to be seen.

Animal based foods have been with humans throughout our history, and they remain a significant source of nutrients and emotional comfort. There currently is such variety of food choices that each person can chose based on their preferences. The diversity of preferences will continue to drive innovation and evolution of food products.

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8
Issues in Biodiversity

Authors: Kao, K.

After reading this chapter you should be aware of:

- List the benefits of biodiversity to human health
- Explain how local and planetary biodiversity are sustained
- Describe how human activity contributes to loss of biodiversity
- Provide examples on how loss of biodiversity impacts negatively on human health

Human interaction with companion animals

- List the potential benefits of companion animals to human health: cardiovascular, exercise, mental health, social capital, service, and therapy
- Explain possible negative health aspects of living with companion animals: zoonosis, parasites, the burden of care; grief
- Explain negative effects of pets on the environment/planet: CO2 emissions from the production of pet food, feces, plastic bags of feces, loss of biodiversity, competition for food
- Disadvantages to human health – feces, methane and carbon dioxide, predation leading to loss of biodiversity.

Loss of Biodiversity

Loss of Biodiversity

What is biodiversity?

Biodiversity means the variety of different living species living within a particular habitat. The concept can range from the bacterial flora in the gut to small ecosystems such as a treetop canopy, to large habitats such as an entire continent. Biodiversity also applies to the planet earth, defining all of the living organisms living in the atmosphere, the land, bodies of water and beneath the surface as well.

Regardless of the size of the habitat, it is important to know that each living individual exists in a relationship with all of the other individuals in its surroundings. How an individual interacts with its neighbours is in part deterministic, based on genetics inherited through the species, but only in a probabilistic manner, depending on many factors, both physical and biological. Likewise, each individual must play a role in the ecological niche that it inhabits – environmental changes can alter the niche, which can either benefit or be detrimental to the individual.

In a balanced ecosystem, multiple species compete or complement each other such that they are able to successfully reproduce. The conditions for successful reproduction can be intricate and highly demanding from an energy perspective. The challenge for a species to survive lies in the ability of its individuals to find or modify their environment and themselves in order to maximize their chances of reproducing successfully. Thus, the term "Reproductive fitness" is a concept that means the ability for a species to pass down their genes to the next generation. Ensuring that all species have the opportunity to be reproductively fit is a requirement to maintain life on the planet.

In this section, there are 4 objectives:

1. **List the benefits of biodiversity to human healt**h – Every species on earth relies on other species for a balanced co-existence. As biological organisms, humans also inhabit a place on Earth that benefits from, and contributes to biodiversity
2. **Explain how local and planetary biodiversity are sustained**– The range of living organisms on the planet is sustained by ensuring their reproductive fitness. Both living and non-living features of the planet are essential to create the conditions that optimize the ability for all species to pass down their genes to subsequent generations
3. **Describe how human activity has contributed to loss of biodiversity** – Since their existence on Earth, humans have exploited the resources of the planet in their favour to ensure an unfair advantage in reproductive fitness over that of other species. Humans shape the planet in ways that protect them from harmful physical elements but also modify themselves with medicines that protect against harmful biological elements, with little or no regard to collateral damage inflicted on other species.
4. **Provide examples on how loss of biodiversity impacts negatively on human health –** As members of the planetary biosphere, humans benefit from their natural relationship with non-human species. The loss of those relationships can lead to consequences impacting health.

Reproductive fitness

Biodiversity, which reflects the vast range of living organisms on earth, has arisen through a process of natural selection, so that only the fittest individuals get to pass down their genes to their offspring. The fitness of a species is defined by their traits – phenotypes that allow them to survive in a defined ecological niche. Individuals within and between species compete to acquire, or maintain their habitat, within the niche. This competitive strategy is the basis for continuation of life to exist as the environment changes. The greater the variability or diversity of phenotypes, the greater the chances of life to continue as the environment shifts.

In that regard, humans can be thought as the ”winners”, hands down, because rather than evolving naturally to adapt to environmental changes, humans engineer the environment to remain evolutionarily static, or at least stable. But over-engineering the Earth has caused uncontrollable shifts in the physical environment that have jeopardized swaths of species –humans seemingly seek to destroy the biological environment that they depend on.

Keywords

1. Ecological niche
2. Habitat destruction

3. Reproductive fitness
4. biodiversity
5. Healthy environments

Benefits of biodiversity to human health

Biodiversity is required for the living, natural infrastructure, the softscaping of living organisms that provide shelter, such coral reefs, forests, dune vegetation and soil. The natural infrastructure provides essentials for human life including clean water, shade, wind protection and retention of symbiotic microorganisms for vegetation required for consumption.

Humans create physical infrastructure for protection but which is still subject to deterioration and destruction by large changes in the physical environment including natural disasters. Living infrastructure is at a much larger scale than anything humans can produce and can adapt to a changing physical environment. On its own, the living infrastructure is much better suited to large changes in the physical environment. However human intervention has threatened to reduce biodiversity, and in so doing threaten their own existence.

The term Symbiosis is used to describe mutually beneficial relationships between species that allow them to thrive independently. The loss of biodiversity has taught us that symbiotic relationships are not only beneficial, but essential to good health. While we may perceive our bodies as a collection of billions of cells all with the same, or closely similar genetic identity, our bodies actually are living spaces for a greater number of microorganisms, several trillion, in fact. These microbes constitute the body's microbiome, which is essential for a healthy life. The gut microbiome produces feces that become recycled into soil to support vegetation which provides food for consumption.

The body's microbiome is perhaps a microcosm for the importance of planetary biodiversity. In fact the existence of a physiological microbiome clearly defines our bodies as part of, or integral to planetary biodiversity. An obvious benefit of biodiversity is of course food, including animal and plant protein, but in our quest to feed as many mouths as possible, too much of a good thing by over-development of agricultural spaces and over exploitation of animal species is a threat to biodiversity.

In our discussion of the importance of inter-species relationships, one of the areas for which biodiversity is important is in the role of certain species which serve as a reservoir for parasitic infections. These species serve as a Buffer zone of sorts, which provide a defense against interspecific transmission to humans, a concept known as zoonosis.

Biodiversity is not only important for physical health. Natural environments have always provided a respite for humans, as an aesthetic retreat for recreation and mental health.

Not all microorganisms are living symbiotically within us, with some parasitic, which can cause infection and for which we have immune systems and medicines to combat. On that note, most beneficial pharmaceuticals have been derived from natural sources. Aboriginal medicine and traditional healing methods, for example are perhaps the earliest form of healing therapy that were derived from natural sources. Chemical technology has refined and concentrated the beneficial elements and include drugs such as digoxin, from the foxglove and anticancer agents from, for example the periwinkle (vinblastine) and the yew tree (taxanes).

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Anticancer drugs derived from plants

Here is an example of how plants have been used to create some of the most important pharmaceuticals used to treat cancer. Drug companies are on the constant search for novel therapies to treat human disease in this approach.

https://www.cell.com/trends/cancer/fulltext/S2405-8033(20)30063-7

What aspects of human activity affect biodiversity?

Unlike the majority of species, humans, in their own way and through evolution of a unique nervous system, seek to create or drastically modify existing physical spaces for protection and optimal growth and development, to allow them to have a selective survival advantage over other species. A single human can easily modify its surroundings to displace or remove species that may immediately and in the long term reduce their chances of reproducing.

Multiply that effect by several billion and you can see why humans in general have become a significant threat to biodiversity. This process of niche destruction, the loss of species and the knock-on effect of loss of interspecies relationships serves only to “burn down the entire house” leading to our own extinction.

In recent decades, there has been an alarming rate of species loss. The threat to reproductive fitness of entire ecosystems and entire classes of living organisms has resulted from predatory extinction through excessive hunting and harvesting. Domestication of single favoured species has out competed the existence of closely related species. As well, genetically isolated species may serve as reservoirs to increase vector borne infection in wild species.

We need to accept that Humans have a shared responsibility with all of the species of the planet, as caretakers of the biosphere.

- Alarming rate of species loss
- Threat to reproductive fitness of entire ecosystems and entire classes of living organisms
- Predatory extinction
- Hunting
- harvesting
- Domestication
- Genetically isolated species may serve as reservoirs to increase vector borne infection in wild species – fish farming
- Habitat destruction
- Loss of niches leading to extinction or incursion into other habitats including human living spaces
- Niche destruction – species no longer able to interact
- Climate change
- Need to accept that Humans have a shared responsibility as caretakers of the biosphere

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Humans (and indirectly all species) are stewards of the environment

- **Human activity that disregards the health of other living organisms affects human health**
- **Altering physical habitats can threaten reproductive fitness of species living in those natural spaces**
- **human populations have grown disproportionately**
- **consume disproportionate amounts energy and produce a disproportionate amount of waste**
- **There is a need to engineer human spaces that minimize impact on other species**

There are 5 ways that humans have threatened biodiversity. In order to make our environment suitable to enjoy a long life, we have shaped the planet to our liking, causing loss of habitat of significant numbers of species.

To generate a lifestyle to satisfy a hunger for power and self image, we have created chemical and petroleum based products that pollute our air and water and have lead to climate change, affecting species migration patterns by elimination of existing habitats.

The explosion of human populations worldwide has resulted in more mouths to feed, causing exploitation of habitats for agriculture and harvesting natural species. In addition, the global movement of large masses of produce, products and people has resulted in the formation of new species relationships, some newly parasitic ones that result in elimination of indigenous ones, thereby upsetting pre-existing extended relationships, many of which can be intricately complex

Examples of how loss of biodiversity affects human and animal health

“Fish Farms a Viral Hotspot for Infection of B.C.’s Wild Salmon, New Study Finds”

Here is a good example of how human activity has directly impacted on biodiversity and subsequent negative consequences to human health and well-being. The thriving salmon farming industry in Canada is a lucrative industry with $1.6 billion in 2019 in British Columbia alone. Evidence has demonstrated that there is a high risk of viral and other parasitic infection in physically isolated fish populations raised using the preferable, open ocean-based farming methods. These infections are lethal and can spread to wild fish populations upon which First Nations communities rely.

- https://thenarwhal.ca/fish-farms-viral-hotspot-infection-b-c-s-wild-salmon-new-study-finds/
- https://thefishsite.com/articles/study-suggests-farmed-salmon-spread-prv-to-wild-fish
- https://www.science.org/doi/10.1126/sciadv.abe2592
- Effect on First Nations Health (https://www.nationalobserver.com/2020/10/05/news/salmon-lifeblood-many-bc-first-nations-communities)

Another example of how loss of biodiversity affects human health is in the ability for some non-passerine species to act as a vectorial “buffer” for West Nile virus infections. These birds include ducks, geese and other waterfowl, which act as less competent hosts as compared to passerines and have been linked to lower rates of infection in Humans. Loss of wetland habitats may lead to reduction in non-passerine birds.

Ezenwa VO, Godsey MS, King RJ, Guptill SC (2006) Avian diversity and West Nile virus: testing associations betweenvbiodiversity and infectious disease risk. Proceedings of the Royal

Society Biological Sciences 273:109–117

Pongsiri, MJ and Roman, J (2007). Examining the Links between Biodiversity and Human Health:An Interdisciplinary Research Initiative at the U.S. Environmental Protection Agency, EcoHealth 4, 82–85.

Another modeling Study showed that biodiversity loss would lead to increased tick infections in humans

LoGuidice K, Ostfeld RS, Schmidt KA, Keesing F (2003) The ecology of infectious disease: effects of host diversity and community composition on Lyme disease risk. Proceedings of the National Academy of Sciences of the United States of America 100:567–571

Finally, here is a very clear demonstration of how deforestation and human settlement displaces species and increases malarial and other parasitic infection risk.

“Deforestation and the incidence of malaria.

Schematic diagram showing how the risk or incidence of malaria first increases and then decreases as deforestation proceeds. Before deforestation (bottom left) the forest is largely pristine, with a low population density and activities that do not cause deforestation. Malaria can be epidemic (1) and mostly driven by environmental/climatic conditions. As deforestation proceeds (bottom middle), humans start to colonize the area, roads (shown in grey) are built, and agricultural (yellow) and urban areas (white) follow. Malaria risk is enhanced (2) at this modified boundary between human settlements and

the forest. Once deforestation is widespread, and after some time that depends on the region and alteration of the landscape (bottom right), the area can sustain only low but endemic malaria transmission (3); however, the risk of infection increases for other diseases transmitted by mosquitoes that thrive in this domesticated environment, such as dengue and Zika.

MacDonald J, and Mordecai, EA (2019) Amazon deforestation drives malaria transmission, and

malaria burden reduces forest clearing 22212–22218 | PNAS | October 29, 2019 | vol. 116 | no. 44 “

We are the champions?

I want to end by circling back to our conceptual understanding of the role of biodiversity and how its precipitous loss is a detriment to planetary health.The late Stephen Jay Gould was one of the most prominent evolutionary biologists of our time. As The Agassiz Professor of Zoology at Harvard University, he was a prolific writer of books on the origin and evolution of life, questioning many of the traditional views of our place on Earth. Gould challenged the anthropocentric view of humans at the top of biological complexity in which the human body represents the epitome of life’s success on Earth.

The basis for his argument is that the largest biomass from the origin of life until now, belongs to the unicellular prokaryotic organisms, the bacteria and blue-green algae. Vertebrates, and in particular humans, are relatively late developments; but their existence depends on the vast diversity of preceeding life organisms. In fact, one could go so far as to say that humans evolved as habitats for the microbiome that inhabits the digestive systems of every person. In todays context, Gould’s book, “Full House”, published in 1996, could not have greater significance and impact to planetary and human health.

In the concluding chapter entitled “The power of the modal Bacter, or why the tail can’t wag the dog” he puts forward his main argument that symbiosis with our single-celled “masters” found in soil, in the air and in the water, is essential for existence of all life on the planet. They form the largest proportion of biomass, which supports all of the more complex organisms including humans These microbes are necessary to recycle the basic nutrients required for all life; altering the physical world jeopardizes planetary biodiversity and extinction of species, including ultimately our own.

Gould’s prophetic work provides the scientific basis for the reasons why biodiversity is essential for the continuation of life on Earth. Humans and complex species are simply the twigs of a massive foundation consisting of a massive trunk of microorganisms and single celled beings – ignoring them and their

relationship to our well-being in the process of an ever changing physical planet threatens our very existence as a species.

WHAT IS BIODIVERSITY?

Sample video on Biodiversity from:

Nature-based solutions in the fight against climate change | Thomas Crowther | TEDxLausanne from (Nature-based solutions in the fight against climate change | Thomas Crowther | TEDxLausanne – YouTube)

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://pressbooks.library.upei.ca/planetaryhealth/?p=638#h5p-3

Biodiversity means the variety of different living species living within a particular habitat. The concept can range from the bacterial flora in the gut to small ecosystems such as a treetop canopy, to large habitats such as an entire continent. Biodiversity also applies to the planet earth, defining all of the living organisms living in the atmosphere, the land, bodies of water and beneath the surface as well.

Regardless of the size of the habitat, it is important to know that each living individual exists in a relationship with all of the other individuals in its surroundings. How an individual interacts with its neighbours is in part deterministic, based on genetics inherited through the species, but only in a probabilistic manner, depending on many factors, both physical and biological. Likewise, each individual must play a role in the the ecological niche that it inhabits – environmental changes can alter the niche, which can either benefit or be detrimental to the individual.

In a balanced ecosystem, multiple species compete or complement each other such that they are able to successfully reproduce. The conditions for successful reproduction can be intricate and highly demanding from an energy perspective. The challenge for a species to survive lies in the ability of its individuals to find or modify their environment and themselves in order to maximize their chances of reproducing successfully. Thus the term “Reproductive fitness” is a concept that means the ability for a species to pass down their genes to the next generation. Ensuring that all species have the opportunity to be reproductively fit is a requirement to maintain life on the planet.

Take a few minutes to enjoy this video by Sir David Attenborough on Biodiversity.

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://pressbooks.library.upei.ca/planetaryhealth/?p=638#h5p-4

9
Human Interaction with Companion Animals

<h2>Authors: McDuffee, L.A.</h2>

After reading this chapter you should be aware of:

<div style=”font-weight: 400″>

Human interaction with companion animals

List the potential benefits of companion animals to human health: cardiovascular, exercise, mental health, social capital, service, and therapy
Explain possible negative health aspects of living with companion animals: zoonosis, parasites, the burden of care; grief

Explain negative effects of pets on the environment/planet: CO2 emissions from the production of pet food, feces, plastic bags of feces, loss of biodiversity, competition for food
Disadvantages to human health – feces, methane and carbon dioxide, predation leading to loss of biodiversity.

Human Interaction with Companion Animals

In the Anthropocene, most vertebrate animals live in captivity as livestock or companion animals (Bovenkirk). North America is the world's leading country in pet-keeping, having over 300 million pets, which is four times the number of children. Approximately 58 % of Canadian households own at least one cat or dog, and in 2020 the dog population was estimated at 7.7 million while the cat population was estimated at 8.1 million. (CAHI). In many households dogs and cats are considered important companions for family members and indeed may be referred to as "a member of the family"(Silcox; AVMA 2012). Other animals can be beloved pets and have similar importance in the lives of humans; however, most of the literature focuses on the most common pets which are cats and dogs.

There are numerous positive health effects reported for pet owners. The COVID-19 pandemic has highlighted the importance of pets promoting social capital in our lives improving our quality of life and mental health (from CAHI)., Wood:Social capital and pet ownership?).

Healthy pets may lead to healthy humans in other ways as well. In terms of physical activity, adults with dogs take 25% more steps per day than adults without dogs, and children with dogs are significantly more active than children without them (Owen et al. 2010). There is evidence that dog and cat owners were less likely to be obese and more likely to report excellent health (Utz 2014), and dog owners got more exercise, were fitter, and were seen less often by doctors than non-owners (Heady, Na, & Zheng, 2008).

Cardiovascular benefits have been reported for pet owners (Beck and Katcher). In a benchmark study in the 80s pet owners discharged from a coronary care unit had better outcomes compared to nonowners and this was attributed to the social support provided by pets (Freidman, E 1980). Subsequently, other similar studies reported that a prospective study found that dog ownership was associated with an increased likelihood of 1-year survival after a myocardial infarction, and dog ownership could be considered an independent predictor of survival (Friedmann &Thomas, 1995). Further evidence has

shown that that pet owners had slightly lower systolic blood pressures, plasma cholesterol, and triglyceride values than non–pet owners (Anderson, Reid, and Jennings (1992).

Health research into chronic pain suggests that dogs may indirectly improve their owners' ability to cope with, manage, and live with chronic pain by providing emotional, social, and mental health benefits. (Carr). However, the benefits may only occur specifically with people who actively use human–animal interactions as a pain-coping mechanism, and care should be taken before recommending companion-animal ownership to all persons suffering from chronic pain (Bradley & Bennet)

Aside from COVID 19 isolation promoting the ownership of pets, previous reports showed that companion animals provided psychological benefits to pet owners with particular benefits to those in one-person households (Antonacopoulos & Pychyl 2010). Female university students were less likely to report being lonely and depressed as a benefit of animals in their room. Psychological effects of pets include a feeling of being needed, and a feeling of well being which were in part a result of increased social interactions between people with dogs such as meeting at a dog park and positive social effects from positive comments and attention by people who are drawn to pets in the community (Wells, 2009).

Other impacts that pets have on wellbeing of humans include alleviation of highly stressful life occurrences such as divorce and death in the family, alleviation of depression and anxiety, and these effects were shown to extend to all members in the household (Lewis, Krägeloh, & Shepherd, 2009). Other studies have shown positive effects of pets on childhood development and healthy aging ((Beck & Katcher). (See SIlcox and add silcox as ref in above statements)

These studies show evidence of the positive impact that pets have on wellbeing. In fact, in several countries pet ownership has been shown to result in savings to the national health program. (in Fine: Understanding Our Kinship with Animals: Input for Health Care Professionals Interested in the Human–Animal Bond Aubrey H.Fine,Alan M.Beck?)

Domestic animals also provide benefits to human health when trained as service and therapy animals. Service animals are trained to provide specific medical care or support to a person with physical, mental or emotional disabilities and reside with that person, while Therapy animals work with more than one person and reside with a handler or at the facility where they work. The best known example of assistance animals is the Guide dog which is highly trained to guide humans with impaired vision. The success of Guide dogs as "adaptive technology" led to the training of dogs to provide other services including hearing, mobility, medical alert needs and many others; and the success with dogs led to training of other species as service animals such as guide ponies and service monkeys (Beckoff encyclopedia).

Therapy animals are not service animals. In animal assisted therapy a person trained in that therapy incorporates an animal into a prescribed therapeutic plan (Beckofff bk 1). Well known examples of therapy animals include horses used in therapeutic riding programs or equine facilitated psychotherapy

and dogs providing affection and comfort to people in hospitals, retirement homes, nursing homes, schools, hospices, disaster areas, and to people with learning difficulties.

Although there are amazing stories of the benefits from the human animal bond and from loyal service and therapy animals, it is important to be aware that the human animal bond (HAB) and its relationship with human mental health is complex (Hill), and the HAB may interfere with self care and contribute to noncompliance of health/medical recommendations. For instance, if there is a contradiction between pet care and self care the owner may choose to put the animal's needs first resulting in noncompliance toward their own therapy. One example is a patient being referred to a rehabilitation facility that does not allow animals. This may not be a viable option to that owner due to lack of pet care and may lead to non compliance by the patient. This could have a critical effect on patient outcome (McNicholas; silcox?). There is also evidence that pets can have no effect or be associated with decreased health and morale in some human animal interactions (Scoresby, K.J, 2021; (Beck and Katcher). Therefore, it is essential to investigate the human animal interactions in the daily life of each patient. This will help the physician make recommendations for the patient which work for the entire family including the pet members.

It is also important to recognize that companion animals interacting and living with humans need to be healthy to provide health benefits. The appropriate veterinary care is important to promote a strong human animal bond. The HAB is defined by the American Veterinary Medical Association as "a mutually beneficial and dynamic relationship between people and animals that is influenced by behaviors essential to the health and wellbeing of both" (AVMA). Unhealthy pets con be a source of zoonotic diseases (Tarazona et al) transmitting infectious diseases to humans when they are not healthy themselves. More on health disadvantages… burden of care??

Moreover, it is also important to acknowledge that pets contribute to poor planetary health. The pet animal population accounts for 25 to 30 per cent of the environmental impact of meat consumption in the United States and are responsible for creating approximately 64 million tons of carbon dioxide each year. They also produce millions of tonnes of feces every year, much of it individually wrapped before being sent to landfills. Whereas feces left in the environment contaminate waterways with bacteria, viruses and parasites. (Suzuki report; Voith)

Cats can have an additional negative effect on the planetary health due to their agency as predators. Many owned cats are allowed to be free ranging, and there are many free ranging feral cats in most communities. Free-ranging domestic cats impact biodiversity through predation, fear effects, competition, disease and hybridization. Prey items include a wide range of animals, including birds, mammals, reptiles, amphibians, fish, and invertebrates like butterflies and dragonflies. (Trowburst) Another indirect impact on the planet is competition with wild animals for food. For example, every mouse eaten by a cat cannot be eaten by a hawk. Domestic cats can also impact wildlife through cat-transmitted diseases like toxoplasmosis, rabies or feline leukemia (Voith).

Overall, there is much evidence of mental and physical health benefits from humans interacting with

domestic animals; however, this is unique to each individual, including patients, and their circumstances. Questions about pets and interactions with animals should be a routine part of history taking for the medical record. (see See Silcox- recommendations for clinicians. supplemental) This information may be pertinent for both mental and physical health aspects of patients. Conscientious and responsible pet ownership should be promoted to optimize health benefits from pets and to protect the planet. Patient-Centered Medical Homes should consider including a veterinarian as one of the health professionals on the team.

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Exploring the differences between pet and non-pet owners: Implications for humananimal interaction research and policy Jessica Saunders1 , Layla Parast1 *, Susan H. Babey2 , Jeremy V. Miles

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III

PART 3: SUSTAINABILITY ISSUES IN CLIMATE CHANGE

Chapters In this Section

- Food Security and Climate Change
- Water Security

What is in this Section

- Climate calamities: drought, crop failure, pestilence, livestock death?
- What is food security?
- What is food safety (what is the role of anti-microbial resistance)?
- What is the relationship to human health? (acute and chronic)
- Physical, mental, and social implications

Sustainability Issues in Climate Change and the need to recognize climate justice

As noted by Porter, Rickards, Verlie, and Bosomworth, et al (2020) Climate justice should be viewed as a framework that highlights the *intersection between climate change and the way social inequalities are experienced as structural violence*.

UN Secretary-General Antonio Guterres, stated, “As is always the case, the poor and vulnerable are the first to suffer and the worst hit.” Climate change will not be borne fairly or equally between rich and poor, women and men, and older and younger generations. On March 2019, former President of Ireland Mary Robinson stated that “we have begun to understand the intergenerational injustice of climate

change.” un.org
The University of British Columbia identifies the need to protect the human rights of those most vulnerable to its effects and a shift to protecting the human rights of the most vulnerable. sustain.ubc.ca

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10
Food Security and Climate Change

Authors: Wahl, M.,

Learner Outcomes

After reading this chapter you should be able to:

- To determine how climate change is impacting food security in Canada
- To determine how climate change is affecting the health of our communities
- To identify those populations who are most at risk in our communities for food

Keywords

Keywords associated with Food Security — edit format here

- Key words: “climate change”, “environmental health”, “Health literacy”, “climate impact”, “sustainability”, “environmental stewardship”, “food security”

1. What is food security?

Food security exists when all people have physical and economic access to adequate amounts of nutritious, safe, and culturally appropriate food to maintain a healthy and active life [1] (IFPRI 2022).

Climate change and food security individually and collectively pose risks for Canadians. Human-induced climate change is already affecting many weather and climate extremes in every region across the globe [2](Bush 2022). Changes in climate weather patterns such as global warming and the frequency and magnitude of wet/dry events, including drought, forest fires, and damage to food production, are increasingly impacting Canada and challenging food security globally[2] (Bush 2022).

In Canada, approximately 12.6% of households were food insecure in 2011–2012, constituting approximately 2.8 million adults and 1.5 million children under 18 [3](Tarasuk et al. 2014). These challenges are disproportionately impacting vulnerable populations, including those living on First Nations reserves, service members of the Canadian Forces, those in custody, including prisons or care facilities, and the homeless population [4](Jessiman-Perreault et al. 2017)

Climate change is leading to changes in our environment and impacting food security across Canada, particularly in areas where regional and geographic challenges exist. These include a decreasing number of food stores in rural Canadian communities and the increasing cost of a healthy diet exacerbated by the expense of travel [5] (Drouin 2009). Challenges with food availability are especially true in northern communities that rely on importing and hunting foods, both of which are tied to the environment [6](CCA 2014). Changes in ice thickness reduce access to traditional hunting and fishing grounds for northern indigenous populations. Changing weather patterns can pose significant safety risks for those living in remote locations or navigating ice roads [6][7][8](CCA 2014, Ford et al. 2009, Centre for Indigenous Environmental Resources 2006). Within Canada's remote northern communities, the cost of foods transported over long distances is significantly inflated, contributing to higher prices and, in some cases, unaffordable market foods. [5][9](Drouin 2009, Erber 2010). Declines in food availability are not merely related to access and cost of market food but include a reduction in the local animal population, including traditional foods like caribou. These factors, combined with lower socioeconomic status, leave many of our most vulnerable people at risk for food security [6][7] (CCA 2014, Ford et al. 2009).

The impact of climate change will continue exacerbating these pressures on those currently struggling with food insecurity. For example, the island of Newfoundland has the lowest number of farms in Canada and the lowest average farmland per total area. Currently, 71% of food in the province is imported from the rest of Canada and around the world. Food shipments generally arrive via ferry service and are limited to 2-3 days' worth of fresh vegetables. Eighty-four percent (84%) of communities in Newfoundland & Labrador do not have an established grocery store [10](FoodFirst NL 2022).

Climate Change and Food Systems in Canada

Canadians represent about 0.5% of the global population, produce about 1.5% of the food in the world, and consume about 0.6% of world food production (Stats Can 2008). In 2004, Canada ranked 8th in the world for cereals, including wheat, barley, and oats; 10th in meat production; and 19th in fisheries and aquaculture production (Stats Can 2008). As the global population increases, the interdependency of food, energy, water, land and biological resources becomes more apparent.

Canada's role in global food production still allows it to produce 70% of its food domestically, including 80% of the meat and dairy products and 76% of the bread and cereals Canadians consume (Ghanem 2008). Imports account for 40% of fish, fruit, and vegetables (Ghanem 2008).

All foods are not created equal, and our reliance on imported fruit and vegetable production is particularly vulnerable to climate change. These foods, which constitute a significant part of Canadian imports, play an essential role in our overall health as lower fruit and vegetable consumption is linked to several metabolic health conditions (Harrison 2020).

With higher global temperatures, crop yields and the quality of these products are expected to diminish, especially in tropical and semi-tropical regions (Shukla et al., 2019). Changing temperatures impact fruit and vegetable crops differently, with warming temperatures reducing fruit crop output and speeding the growth of annual vegetables (Shukla et al., 2019). Faster crop growth is not necessarily a positive variable for vegetables, as changes in harvesting times, loss of quality and shifts in supply chain availability lead to more significant food loss and waste (Mbow et al., 2019). Adaptation to longer, warmer growing seasons is possible and can lead to greater yields of some crops; However, many plants require seasonality and cold periods to produce good products (Mbow et al., 2019).

Climate change may increase the ability for Canada to produce certain crops. Climate change data has shown that yields of some crops (e.g., maize and wheat) in many lower-latitude regions have been affected negatively by observed climate changes. In contrast, in the higher-latitude areas, yields of some crops (e.g., maize, wheat, and sugar beets) have been affected positively over recent decades (Mbow et al., 2019). However, the increase in CO_2 accompanied by higher temperature is projected to lower nutritional quality in many crops (e.g., wheat grown at 546–586 ppm CO_2 has 5.9–12.7% less protein, 3.7–6.5% less zinc, and 5.2–7.5% less iron) (Porter et al., 2014). Increasing temperature extremes and variability, changes in precipitation patterns, and extreme weather events can all cause damage to crops, reducing productivity and decreasing yield (Vodden 2021). For example, the Canadian Prairies are seeing reduced groundwater quality and quantity as rainfall accumulation during peak growing months is decreasing and necessitating additional crop irrigation (Vodden 2021).

Canada has been no exception to climate change-related weather events. In 2021 a Calgary hailstorm and flooding in the province of British Columbia flooding resulted in a combined insured loss of $2.01 billion. These disasters constituted Canada's most significant cost related to climate change events

(Canada’s Food Price Report 2022).

Global warming causes significant negative impacts around the world. Warming compounded by dry conditions caused significant adverse effects on yields in parts of the Mediterranean. Based on indigenous and local knowledge (ILK), climate change affects food security in drylands, including those in Africa, Asia, and South America (Mbow et al., 2019).

Climate change challenges globally are impacting food security. Food price increases of 5% to 7% in 2022 have marked the highest increase in food prices since the creation of Canada’s Food Price Report. All indications are that the global supply chain is being impacted, and climate change is a significant factor (Canada’s Food Price Report 2022).

Food Security, Climate Change and Health

The linkages between food security and health outcomes have been well documented. Birth outcomes and maternal health, child development, chronic diseases, mental health, emotional wellbeing, and even increases in health care costs may emerge in food insecure households (Li et al. 2016). Food security includes both access to food and adequate nutrition from food (Friel et al., 2019). Dietary risk factors resulted in more than 800,000 years of disability and the death of approximately 48,000 Canadians (Tarasuk et al., 2015). In Canada, an unhealthy diet is now considered a leading risk for death and disability (Bacon et al., 2019). Many of our most vulnerable community members struggle with food security. Organizations such as food banks are essential in providing immediate solutions to severe food deprivation. However, they are limited in their capacity to improve overall food security outcomes due to the limited provision of nutrient-dense foods in insufficient amounts, mainly from dairy, vegetables and fruits thereby impacting an individual’s health and wellbeing (Bazerghi et al. 2016). The increasing availability of processed and convenience foods has led to over half of Canadians consuming diets that exceed the recommended levels of sugar, saturated fats and sodium (Bacon et al., 2019). These unhealthy diets have also tended to lack appropriate intakes of whole grains, nuts and seeds, fruits, and vegetables (Bacon et al., 2019).

Food availability is only part of the challenge as the quality of food produced is being impacted by climate change. Although numerous studies over the years have indicated that increasing concentrations of atmospheric CO2 can increase photosynthesis resulting in higher crop yields, research has also shown that it could have adverse effects on the nutritional content of some crops (Porter 2015, Ziska 2015, Meyers 2017). Food crops subjected to high CO2 levels have shown decreased concentrations of protein, iron, zinc, and critical minerals (Porter 2015, Ziska 2015, Meyers 2017).

As a changing climate impacts the locations and conditions under which food grows, it may also influence the types and frequency of pesticide use (USGCRP 2014). Higher water temperatures and estuarine salinities have enabled an oyster parasite to spread farther north along the Atlantic coast (USGCRP 2014). Changes in arctic temperatures have led to new pathogens, viruses, and parasites that

impact wildlife, including salmon diseases in the Bering Sea and the Yukon Chinook Salmon (USGCRP 2014). Finally, warmer temperatures have caused disease outbreaks in coral, eelgrass, and abalone, among other sea life (USGCRP 2014).

Household food insecurity has well-established adverse effects on mental health, which is an example of the implicit impact of climate change that may go unrecognized. As the levels of food insecurity grow higher, so does the risk of adverse mental health conditions (Jessiman-Perreault et al., 2017)

The Role of the Physician

Medical experts who work directly with the public play an important role in improving the health literacy of their patients. As advocates for more sustainable approaches to food security in our communitiesthese individuals can provide essential information on diet and nutrition by referring the patient to dietitians and allied health team members. In turn, allied health team members promote lifestyle changes which can have a positive impact on the overall health of the patient.

Efforts to promote healthy plant-based diets and gardening among patients have resulted in improved health outcomes and a treatment model template that other health care practitioners can use.

CBC – Absolutely Canadian – Plantify Episode. Season 19 Episode 7, 2018. Absolutely Canadian – Plantify (CBC, 2018)

Climate change is directly impacting food security in Canada and around the world. Populations with decreased access to healthy foods, more significant challenges concerning socioeconomic health, geographic isolation and cultural reliance on the environment will face even greater climate change-related threats to their way of life and overall health.

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2.

11
Water Security and Climate Change

Authors: Hilda Swirsky

Learning Objectives

At the end of this section the student should be able to:

- Determine how climate change is impacting water security in Canada
- Determine the components of water security
- Determine how water security is impacting the health of our communities including equal accessibility to income and food security
- Identify those populations who are most at risk in the communities and most vulnerable to water insecurity

Key Words

The important keywords for this chapter are:

- Water Security, climate justice, traditional knowledge

What is water security?

Water security is an essential element for all ecosystems. Without it, individuals cannot maintain well-being and communities cannot remain healthy.

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://pressbooks.library.upei.ca/planetaryhealth/?p=693#oembed-1

Achieving and s impacts the physical, psychological, economical, spiritual, religious and cultural traditions affecting our overall well-being, productivity and food security.
On March 22, 2013, UN world-wide experts, on the UN Water Task Force, developed and defined water security as" The capacity of a population to safeguard sustainable access to adequate quantities of and acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability." Going beyond this definition is the beneficial impact of water security on the spiritual and cultural components of our health and well-being and for the Indigenous populations, they believe that water is sacred. (Khayat & Diego 2021).
The Jewish population identifies water as a fountain of blessings and life.

Impacts on water security Groundwater resources represent more than 90% of fresh water and up to 40% of drinking water. (United Nations 2006). An interactive H5P element has been excluded from this version of the text. You can view it online here: https://pressbooks.library.upei.ca/planetaryhealth/?p=693#h5p-9 One of the Sustainability Development Goals, the UN is striving to achieve by 2030 is Sustainability Goal #6, the goal of ensuring availability and sustainable management of water and sanitation for all. This goal of

having universal and equitable access to safe and affordable drinking water for everyone is especially critical and essential when the impacts of climate change include the unpredictability of changing precipitation patterns including seasonal redistribution and changing times, duration and properties of precipitation and reduced snow cover and rapid loss of glaciers melting, increasing risks of floods and drought and changes to the availability of fresh water and the health of our oceans. (Martin & Volt, 2019) Canada's rate of climate warming is among the highest in the world resulting in rising sea levels, rapid warmth of water temperatures in cold regions and therefore unpredictable guides to reliable water availability and unreliability of warming water temperatures, decreasing or increasing rainfalls and extreme weather events such as sudden, severe storms, flooding, drought and mudslides, freezing rain and ice storms and therefore adapting and mitigation will impact whether or not we meet Sustainable Goal #6.(Martin & Void, 2019, Schuster-Wallace, Sandford, Merrill, 2019, Berry et al, 2014).

Climate change challenges to water security:

There could be decreased access to available food as oceans become more acidic impacting shellfish and their ability to build shells which will also threaten vast fisheries. (Fisheries and Oceans Canada. Video). As we see already, this can result in increasing food costs as food security is impacted. (Marshman, Blay-Palmer & Landman (2019).

Recently, Hurricane Fiona has been a devastating example

of the threat to coastal communities becoming a reality when it arrived in the Maritimes on September 23d and 24th 2022, This is only one incident of the destruction and damage that could more frequently take place because of climate change. Parts of Prince Edward Island, Nova Scotia and Newfoundland were all affected after it had travelled from Puerto Rico. Cape Breton in Nova Scotia and Port Aux Basques in Newfoundland were hit the hardest. As of October 20, the Canadian Red Cross has provided emergency shelter to 1200 individuals and registered more than 95,000 households impacted by the hurricane (Canadian Red Cross, 2022). Nova Scotia's Emergency Management Office reminded Nova Scotians that floodwaters have also impacted food safety and that drinking water coming from untreated, non-municipal water sources such as lakes, rivers and streams should boil their water before consuming it. (Government of Nova Scotia, Emergency Management Office, September 24th). CTV News Atlantic reported that the Insurance Bureau of Canada stated that this is the most costly extreme weather event recorded in Atlantic Canada affecting high risk flood areas and flood plains. Initial insured damage is recorded at $660 million (CTV Atlantic October 19th, 2022)

As sea levels rise and arctic ice melts providing the possibility of Artic passages, there will be an additional risk to our peace and security as opposing countries may decide to weaponize water as is currently being done in the Ukraine.

Which populations will be impacted the most: children, pregnant women, seniors, Indigenous people, low

socioeconomic populations and people will chronic illnesses ** Climate justice removed from here For example, in this water rich country of Canada: The Council of Canadians still reported 34 long term drinking water advisories on reserves (Safe Water for First Nations): Retrieved October 20, 2022 from https://canadians.org/fn-water/

Indigenous populations stewardship in water security

The policy brief Indigenous people, water, & climate change (2020) pinpoints that Indigenous populations are custodians to many fragile, important water ecosystems and headwaters where they live. They see water as a living entity and have a powerful ethical connection to water stewardship built on their social-cultural values. We can learn from their traditional knowledge about climate resilience and how women keep the traditional ecological knowledge and they deserve to be respected.

Water insecurity:

Affects food security as waters become warmer and there are also fluctuations in agricultural yields and the stress on agriculture. Warmer water temperatures also increase the growth of toxic blue-green algae that kills off marine life. (Martin & Vold, 2019)

Role of Physician:

Physicians and nurses, as the two biggest health care providers, have a critical and collaborative role to play in advocating for the Sustainability Development Goals including the goals that link with water security such as food security, health and well-being, gender equity and climate action As respected leaders who work in

interdisciplinary communities, actions for equitable planetary health are priorities.
Powerful actions include being a committed, influential consumer and voter buying products and voting for Planetary Health.
Physicians share and convey their knowledge of Planetary Health to patients, the public, politicians, faith groups, academics and emphasize the vital importance of Planetary Health.
Caring, empathetic culturally sensitive physicians are aware of the impacts of climate changes on a patient's mental, physical, spiritual and economic insecurities especially if there is grief and loss of their home, their forced change in residence and livelihood.
Physicians assist pregnant women to keep adverse birth outcomes to a minimum for example< recommending and encouraging that they get enough rest since getting enough rest is difficult to do. (Howard, Rose, Rivers (2018)
Physicians can enlighten everyone about the importance of emergency preparedness and direct the public and our colleagues to local resources such as local farms and contributions to local food security especially if patient and family are climate migrants who have been displaced and lost everything because of an extreme weather event.
Physicians can learn, understand and teach climate science in order to educate the public, our patients and our governments in calling for meaningful actions and in the importance of community-building and a community response.

Collectively, physicians can join an organization such as the Canadian Association of Physicians for the Environment and support actions for a healthy planet such as writing letters to the editors or signing petitions.
Physicians can keep track of the spread of diseases due to climate change such as West Nile Virus spreading northward
Physicians can learn and incorporate Indigenous values into their environmental work.
Physicians will be dealing with a high percentage of mental health traumas and distressed communities when dire climate change events has drastically impacted their mental health and well-being becoming a risk amplifier disrupting important supports for good mental health. (Lawrence, Thompson et al, 2022). Symptoms may include post-traumatic stress, grief from devastating losses of homes, livelihoods, friends and having to start all over again and may not even have clean water to drink. (McCue, D. 2018). Patients may have eco-anxiety, eco-paralysis or solastalgra. (Albrecht 2011). Striving to provide a respectful, secure place for discussion of water challenges that impact everyone, the University of Saskatchewan's Virtual Water Gallery has been a Global Water Funded pilot project that scientifically addressed past, current and future water challenges by combining both science and art in a safe, inclusive, considerate and collaborative space for discussions between scientists, artists, and the general public. The outcome of this gallery space resulted in creative art pieces designed by the artists in a variety of media exhibited for all to see, to

interact with and to converse about water challenges.(Arnal, Pomeroy et al, 2020).

Conclusions

To achieve the UN's Sustainable Development Goals, respected, knowledgeable physicians, who are leaders and role-models, will unite in interdisciplinary collective, collaboration actions, speaking out as agents of change and advocacy, teaching and caring for patients and their communities and interacting with decision-makers in continuing necessary conversations and actions to achieve the human right to have equally accessible, secure clean water.

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12
Sustainable Healthcare Delivery

Reshef-Kalogirou, M., and Campbell, A.

What's in this chapter?

The Material in this chapter is organized into two main sections.

The first section reviews the importance of practicing conscientious and sustainable healthcare delivery.

The second section reviews the important information related to working toward interprofessional problem solving and being an advocate for community development (the built environment).

Learning Objectives

After reading this chapter the learner should be able to:

1. Define sustainable healthcare delivery
2. Identify current leaders and initiatives in sustainable healthcare
3. Define co-benefits and describe how co-benefits relate to health
4. Define the built environment and identify the role of different disciplines within the built environment

Keywords

Essential Key words for this chapter include:

- sustainability
- sustainable healthcare
- healthcare delivery
- health outcomes
- conscientious healthcare
- green healthcare
- built environment
- interdisciplinary collaboration

Section 1: The importance of practicing sustainable healthcare delivery

Background

In 2015, pollution was estimated to be responsible for 9 million premature deaths; which comprised 16% of global deaths (Landrigan et al., 2018). According to the Lancet Commission on Pollution and Health report (2018):

Exposures to contaminated air, water, and soil kill more people than a high-sodium diet, obesity, alcohol, road accidents, or child and maternal malnutrition. They are also responsible for three times as many deaths as AIDS, tuberculosis, and malaria combined, and for nearly 15 times as many deaths as war and all forms of violence. (Landrigan, et al., 2018, p. 1).

Many of the pollutants that harm our health are major greenhouse gasses (GHGs) and are harming the health of our planet's natural systems (Landrigan, et al., 2018). Human sectors contribute to the emission of these pollutants and GHGs, with healthcare being a top emitter. In fact, it has been suggested that if the global health sector were considered a country and its emissions were compared to that of other countries, it would be the fifth-largest emitter in the world, responsible for approximately 4.4% of global net emissions (Healthcare Without Harm [HCWH] & Arup, 2019). Besides harming our natural systems and being a significant contributor to climate change, these GHGs and pollutants are linked with negative human health outcomes. In Canada, it is estimated that healthcare emissions alone result in 23,000 disability-adjusted life years lost annually (Eckelman et al., 2018).

Interestingly, when ranked against other national healthcare systems, Canada's health sector is considered the 9th worst GHG emitter. However, if you look at emissions on a per capita basis, one begins to see a different picture; Canada's health sector is the second highest GHG emitting healthcare system on a per capita basis. In other words, while in total our health system does not emit as much as other health systems do globally, when emissions are examined on a per capita basis (i.e., on the basis of how many emissions are produced on the basis of each individual healthcare user), Canadians are emitting significantly more GHGs (over 1 metric ton of carbon dioxide emitted per person) than citizens of other countries. This indicates that the Canadian health sector still has a great deal of work to do in terms of developing a healthcare system that is sustainable and promotes the health of our natural systems and humanity.

Generally speaking, the health sector's main purpose around the world is to protect and promote human health, but due to its significant emissions, it can be paradoxically stated that the health sector, directly and indirectly, harms human health. Moreover, the health sector's organizational systems and structures are extremely vulnerable to the effects of climate change (Smith et al., 2014). Considering healthcare's climate vulnerability and its moral and ethical mandate to support, protect, and maintain human health, it is clear that now, more than ever, there is a critical need for a healthcare system that is sustainable and driven by a planetary health perspective.

Healthcare professionals (doctors, nurses, midwives, and others) are essential players in the development of sustainable healthcare systems as they are uniquely situated to be leaders in this field. These professionals both act on what science and research demonstrate as best evidence and speak with ethical and moral authority. Healthcare professionals are often the most trusted professionals in the eyes of the public and can help persuade people and nations to reduce their emissions and strive for a healthy planet. "Most importantly, they are powerful advocates for the very thing that people worldwide care about most and are most threatened by climate change: our health and well-being and that of future generations" (Al-Delaimy, Ramanathan, and Sanchez Sorondo, 2020, p. 396).

Healthcare Emissions

Generally speaking, every country's health system, directly and indirectly, emits GHGs via product procurement, active care delivery, and services and technologies from a carbon-intensive supply chain (HCWH & Arup, 2019). The most significant source of emissions (71%) are derived from healthcare's supply chain via production, transportation, and disposal of goods and services such as pharmaceuticals, food and agricultural products, medical devices, hospital equipment, and instruments. (HCWH & Arup, 2019). Another 17% of emissions result directly from healthcare facilities and vehicles owned by health organizations. The final 12% are indirect emissions that are derived from purchased energy, such as electricity, steam, cooling, and heating (HCWH & Arup, 2019). "Fossil fuel consumption is at the heart of health care's emissions. Energy — primarily the combustion of fossil fuels — makes up well over half of health care's climate footprint when measured across all three scopes" (HCWH & Arup, 2019, p. 4).

Theoretical Models

We can use theory to help guide our thinking regarding the problems and solutions related to the development of sustainable healthcare systems. Theory gives us a unified starting point when examining sustainable healthcare systems. We propose Systems Thinking Theory as one that is useful for our explorations.

Systems Thinking Theory

Traditional healthcare systems and education have been built on mechanistic, cause-and-effect scientific models. While historically helpful, these models are limited in that they "do not fully explain the complexity of humans, our relationships and the interconnectedness of all life" (Al-Delaimy, Ramanathan and Sanchez Sorondo, 2020, p. 213). If we are going to succeed in promoting planetary health and limiting the pressure humanity is placing on our planetary boundaries (Image 1), a more holistic model of health is necessary. Planetary boundaries refer to the limits placed on our planet via anthropogenic forces (i.e., climate change, freshwater usage, land-system changes, etc.); there are safe operating zones, zones of uncertainty, and beyond the zones of uncertainty that identify high risk to planetary health (Steffen et al., 2015). A holistic model of healthcare suggests that we are dynamic, social, and complex beings that are in constant, intimate relationships with all other living things on Earth. "Individual, community and planetary health are inseparable" (Al-Delaimy, Ramanathan, and Sanchez Sorondo, 2020, p. 213). This holistic perspective is at the heart of planetary health and is necessary for the development of sustainable healthcare; we require a health system that promotes

both human health as well as the health of our planet and its natural systems.

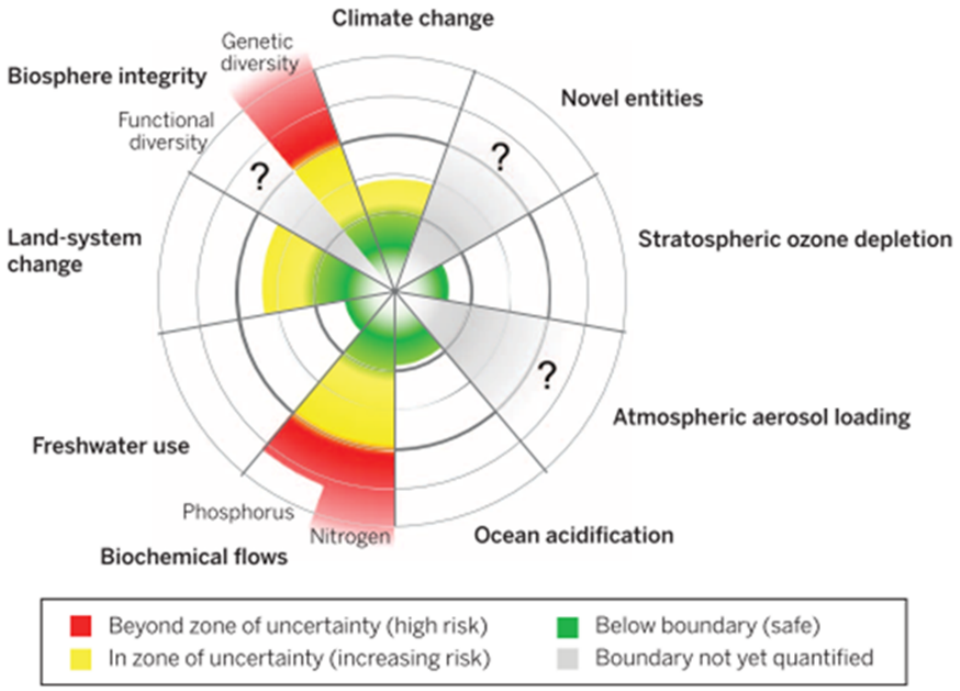

Image 1: Planetary boundaries (Steffen et al., 2015)

What is Sustainable Healthcare?

To start, the term sustainability should be understood. Knut et al. (2013) state that sustainability is a complex term with consistent themes in the literature, such as the idea that we need to work on things now so that we (and future generations) can enjoy them in the future. This idea brings about a sense of longevity, resilience, cycles, and permanence; "a steady-state approach rather than a frontier mentality" (p. 17). Sustainability is concerned with relationships and the interconnectedness of our planet and its natural system; it is concerned with resource preservation, reducing our consumption, and appropriate disposal of waste products. When we think sustainably, we acknowledge the planetary boundaries and look for ways to thrive while remaining safely within them; we view humanity as guardians of the planet's natural systems and resources, not as its owners. Finally, there is a distinct leaning towards upholding social justice. In other words, sustainability inherently recognizes that it is unjust for some communities to exploit the earth's natural resources at the expense of others.

Sustainable healthcare, then, refers to the delivery of healthcare services that does not put detrimental stress on either human or natural systems (Knute et al., 2013). It is a style of healthcare delivery that consciously works at promoting planetary health by reducing its GHG emissions, waste, and overall

environmental impact. Health systems can achieve this through various methods, and some examples include retrofitting buildings so that they run on more sustainable sources of energy, offering more plant-based meals for patients and their families as it is known that meat and associated farming practices are extremely carbon intensive, reducing consumption of resources and materials and properly diverting waste, paying attention to transportation GHGs associated with either health system processes (e.x., driving lab samples to a local laboratory for analysis) or with travelling to/from the health building (e.x., patients travelling to the hospital to access medical services or healthcare employees getting to work), and addressing and de-carbonizing the supply chains associated with procuring healthcare equipment and resources. This is not an exhaustive list, and there are many ways to reduce healthcare's planetary impact when paying attention to these areas and beyond. In fact, several leaders are already starting to do this important work.

Organizational Leaders in Sustainable Healthcare

There are many leaders in this field who are already helping develop sustainable healthcare systems around the world, such as the Canadian Coalition for Green Health Care (CCGH) and Health Care Without Harm (HCWH). The CCGH is a national group that works closely with individuals, agencies/organizations, and others who are actively involved in healthcare delivery by sharing best practices related to sustainable healthcare delivery. HCWH works with healthcare delivery leaders and supports them in several areas: Canadian health sector data collection, green leadership, green purchasing, health and environment, local and sustainable Foods, safer chemical policies/toxics reduction, sustainable buildings, sustainable energy and GHG, sustainable transportation, and finally, waste management and minimization (Canadian Coalition for Green Health Care, n.d.).

HCWH's main mission is to transform healthcare worldwide so that the sector can be a world leader in the global movement for health and justice (Health Care Without Harm, n.d.). More concretely, they have actively made international healthcare systems more sustainable through various initiatives, including (but not limited to): a) helping close more than 4,400 incinerators that burned carcinogenic medical waste (which helped hospitals save money, reuse and reprocess resources, and utilize alternative waste treatment strategies); b) they launched the Health Care Climate Challenge – an initiative that has over 300 participating institutions (representing over 22,000 hospitals) across 40 countries committing to climate action; c) created the Greenhealth Approved program which helps healthcare providers quickly identify safe, sustainable products and thereby supporting them in making the often challenging decisions of whether a product is more/less harmful for the environment; and d) supported hundreds of hospitals in adopting the "green operating room" strategy, which helps save money and valuable resources while also reducing pollution and waste (Health Care Without Harm, n.d.).

Role of Healthcare Professionals

There are many different ways for healthcare professionals to assist with developing sustainable health systems. First, they must educate the public, developers, and decision makers about the health

consequences of ignoring planetary health. Second, health professionals should conduct research that explores and expands the intersection between planetary health, climate change, climate action, and healthcare. This research must be translated into easy-to-read/understand material for the public so they can also incorporate this information into their daily lives (Kalogirou et al., 2021; Landrigan et al., 2018). Finally, and perhaps most importantly, health professionals must advocate for planetary health.

Research suggests that advocacy requires both a top-down and a bottom-up approach (Kalogirou et al., 2021). In other words, while significant change is required to come from decision-makers and leaders in the health sector (top-down), health professionals and even healthcare users need to advocate for the prioritization of planetary health and push leadership in this direction (bottom-up). Without this bottom-up advocacy and a clear demonstration from health professionals that planetary health is important to strive for, it is unlikely that decision-makers will make the necessary changes in a short enough time frame. One clear way for healthcare professionals to advocate for the integration and prioritization of planetary health is to "reclaim [their roles] at the heart of environment and development policies, taking a more proactive approach." (Al-Delaimy, Ramanathan and Sanchez Sorondo, 2020, p. 97). For example, nurses in one study objected to the practice of disposing of narcotics down the drain; they recognized that the narcotics were getting into water systems and harming surrounding natural systems (King and McCue. 2017). The nurses advocated for a change in policy and a change in what it meant to properly dispose of narcotics in their workplace. Another example includes doctors who objected to the use of certain anaesthetic gasses in the operating room on the premise of them being harmful GHGs. These doctors also advocated for changes in policy and practice to support the health of the planet as well as humans (Özelsel, Sondekoppam & Buro, 2019.

Outcomes of Sustainable Healthcare

The outcomes of sustainable healthcare are perhaps best explored through the lens of co-benefits. According to Knute et al. (2017), co-benefits have a triple bottom-line: healthy planet, healthy people, and economic profit. In other words, co-benefits are actions that are good for the planet and for either human health or the economy. "Substantial health gains can be achieved from taking action to prevent climate change… [and pursuing] efforts to limit temperature increase to 1·5°C could make economic sense in some scenarios and countries if health co-benefits are taken into account" (Markandya, Sampedro, Smith, Van Dingenen, et al., 2018). An example of a co-benefit is related to Canada's plans to phase out coal-fired power by 2030; this will avoid more than 1,000 premature deaths associated with corresponding air pollution and yield an additional $5 billion in health benefits by 2035 (Environment and Climate Change Canada, 2021).

Add picture here

We need another paragraph here I think that explicitly talks about the connection between sustainable health systems and the benefits that brings to populations… but I will need more time to finish this. So

this is a placeholder for that paragraph. I will generally discuss co-benefits related to health – less GHGs emitted = better air quality = better lung and heart health. Encouraging health users and employees to use low-emissions forms of travel (car-pooling, biking/walking/active transportation, light rail train) = less GHGs emitted and more exercise (biking/walking) = better health. Including more plant-based meals within health facilities for patients, families, and staff = lower GHG emissions related to food = better health through diet. Green roofs, retrofitting building, composting, presence of gardens (that can be used to help support meal services) = lower emissions and carbon reduction = better health and better mental health (more green spaces = better mental health).

Health Professionals and the Built Environment

The environment is more than an area's trees, cars, people, and wildlife. It represents the totality of life and various interactions among and between people and any area of the planet. There will be profound impacts on the environment of future generations that are derived from decisions made in the past and today. The built environment consists of many features that have been constructed and modified by humanity. For example, how rooms are laid out, the construction of homes and various land uses in a neighborhood. The built environment even extends to the structure of neighborhoods in metropolitan areas, to the way regional and national geography and infrastructure interact to protect from natural disasters.

The built environment provides a blueprint for how our daily lives are conducted, it influences health across life spans (both human and animal), and represents important pathways through which individuals come into contact with many health risks. There is growing evidence that some environments promote health, while others increase morbidity and mortality. However, the associations between the built environment and health have only been examined closer over the past two decades, and efforts to implement interventions to address health concerns pertaining to the built environment are only in their infancy (Elf, Anåker, Marcheschi, Sigurjónsson, & Ulrich, 2020; Lopez, 2012).

Features of the built environment reflect the interplay of economic, political, and other similar factors. Some of these factors directly influence the built environment; others are more indirect. These include, but are not limited to:

- Laws: development takes place within a legal and constitutional framework
- Geology: soils, coastlines, tectonic factors
- Economics: economic trends, incomes, local economic factors
- Personal and societal values: neighborhood preferences, social factors
- Health assumptions: beliefs regarding causes of morbidity and mortality
- Ideology and political theory: theories of poverty, personal liberty, private property
- Technology: automobiles, Internet, pollution prevention
- Science: research, theories

Collaboration between interdisciplinary professionals (i.e., healthcare providers, welfare, social work)

are becoming key elements to support the built environment through efficient and productive efforts at promoting health. Interprofessional teams have been found to increase provider and patient satisfaction, reduce the number of medical errors and other patient safety issues, promote workforce retention and reduce system inefficiencies resulting in higher costs. (Al-Delaimy, Ramanathan and Sanchez Sorondo, 2020; Lopez, 2012). The table below summarizes different professional groups that contribute to the built environment, and their roles.

TABLE 1. Healthcare Without Harm

Area of Interest	Description
Public Health	Closely related to but broader than medicine, public health is concerned with the health of groups as well as individuals; practitioners focus more on prevention of disease and preservation of health than they do on diagnosis and treatment of individual illnesses. Public health professionals conduct studies, design interventions, administer programs, and evaluate services.
Architecture	Architectural practice can range from the design of open spaces (usually referred to as landscape architecture) to the design of individual buildings, neighborhoods, or cities. As will be seen, architecture is heavily influenced by theories of design and has a long history of trying to improve health. However, it should be noted that architects are not the only designers of buildings. Many are designed by engineers, and the design of buildings in developed societies is heavily shaped by building and other safety codes.
Ecology	Ecological analysis and environmental science have played an important role in shaping the built environment. Through its tools that include the concept of an ecosystem being a series of energy flows, for example, it assists in the understanding of how the built environment can shape human behavior.
Economics	There are many subfields within economics and though some may seem far removed from the study of the built environment, even the most distant can provide insight on the impacts of the built environment. For example, macro economics, which includes the size and rate of expansion of the money supply, can have an impact on the built environment through interest rates, which can either promote speculative building or severely curtail construction activity.
Epidemiology	This subfield of public health focuses on the factors that cause, prevent, and may influence disease. Epidemiology is a technical field that uses a number of statistical and other techniques that aim to provide basic scientific evidence that may inform health practice and public policy.
Landscape Architecture	Landscape architects tend to design the outdoor spaces for a given project or for a larger community. They may often work closely with architects and urban designers in these efforts.
Law	The legal framework of a society profoundly impacts what can be built where. Therefore the study of the law, the identification of how laws are made and how they have been implemented, can assist in our understanding of how the built environment is constructed or how it can be improved.
Medicine	Physicians are on the front line of diagnosing and treating disease. Though many doctors also have public health degrees and work extensively in public health, most physicians' preventive health services are performed on the individual rather than the population level.
Nursing	Nurses work with physicians and others to provide direct care to patients. Many nurses also work on the population level to help address health risk behaviors and other types of preventative interventions.
Sanitary Science	Taking their name from the great sanitary surveys of the nineteenth century, sanitarians are those professionals involved in implementing laws and regulations meant to protect public health, including food safety, water quality, and other similar types of inspections and enforcement.
Sociology	Sociologists, along with their colleagues, anthropologists, study the rich texture of human interactions and how individuals see themselves in relationship to others. They also study human behaviors and the behaviors of groups.
Urban Design	An urban designer often works on the overall physical appearance of, and relationships between, buildings, streets, and open spaces over an area that can range from an individual parcel to an entire community. In contrast to urban planners, who tend to focus on programs and policies, urban designers usually produce plans and design guidelines targeted to a specific location.

Area of Interest	Description
Urban Planning	This field aims to shape and influence the overall nature of neighborhoods, cities, and metropolitan areas. Many urban planners focus on designing and implementing policies and programs that promote economic development, create affordable housing, provide emergency services, administer public programs, manage infrastructure, plan transportation improvements, and so on.

(Lopez, 2012)

13
Anti-Microbial Resistance and Food Safety

Authors: Daley, P.

Introduction

Antimicrobial Resistance (AMR) among bacteria which cause human infectious disease has emerged among the top ten leading threats to global public health as defined by the World Health Organization, associated with 4.95 million deaths in 2019,1 which is projected to increase to 10 million deaths by 2050.2 With a declining rate of new antimicrobial discovery due to low product profitability for the pharmaceutical industry,3 AMR threatens the efficacy of current antimicrobials and the current standard of medical care that relies on effective antimicrobials. AMR is caused by many factors, the leading factor being selection towards expression of antimicrobial resistance genes (ARG) within the community of microbial flora (microbiome), due to antimicrobial use (AMU). Beside implications for human health, increasing AMR may impact animal health, climate change, global trade and sustainable industries.

Antimicrobial stewardship has emerged as one solution, leading to a five percent reduction in AMU among humans in Canada between 2015-2019.4 The COVID-19 pandemic was also associated with a significant reduction in AMU among humans.5 However, global AMU rate is increasing and is highly variable between countries.6 Reduction in AMU may reverse AMR, but other strategies including reduction in transmission, sanitation, access to clean water, accurate diagnostics and migration must

also be considered.7 With evidence that AMU among animals may contribute to AMR among humans, a One Health strategy has begun to define new interventions including antimicrobial stewardship. One Health considers the intersection between the health of humans, animals and environment, including social, political and economic contexts.8

AMR among food animals threatens the safety of the food production industry because AMR may be transmitted from animals to food consumers and food industry workers. Food safety is an essential fundamental to the achievement of the United Nations Sustainable Development Goals, and food safety impacts food security, animal health, the environment, climate change and socioeconomic development.9 Because AMR can be transmitted between animals, humans and the environment, AMR impacts planetary health.

Antimicrobial Use and Antimicrobial Resistance among Food Animals

Eighty percent of antimicrobials produced in the USA are given to animals.10 AMU among animals is projected to continue to increase globally.11 Antimicrobials are given to food animals for growth promotion, prophylaxis and treatment of bacterial infections.12 Because antimicrobials are intended for treatment of significant bacterial infections, use for growth promotion and prophylaxis are considered inappropriate use. Because the food industry gains profit from the use of antimicrobials through increased production, there is a disincentive to control AMU.

AMR predates AMU, since AMR has been described from ancient soil, isolated caves, permafrost and the gut of preserved human remains dating from approximately 1000 AD.13-15 Where antimicrobials are present within food animal production at a concentration between mutant selection concentration (enough antimicrobial to induce gene expression and alter population phenotype) and growth inhibition concentration, AMR is selected among the animal microbiome.16 There is also evidence of AMR selection due to the use of disinfectants, biocides, and heavy metals used in the livestock industry.17 ARG have been identified in many food products, including meat, poultry and dairy products from high income and low income countries,18 and in aquaculture.19 AMU and ARG expression among food animals is not always correlated, as on Danish pig farms, antimicrobial exposure had both positive and negative influence on corresponding ARG expression.20

It is not clear if reducing AMU in the food production industry will reduce AMR among animals or humans, as available studies are observational, not randomized trials. In a meta-analysis of 29 studies, reduction in AMU among animals was associated with both reduction in expression of ARG and stable expression of ARG among human and animal flora.21 Mathematical models have been proposed to generate estimates of the relationship between animal AMU and human AMR.22

AMR transmission from food animals to environment

ARG carried in the food animal gut is transferred to the environment through the spreading of manure in fields, and the contamination of the surface of fruits and vegetables with soil, fertilizer and irrigation water. The concentration of ARG in industrial wastewater is similar to that in the human gut, and higher than in control soil, water and sediment specimens, indicating environmental contamination due to industrial antibiotic pollution.23 Bacteriophages in soil acquire ARG and transfer them horizontally between bacteria through transduction.24 Environmental flora may therefore represent a latent "bank" of ARG with the capability to impact human or animal health in future.

AMR transmission from environment to humans

The role of transmission of AMR from the environment to humans is not known. Many environmental organisms lack the virulence to colonize humans. ARG identified in the environment could not be directly correlated with human colonization.25 Furthermore the direction of transfer between the environment and humans could be bilateral.

AMR transmission from food animals to humans

AMR transmission from animals to humans may be a result of direct contact with animals, including animal or fish handlers or abattoir workers, or indirectly through food consumption. Direct transmission is more common in low-income countries, where close animal exposure is common, and indirect transmission is more common among high-income countries.18 Evidence of indirect transmission includes identification of genetically identical organisms present in animals and humans without occupational exposure to animals.26 However, this evidence does not implicate food as the cause of contamination.27

Foodborne Illness in Humans

Food may become unsafe during production, distribution, sale, preparation or consumption. Safe food does not cause harm to the consumer, because the food is free of damage, deterioration or biological or chemical agents.9 However, food which contains antimicrobials or ARG may be associated with negative health outcomes in humans, primarily affecting low and middle income countries.18

Foodborne illness is disease caused by ingestion of contaminated food or water, generally associated with lack of access to clean food and water supply. Foodborne illness caused 600 million human cases and 420,000 premature human deaths globally in 2010,28 disproportionally affecting children, pregnant women and elderly, with the highest incidence observed in Africa.29 Approximately 1,000,000 children die annually of diarrheal illness in South East Asia.30 The principle bacterial causes of foodborne

illness are Salmonella, Campylobacter and E.coli,31 organisms that are included in the World Health Organization list of priority pathogens identified as global AMR concerns.32 Besides gastrointestinal illness, foodborne urinary tract infection may be associated with gut colonization with resistant organisms.33

The impact of increasing AMR among food products on global human foodborne illness and death rates is unknown. If humans or animals are treated with antimicrobials for foodborne illness, but the antimicrobials are ineffective due to AMR, mortality may increase due to lack of treatment response. Many foodborne illnesses are not treated with antimicrobials, due to self-limiting disease or lack of access to treatment in low-income settings, so treatment failure due to AMR may not influence outcome among these cases.

Food Safety and Food Security

Increasing AMR among food products may impact the achievement of the World Health Organization Sustainable Development Goals focused on poverty, hunger and socioeconomic development, and may impact climate change. With global population projected to reach 11.2 billion by 2100,34 the loss of approximately one third of food production due to waste, and the high proportion of poverty and malnutrition,35 any reduction in global food production could impair food security. Food security is already poor in some low-income countries, where AMR rates are high.

If AMR reduces treatment effectiveness among animals, animal mortality due to endemic or outbreak infections could reduce food production and increase food prices. Modern industrial farming techniques may increase animal crowding and infection transmission, increasing the demand for AMU.36

The impact of AMR on global prosperity has been estimated at a loss of $100 trillion over the next thirty-five years,2 with the largest impact in low-income countries which have economies dependent on food production. Foodborne outbreaks have been associated with enormous financial impact.37 Disease outbreaks may create disruption in the trade of food between countries.38

AMR and the Environment

The use of antimicrobials in animal husbandry, agriculture and fish farming releases antimicrobials in their active form into wastewater, groundwater and soil.39 AMR associated with runoff is observed in river water downstream of cattle feedlots.40 The ocean is the largest reservoir of ARG in the environment, with higher concentrations observed in coastal runoff compared to runoff from forested areas.41 Recreational use of water during swimming, diving or watersports may expose humans to ARG. Sub-inhibitory concentrations of antimicrobials were detected on carrots and lettuce irrigated

with contaminated water.42 Manure fertilization is associated with AMR in soil, even if the manure is collected from animals not treated with antimicrobials.43

Animal agriculture is the second largest contributor of greenhouse gases, next to fossil fuel harvesting.44 Greenhouse gases contribute to climate change. Cows treated with the antimicrobial tetracycline produce increased methane, which is a greenhouse gas.45 Sixty percent of global fresh water and thirty percent of available land is dedicated to animal production.46 The demand for increased food production in the near future will increase demand for antimicrobial use and greenhouse gas production.

Conclusions

The evidence connecting observed increasing AMR rates in food with reduced food safety is emerging, but not definitive. Surveillance of AMR and AMU trends is a focus of new national and international programs. Many questions regarding AMR are unanswered, such as the relationship between AMU and AMR, the role of AMR transmission between humans, animals and environment, and the impact of AMR on human, animal and environmental health.47 Furthermore strategies to reduce AMR among the food production industry and the environment are also new. Appropriate AMU restrictive measures among animal production are being explored.48

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IV

PART 4: PLANETARY HEALTH IMPACT ON HUMANS

Chapters in This Section

In this fourth section, information will be presented that discusses the principles of Planetary Health with regard to relationships between humans and animals

- Chapter 14: Planetary Health and Infectious diseases
- ??

Chapter 15: Antimicrobial Resistance and Food Safety

- ??

Chapter 16: Effects of Climate Change on Mental Health

- ??

Chapter 17: Human development and health from a planetary health perspective

- ??

The Physician and Planetary Health

Wiesing U. Climate change and the different roles of physicians: a critical response to “A Planetary Health Pledge for Health Professionals in the Anthropocene”. Med Health Care Philos. 2022;25(1):161-164. doi:10.1007/s11019-021-10051-2

14

Planetary Health and Infectious diseases

Authors: Grynszpan, D., & Russell, R.

What's in this chapter?

- What are Emerging Infectious Diseases (EIDs)?
    - What is zoonosis?
- What are the epidemiological considerations?
- What is the relationship to human health? (acute and chronic)
    - Physical, mental, and social implications

Learner Outcomes

After reading this chapter you should be able to:

- List key modalities in which the ecosystem and human infectious diseases are interconnected
- Describe the impact that changes in the climate and the ecosystem can have on human infectious diseases
- Explain the emergence of novel human infectious diseases from zoonoses
- Recognize how physicians can apply knowledge of the relationship between planetary health and human infectious diseases to their clinical practice (through case studies?)

15
Effects of Climate Change on Mental Health

Nettan, A., & Fenech, A.,

What's in this chapter?
example … The material in this chapter will focus on anxiety and other aspects of mental health that are influenced

by climate change and extreme weather events.

Learning Objectives

After reading this chapter the learner should be able to:

use action words here — do not use understand …

1. Define …

Keywords

Essential Key words for this chapter include:

- climate change
- anxiety ….

Introduction

Plop — see chapter MWahl for Ziska reference — Climate change events are linked with increased psychological stress for those involved. Vulnerable communities include communities of colour, low-income populations, immigrants, and individuals considered to have limited english proficiency (LEP), all of whom are more likely to experience stress-related mental health impacts (Ziska 2015).
text goes here …

16
Human development and health from a planetary health perspective

Authors: Grynszpan, D., Kao, K., & Montelpare, W.

What's in this chapter?

- Defining human development and its impact on planetary health
- The negative consequences of planetary health on non-infectious diseases (chronic Disease: factors that affect the climate that also affects human health e.g. UV irradiation, environmental pollutants, Xenoestrogens, light pollution)

Learner Outcomes

After reading this chapter the reader should be able to:

- Provide a definition of human development from a variety of perspectives
- Understand the effect of human development on Planetary Health
- Understand the effect of Planetary Health on human development
- The importance of practicing conscientious and sustainable healthcare delivery

After reading this chapter the learner should be able to:

1. Define and understand sustainable healthcare delivery
2. Understand the principles and practices related to sustainable healthcare delivery
3. Understand how sustainable healthcare delivery impacts health outcomes in various healthcare settings

Key Words

Type your key takeaways here.

- First
- *sustainability, sustainable healthcare, healthcare delivery, health outcomes, conscientious healthcare, green healthcare*

Understanding the Importance of Human Development on Planetary Health

What is Human Development?

- Is human development specifically fetal growth resulting from environmental conditions that influence the intrauterine development of the fetus (Olusanya, 2010; Eriksson, 2005)?

- Does human development refer to the physical and intellectual growth within the human species that is measured in metrics which can include but is not limited to body mass indices and cognitive achievements (Dordic, Tubic, and Jaksic, 2016)?

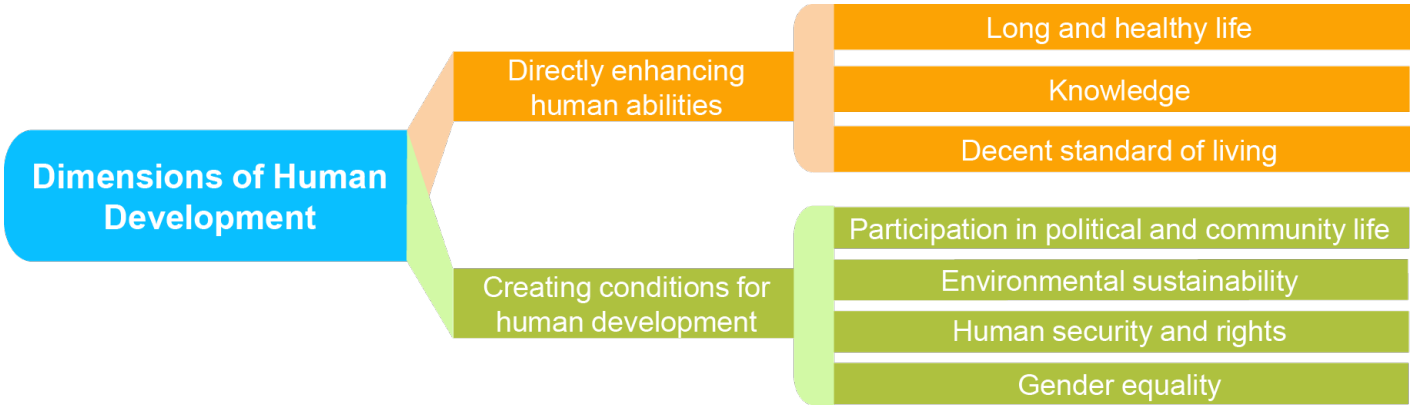
- Is it a function of the interaction of societal influences as described by Developmental Systems Theories (Osher, Cantor, Berg, and Steyer, et al, 2020) where such theories describe the relationships which exist between environment and societal structure?

- Is human development generational and reflective of local cultural pressures and the interaction that an individual has with proximal processes as suggested by Bronfenbrenner's bioecological model (Ashiabi and O'Neal, 2015)?

- Or, is human development a score that is achieved by demonstrating economic growth or based on an environmentally centered sustainable development index in light of increased contributions to *climate change, biodiversity loss, chemical loading (nitrogen and phosphorous), and land-system change* (Hickel, 2020; Biggeri and Mauro, 2018)?

The answer is that human development is all of the above and more!

Let's begin this conversation by suggesting that human development is multidimensional.



With specific regard to planetary health, research indicates that human development is not only impactful on planetary health but the development of humans is impacted, often adversely, by our pursuit of advanced development. Phenotypic responses, defined as the impact of the environment on the human genome, show that fetal development is negatively influenced by poor planetary health.

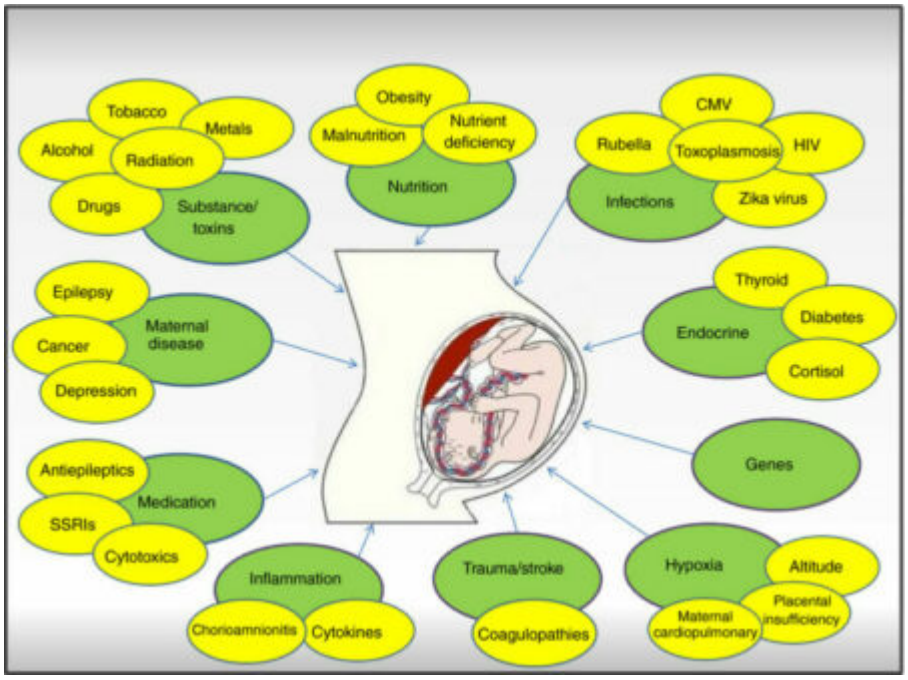
For example, research by Coussons-Read (2013), Glover (2011), and Mastorci, Vicentini, Viltart, and Manghi et al (2009) showed that stress during pregnancy can have adverse health consequences throughout the lifespan including but not limited to cardiovascular disease, lack of neurodevelopment, and negative behavioral and cognitive outcomes.

In addition to our **self-imposed** adverse environmental stresses such as the effects of cigarette smoking on the fetus, pregnant mothers are also at risk from **uncontrollable** environmental stresses such as:

- extreme weather events,
- food insecurity,
- exposure to contaminated water
- and most notably exposure to contaminated air *(Triche and Hossain, 2007)*

To this list we can also add the adverse social situations which propagate adverse childhood experiences that have a direct effect on human development and long term health (Gentner and

O'Connor-Lepert, 2019) .



Similarly, human development is impactful on planetary health as we have seen throughout the Anthropocene.

The list of negative human health consequences resulting from our deterioration of planetary health is growing well beyond the climate-sensitive physical health risks noted by Mailloux, Henegan, Lsoto, Patterson et al (2021) as "heatwave mortality, malnutrition from reduced crop yields, water- and vector-borne infectious diseases, and respiratory illness from smog, ozone, allergenic pollen, and wildfires". Given that health is a Gestalt comprised of social, mental, physical, spiritual, and emotional elements, that together form the well-being of our human species, we cannot discount the effect of planetary health on the composite of human health. In March 2019, the United Nations global human development program published a *Guidance Note* that provided direction with regard to planetary health and human health. In this guidance note Jon Hall and Midori Paxton report that planetary health and specifically biodiversity are directly linked to human development and subsequently human health.

Humans despite their best intentions have for the most part destroyed the biodiversity of our planet and therefore continue to have a direct negative impact on the capacity to maintain a healthy human civilization. The report by Hall and Paxton outlines the loss of biodiversity over the past xxxx years and the subsequent impact of such destruction on the constituents of the biosphere upon which human civilization depends. Air, water, land management, and food security, are all essential to maintaining a healthy human civilization. However, in our pursuit of human development we have for the most part ignored many of the elements that make earth diverse and which provide for us as a human species.

Planetary health and human development considered either independently or combined, represent a wicked problem. That is, human development is messy it is complicated and it creates complex outcomes which cannot be resolved simply and especially when we have directly impacted the species upon which we depend. For example, there have been several reports of the loss of our pollinators as a result of our loss of biodiversity. Combine these losses with the effects of drought and severe intense heat in our environments and it is no wonder that we are becoming a planet that is food insecure for much of our civilization. We cannot continue to maintain adequate food sources for the world if we continue to destroy the biosphere through our wilful social and economic development which are often based on wasteful practices, human greed, and of course war.

EXPOSOMES — and the relation to phenotypic effects.

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Bronfenbrenner's Biological Model describes proximal processes as the activities in which an individual learns through engagement with people, environments, or items.
Image Source for Figure 1 -- https://hdr.undp.org/en/file/what-human-development
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17
Antimicrobial Resistance and Food Safety

Authors: Daley, P., MD MSc FRCPC DTM+H

Learning Objectives

At the end of this section the student should be able to:

Key Words

The important keywords for this chapter are:

Introduction

Antimicrobial Resistance (AMR) among bacteria which cause human infectious disease has emerged among the top ten leading threats to global public health as defined by the World Health Organization, associated with 4.95 million deaths in 2019,1 which is projected to increase to 10 million deaths by 2050.2 With a declining rate of new antimicrobial discovery due to low product profitability for the pharmaceutical industry,3 AMR threatens the efficacy of current antimicrobials and the current standard of medical care that relies on effective antimicrobials. AMR is caused by many factors, the leading factor being selection towards expression of antimicrobial resistance genes (ARG) within the community of microbial flora (microbiome), due to antimicrobial use (AMU). Beside implications for human health, increasing AMR may impact animal health, climate change, global trade and sustainable industries.

Antimicrobial stewardship has emerged as one solution, leading to a five percent reduction in AMU among humans in Canada between 2015-2019.4 The COVID-19 pandemic was also associated with a significant reduction in AMU among humans.5 However, global AMU rate is increasing and is highly variable between countries.6 Reduction in AMU may reverse AMR, but other strategies including reduction in transmission, sanitation, access to clean water, accurate diagnostics and migration must also be considered.7 With evidence that AMU among animals may contribute to AMR among humans, a One Health strategy has begun to define new interventions including antimicrobial stewardship. One Health considers the intersection between the health of humans, animals and environment, including social, political and economic contexts.8

AMR among food animals threatens the safety of the food production industry because AMR may be transmitted from animals to food consumers and food industry workers. Food safety is an essential fundamental to the achievement of the United Nations Sustainable Development Goals, and food safety impacts food security, animal health, the environment, climate change and socioeconomic development.9 Because AMR can be transmitted between animals, humans and the environment, AMR impacts planetary health.

Antimicrobial Use and Antimicrobial Resistance among Food Animals

Eighty percent of antimicrobials produced in the USA are given to animals.10 AMU among animals is projected to continue to increase globally.11 Antimicrobials are given to food animals for growth promotion, prophylaxis and treatment of bacterial infections.12 Because antimicrobials are intended for treatment of significant bacterial infections, use for growth promotion and prophylaxis are considered inappropriate use. Because the food industry gains profit from the use of antimicrobials through increased production, there is a disincentive to control AMU.

AMR predates AMU, since AMR has been described from ancient soil, isolated caves, permafrost and the gut of preserved human remains dating from approximately 1000 AD.13-15 Where antimicrobials are present within food animal production at a concentration between mutant selection concentration

(enough antimicrobial to induce gene expression and alter population phenotype) and growth inhibition concentration, AMR is selected among the animal microbiome.16 There is also evidence of AMR selection due to the use of disinfectants, biocides, and heavy metals used in the livestock industry.17 ARG have been identified in many food products, including meat, poultry and dairy products from high income and low income countries,18 and in aquaculture.19 AMU and ARG expression among food animals is not always correlated, as on Danish pig farms, antimicrobial exposure had both positive and negative influence on corresponding ARG expression.20

It is not clear if reducing AMU in the food production industry will reduce AMR among animals or humans, as available studies are observational, not randomized trials. In a meta-analysis of 29 studies, reduction in AMU among animals was associated with both reduction in expression of ARG and stable expression of ARG among human and animal flora.21 Mathematical models have been proposed to generate estimates of the relationship between animal AMU and human AMR.22

AMR transmission from food animals to environment

ARG carried in the food animal gut is transferred to the environment through the spreading of manure in fields, and the contamination of the surface of fruits and vegetables with soil, fertilizer and irrigation water. The concentration of ARG in industrial wastewater is similar to that in the human gut, and higher than in control soil, water and sediment specimens, indicating environmental contamination due to industrial antibiotic pollution.23 Bacteriophages in soil acquire ARG and transfer them horizontally between bacteria through transduction.24 Environmental flora may therefore represent a latent “bank” of ARG with the capability to impact human or animal health in future.

AMR transmission from environment to humans

The role of transmission of AMR from the environment to humans is not known. Many environmental organisms lack the virulence to colonize humans. ARG identified in the environment could not be directly correlated with human colonization.25 Furthermore the direction of transfer between the environment and humans could be bilateral.

AMR transmission from food animals to humans

AMR transmission from animals to humans may be a result of direct contact with animals, including animal or fish handlers or abattoir workers, or indirectly through food consumption. Direct transmission is more common in low-income countries, where close animal exposure is common, and indirect transmission is more common among high-income countries.18 Evidence of indirect transmission includes identification of genetically identical organisms present in animals and humans without occupational exposure to animals.26 However, this evidence does not implicate food as the cause of contamination.27

Foodborne Illness in Humans

Food may become unsafe during production, distribution, sale, preparation or consumption. Safe food does not cause harm to the consumer, because the food is free of damage, deterioration or biological or chemical agents.9 However, food which contains antimicrobials or ARG may be associated with negative health outcomes in humans, primarily affecting low and middle income countries.18

Foodborne illness is disease caused by ingestion of contaminated food or water, generally associated with lack of access to clean food and water supply. Foodborne illness caused 600 million human cases and 420,000 premature human deaths globally in 2010,28 disproportionally affecting children, pregnant women and elderly, with the highest incidence observed in Africa.29 Approximately 1,000,000 children die annually of diarrheal illness in South East Asia.30 The principle bacterial causes of foodborne illness are Salmonella, Campylobacter and E.coli,31 organisms that are included in the World Health Organization list of priority pathogens identified as global AMR concerns.32 Besides gastrointestinal illness, foodborne urinary tract infection may be associated with gut colonization with resistant organisms.33

The impact of increasing AMR among food products on global human foodborne illness and death rates is unknown. If humans or animals are treated with antimicrobials for foodborne illness, but the antimicrobials are ineffective due to AMR, mortality may increase due to lack of treatment response. Many foodborne illnesses are not treated with antimicrobials, due to self-limiting disease or lack of access to treatment in low-income settings, so treatment failure due to AMR may not influence outcome among these cases.

Food Safety and Food Security

Increasing AMR among food products may impact the achievement of the World Health Organization Sustainable Development Goals focused on poverty, hunger and socioeconomic development, and may impact climate change. With global population projected to reach 11.2 billion by 2100,34 the loss of approximately one third of food production due to waste, and the high proportion of poverty and malnutrition,35 any reduction in global food production could impair food security. Food security is already poor in some low-income countries, where AMR rates are high.

If AMR reduces treatment effectiveness among animals, animal mortality due to endemic or outbreak infections could reduce food production and increase food prices. Modern industrial farming techniques may increase animal crowding and infection transmission, increasing the demand for AMU.36

The impact of AMR on global prosperity has been estimated at a loss of $100 trillion over the next thirty-five years,2 with the largest impact in low-income countries which have economies dependent on food production. Foodborne outbreaks have been associated with enormous financial impact.37 Disease outbreaks may create disruption in the trade of food between countries.38

AMR and the Environment

The use of antimicrobials in animal husbandry, agriculture and fish farming releases antimicrobials in their active form into wastewater, groundwater and soil.39 AMR associated with runoff is observed in river water downstream of cattle feedlots.40 The ocean is the largest reservoir of ARG in the environment, with higher concentrations observed in coastal runoff compared to runoff from forested areas.41 Recreational use of water during swimming, diving or watersports may expose humans to ARG. Sub-inhibitory concentrations of antimicrobials were detected on carrots and lettuce irrigated with contaminated water.42 Manure fertilization is associated with AMR in soil, even if the manure is collected from animals not treated with antimicrobials.43

Animal agriculture is the second largest contributor of greenhouse gases, next to fossil fuel

harvesting.44 Greenhouse gases contribute to climate change. Cows treated with the antimicrobial tetracycline produce increased methane, which is a greenhouse gas.45 Sixty percent of global fresh water and thirty percent of available land is dedicated to animal production.46 The demand for increased food production in the near future will increase demand for antimicrobial use and greenhouse gas production.

Conclusions

The evidence connecting observed increasing AMR rates in food with reduced food safety is emerging, but not definitive. Surveillance of AMR and AMU trends is a focus of new national and international programs. Many questions regarding AMR are unanswered, such as the relationship between AMU and AMR, the role of AMR transmission between humans, animals and environment, and the impact of AMR on human, animal and environmental health.47 Furthermore strategies to reduce AMR among the food production industry and the environment are also new. Appropriate AMU restrictive measures among animal production are being explored.48

V

BIBLIOGRAPHIES

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In this section, the bibliographies for each chapter will be presented for the Pressbook — Principles of Planetary Health. The references follow the style recommended by the AMA, and use the following structure:

Author last name Initials. Article title. Journal Name. Year; Volume(Issue): Page range. DOI or URL. An example from Chapter 1 is shown here:

2. Folke J, Jansson A, Rockstrom J, Olsson P, et al. Reconnecting to the Biosphere. AMBIO, 2011;40:719–738. DOI:10.1007/s13280-011-0184-y.

This is where you can add appendices or other back matter.

Supplemental Information for Chapter 7

Suggested supplemental material (Chapter 7)

LAURIE MCDUFFEE

video of HAB, Mike Wahl podcast, Zoonosis table from Tarazona, Silcox- recommendations for clinicians. Environmental impact of pets may mean it's time to 'eat the dog' | CBC Radio; Podcast | Wellness Webinars (mikewahl.ca)

See Beck and Latcher: "all future studies of human health should consider the presence or absence of a pet in the home and, perhaps, the nature of this relationship with the pet, as a significant variable. No future study of human health should be considered comprehensive if the animals with which they share their lives are not included. (Beck & Glickman, 1987)"

From Fine Ch 3 Forward thinking: FIGURE 3.1 The spectrum of animal-assisted interventions.

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All referencing in this text will follow the Vancouver Style also known as the AMA format. This style uses a number format in the order that the citation appears in the text. The structure is presented here:

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