Ecological Public Health for Nursing and Health Professionals in the Anthropocene

Alice M.L. Li

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To my families with love

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Preface

Global environmental and climate changes have imposed actual and potentially catastrophic implications on human health. An emerging paradigm of ecological public health is required to tackle all such broader changes, and a revolution in health systems is an urgent necessity. This new wave towards sustainable healthcare systems will be of compelling and pervasive relevance to the center stage of reform from multiple perspectives; it is not only about sharing professional development opportunities and responsibilities in healthcare, but offering revolutionary synergies with an interface for the next decade of changes under a new paradigm.

Ecological public health education and principles provide a framework for understanding the key influencing factors and driving forces of the underlying determinants that attributed to sustainable health developments and health-related problems on a global-scale. A transitional paradigm with ecological public health principles for sustainable health development is not just an idealistic way of thinking with anew paths but is rather a realistic course of actions and commitments that is meant to be advanced toward this new changing global context of public health needs. And this new transitional paradigm signifies the role of nursing and health professionals for educational reform as for the practical reason to proactively transform our intellectual understandings prospectively to encounter with those mediated health threats arising from these global environmental and climate crises under this new epoch of the Anthropocene.

A professional journey must be undertaken to enact action-oriented approaches and to allow the identification of the promising points of unfinished transformational agendas. These aspects can become an integral part of a synergistical roadmap for sustainable health developments and lead towards sustainable healthcare during this age of environmental and climate mediated health risks. Our planet and all living organisms, including us as "*Homo sapiens*", are what they are because of the elements that exist and the way they form. This 'age' poses many challenges at different levels in our globalized society, both theoretically and practically, which certainly affects our ways of knowing and doing concerning some of the fundamental characteristics of our humanity. It also indicates how our planet has conditioned the development of these characteristics. The current manifestations of these characteristics and our being in the midst of the Earth's sixth mass extinction crisis with the global environmental and climate changes underway. This new epoch of the Anthropocene combined together with the global ecological effects of anthropogenic pollutions that continuously imposed transitional health risks plus with actual and potential catastrophic public health impacts on a global-scale that further threaten our human health possibly across future generations. If these predicaments are not beyond our reach, intellectual and scientific tools can serve as the means of change through synergistical public health interventions. The educational platform is one of the ultimate way for this process of change through the connectivity of this transitional humanity in order to mitigate these adverse impacts and those future hazards of health threats that arise from the global and ecological determinants of health at the present time and in the future. We have to set the itinerary for re-kindling the virtuosity of our civilization. This is a journey of caring praxis which will allow humanity a new start.

Perhaps, it is also a journey keeping me moving with professional spirit towards 'life'. This idea is very much related to Albert Einstein's famous quote as written in a letter of 5th February 1930 to his son Eduard: "*Life is like riding a bicycle. To keep your balance, you must keep moving*".

This book presents a sensible hope and direction for our necessary journey towards an ecological civilization that could make possible a better eco-environments for our planet. Civilization comes not just from virtues; most importantly it comes from transforming our sense of interrelatedness, not just within human systems, but the emerging view of new revolution of extraordinary 'trans-reality' towards an understanding of how 'life' being formed for its co-existence and global interdependence. For the purpose of progressing the necessity of ecological dimensions of our wellness, it definitely requires a paradigm in transition for emerging ecological public health education, together with new waves of public health movements towards planetary health for global eco-environments, which is absolutely essential for the totality of this predicament in the Anthropocene. And therefore, we as health professionals have to understand such changing demands for blending sustainable health developments in the healthcare environment.

Scientific advancements in the 21st century are continuously widening our horizons and fostering insights into many complex issues with different perceptions and interpretations of responses, reactions, or even decisions. The dimensions of our intellectual and professional capacity may be one of the crucial factors affecting the ways in which we deal with those matters interrelated to transdisciplinarity in education. Sustainability development is the progressive position for further ecological public health education and represents the sum of the parts of healthcare reform through professional competencies in terms of applying this necessary knowledge for sustaining the full potential of healthy developments. Knowledge dissemination through educational reforms and an educative process directed at the necessary change of mentality and mindset ought to be cultivated in this sense.

In healthcare as an academic field, our belief is that education is the vehicle for achieving necessary change. Through the process of education, knowledge transformation can serve meaningful change; it is my utmost hope that this book may serve as a catalyst of this necessary change, that it may aid in moving forward with ecological public health education as part of future professional competencies embedded with practical knowledge for sustainable health developments.

The content of this book intends to sharpen the ecological understanding of health-related problems arising as a consequence of the Anthropocene and to suggest a promising and coherent set of interventional strategies or visions with synergistical systems thinking based on values and meanings geared toward the collective actions and responsibilities in the form of a professional journey of learning. The ultimate goal is, yet again, to widen the intended roadmap towards sustainable healthcare. Perhaps, keeping moving in a direction with free minds, free spirits and free intellectuals will be the roadmap for a successful journey after all. Such an attitude can inspire our new ways of systems thinking, and reveal the importance of holistic views of ecological values and meanings that pave the way towards more harmonious and sustainable ways of living, acting, and being. It can motivate us to gain scientific understandings of how to foster sustainable healthcare with the aid of an ecological civilization, which in turn can preserve our common home for generations. Ecological public health education is also the roadmap for our professions to carry on in this journey of humanity, and to become more ecologically conscious health professionals for promoting sustainable health developments across future generations.

I will always cherish this opportunity of writing this book, and my sincere thanks certainly go to many scholars and scientific contributors for their devoted efforts in research and studies that have generated enormous inspirational scientific and insightful views in this area. They have opened up the furtherance of our professional horizons to tackle such a complex transitional risks and mediated health-related problems that arising under this age of global environmental and climate crisis in the Anthropocene.

I, also particularly wish to express my gratitude to Professor William Steffen, Professor Barry Popkin, Professor Jonathan Salk, Professor Jan Willem Erisman, Professor Matthew H. Bonds, and Professor Roland Geyer for their academic support and kind permission to use their intellectual and inspirational materials (as referred to in the cited Figures and graphical data), with which my points have been illustrated much more clearly together with many factual assertions. A special tribute is due to my late Professor Anthony J. Hedley, our research team supervisor of several decades ago; I feel privileged to use some of his inspirational material in this book, notably the concept of the "pyramid effect" (as cited later). Last but not least, I would certainly like to extend my utmost sincere thanks to the team at Cambridge Scholars Publishing for preparing this book for publication.

Alice Miu Ling LI
The Author

Former Assistant Professor
The Hong Kong Polytechnic University
&
Former Programme Director, HKU SPACE
The University of Hong Kong

CHAPTER 1

PLANETARY HEALTH FOR GLOBAL AND ECO-ENVIRONMENTS IN THE ANTHROPOCENE

Our universe is believed to have formed about 15 billion years ago. Planet Earth came into existence about 4.5 billion years ago, its atmosphere composed of a variation of geophysical origins, including the influence of cosmic impacts and the infusion of energy for the development of air, water and the substances that were to become early forms of food, which then became key ingredients for the origins of life (White, Stallones and Last, 2013). Earth is an old planet, a third of the age of the entire cosmos, with a geological record that unfolds over 4.54 billion years (Ga) (Heikkurinen, 2017). Fossil evidence indicates that these early photo-synthesizers existed at least 3.5 billion years ago and perhaps earlier; however, there was insufficient oxygen in the atmosphere for animal life to exist in the early history of the planet. Instead, Earth's primitive atmosphere contained large amounts of methane (CH_4), but these molecules were split apart by solar radiation, and the carbon combined with the little oxygen that existed to form carbon dioxide (CO_2).

The origin of life is one of the most intriguing, difficult, and enduring questions in science; our knowledge of the materials from which life originated, and where, when, and in what form it first appeared, stems from geological investigations of rocks and minerals that represent the only remaining evidence (National Research Council, 2008). Early life-forms, including bacteria, blue-green algae, and phytoplankton, used the CO_2 for metabolism, producing oxygen as a by-product that allowed the continued evolution and spread of plants, which increased the amounts of oxygen in the atmosphere and enabled oxygen-breathing animals to evolve (Merritts, Menking and de Wet, 2014).

An issue of particular interest in the early Earth is this rise of atmospheric oxygen (Rollinson, 2009). Increased levels of oxygen in Earth's atmosphere allowed for the formation of the ozone in the upper atmosphere, which shields organisms from ultraviolet (UV) radiation given off by the sun. UV radiation can lead to sunburn, genetic defects, and cancer, so only when the atmosphere contained enough ozone could animals evolve on land (Merritts et al., 2014). This stratospheric ozone was in fact created in the atmosphere gradually around 3.5 billion years ago, and the ozone layer can be considered as a product of life on Earth to shield against solar ultraviolet radiation, which should not be confused with the ground-level ozone that is a harmful secondary air pollutant resulting indirectly from human activities (Poulopoulos and Inglezakis, 2016).

Most of us have wondered how our dynamic planet evolved, how it became a living world; and because of our remarkable and cumulative knowledge today, we know a great deal about Earth (Hazen, 2012). Around 400 million years ago, aqueous plants (the above-mentioned phytoplankton) were able to migrate onto the now-protected land and evolve into terrestrial plants, in other words becoming the beginning of the food chain. Animal life which fed on plants followed and life evolved via several evolutionary paths, through herbivorous and carnivorous dinosaurs, mammals, and omnivorous humans (Poulopoulos and Inglezakis, 2016). Some of these animals (herbivores) relied on consuming plant matter for energy, while others (carnivores) preyed on other animals to fuel their metabolism (Merritts et al., 2014).

The originally intuitive connection between organisms and their environment was ultimately translated into evolutionary theory; and today, our knowledge of the physical history of the Earth and other planets, and the physical limits for life, is increasing rapidly. Such questions as “How did life on Earth arise?” and “How have physical parameters constrained, molded and triggered the evolution of life on our planet?” continue to provide ample research topics (Rothschild and Lister, 2003). The structure of our planet is well known today based on seismic data and the oscillations of the Earth, in which the composition of external shells contains Earth’s crust, hydrosphere, and atmosphere (Sorokhtin, Chilingarian and Sorokhtin, 2011). The biosphere interacts with other spheres, such as the lithosphere (i.e., the outermost surface of the Earth – Earth’s crust), the atmosphere, and the hydrosphere.

The biosphere refers to all living organisms on Earth and is often called the global ecosystem of the Earth system, that is to say, the place where life exists. The composition of the biosphere is similar to that of Earth’s other systems: it consists of 99% hydrogen, oxygen, carbon, and nitrogen, though its high percentage of carbon distinguishes it from all of the other major systems of the Earth. All fossil fuels (oil, coal, and natural gas) were formed from organic molecules that originated in the biosphere but were buried by sediments to become part of the lithosphere (Merritts et al., 2014).

In the Phanerozoic Eon is the backdrop to the extraordinary biodiversity of life at present, which includes our species, *Homo sapiens*, evolving some 195,000 years ago in Africa (Heikkurinen, 2017). The environmental conditions of the Holocene epoch that began approximately 11,700 years ago around the end of the last Ice Age, have been particularly conducive to human health; this is primarily due to its stable climate well-suited to human life across most of the globe, and its creation of predictable growing seasons that enabled the development of increasingly complex agricultural civilizations (Zywert and Quilley, 2020). The initial development of agriculture from about 10,000 years ago resulted in subsequent major modification of the landscape and the increasing influence of humans over species and ecosystems evolution (Heikkurinen, 2017). Since the Agricultural Revolution began some 10,000 years ago, human activities have had a significant impact on the distribution and types of forests of the world. The period before agriculture is known as the Paleolithic Era (*Paleo* = old + *lithic* = stone), and the period after the start of agriculture is known as the Neolithic Era (*Neo* = new + *lithic* = stone); the latter is the clear reason for the rise in the world's population.

With the increased ability to grow more food and feed a rising population, especially since 1750 or so, farmers have been able to grow more food with better seed varieties and farming techniques; use chemical fertilizers to boost soil nutrients; work with machinery to sow seeds, harvest crops, and process food stuffs; and store and transport food to urban cities (Sachs, 2015). We live on a human-dominated planet and the momentum of human population growth, together with the imperative for further economic development in most of the world, ensures that our dominance will increase; often it is the waste products and by-products of human activity that drive global environmental change (Curtin and Allen, 2018).

The history of the centuries-long effort of climate change science is now contributing to the foundation of a new interdisciplinary approach to understanding our environment (Le Treut, Somerville, Cubasch, Ding, Mauritzen, Mokssit, Peterson and Prather, 2007). Although global-scale human influence on the environment has been recognized since the 1800s, climate change has brought into sharp focus the capability of contemporary human civilization to influence the environment at the scale of the Earth and its planetary systems. It has been emphasized most acutely in the evolution of the Anthropocene as humanity proceeds into the twenty-first century, with the extent of these profound changes to our relationship with the rest of the living world becoming clearer (Steffen, Grinevald, Crutzen and McNeill, 2011). There is scientific consensus that our planet is in danger and that climate change is the most compelling public health challenge of our time: a warming planet has negative consequences in terms of environmental degradation, extreme weather events, social disruption and drastic health and economic consequences (Hellerstedt et al., 2017). In light of the evidence, the American Association for the Advancement of Science (AAAS) has affirmed the "What We Know Initiative" with three key messages (Hellerstedt et al., 2017):

1. **Reality**: About 97% of climate scientists have concluded that human-caused climate change is happening,
2. **Risks**: We are at risk of pushing our climate system toward abrupt, unpredictable, and potentially irreversible changes with highly damaging impacts, as Earth's climate is on a path to warm beyond the range of what has been experienced over the past millions of years.
3. **Response**: The sooner we act, the lower the risk and cost.

The New Epoch of the Anthropocene

The Anthropocene represents humanity's entrance into a new era of sustainability challenges, in which the planet's environment is under significant pressure from social, economic, and demographic forces. These impacts will also be mediated through nonlinearity effects which threaten the human and environmental systems on an ecological and biogeochemical level, as coevolving systems which are inextricably coupled with human anthropogenic interferences in a wide range of ways. While our flow of production continues to keep up with this ever-expanding web of resource consumption, our stocks have approached scarcity, our waste absorption capacity through ecosystems is limited, and the carbon emissions into our atmosphere are worrisome (Layer, 2006). Thus, this challenge is complicated because the problem of greenhouse gases (GHG) emissions goes to the core of this modern economy and the solutions to climate change are indeed inherently complex (Sachs, 2015). In striving to prevent our society and future generations from tipping into disastrous states, sustainable development has remained one of the primary policy goals in the large majority of countries all over the world (Fang, Heijungs, Duan and de Snoo, 2015).

The term "Anthropocene" has in fact been coined three times: the first time was in 1922 by the Soviet geologist Aleksei Petrovich Pavlov, who proposed "Anthropocene" or "Anthropogene" as a name for the time since the first humans evolved about 160,000 years ago (Angus, 2016); the second time was in the late 1980s by the American marine biologist Eugene Stoermer who used it in some published articles (Malhi, 2017; Angus, 2016); and the third, which is when the term became more popular, was by the Dutch chemist and Nobel recipient Paul Crutzen who published, with Stoermer, a paper in the *Global Change Newsletter* entitled "The Anthropocene" in the year 2000 (Malhi, 2017). However, the formalization of the Anthropocene as a new geological epoch was officially confirmed back in 2016 by the Anthropocene Working Group (AWG) of the Sub-commission on Quaternary Stratigraphy (Heikkurinen, 2017).

In fact, this modern history of the Anthropocene starts with a small meeting of the International Biosphere-Geosphere Programme (IGBP) in Cuernavaca, Mexico, in February 2000, which had been formed in 1987 to coordinate research into what scientists call "global change", that is not just climate change, but all matters involved with the Earth's functions as an integrated system of interacting physical, chemical, biological and human components (Lewis and Maslin, 2018). This knowledge is vitally important for providing essential clues to its present physical, chemical, and biological state and leads to an understanding of the large-scale processes that bring about change in and on our planet.

Humans are the greatest evolutionary force, for that reason we have named this changing environment the Anthropocene Epoch and positioned it on the geologic timescale, because of the reality of human domination and evolutionary pressure (WHO, 2009). A key finding in this regard is the rapidly increasing population growth accompanied by profligate consumption and the proliferation of anthropogenic human activities that are continuously impacting the environment. Many scientists and studies have suggested that excessive unsustainable consumption will exceed the long-term carrying capacity of our environment as part of an ecological overshoot that could lead to resource depletion, environmental degradation, and reduced ecosystem health. So far, looking back in time, the human population took hundreds of thousands of years to reach the one billion mark, attained it in around 1820, took another 110 years (c. 1930) to add the next billion, but since 1960 it has required only 12–13 years to add almost each subsequent billion (Oosthoek and Gills, 2008).

The Earth systems paradigm is now strongly influencing issues in global change (Rollinson, 2009). The key features of these changes that propelled the Anthropocene often have an emphasis on their global and pervasive nature (Malhi, 2017):

a. the multifaceted nature of global change beyond just climate change, including biodiversity decline and species mixing across continents, the alteration of global biogeochemical cycles and large-scale resource extraction and waste production;
b. the two-way interactions between humans and the rest of the natural world, such that there can be feedbacks at a planetary scale such as climate change; and
c. an imminent fundamental shift in the functioning of our planet as a whole.

Crutzen thought the epoch should be renamed from the “Holocene” to the “Anthropocene” to reflect the impact of humans (Frumkin, 2017). In this sense, it is important to point out the broad implications of the Anthropocene, which emphasizes (i) the acceleration of degradation of the biosphere in recent decades and (ii) concludes that humanity has already abandoned the previous period of stability (Franchini, Voila and Barros-Platiau, 2017).

It connotes a time when humans have become agents of geological change, driving significant global chemical, physical and biological modifications to the atmosphere, landscape and oceans, in addition to climate change. As suggested, the threshold of ~2ºC, if crossed, could cause continued warming and a “Hothouse Earth”, even if and as human emissions are reduced; therefore humanity is now facing the need for critical action (Steffen et al., 2018).

These changes are global and viable not just in terms of the geological time of the Earth, but the profound influence of humans across the planet can be recognized with a broader spatial and deeper temporal understanding of life (Heikkurinen, 2017). This marks the important implication that human activity now rivals geological forces in its ability to affect essential planetary processes, which is deemed the beginning of the “Great Acceleration”. And this age is marking the history of our species by referencing to the facts of many human anthropogenic activities are indeed dated back to the mid-twentieth century, to around 1950.

The Great Acceleration

The transition to the Anthropocene is a new geological epoch that dates from the commencement of the time period coinciding with the Great Acceleration in the mid-twentieth century. The rapid growth of the world economy since 1750 is the result of 250 years of technological advances, starting with the steam engine and steam-powered transportation, and progressing with the internal combustion engine, electrification, industrial chemistry, scientific agronomy, aviation, and nuclear power, as well as culminating in today's information and communications technologies (ICTs), which are the main driver of long-term global economic growth throughout our study of sustainable development in the world economy. However, coincidentally, these advances also come with negative side effects, such as damage to the planet (Sachs, 2015). As the sum of the planet's physical, chemical and biological processes is known as the Earth system, which comprises many interconnected processes (such as evaporation, transpiration, and photosynthesis) that store, transfer, and transform matter and energy according to the laws of physics and biogeochemistry (Meyer and Newman, 2018).

Therefore, we continually need environmental footprint indicators to measure emissions and the use of natural resources while the planetary boundaries provide levels of perturbation that are believed to ensure that the Earth system is kept in Holocene-like conditions that are favourable for humanity (but which are now apparently over the limit). As according to the indicators of "Socio-economic trends" and "Earth system trends" that indicated the increase of unprecedented environmental breakdown. And it covers the age when the rate and scale of changes in global environmental degradations quickened significantly. As the WHO has stated, the scale of change ranges from microscopic to planetary and affects the basic supports of life – air, water, food and fire; in addition the rate of change is now being measured in decades versus the millennia of previous epochs (WHO, 2009). Such accelerations are largely driven by population growth, economic development, and lifestyle changes, and which also a prime driver of changes in the Earth system and resulted in severe environmental degradation beyond acceptable global limits, leading to the anthropogenic perturbation of crucial Earth system processes. It thus marks a move away from a safe planetary operating space for human activities (Häyhä, Lucas, van Vuuren, Cornell and Hoff, 2016).

In the studies by Rockströmet et al. (2009) and Steffen et al. (2015), both sets of researchers identified nine critical processes that regulate the functioning of the Earth system (as cited in Vanham et al., 2019). Such records demonstrate how human activity has pushed the Earth's ecosystem beyond the boundaries of its natural course (Lambin, 2012). Figure 1-1 presents a framework for the limits of these planetary boundaries in the Earth system process, comparing its current state against its pre-industrial state, but excluding atmospheric aerosol loading and chemical pollution (as they cannot be determined as of yet).

Planetary Boundaries				
Earth system process	**Parameters**	**Proposed boundary**	**Current value**	**Pre-industrial value**
Climate change	Atmospheric CO2 concentration (parts per million by volume)	350	387	280
Rate of biodiversity loss	Extinction rate (number of species per million species a year)	10	>100	0.1 – 1
Nitrogen cycle	Amount of N2 removed from atmosphere for human use (millions of tons per year)	35	121	0
Phosphorus cycle	Quantity of P flowing into oceans (millions of tons per year)	11	8.5 – 9.5	-1
Stratospheric ozone depletion	Concentration of ozone (Dobson unit)	276	283	290
Ocean acidification	Global mean saturation of aragonite in surface sea water	2.75	2.90	3.44
Global freshwater use	Consumption of freshwater by humans (km3 per year)	4000	2600	415
Change in land use	Percentage of global land cover converted into cropland	15	11.7	Low

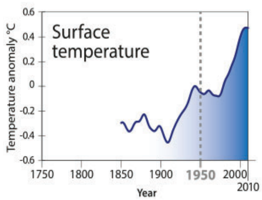
Figure 1-1: Limits of Planetary Boundaries (Li, 2017b as adapted based on Schroeder, Thompson, Frith & Pencheon, 2013).

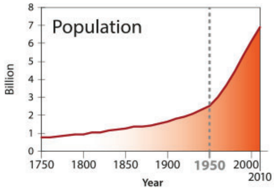
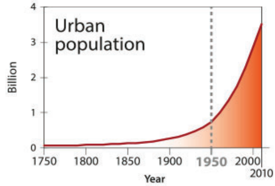
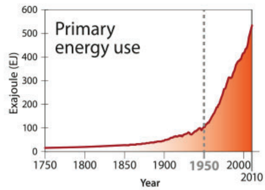
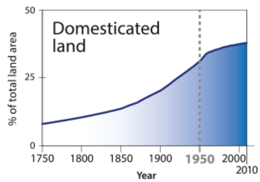
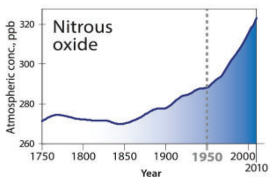
The current values of the footprints above are in fact indicators of the pressure of human activities on the environment; they are quantified based on life cycle thinking along the whole supply chain (from producer to consumer, and sometimes to waste management), which aimed to give a comprehensive picture of each footprint regarding a particular environmental concern, being measured either by resource appropriation, pollution/waste generation, or both (Vanham et al., 2019). As the values illustrate, environmental degradation is caused by human anthropogenic activities that evidentially constitute profound and unprecedented challenges in human history. The potential consequences from the intensity of continuous demands on ecosystems will eventually lead to ecological deterioration, as the ecosystem services have only a limited amount of "fuel" or "production factor" within the planet's biocapacity. This planet's biocapacity is its renewable natural capital that can only be provided through ecosystem services.

Over the past 50 years, a broad agreement has been arrived at that humans have changed ecosystems more rapidly and extensively than in any comparable period of time in human history, largely to meet rapidly growing demands for food, freshwater, timber, fiber, and fuel. Human activities are thus dominating many aspects of the Earth's natural environment (Angus, 2016). The Anthropocene implies that the human imprint on the global environment is now so large that it can be seen from the structured formula “Population x Affluence x Technology = Human Impact” (or the “IPAT formula”) that has been growing steadily since the industrial revolution and began to grow exponentially after World War II. This was the commencement of the phase scientists call the Great Acceleration (Steffen et al., 2011).

Consumption of natural resources on a global scale has increased rapidly in recent decades. The original Great Acceleration graphs of social and environmental trends from 1750 to 2000 were published in 2004 and in 2015. Steffen and other associates updated the data and extended the planetary dashboard to show the “Great Acceleration” in human activity up to 2010, in which the evidence of large-scale shifts in the Earth system’s functioning prior to 1950 is weak. However, the post-1950 acceleration in the Earth system indicators remains clear and shows a start date for the Anthropocene; the beginning of the Great Acceleration is by far the most convincing from an Earth system science perspective (Steffen, Broadgate, Deutsch, Gaffney and Ludwig, 2015).

The scientific evidence unfolds our understandings with evidential indicators as shown in the “Socio-economic trends”, “Earth system trends” and “Ecological footprint” of human influence on the planetary Earth system through human anthropogenic processes, which are summarized below in Figure 1-2.

Increasing human anthropogenic influences*	Graphical data of Socio-economic trends and Earth system trends**
The surface temperature has been rising (with few anomalies) from 1951 onward, which is one of the most obvious signals of climate change over the past several decades. There were also more high and fewer low temperature extremes than nearly the entire extremes recorded dating up to the mid-20th century. In 2014, the Intergovernmental Panel on Climate Change (IPCC) indicated that Anthropogenic greenhouse gas emissions (GHGe) (mainly carbon dioxide, methane and nitrous oxide) were extremely likely to be the dominant cause of the observed global warming since the mid-20th century, and there is strong scientific consensus about the threat posed by unabated climate change. Levels of GHGe rose to new highs, including carbon dioxide, methane and nitrous oxide—all of which reached record levels.	

<table>
<tr><td>Historically, John Graunt (1662) is credited as the first demographer to describe population growth in the 17th century as a doubling rate and this later became the basis for Malthus (1888). There has been a tenfold human population growth in three centuries. This global growth amounts to over 80 million annually from 1 billion in 1800. Now the population is more than 7.5 billion in the 21st century.</td><td>
</td></tr>
<tr><td>Urban transitions are underway with increasing resource intensity of the energy, materials and water required to produce units of goods and services, and the ways in which each society adapts to this change, e.g., the process through which cities grow due to further urbanization. The urban population has increased from 43% in 1992 to 50% in 2012.</td><td>
</td></tr>
<tr><td>We are in the process of exhausting fossil fuel reserves that were generated over several hundred million years. There has been a 16-fold increase in energy use in the twentieth century, raising air pollutants such as sulphur dioxide, nitrogen oxides, carbon monoxide, ozone, particulate matter and lead emissions to over twice natural levels.</td><td>
</td></tr>
<tr><td>Nearly 50% of the Earth's land surface has been transformed by direct human action and even wetlands have shrunk by one-half, which has had significant consequences for biodiversity, nutrient cycling, soil structure and biology, as well as climate. Humans have claimed more and more land to grow grains, raise livestock, and provision ourselves with forest products and fibers from the natural capital of the ecosystem. Population dynamics and land cover change have been intrinsically linked.</td><td>
</td></tr>
<tr><td>Nitrous oxide (N_2O) is the third most important long-lived GHG after carbon dioxide (CO_2) and methane (CH_4), which is also one of the main stratospheric ozone depleting substances on the planet. Nitrous oxide levels are on the rise from the use of nitrogen-fixing fertilizer and combustion of fossil and biofuels.</td><td>
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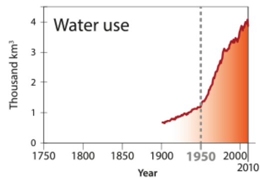
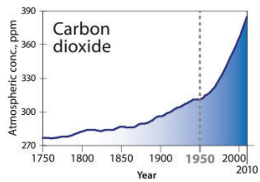
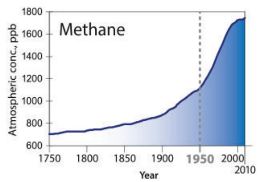
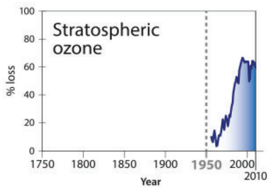
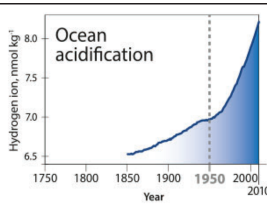
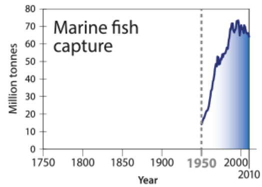
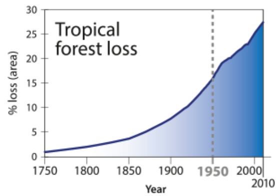
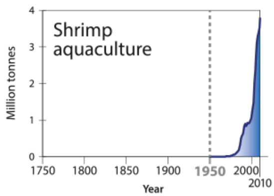
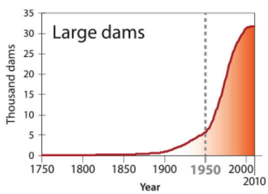
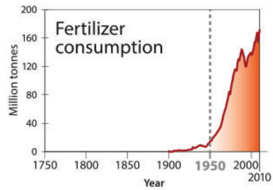
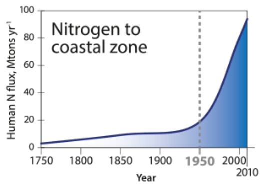
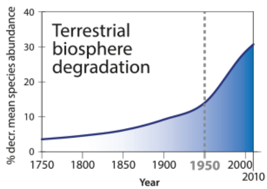
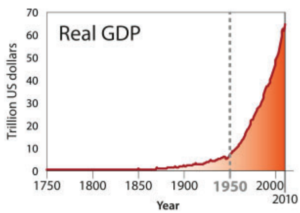
More than half of all accessible freshwater is used directly or indirectly by humankind, and underground water resources are being depleted rapidly. Humanity has consumed huge amounts of water, especially to grow food, and now faces water crises in many parts of the world. Adverse effects on water availability and quality are impacting biodiversity, the functioning of ecosystems, human health and food security.	
According to the limits of planetary boundaries seen in Figure 1-1, the proposed boundary atmospheric CO_2 concentration is 350 parts per million (ppm) by volume. And evidence now shows the record average global CO_2 concentration was reached in 2018 at 407.4 ppm. This is the highest ever level in modern 60-year measurement records and those created from ice-core samples dating back as far as 800,000 years.	
Methane (CH_4) is mainly produced in the guts of ruminant livestock, such as cattle and sheep, who have a fore-stomach containing microbes called methanogens that are capable of digesting coarse plant material with by-products of methane. The dietary trends are of environmental concern for livestock productions, given their maintenance of 1.4 billion methane-producing cattle. The impact on climate change of one unit of methane is roughly 30 times greater than that caused by one unit of CO_2 over a 100-year period.	
The stratospheric ozone layer absorbs ultraviolet radiation, preventing dangerous UV rays from hitting the Earth's surface and harming living organisms. Ozone depletion in the stratosphere is caused by ozone depleting chemicals/substances (ODSs). There are some examples of banning ODSs, such as the 1987 Montreal Protocol, which was then being initiated for controlling chlorofluorocarbons (CFCs) production.	
Oceans cover three-quarters of the Earth's surface area. Ocean acidification is the drop in seawater pH. Industry is responsible for a large proportion of incineration and combustion processes which do not emit CO_2 alone, but also large amounts of other gases that act as acids when they come into contact with water, especially nitric and sulfur oxides (NO_2 and SO_2) which contribute to	

Oxonium ($H3O^+$) formation. Other human-caused changes in marine ecosystems occur through poisoning the ocean with pollution, changing ocean chemistry, the physical destruction of ocean features such as sea beds and coral reefs, and the overfishing and overharvesting of marine life.	
About 22% of recognized marine fisheries are overexploited or already depleted, and 44% are at their limit of exploitation. Overfishing and overharvesting of marine life have had an adverse effect on marine biodiversity and disrupted the food chain. One of the highlighted unexpected consequences of human activity has been the lack of recovery of cod populations on the Grand Banks despite nearly two decades of fishery closures.	
Forests remain one of the major parts of terrestrial ecosystems on the planet, covering 31% of the total land area. Destruction of tropical rainforests and deforestation have imposed serious consequences on environmental degradation and ecological disruptions. Mangroves are also a type of tropical forest with a unique position at the dynamic interface of land and sea. The functioning of their ecosystems is invaluable, and the losses of mangroves have escalated in the past 50 years.	
Shrimp farmers have to destroy mangroves to create shrimp ponds for shrimp aquaculture, which has imposed permanent damage on an enormous amount of the world's mangroves. Yet, mangrove forests are among the most productive and biologically important ecosystems with high ecological value. Despite this, the integrated mangrove-shrimp aquaculture is theoretically a sustainable farming system and was only initiated in 2006.	
Coastal and marine habitats are being dramatically altered, including mangroves which have been removed for widespread dam building and river diversion. Nearly 700 dams were built every ten years up to the 1950s, with this number growing rapidly after the 1950s. Dams have both positive and negative effects, as on one hand they control stream regimes and prevent floods, obtaining domestic and irrigation water. On the other hand, they are complicated in terms of climatic hydraulic, biological, social, cultural, archaeological etc., effects.	

The nitrogen cycle has been massively altered over the past century following the discovery in the early 1900s of the Haber-Bosch process that creates fertilizer from unreactive atmospheric nitrogen. Humanity has come to dominate the nitrogen cycle, turning atmospheric N_2 into reactive nitrogen (such as nitrates, nitrites, and ammonia), and more than twice as much nitrogen fertilizer in agriculture is used naturally in all terrestrial ecosystems combined.	
Aquatic and marine dead zones can be caused by an increase in nutrients (particularly nitrogen and phosphorus in biogeochemical flows) in the water, known as eutrophication. They can lead to an algal bloom that increases the mortality of mangroves. Recent reports have indicated that even a single low-level exposure to algal toxins can result in physiological changes indicative of neuro-degeneration. Nitrogen in coastal zones can also affect coral reefs, which function as buffers against strong wave energy, protecting the coast from erosion.	
The biosphere is often called the global ecosystem of the Earth system (i.e., where life exists). Human populations and their use of land have transformed most of the terrestrial biosphere into anthropogenic biomes (anthromes), causing a variety of novel ecological patterns and processes to emerge, especially and intensively so in the past century. This is one of the influential factors that has significantly altered the terrestrial biosphere of Earth's systems.	
The relationship between economic growth and the environment is complex, but not all forms of economic growth cause damage to the environment. However if an increase in real Gross Domestic Product or output (real GDP) includes the increased consumption of non-renewable resources, this results in higher levels of pollution, global warming and the potential loss of environmental habitats. Thus, the "IPAT formula" finds its expression in the current human society's relation to its environment.	

The growing extensive intensity and velocity of global interconnectedness relates to a speeding up of global interactions due to the development of worldwide systems of transport and communications that simultaneously increase the speed of the global diffusion of ideas, goods, information, capital and people; eventually, these have enormous global consequences. The “IPAT formula” is also explicitly applied to the following four “socio-economic trends" indicators: international tourism; transportation; paper production, and telecommunications.

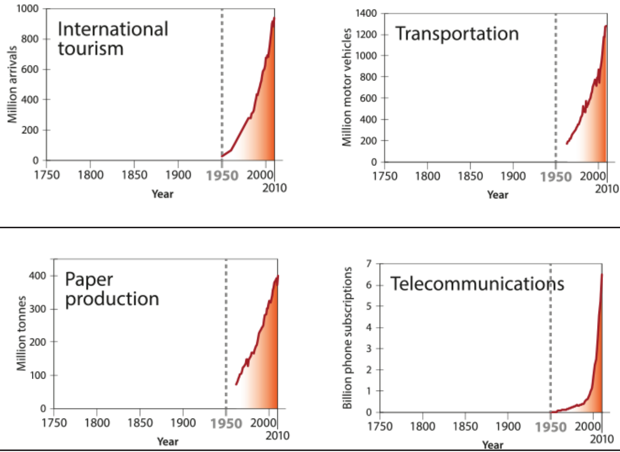


Figure 1-2: Increasing human anthropogenic influences* with indicators from graphical data of Socio-economic trends and Earth system trends**. (*Adapted from: NOAA, 2019; Butz, Liechti, Bodin, and Cornell, 2018; Henderson and Loreau, 2019; Hancock, Spady & Soskolne, 2015; Raffaelli and Frid, 2010; Sachs, 2015; Duke, Nagelkerken, Agardy, Wells and van Lavieren, 2014; Tahmiscioğlu, Anul, Ekmekçi & Durmuş, 2011; Steffen et al., 2015; Portier et al., 2010; Ellis, 2011; Blewitt, 2018; Angus, 2016. **Graphical data used with permission from Steffen, Broadgate, Deutsch, Gaffney & Ludwig, 2015.)

Science is increasingly able to identify precautionary boundaries for critical Earth system processes (Butz et al., 2018). For the first time in human history those manifestations have reached global proportions, and their unprecedented magnitude suggests a quantum leap in the way that humanity impacts on the biosphere (Lautensach, 2015). The current global extent, duration, type and intensity of human transformation of ecosystems have already irreversibly altered the terrestrial biosphere at levels sufficient to leave an unambiguous geological record differing substantially from the previous epoch of the Holocene (Ellis, 2011). Humankind is now disrupting at a global level the biosphere’s life-support systems that provide environmental stabilization, replenishment, organic production, cleaning of water and air, and recycling of nutrient elements, and these changes to Earth's basic life-supporting processes pose long-term risks to human population health (McMichael & Beaglehole, 2003).

In the Anthropocene, the Earth's climate is destabilizing, overall temperatures are warming and are becoming more extreme at local scales, and drought and flooding are exacerbated. And, together with sea levels rising, the atmosphere is being overloaded with GHGe, the oceans are becoming more acidic, biodiversity is plummeting, and biogeochemical cycles are shifting. The Anthropocene is named as such because of all these defining characteristics which describe the unprecedented effects of human activities on the planet's biophysical systems (Zywert and Quilley, 2020). The 2005 Millennium Ecosystem Assessment (MEA) Report reaffirmed that human activity is putting such strains on the natural functions of Earth that the ability of the planet's ecosystems to sustain future generations can no longer be taken for granted (Corvalán, Hales, McMichael, Bulter, McMichael, MEA Programs & WHO, 2005). This MEA Report chronicles the continued degradation of the natural environment, which is further amplifying the growing awareness that healthy people cannot live on a sick planet, as the resilience of the community of life and the wellbeing of humanity depend upon preserving a healthy biosphere with all its ecological systems for a rich variety of plants and animals, fertile soils, pure waters, and clean air (Guenther and Vittori, 2008). From this perspective, the complexity of relevant conditions defined as factors contributing to the ecological determinants of health will be further illuminated from different perspectives based on concepts, citations, examples, and models, in conjunction with harmful consequential effects of human-induced disturbances to our environments and food systems, together with the burdens from ecosystem disruption, environmental hazards and loss of ecosystem functions (Li, 2017a).

In the last fifty years, global achievements in economic growth, poverty reduction and improved welfare have been counterbalanced by an increasing strain on the biosphere; for instance: (i) forests, particularly in tropical zones, are cut faster than they can re-grow; (ii) fish are caught faster than they can be restocked; (iii) global per capita food and services consumption has grown during the last four decades; and (iv) global extraction of natural resources (e.g., biomass, fossil fuels, metal ores, and other minerals) has increased by nearly 45 percent in the last twenty-five years (Wackernagel & Galli, 2012). Anything we get from our environment comes from these resources, which are used to meet our needs and wants. They can be strictly classified into three major types according to their degree of renewability: potentially renewable, such as soil; nonrenewable, e.g., fossil fuels and metals; and perpetual, e.g., solar energy (Merritts et al., 2014). Natural capital, which encompasses the stock of renewable and non-renewable resources, is often termed "ecosystem services", and in fact most of the UN's Sustainable Development Goals (SDGs) are either directly concerned with or strongly dependent on those natural capitals (Independent Group of Scientists appointed by the Secretary-General, 2019). Figure 1-3 shows examples of renewable and non-renewable resources.

Renewable Resources	**Non-renewable Resources**
Solar energy	Coal
Wind energy	Oil
Geothermal energy	Peat
Water	Uranium
Air	Gold
Soil	Aluminum
Cultivated Plants	Sand
Biomass	Iron
Biofuels	Phosphate rock
Animals	Rare Earth elements

Figure 1-3: Examples of renewable and non-renewable resources

The environmental and health impacts of widespread mining, metallurgical activities (such as smelting and refining) and fuel extraction (such as coal) also became increasingly apparent from those terrestrial mineral resources including abundant metals, scarce metals, water, soil, building materials, and a wide range of chemicals, including carbon-based fuels and nuclear energy sources. The Industrial Revolution was also associated with a growing incidence of occupational diseases, such as lung disorders (examples include coal workers suffering from pneumoconiosis, silicosis, and asbestosis), occupational cancers, and poisoning from various toxic compounds (including lead, white phosphorous, mercury, cadmium, arsenic and radioactive agents) [Cook, 2013]. In addition, non-sustainable resource use adds to the vulnerability of climate change, for instance the conversion of natural habitats for human use with high harvesting rates of resources from the environment, or cultivation and grazing practices that fail to protect soils from degradation, and pollution of air and water (IPCC, 2001). Consequentially, high levels of pollutants have been released into the atmosphere, waterways and soils (Cook, 2013).

Furthermore, the major changes in land use result in profound habitat fragmentation, ecological compartmentalization edge effects, runoff from impervious man-made surfaces, groundwater and/or surface water degradation, and partial or complete loss of habitat—all of which influence disease incidence (National Academy of Sciences, 2007). Freshwater habitats such as lakes, rivers and wetlands are the source of life for all humans, yet they are also the most threatened, strongly affected by a range of factors including habitat modification, fragmentation and destruction; invasive species; overfishing; pollution; disease; and climate change (WWF, 2018).

The world is going through a process of significant transformations, characterized by the acceleration and deepening of the various dimensions of globalization, an intense population growth, and a noticeable increase in the consumption of energy, goods, and services at a global level (Franchini et al., 2017). By the late twentieth century, the tropical forests of the developing countries have also attracted a great deal of attention, which yet again has led to further deforestation; the amount of wood consumed has increased 250% since 1950, and has resulted in environmental problems and atmospheric pollution such as acid deposition, stratospheric ozone depletion, and increased concentrations of greenhouse gases and climatic change (MacKenzie, 1998).

As McMichael (2014) postulated regarding current trends in the late-stage Anthropocene—including continued population growth and today's depleting and disrupting of Earth's biophysical, life-supporting, systems—sooner or later these factors will translate into a substantial decline in population health. Indeed, the adverse health impacts of climate change illustrate well the present and likely future health consequences of humankind's overloading of nature's capacities. These discrete and cumulative human-induced global impacts have not only diminished the environmental and natural capital of the planet but have also yielded an array of health concerns that have been arising over the past 30 years, from which impacts on the health of the planet can be classified into four areas of environmental concern (Aguirre, Ostfeld & Daszak, 2012, p. 6):

1. "Increasing biological impoverishment, including loss of biodiversity, habitat destruction, and degradation and modification of ecological processes.
2. Increasing global 'toxification', including the spread of hazardous wastes and toxic substances and the impact of pervasive low-level pollutants such as endocrine-disrupting chemicals.

3. Global climate change.
4. Global transport of species, including but not limited to pathogens and parasites, into novel environments."

The relevance of the ecological footprint for global public health is that the current level of health is due primarily to high levels of social and economic development, rather than the provision of quality healthcare services, and this social and economic development has in turn been based upon the exploitation of the Earth's resources—notably energy, forests, soils, minerals, and the oceans—and the accompanying widespread pollution of the planet (Breslow, 2002). Human activity is indeed pervasive and the planet exhibits a heavy human footprint, especially as humanity has increased in number, roughly ten times since around 1750, and as our humanity puts pressure on terrestrial ecosystems of all kinds, biodiversity is continuously and massively put under threat (Sachs, 2015). The concept of planetary health advances our understanding of the dynamic and systemic relationships between global environmental changes, their effects on natural systems, and how changes to natural systems affect human health and wellbeing (Pongsiri et al., 2019).

Humans have significantly altered nearly all of Earth's systems and the terrestrial biosphere. Taken together over the past 300 years, these anthropogenic changes in the atmosphere, hydrosphere, lithosphere, and especially in atmospheric chemistry and the global climate, provide strong evidence that humans have altered the Earth system sufficiently to indicate the emergence of a new geological epoch of the Anthropocene (Ellis, 2011). We are now creating unprecedented pressures on the natural resources of Planet Earth; it is essential that we describe our unsustainable human civilization and highlight the complexity of the interrelated vitality of all forms of beings on the planet. Ecological and complexity-based thought in the mid-20th century expanded through a heterogeneous mix of disciplines and thinkers. Kenneth Boulding, the British-American economist who presented a lasting contribution, was perhaps the revival of an older specification of the economy which recognized natural limits, now known as ecological economics (Rayner and Lang, 2015). Ecological economics represents an alternative form of environmental economics that "addresses the relationship between ecosystems and economic systems in the broadest sense which also implies a broad, ecological, interdisciplinary and holistic view of the problem of studying and managing our world (Costanza, 1989)" (Scholz, 2011, p. 296).

As the endpoint results generally show, rapid economic growth has always entailed serious disruption, and the relationship between economic growth and public health is complex since such '**D**isruption' always threatens to spill over into '**D**eprivation', '**D**isease' and '**D**eath'. As a consequence, these multidimensional disruptions may imperil the capacity of both economic growth and public health (Szreter, 1999). Yet again, it is important to repeat this—not all forms of economic growth cause damage to the environment, only an increase in real output (real GDP) that includes the increased consumption of non-renewable resources, higher levels of pollution, global warming and the potential loss of environmental habitats. All these factors of course have adverse environmental impacts.

Thus, the emergence of "Ecological economics" is the scientific domain dealing with the availability, use, and allocation of natural resources; it envisages sustainable development within a societal equilibrium and places ecosystem goods and central services as key factors of critical importance in understanding the properties of ecosystems' functioning, such as carrying capacity, habitat range, and ecosystem resilience. In fact, this "ecologically sustainable economic development" should be "Our Common Future" (Vannevel and Goethals, 2020). In this regard, the dynamics involved in the contexts of economic, socio-cultural and environmental changes are part of the evolving concepts of health which are concerned with combining our understanding of human impact on the Earth's environment together with ecological principles of human health in order to help and guide professional direction towards sustainable developments in health—and indeed, towards making such developments as the fundamental basis of sustainable healthcare as a whole.

Can we change unsustainable human civilization from human anthropogenic interference?

How can society generate the proper knowledge and synergistical interventional strategies for maintaining sustainable health developments?

Especially, our planet has ecological limits and boundaries, and sustainable economic performance cannot be secured unless we operate within the safe limits of these boundaries, an ecological footprint acts as a resource accounting tool that is comprised of two primary indicators: the first quantifies the demand humanity makes on the biosphere's renewable natural capital, and the second quantifies Earth's biocapacity, i.e., the limits of its supply (Wackernagel & Galli, 2012). We hope, concerning these environmental issues, that scientific organizations are in a position to understand, integrate and provide operationalizing complementarities for initiatives to encounter these arising health-problems accordingly. In fact, there are ongoing and collaborative scientific efforts from different organizations and authorities that have taken collective action towards those concerns; they include:

1. The United Nations Environment Programme (UNEP), created in 1972;
2. The Vienna Convention for the Protection of the Ozone Layer in 1985;
3. The Montreal Protocol on Substances that Deplete the Ozone Layer of 1987;
4. The Brundtland Report (officially entitled "Our Common Future") prepared by the World Commission on Environment and Development in 1987;
5. The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal of 1989;
6. The Intergovernmental Panel on Climate Change (IPCC), created in 1989;
7. The United Nations Conference on Environment and Development in Rio de Janeiro, better known as the 1992 Rio Summit;
8. The United Nations Framework Convention on Climate Change (UNFCCC) and the Biodiversity Convention Department (CBD), signed in 1992;
9. The United Nations Convention to Combat Desertification (UNCCD) in 1994;
10. The Kyoto Protocol to mitigate Climate Change, 1997; and
11. The Millennium Ecosystem Assessment.

This last piece of collective action was called for by the United Nations Secretary-General Kofi Annan in 2000 and was launched in 2001. Until 2005 the Millennium Ecosystem Assessment Report was published with overall conclusions indicating that two thirds of the world's ecosystems ranging from wetlands and coastal areas to forests and soils are either degraded or being managed unsustainably. The Millennium Ecosystem Assessment (MEA) has worked to assess the consequences of ecosystem change for human well-being, and establish the scientific basis for actions needed to enhance the conservation and sustainable use of those systems (WHO, 2005). The MEA has noted:

1. Ecosystem services are indispensable to the well-being and health of people everywhere around the world.

2. The causal links between environmental change and human health are complex because often they are indirect, displaced in space and time, and dependent on a number of modifying forces.
3. As a result of human actions, the structure and functioning of the world's ecosystems changed more rapidly in the second half of the twentieth century than at any other time in human history.
4. Ecosystem services and human health involve:
   a. Filtering of freshwater, including the removal of various chemicals and potentially toxic elements
   b. Contributing to productive terrestrial and marine ecosystems, both wild and managed, providing us with the source of our food
   c. Producing timber, fiber and fuel
   d. Using biological products collected from ecosystems for medicinal purposes
   e. Nutrient and waste management, processing and detoxification
   f. Regulation of infectious diseases
   g. Cultural, spiritual and recreational services
   h. Climate regulation.
5. The dual trends of growing exploitation of ecosystem services and the declining condition of most ecosystems are generally unsustainable and likely to lead to irreversible changes.

Furthermore, a growing body of natural and social science indicates that biodiverse ecosystems are important for achieving sustainable development and supplying the fundamental services and conditions necessary for human well-being (Seddon et al., 2016). Human societies would achieve benefits for well-being and health by restructuring and managing various ecosystems so that they could continue to supply the services that underpin all aspects of human life. As noted, the identification of the nature of human impact on the global biophysical system has become so dominant that scientists have proposed a new geological epoch, termed the Anthropocene, which reflects these changes. This recognizes that the history and dynamics of environmental systems are embedded in human systems and that human domination and the rapid changes of global and local patterns of biodiversity or natural diversity have become a growing matter of scientific concern. Pivotal aspects of anthropogenic land surface changes include:

- Deforestation, destruction of mangroves, and road construction;

- o Agricultural encroachment and water projects (e.g., dam building, irrigation, and wetlands modification);
- o Urban sprawl; and
- o Extractive industries such as mining, quarrying, and oil drilling.

These land surface changes cause a cascade of factors that heighten health threats, including infectious disease emergence and pathogen introduction, pollution, poverty, and human migration. The scale and rapidity of biodiversity loss has grown (as also reflected in the term "Anthropocene") as a major hallmark of this period in the transformation of ecosystems for human use, a process leading to the loss of wilderness and one which has multiple impacts on ecosystems, from biotic homogenization to the rapid erosion of species richness, both in the most highly transformed areas of Earth and on a global scale (Seddon et al., 2016).

For instance, mangroves are one of the most undervalued ecosystems on Earth and the loss of mangroves contributes to nearly one-fifth of global emissions from deforestation. The United Nation Environment Programme Report warns of deforestation's devastating effects on coastal habitats, costing billions in economic damages and impacting millions of lives as the escalating destruction and degradation are driven by land conversion for aquaculture, agriculture and coastal development (Duke et al., 2014). Ecologically, mangroves act as a vital natural protective barrier and buffer zone: they protect marine rangelands and reefs by filtering pollutants; they contribute to the catch of economically valuable fish and crustacean species by providing nesting and nursing grounds; they reduce coastal erosion and protect against extreme events such as Tsunamis; and they offer high recreational value (UN, 2012).

Extreme anthropogenic alterations exert a drastic impact on energy flow and biogeochemical cycles in ecosystems (Rapport, Gaudet and Calow, 1995) and human activity is considered to be the major driver of global environmental changes; it has a great force on the Earth system through direct and indirect impacts and environmental stress (Lu et al., 2015). As the nature and extent of our interactions with the natural environment have a profound impact on human well-being (National Academy of Sciences, 2007), a need for a revolutionary alternative of ecological public health and for understanding anthropogenic signatures in relation to those ecological and global determinants that are associated with human health in its social, cultural, economic and environmental contexts—particularly given today's pressing global environmental and climate mediated health threats—are absolutely indispensable. This view, not long ago, became the dominant one, given the unprecedented health threats imposed by the Anthropocene. Indeed the term itself helped highlight a growing sense of urgency to better understand the processes of transformation and innovation and to gain the knowledge and understanding of complex social-ecological interactions, in order to build the capacity to both respond to new disturbances and emerging risks, and to move towards sustainable pathways (Olsson, Moore, Westley and McCarthy, 2017). Therefore, at the end of the 20th century, the dominance of biomedicine and the need to have a greater emphasis on ecological dimensions and contexts in the study of human health and disease was increasingly growing as the emerging new paradigm of public health (Tarkowski, 2009).

Determining these interconnected challenges of our time demands that all medicine be viewed from an ecological health perspective, as the disconnection from the natural environment could further impose adverse health effects (Nelson, Prescott, Logan and Bland, 2019). To use one basic visionary example, for instance, "elevated disease prevalence in both plants and animals is one of the key indicators of ecosystem pathology, and conversely, pathologic ecosystems place increased risks to the health of all components, thus ecosystem health becomes a major determinant of risks to the health of component populations" (Rapport, 1999).

Modern industrial civilization in particular continues to exacerbate that contradiction due to its retrograde social relations with our environment. Its sophisticated and advanced scientific condition of factual disciplinary knowledge about cause-impact relationships, such as species decline caused by human impacts, is a necessary prerequisite for an adequate appraisal of (human-caused) environmental change (Scholz, 2011). This implies that generations in the future will be left to cope with the results of excess resource extraction, pollution and degradation of ecosystems caused by those living now (WHO, 2009).

We have been mortgaging the health of future generations by unsustainably exploiting nature's resources; human civilization has flourished with economic and development gains, but now risks substantial health effects from the degradation of nature's life support systems in the future (Whitmee et al., 2015). The current scientific evidence indicates that the extent of ecological destruction is greater than first foreseen, which implies progress towards a more sustainable form of development will prove to be much more complex and difficult than it was first hoped decades ago when the Brundtland Report was released in the World Commission on Environment and Development in 1987 (Boischio, Sánchez, Orosz and Charron, 2009). Henceforth, it is of significance to develop scientific understandings so as to identify principles for the responsible management of global environments and climate change as the arising problems affecting not only a selection of countries but also future generations globally. In fact, every part of the world is contributing to those arising problems, and nowadays the real planetary boundaries are the prime concerns of ecological changes, rather than just those limits of minerals or ores as previously understood back in 1972. Since then of course, delegates from more than 100 countries in the four big international research programmes on global environmental change have endorsed the "Amsterdam Declaration" of 2001. That novel revolution set the stage for what one might call a second Copernican Revolution in several crucial ways (Schellnhuber, Crutzen, Clark, Claussen and Held, 2004):

1. The scientific eye was re-directed from outer space to our "living Earth".
2. The scientific ambition was re-qualified by fully acknowledging the limits of cognition as highlighted by the notorious uncertainties associated with nonlinearity, complexity, and irreproducibility.
3. The scientific ethos was re-balanced at last by accepting that knowledge generation is inextricably embedded in the cultural-historical context and becomes the (post)normal way of coping with the cognitive "challenges of a changing Earth".

Regeneration in light of these new insights is vital; our current understanding of the Earth's system does show that we, the 7 (and a half) billion of us now on the planet, are big players in the story of this planet, and that the influence of our actions now will change the global environment for at least hundreds of human generations to come (Kress and Stine, 2017). We are convinced that ensuring a healthy and resilient planet for generations to come requires human development that is decoupled from environmental degradation, as well as climate change.

The last 200 years have produced a "perfect storm" of environmental stress in that they have witnessed fabulous and unprecedented economic growth with the emergence of more energy-intensive economic activities and a pollution-intensive fossil fuel energy regime overwhelmingly relying on coal, oil and natural gas (Oosthoek and Gills, 2008). The fact is that the acceleration of human pressure on the planet has opened up the possibility of a profound disruption of the system; thus there is the risk of overcoming a series of planetary boundaries that are central for its stability and capacity to sustain life (Rockström et al., 2009). These evidential facts have also been reinforced by the attending group of 3,000 leading scientists who released a State of the Planet declaration, and called for immediate action and policy reform in the "Planet Under Pressure Conference 2012", which advocated that (Muñoz and Gladek, 2017):

> *"Global sustainability must become a foundation of society as consumption accelerates everywhere and world population rises, it is no longer sufficient to work towards a distant ideal of sustainable development while the defining challenge of our age is urgently needed to safeguard Earth's natural processes to ensure the wellbeing of civilization through supporting human and ecosystem health".*

The most recent environmental mega-conference was in 2012 – "Rio+20", entitled "The future we want". It was organized by the United Nations Conference on Sustainable Development. Later in 2015 came "Transforming our world: the 2030 Agenda for Sustainable Development"; after which in 2016 the United Nations decided to produce a report quadrennially by an independent group of scientists, *The Future is Now: Science for Achieving Sustainable Development*. The first quadrennial Global Sustainable Development Report was in 2019, with specific key messages including (Independent Group of Scientists appointed by the Secretary-General, 2019):

- ☞ Greater resilience is needed to secure gains in well-being.
- ☞ Health and education provision also need to evolve to meet new demands.
- ☞ Achieving all the SDGs requires more forceful action and transformation in the ways that societies foster human well-being and build human capabilities.
- ☞ Integrated pathways for transformation.

This report further points out that the diversity of species on land and in oceans plays a key role in ecosystems and the services they provide. There is the danger of a further acceleration in the global rate of species extinction, which is already at least tens to hundreds of times higher than it has averaged over the past 10 million years, with adverse damage to the atmosphere including climate change, air pollution, stratospheric ozone depletion, and accumulative persistent organic pollutants (POPs). These are the four main challenges impacting the state of the atmosphere, and they have important deleterious effects on oceanic and terrestrial ecosystems (Independent Group of Scientists appointed by the Secretary-General, 2019).

Ecological Effects of Environmental Pollutions

Climate change reflects negative impacts that not only affect ecosystems and species directly or indirectly, but of which the cumulative impact is continuously leading to dramatic ecological changes to eco-environments. The risks are adverse consequences resulting from further environmental pollution and other stresses on ecosystem structure and function. Environmental pollution is defined simply as the introduction of pollutants into the natural environment, and causes many adverse effects; there are numerous different types of pollutions, too, such as air pollution, water pollution, soil contamination, noise pollution, radioactive contamination, light pollution, chemical pollution and plastic pollution. Environmental pollution is reaching worrying proportions worldwide. The impacts of environmental contamination are broad, including changes in atmospheric conditions and negative effects on human performance and wellbeing. Edelstein has called contaminants leftovers of the modern, industrial society and a “second invisible layer of the built environment” (Scholz, 2011).

Moreover, urbanization and industrialization—along with economic development—have led to an increase in the built environment, energy consumption, and waste discharges. Exposure to environmental pollution remains a major source of health risks throughout the world, especially in the long latency times, the effects of cumulative exposure, and multiple exposures to different pollutants which might act synergistically—all of which create difficulties in unraveling associations between environmental pollution and health (Briggs, 2003). This global environmental pollution, including GHGe and acid deposition, as well as water pollution and waste management are considered international public health problems. Therefore, our understandings of how these forms of pollution exert their influences within the context of natural ecosystem processes and how the pervasive influence of humans affect ecosystems (with each type of environmental pollution) have become global public health concerns—especially those increasingly persistent organic pollutants (POPs) that influence climate change and environmental degradation, as well as the consequential impacts on our health. And those POPs are also chemicals of global concern due to their potential for long-range transport, persistence in the environment, and ability to bio-magnify and bio-accumulate in ecosystems. Alongside this, those POPs have imposed the most crucial and significant negative effects on human health and the environment in a variety of ways, through the food we eat and the air we breathe (WHO, 2020).

Plastic pollution

Plastic, one of the most preferred materials in today's industrial world, is posing a serious threat to our environment and consumer health in many direct and indirect ways (Rustagi, Pradhan and Singh, 2011). Plastic waste both on land and sea is increasingly out of control, as plastics have outgrown most man-made materials. Around 4900 million tones (Mt)—60% of all plastics ever produced—have been discarded and are accumulating in landfills or in the natural environment. Figure 1-4 shows the global plastic production, use, and the fate of polymer resins, synthetic fibers, and additives (Geyer, Jambeck and Law, 2017).

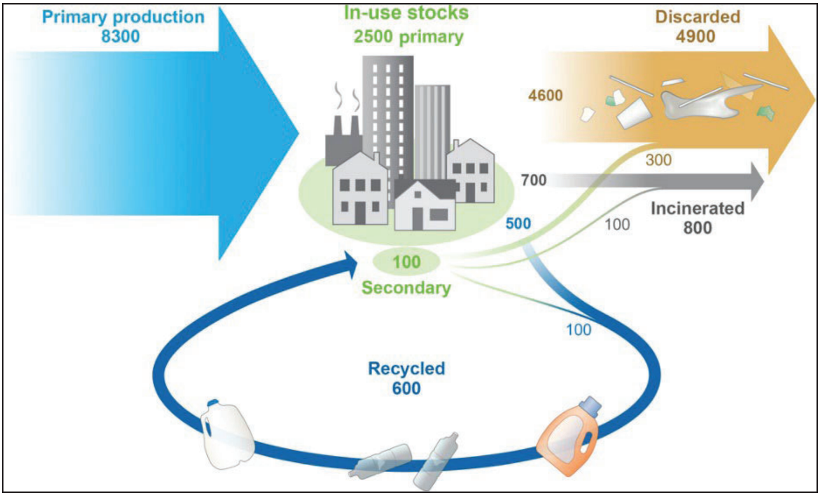


Figure 1-4: Global plastic production, use, and fate of polymer resins, synthetic fibers, and additives (data gathered from 1950 to 2015 with unit in million metric tons). Used with permission from Geyer, Jambeck and Law, 2017.

With such an amount of plastic having been discarded and accumulating in landfills or in the natural environment, not just the natural environment has been affected, but harm has been imposed on plants, animals, and humans. Those plastics have released toxic pollutants that pollute water and soil, thereby adversely affecting wildlife, wildlife habitats, and humans. Human health risks from plastic pollution are further elaborated on in Chapter 3.

Air pollution

Air pollution has always been part of human life. Early humans contended with natural air pollution from forest fires, volcanic eruptions, and decay of organic matter, and later humans created air pollution by using fire for cooling and heating, and generating waste(s), including the burning of fossil fuels such as coal. Humans have lived on the planet for thousands of years and influenced the composition of the air through their many activities, generating air pollutants from thousands of chemicals commonly used throughout the world for industrial, agriculture, and domestic purposes. Those pollutants can affect the health of humans, plants and animals, as well as nonliving materials such as paints, metals, and fabrics (Spellman, 2009). The current chemical burden on our health is unprecedented in human history, with mounting scientific evidence confirming the presence of hundreds of potentially harmful chemicals such as heavy metals, dioxins, and pesticides in the blood, urine, and breast milk, which indicating that the human body is becoming a reservoir for the toxic chemicals found in the air, in water, food, household products, and even in products commonly used in the provision of healthcare (American Nurses Association [ANA], 2007).

Atmospheric aerosol loading can be mixed with those pollutants and carried by wind over long distances and then fall on the land or a water surface either with precipitation or by the deposition from the air, with many unwanted chemicals infiltrating terrestrial, freshwater, and marine ecosystems. Aerosol particles in the atmosphere are detrimental to human health and are well known to affect climate with emissions of the aerosol "black carbon" that may be the second most important contributor to global warming after carbon dioxide emissions (Campbell et al., 2017). Furthermore, toxic air pollutants affect both aquatic and land wildlife with toxins which contribute to birth defects, reproductive failure and disease in animals; they also impose on the environment, contributing to acid rain, global warming and greenhouse effects, stratospheric ozone depletion, and the production of photochemical ozone (i.e., smog). Furthermore, they are also guilty of introducing toxins into the food chain. Human health risks from air pollution-related health effects are further elaborated on in Chapters 3 and 4.

Chemical pollution

The ecological effects of chemical pollution are many and varied. They include emissions from industries, waste disposal and incineration, as well as the intensive use of chemicals in agricultural production, such as fertilizers and pesticides. Regarding the latter, residues remain in fruit, grains and vegetables that can reach the environment, and all of these can reach the consumer through food consumption with bio-accumulative chemicals in the food chain and the environment—for instance heavy metals and POPs that can be found in fish, meat and dairy products. Dioxins that have accidentally contaminated poultry feed can also move up the food chain to humans; similarly using feeds that contain diseased animal remains can cause the so-called “mad cow disease” or Bovine spongiform encephalopathy (BSE) in livestock, which has been linked to a new form of Creutzfeldt-Jakob disease in consumers (OECD, 2001). This, together with unsafe livestock feeding practices—e.g., in feed additives and medication—means that toxins reach the food chain unintentionally.

As the World Health Organization has suggested in examples from their global assessments, emissions of increasing numbers of chemicals at increasing rates have already reached the point where vital ecosystems are being eroded, threatening not just the health of individual people but the well-being of societies at large (UNEP, 2013). For example, organic chemicals can contribute to local and regional losses of freshwater biodiversity and ecosystem services, and in fact, chemical pollution is a large-scale environmental problem, with chemicals threatening the ecological integrity and consequently the biodiversity of almost half of the water bodies on a continental scale. Therefore the protection of freshwater ecosystems from organic pollutants is important to preserve biodiversity and also the goods provided to society (Malaj et al., 2014).

There is widespread consensus that the harms of chemical pollution should be minimized, and that some chemical pollutants should be banned or severely restricted because of their hazardous effects (Häyhä, Cornell, Lucas and van Vuuren, 2018). Many different types of chemicals can be endocrine disrupting chemicals (EDCs), which include compounds with important agricultural, industrial and pharmaceutical uses that alter the function of the endocrine system and consequently are capable of causing adverse effects to humans or wildlife (Godfray et al., 2019). In fact, tens of thousands of synthetic chemicals are also substances known to disrupt the immune, endocrine and hormone systems of virtually all organisms (Curry, 2011). As a result, that is one of the adverse effects for a large percentage of new emerging infectious diseases derive from zoonoses. Another major threat is improper or over use of antibiotics, leading to antimicrobial resistance in human pathogens, all of which mostly derives from the large-scale use of antibiotics in animal husbandry and agriculture (De Paula, 2018).

Acid rain

Robert Angus Smith first used the term acid rain in his description of the acidic rain, fog, hail and snow around the industrial city of Manchester (UK) in 1872, in a paper entitled "The air and rain beginning of chemical climatology" (Singh and Agrawal, 2008). Acid rain, also known as acidic atmospheric deposition, has been linked to forest damage and acts on an ecosystem through two major pathways: directly through the deposition of acidic aerosols and gases on leaves, or soil acidification (Crutzen and Brauch, 2016), in which the emissions of sulphur dioxide and nitrogen oxides and the ozone to some extent are the primary causes. These pollutants originate from human activities such as combustion of burnable waste, and the use of fossil fuels in thermal power plants and automobiles (Singh and Agrawal, 2008).

Acid rain and deposits can also rob the soil of essential nutrients (such as calcium) and leach aluminum into the soil, making it difficult for trees to take up water. Acidification of precipitation and acid deposition do damage to receiving ecosystems, including aquatic and marine ecosystems, which in turn impose many ecological effects on lakes, streams, wetlands, and aquatic environments. These acidifications are further degrading eco-environments, as fish and other aquatic organisms, as well as forests, crops, and soils are highly sensitive to pH change (MacKenzie, 1998).

Ocean acidification

The gradual acidification of the ocean is another potential threat to the well-being of our planet which must be addressed seriously, as the fate of much of the CO_2 we produce is to enter the ocean. Especially so while industrialization continues to drive atmospheric CO_2 concentrations upward, the surface-ocean responds by taking up more of this gas, which reacts with the water, reducing surface-ocean pH and carbonate ion concentrations (Gattuso and Hansson, 2011). Over the period from 1750 to 2000, the oceans have absorbed about one-third of the CO_2 emitted by humans; as this CO_2 dissolves in seawater, the oceans become more acidic. Anthropogenic CO_2 emissions between these dates have already led to a decrease of surface-ocean total pH (pH_T) by ~0.1 units, i.e., from ~8.2 to ~8.1. It is worth noting that "surface-ocean pH_T has probably not been below ~8.1 during the past 2 million years" (Gattuso and Hansson, 2011).

Climate change and ocean acidification (OA) will affect microbial distributions and functions in similar ways to macro-organisms, affecting both community composition and abundance (Gillings and Paulsen, 2014).

In addition, OA and ocean de-oxygenation have been identified as potentially devastating for large parts of the marine ecosystem (Allison et al., 2011), as they affect organisms' ability to hold on to their ecological niche (Gattuso and Hansson, 2011). OA is a direct result of the rising CO_2 levels that have major effects on marine ecosystems, with possible adverse consequences on fish stocks (Stern, 2008), losses to key aquatic life and damage to coral reefs, and the threatening of shell-forming organisms such as corals and the species that feed on them, the last of which is one of crucial factors causing further ecological disturbances. As the overall relevance of marine microorganisms to ocean ecosystems is being disrupted through altering pH conditions to well outside their recent historical range, a negative effect is then had on their intracellular pH homeostasis too (Cavicchioli et al., 2019). The gradual acidification also affects calcium carbonate producing organisms, as $CaCO_3$ dissolves under acidified conditions (Ryberg, Owsianiak, Richardson and Hauschild, 2018). As a result, global OA could be equivalent to global crises with adverse impacts on economic related issues and food security, as displayed in Figure 1-5.

Changing ocean chemistry	☞ CO_2 dissolves in seawater and forms carbonic acid (HCO_{3-}) and release of hydrogen ions (H^+), and H+ combines with carbonate ions (CO_3^{2--}) to form bicarbonate (HCO_{3-}). ☞ Formation of HCO_3^- removes CO_3^{2-} so they are less available for calcifiers such as corals.
Economic related issues	☞ Most significant losses come from the erosion of coral reefs that will cost the world economy $1.09 trillion per year at the end of the century. ☞ The food web that supports commercial finfish is likely to be altered due to the prey at the bottom of the food chain declining. ☞ OA impacts food webs such as calcifiers (lobster, shrimp, scallops, crab, and oysters) and pollock, salmon, and tuna.
Seafood = Food Security	Seafood is a primary source of protein for one billion people, and 1 in 7 people depend on seafood from the ocean for protein. Overfishing and habitat destruction decline seafood stocks, and now OA has imposed further threats.

Figure 1-5: The adverse impacts of ocean acidification (OA). Adapted & modified from Spalding (2016).

OA heavily affects the very base of the food chain, the krill and pteropods that bigger fish feed on for growing, which then allows for human consumption. If all of the commercial fish species which feed on phytoplanktonic calcifiers are being affected, then the base of the food chain will have rippling effects throughout the food webs, on reef fish, coral reefs, kelp forests and other habitats harmed by lower pH. Other additional stressors compounding the situation are overfishing and marine pollution. There is a growing concern that OA caused by fossil fuel emissions, in conjunction with the effects of other human activities, will cause significant changes in the biodiversity and function of marine ecosystems, with drastic consequences for natural resources and services that are essential to society (Gattuso and Hansson, 2011).

Soil contamination and acidification

In 400 BCE, Hippocrates published a list of things that should be considered part of a proper medical evaluation, a list that included the nature of the ground. In 60 BCE Columella wrote about the hidden diseases from marshes. In both cases, the idea advanced was that soil is important to human health. Soil is an irreplaceable resource that sustains life on the planet; soil contamination and soil pollution constitute an essential issue to be addressed if we are to secure the life quality of present and future generations (Hernández-Soriano, 2014).

In 1957, the USDA (United States Department of Agriculture) brought about the realization that soil could supply toxic amounts of elements to the human diet; since then the idea that soil could affect human health has gained widespread acceptance (Steffan, Brevik, Burgess and Cerda, 2018). From these first realizations, studies into the relation between soil and human health have continued to increase; for instance, in 1959, André Voisin published extensively on the potential links between soil and human health in what was probably the most comprehensive study on the subject up to that time (Steffan et al., 2018). Environmental pollution is one of the burning topics of the day, in which air, water and soil alike are being polluted as a result of many activities and experiments done by mankind. Soil pollution is defined as the build-up in soils of persistent toxic compounds, chemicals, salts, radioactive materials, or disease-causing agents, which have adverse effects on plant growth and animal health (Hernández-Soriano, 2014). Natural soil usually has little anthropogenic contamination, whereas in soils in agroecosystems, urban areas, mines, oil and gas extraction areas, landfill sites and other locations, anthropogenic contamination is more likely, as the soil may be contaminated either naturally or through anthropogenic activities with chemical elements and substances that are toxic in amounts when ingested or inhaled, adversely affecting human health (Steffan et al., 2018). Yet the presence of toxic contaminants does not just pose a significant health risk to humans, but other ecological systems too (Murtaza, Murtaza, Niazi and Sabir, 2014). A soil pollutant is any factor which deteriorates the quality, texture and mineral content of the soil or which disturbs the biological balance of the organisms in the soil, which is often associated with (Hernández-Soriano, 2014):

a. indiscriminate use of fertilizers;
b. indiscriminate use of pesticides, insecticides and herbicides;
c. dumping of large quantities of solid waste; and
d. deforestation and soil erosion.

The most widely recognized function of soil is its support for food production, as 95% of our food is directly or indirectly produced on or in soils, and only healthy soils supply the essential nutrients, water, oxygen and root support for the basis of healthy food production. Therefore the key facts and concerns are (FAO, 2015):

☞ It can take up to 1,000 years to form one centimeter of soil but intensive crop production has depleted the soil.
☞ A shortage of any one of the 15 nutrients required for plant growth can limit crop yield.
☞ By 2050, agricultural production must increase by 60% globally—and by almost 100% in developing countries—in order to meet food demand alone.

The most striking aspect is ensuring food as sustenance to continue to feed us: we need to safeguard its soils, as soil once eroded or depleted takes centuries—millennia even—to recover (Rhodes, 2012).

Biogeochemical flows and eutrophication

Nitrogen is an essential nutrient for the growth and functioning of plants, animals and humans, and an essential element for food security. Humankind seeking different ways to increase crop production to provide food to sustain a growing population has led to the development of synthetic fertilizer production based on the Haber–Bosch process for reactive nitrogen (N_r). However, humankind's increasing use of reactive nitrogen in fertilizers, plastics, and explosives, among many other products, leads to problems, as most of those N_r is leaked back into the environment. This causes wide-ranging impacts on greenhouse balance including global warming, acid rain, and eutrophication, as well as declines in the qualities of air, water and soil (UWE, 2013).

All of these effects can be harmful to humans and the ecosystems we depend upon. These effects also link the nitrogen boundary to most other planetary boundary (PB) processes, namely land, biosphere, climate, aerosol and ozone PBs, and indirectly the water PB (affecting usable quality, rather than quantity). As a consequence, altered nitrogen flows (as well as those of phosphorus) are causing undesired nonlinear changes in terrestrial, aquatic, and marine systems on regional to global scales, while simultaneously influencing anthropogenic climate change (Häyhä et al., 2018). The following diagram (Figure 1-6) shows the exceedance (red bar) of the effect levels of N_r for ecosystems or human population, and the contribution of N_r (blue bar) to the total effect, extending from the local scale to the global/stratospheric scale (Erisman et al., 2013).

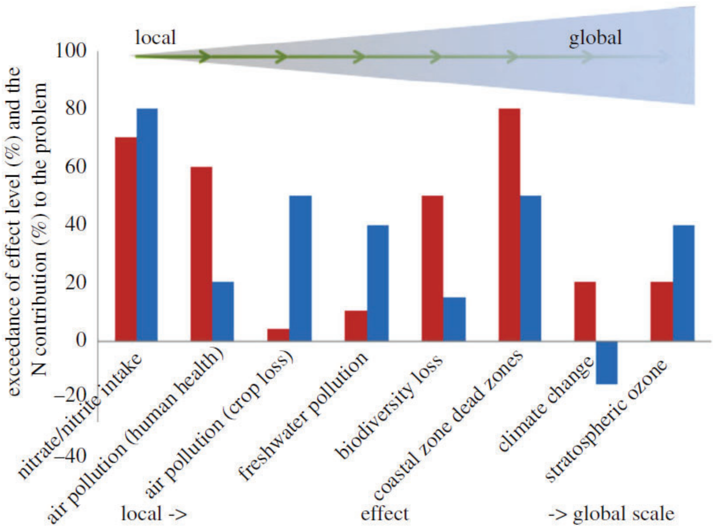


Figure 1-6: The exceedance (red- 1st bar) of the effect levels of N_r for ecosystems or human population, and the contribution of N_r (blue- 2nd bar) to the total effect, relative to other components or causes (e.g., natural) of the problem. This figure extends from the local scale to the global/stratospheric scale and thus represents the N_r cascade (top green arrow). Used with permission from Erisman et al. (2013).

Many thresholds for human and ecosystem health have been exceeded owing to N_r pollution, including those for drinking water (nitrates), air quality (smog, particulate matter, ground-level ozone), freshwater eutrophication, biodiversity loss, stratospheric ozone depletion, climate change and coastal ecosystems (dead zones) (Erisman et al., 2013). The Earth's freshwater resources depletion is subject to increasing pressure in the form of consumptive water use and this kind of N_r pollution, as that will continue to degrade freshwater and marine ecosystems (Hoekstra and Mekonnen, 2012).

The direct large-scale effects of the release of excess nitrogen into the environment, which increases concentrations of reactive compounds in the atmosphere, soils, water-bodies and the oceans through consecutive transformations into different compounds is the process of so-called "nitrogen cascade". That in turn causes multiple consecutive impacts in the different environmental compartments (Häyhä et al., 2018). The nitrogen cycle and our influence on it are complex, given 78% of the world's atmosphere is composed of di-nitrogen gas (N_2), which is relatively unreactive. However, our demand for more food is increasing fertilizer and land use, and the demand for more energy is also increasing fossil fuel combustion, leading to enhanced losses of reactive nitrogen (N_r) to the environment.

The fixation of atmospheric nitrogen by humans in large quantities is changing the "Earth system baseline" for nitrogen flow, which alters both the quantitative relationships of different chemical elements available for organisms to use (shifting nutrient limitation) and the spatial patterns and dynamics of nutrient flows between land, atmosphere, aquatic ecosystems, and oceans. These fundamental changes to the systemic interconnections of Earth system components are the rationale for the planetary boundary regarding biogeochemical flows for both nitrogen and phosphorus cycles, a concept will be elaborated on in Chapter 4.

> "Excess reactive nitrogen represents a major environmental threat that is only now beginning to be fully appreciated. At a global level, humans have more than doubled the production and cycling of reactive nitrogen, leading to a plethora of impacts that interact across all global spheres: atmosphere, biosphere, hydrosphere and geosphere."
>
> Sutton et al., 2009 (UWE, 2013 p. 8).

Land conversion and loss of biodiversity

The impact of land use resulting in major changes in biodiversity is complicated and the expansion and intensification of human land use in recent decades will likely have the largest effect on terrestrial ecosystems in the coming century (Hansen, DeFries and Turner, 2004). This landscape change is often driven by economic, demographic and cultural factors operating at a range of spatial and temporal scales due to agricultural expansion, industrialization and urbanization, with the drive to maximize the return on an investment often being deemed most important (Neldner, 2018). This is especially due to rising populations putting increasing demands on land use changes for the production of food, fuel and fiber, which further imposes serious implications for eco-environments (Environmental Pillar, 2012).

In cities and other landscapes comprising anthropocentrically formed areas of the Earth's surface, people should create a built environment in which bioecological knowledge serves as a center-piece of sustainability sciences (Scholz, 2011). It is because of habitat loss through increasing intensity of landscape change and the direct impacts it has on the biota of a given area that land clearing is one of the greatest threats to terrestrial biodiversity. Because more intensive land use results in a greater share of resources and energy flowing to human uses, meaning there is less to sustain other species, there is often an extended extinction debt to be realized (Neldner, 2018). Human activities in the matrix around natural habitats can alter ecological processes and organisms within the reserves, but perhaps our increasing appreciation of the interdependence between healthy ecosystems and healthy human communities will lead toward more sustainable approaches for land use (Hansen, DeFries and Turner, 2004). The ability to cycle nutrients is a fundamental function of all ecosystems; they are within their catabolic capacity to degrade and mineralize molecules of varying complexity, including pollutants, which give a value to ecosystems (Hernández-Soriano, 2014). In 2017, the United Nations special rapporteur, J. H. Knox stressed that:

> *"The full enjoyment of human rights, including the rights to life, health, food and water, depends on the services provided by ecosystems. The provision of ecosystem services depends on the health and sustainability of ecosystems, which in turn depend on biodiversity"* (Morand and Lajaunie, 2018, p. xv).

The value of biodiversity here refers to the wide variety of ecosystems and living organisms: animals, plants, their habitats and their genes, all of which are part of our natural capitals (Environmental Pillar, 2012). Biodiversity loss reduces adaptive potential to global change and the loss of species (e.g., pollinators) and ecosystem degradation is also affecting food security; furthermore, the irreversibility of biodiversity loss (from genes to ecosystems, including pollinators) at all levels reflects an ongoing major extinction event (Gupta et al., 2019).

The overall deterioration of eco-environments through human anthropogenic activities has imposed many adverse effects, from the destruction of sustainability of biocapacities and natural habitats to the depletion or destruction of resources. These events have adversely altered the Earth's biota and driven us into the midst of the sixth mass extinction crisis, causing serious ecological consequences that threaten the survival of our human civilization and public health on a global scale.

In the Midst of the Earth's Sixth Mass Extinction Crisis

Progress is understanding that Earth's natural environment has been a bountiful source of resources as well as a remarkable life support system that has allowed human civilization to develop and flourish. This relationship of humans with the Earth's environment has continuously changed throughout the evolution of *Homo sapiens* and the development of societies (Steffen et al., 2004). During the early, still poorly understood, stage of Earth's development, tremendous changes must have taken place, accompanied by myriad catastrophic events, all leading ultimately to a setting in which life could develop and eventually thrive (National Research Council, 2008).

But now the Earth's biota is experiencing the sixth great extinction event. It is unique in its history because of its cause; while the previous five extinctions were caused by natural processes, but this current crisis is a consequence of human activities (Steffen et al., 2004). We know that geological events and meteoroid impacts have caused massive extinctions in the past and influenced the course of evolution. The development of life has clearly been influenced by these events and its effects on the conditions of the Earth's surface, while in turn the Earth's surface has also been influenced by the activities of life forms (National Research Council, 2008).

Henceforth, it is worth emphasizing that the current sixth mass extinction is (i) being driven by a single species, *Homo sapiens*, rather than a planetary or galactic physical process as happened in the previous five extinctions, and (ii) causing an estimate of 30,000 species per year to be driven to extinction (compared with the natural background rate of one extinction per million species per year). This is the reason why scientists refer to it as a crisis unparalleled in human history (Center for Biological Diversity, 2019). Figure 1-7 summarizes these waves of extinctions and discusses some of their differing causes (Ceballos, Ehrlich and Dirzo, 2017; Eldredge, 2005).

Waves of Extinctions: From the first mass extinction until now in the midst of the Earth's sixth mass extinction crisis.
The first mass extinction occurred about 440 million years ago, at the end of the Ordovician Period, as a result of a fall in temperature and the ocean levels; it targeted large vertebrates hunted by hunter-gatherers.
The second mass extinction wave took place during the late Devonian Period around 370 million years ago, again due to temperature fall and sea reliction.
The third mass extinction happened at the end of Permian Period, approximately 245–250 million years ago; 95% of marine species and nearly 70% of terrestrial ones disappeared. This is the largest mass extinction event in Earth's history, affecting a range of species, including many vertebrates.
The fourth mass extinction happened in the late Triassic, around 200–210 million years ago.
The fifth mass extinction hit the Earth around 65 million years ago.
Our Earth is now in the midst of a sixth mass extinction due to climate change and humans causing vast physical changes on the planet. This sixth global wave of extinction is the result of human activity with two discrete phases: 1. Phase One – when the first modern humans began to disperse to different parts of the world about 100,000 years ago. 2. Phase Two – about 10,000 years ago when humans turned to agriculture. This larger wave began 10,000 years ago as the discovery of agriculture caused a population boom and a need to diminish wildlife habitats, divert streams, and maintain large herds of domestic cattle.

Figure 1-7: Waves of Extinctions: From the first mass extinction until now (in the midst of the Earth's sixth mass extinction crisis). (Adapted & modified from: Ceballos, Ehrlich and Dirzo, 2017; Eldredge, 2005.)

Other than invasive species and diseases, and climate change, extinction rates are increasing sharply in marine and terrestrial ecosystems around the world; the Earth is now in the midst of its first great extinction event caused by the activities of a single biological species, humankind. Extinction is the most serious, utterly irreversible effect of an unsustainable human population (Center for Biological Diversity, 2019). In the current sixth mass extinction, it implies that we are tearing apart the great web of life, of which we are also a part (Hancock, 2019). The devastation of our planet and the biodiversity crisis is resulting in the fastest mass extinction in Earth's history, largely due to (Eldredge, 2005):

☞ Human destruction of ecosystems;
☞ Overexploitation of species and natural resources;
☞ Human overpopulation;
☞ The spread of agriculture; and
☞ Pollution.

This current mass extinction is more severe than initially perceived when looking exclusively at species extinctions. A more detailed assessment highlights a whole set of parameters that are increasingly critical in considering the Anthropocene's biological extinction crisis (Ceballos et al., 2017). Additionally, the current population growth trends indicate that the number of threatened species will increase by seven percent over the next twenty years and fourteen percent by 2050; and that's without the addition of global warming's impacts.

The inexorable links between biodiversity, ecosystems, the provision of these benefits, and human health are deeply entrenched as reflected in the 2050 Vision of the Strategic Plan for Biodiversity that stresses the value of biodiversity and how it is vital to maintain ecosystem services for sustaining a healthy planet and delivering its essential benefits for all people (WHO, CBD and UNEP, 2015).

As human domination of the Earth is well established, we must further reinforce the Manhattan Principles on "One World, One Health", which "recognize the essential link between human, domestic animal and wildlife health and the threat disease poses to people, their food supplies and economies, and the biodiversity essential to maintaining the healthy environments and functioning ecosystems we all require" (Cumming and Cumming, 2015, p. 39).

This, in turn, reinforces the functioning of the natural ecosystem services indispensable to the wellbeing of all people in the world. The world's climate system is also an integral part of the complex of life supporting processes, and as the IPCC has indicated there is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities (Li, 2017b). As Lueddeke (2019) postulated, The Rockefeller report[1] underscores how "this environmental degradation can pose a serious threat to human health", and reiterates

[1] The full title of the report is "Safeguarding human health in the Anthropocene epoch: Report of The Rockefeller Roundation–Lancet Commission on planetary health".

human impacts on natural systems; Lueddeke quotes a summary on the state of the planet by Professor Sam Myers of Harvard University:

> "*Driven by rapid increases in the size of the human population and even steeper growth in per-capita consumption, the scale of human impacts on our planet's natural systems is hard to overstate: to feed ourselves, we annually appropriate about 40% of the ice-free, desert free terrestrial surface for pastures and croplands; we use about half of the planet's accessible water, largely to irrigate our crops, and we exploit 90% of global fisheries at, or beyond, their maximum sustainable limits. In the process, we have cut down 7-11 million km^2 of the world's forests and dammed more than 60% of its rivers. The quality of air, water, and land is diminishing in many parts of the world because of increasing global pollution. These and other processes are driving species to extinction at roughly 1000 times baseline rates while reducing population sizes of mammals, fishes, birds, reptiles, and amphibians by half in the past 45 years.*"

Yet again, this indicates ecosystems will be particularly vulnerable to climate change, with one study estimating that around 15–40% of species face extinction with 2°C of warming. For instance, strong drying over the Amazon, as predicted by some climate models, would result in the dieback of the forest with the highest biodiversity on the planet (Stern, 2008). By investment in education, raising awareness among the world's people, and in influencing the policy process to increase the recognition that we must better understand the relationships between health and ecosystem integrity, we will succeed in improving prospects for a healthier planet. No one nation can reverse the patterns of habitat loss and extinction that can and do undermine the health of people and animals (Cumming and Cumming, 2015). It must be a global effort.

Planetary Health: Ultimate Ecological Determinants of Human Health

Traditionally, environmental health concerns have focused on toxicological or microbiological risks to health from local exposures. However, the scale of environmental health problems is increasing and various larger-scale environmental hazards to human population health have begun to appear, which leads to the appreciation of this scale and type of influence on human health from an ecological perspective (McMichael, 2003). These large-scale changes of global environmental degradation and climate crisis in the Anthropocene are predominantly caused by human anthropogenic activities imposing challenges for human health. Under such devastation to the complexity of the biosphere's life-supporting ecological and physical Earth systems, our subsequent concerns are indeed focused on the infinity linkages and its consequential influences in order to maintain sustainable health developments across future generations.

Though the Earth's crust constitutes far less than one percent of the entire planetary mass, it represents the nurturing substrate for virtually all life on land and much of the life in the oceans. The biosphere predominantly occupies the near-surface skin of the solid crust—the upper, illuminated portions of the oceans and the lowermost zones of the atmosphere (National Academy of Sciences, 2007). To investigate and quantify effects on human health and longevity due to the presence and bioassimilation of Earth materials, we need to understand the nature of the constituents that make up the Earth's crust—i.e., minerals and rocks. The human environment is heavily dependent on the continuum between soil, water, and air that is located at the Earth's surface. Ultimately this continuum—and the interactions between the physical, chemical, and biological properties of each component—moderates many of our activities. The geological zone between the land surface and subsurface ground water, the vadose zone, consists of unsaturated organic and Earth materials. A subset of this vadose zone is the near-surface soil environment, which is in direct contact with both surface water and the atmosphere.

Soil directly and indirectly influences our quality of life: it is taken for granted by most people but is essential for our daily existence. It is responsible for plant growth and for the cycling of nutrients through microbial transformations, and has a major effect on the oxygen/carbon dioxide balance of the atmosphere. Because of our reliance on soil, any disturbance of soil or the vadose zone, or modification of natural soil-forming processes, has the potential for adverse public health effects. Soil also plays a critical public health role in regard to pollutants that have been disposed of at the Earth's surface, as it can promote or restrict transport to groundwater, the atmosphere, or food crops. Soil has proven to be a treasure chest of natural products critical to maintaining human health and welfare (National Academy of Sciences, 2007).

In 1972, physician ecologist Frederick Sargent II, MD advocated for a greater understanding of the interrelations between the "planetary life-support systems" and health; the term planetary health then emerged from the annals of preventive medicine, health promotion and the environmental health movement (Prescott, Logan and Katz, 2019). In fact, planetary health does not claim to be a complete new movement, but an evolving paradigm that was then introduced by Richard Horton and colleagues in

2014, and expanded in a Lancet Commission report in 2015 (De Paula, 2018). The term planetary health—denoting the interconnections between the health of person and place at all scales—emerged from the environmental and holistic health movements of the 1970–80s. In 1980, Friends of the Earth expanded the World Health Organization definition of health by stating:

> "*Health is a state of complete physical, mental, social and ecological well-being and not merely the absence of disease – personal health involves planetary health. By the 1990s, the concept of planetary health was part of the fabric of integrative medicine; more recently, after the 2015 Lancet Commission on Planetary Health report, the concept has penetrated mainstream academic and medical discourse"* (Prescott and Logan, 2019, p. 98).

It extends the WHO's definition of health adopted on 22 July 1946 (at the start of the WHO's constitution), which stated that "Health is a state of complete physical, mental, and social well-being, and not merely the absence of disease and infirmity". This "old version" of a definition for health has already received much criticism over the years and has been considered inadequate at capturing variations in health (Li, 2017a). To this point in time the health sector has taken planetary health for granted, but now a body of evidence is unfolding that indicates how these planetary ailments impact on our human health and how they represent the biggest global health threats of the 21st century. As famously described in the *Lancet*, there is a clear actual and potential danger that we are still collectively sleepwalking into such a public health catastrophe (Schroeder, Thompson, Frith & Pencheon, 2013).

Our ambition is to go beyond that and critically examine the relationship between human beings and nature and the threats we pose to the complex natural systems on Earth that are the preconditions for all life. Our humanity is facing a critical reality with the hard impacts of global environmental change, where the biosphere cannot handle additional stress; it is a necessity to implement a vision that perceives the living biosphere and natural resources as prerequisites for prosperity and development in the future (Wijkman and Rockström, 2012). We can reframe the phrase "form follows function" to refer to the situation, in terms of (i) how cosmic history has produced the solar system and the planet where we live and thus the great variety of plants and animals (with some fundamental characteristics of humanity), and (ii) how our Earth has conditioned their development, as in the course of history we have tried to increase our understanding of the human situation that has produced our global civilization from the beginning of the universe to today (Alvarez, 2017).

With scientific advancements, this reality signifies the practical reason for action-oriented approaches to imperatively and proactively project our intellectual history prospectively for "the needs of the present without compromising the ability of future generations to meet their own needs", as stated in the 1987 Brundtland report. The feasibility of this vision perhaps depends upon whether we can see regularities in the unfolding of the past or whether history is all disorganized confusion. Walter Alvarez, in his discussion of Isaac Newton and the advancements of the seventeenth century—during which scientists discovered that there are unbreakable mathematical laws governing the motions of objects and all transformations of energy—suggested that this scientific progress led to the idea that beneath the seemingly capricious events of daily life there might be an underlying order and that it might even be possible to discover fundamental laws of history itself (Alvarez, 2017). Or perhaps, the notion may direct believers toward a more profound moral case for treating the planet and its creatures responsibly, whether this is through stewardship that arises from a mandate from God, moral responsibilities, sensing a "one-ness" with the natural world, or through an ethical obligation that transcends relationships among people and creates duties and rights with species and ecological communities *per se* (Guidotti, 2015). Resolving this requires a fundamental transformation that involves a paradigm shift towards an economy that uses natural resources in an efficient and fair manner, in order to preserve the habitability and resilience of this planet for future generations (Muñoz and Gladek, 2017). Figure 1-8 "Our duty Our legacy" symbolizes the needs of sustainable development for our future generations.

Science evolves, responding to its foremost challenges as they change through history, and in every age, science is shaped around its leading problems, and the recognition of their complexity, implying the legitimacy of a plurality of perspectives and ways of knowing. This perhaps is the greatest collective task now facing humanity (Curtin and Allen, 2018). Yet again, while modern medicine continues to make headway, some existing challenges now face us in the 21st century that have to be addressed collectively and collaboratively as our human health is facing actual and potential health threats arising from the global environmental and climate mediated crisis, which have increasingly gained prominent awareness as representing one of the biggest public health risks across the globe and generations. The ultimate goal of implementing ecological public health principles for sustainable health developments is not just an idealistic way of thinking for the future but is rather a realistic course of action and set of commitments that are utterly essential to advance our greater duty towards the global context of public health needs in transition.

Figure: 1-8: This figure "Our duty Our legacy" symbolizes the needs of sustainable development for future generations. (Adapted & modified from Li, 2014b.)

There is no scientific uncertainty that the global environmental and climate crisis is occurring more rapidly than predicted. Public health surveillance serves as an early warning system in assessing and identifying the impact and trend of new emerging health problems, while also providing the scientific database essential for decision making and appropriate public health function and action. The World Health Organization in 2012 defined public health surveillance as the continuous, systematic collection, analysis and interpretation of health-related data needed for the planning, implementation, and evaluation of public health practice (Kumar and Raut, 2014). Surveillance concepts hold great promise for prevention and public health as the access to real-world evidence will play a critical role in better understanding the impacts of those arising ecological determinants of health and their risks that we are facing in this new era of the Anthropocene.

Assessing planetary health allows us to recognize global environmental and climate mediated health risks arising from the changing ecological and global determinants of health during this transitional period. The human condition is also tied to these natural systems of Planet Earth that propel our health into this transition. The core value within the planetary health approach is the health of both living and future human generations, applied to individuals, communities, and the population as a whole. It includes a broad spectrum of scientific disciplines such as human medicine, ecology, and other environmental sciences, and focuses on mitigating and responding to threats to human health and wellbeing, as well as on the sustainability of the entirety of human civilization (Rüegg, Buttigieg, Goutard, Binot, Morand, Thys and Keune, 2019). The evidence is clear that the rate of global environmental and climate change is accelerating, and we have been in the new geological era of the Anthropocene since the middle of the 20th century. This further affirms the health of the Earth system is deteriorating, which has implications for our human health with adverse impacts on sustainable health developments across all generations. Thus, planetary health has been described as "the ultimate ecological determinant of health" for the 21st century (Nelson, Prescott, Logan and Bland, 2019).

> "Earth will survive, but the living creatures may perish."
> … "Human health is the common denominator that overlaps all boundaries …"
>
> Lemery and Auerbach, 2017.

Conclusion

Earth's surface temperature seems to have remained within relatively narrow limits for most of the past 4 billion years (National Research Council, 2008). The Earth's surface has now changed considerably over the past centuries since the start of the Industrial Revolution in the early 1700s and since humans from the "Old World" started to colonize the "New World" (Goldewijk, 2005). Since the picture of "Earthrise" was taken by astronaut William Anders on December 24, 1968, during the Apollo 8 mission—giving those on Earth their first view of what the planet looked like from space—a more holistic view of the Earth and humanity's role as steward of our fragile planet have been promoted. From climate change to species extinction, humanity is confronted with an increasing array of societal and environmental challenges that defy simple quantifiable solutions despite hope or good models to emulate being provided. However the magnitude of these beneficial actions is not yet commensurate with the magnitude of the crisis, of its impacts or their consequences (Curtin and Allen, 2018).

This image of "Earthrise" indeed represents the dramatic changes that have occurred over the past 50 years, as satellites now reveal images of the shrinking of the tropical rain forests; the intensification of agriculture; the loss of wetlands; and the expansion of urban centers with the advancement of new technology that can measure changes in global photosynthesis, the water cycle, and other major geophysical cycles linked to human activities. These affirm we live in unique times in human history (WHO, 2009).

Historically, as humans entered the previous Holocene epoch around 11,700 years ago, a planetary transformation began to occur as a result of the quickening pace of human activity and population growth. Today we are in the new era of the Anthropocene, and almost a third of Earth's arable land has been converted to cropland or pasture and more than 90 percent of monitored fisheries are harvested at or above sustainable yield limits, amongst other global transitions that have altered our planet profoundly (Kress and Stine, 2017). Present day landscape processes cannot be fully understood without recognizing the past processes that have shaped terrestrial and aquatic ecosystems around the world for millennia; thus recognizing the long-term human shaping of global biodiversity is definitely the key to understanding contemporary human–ecology interactions. Determining the consequences of past ecological change will then also inform predictions of how modern communities may respond to ongoing anthropogenic or climatic factors (Bolvin et al., 2016).

The human species has exhibited a tremendous capacity to induce environmental change throughout human history, and as these changes increase in variety, magnitude, pace, and spatial scale, they threaten the structure and function of the biosphere, atmosphere, and hydrosphere, and in doing so affect the global climate (Schellnhuber et al., 2004). This influence upon the atmosphere, climate, ecosystems and biodiversity, has enormous implications for human health, many of which are deeply disturbing (Bulter, 2016).

Historically, many health fields have focused on individual-level health determinants and interventions (Breakey, Corless, Meedzan and Nicholas, 2015), despite there being different levels of health determinants affecting our health and well-being. More often than not, ecological determinants of health and disease have seemingly received peripheral attention, especially in the past, despite our eco-environment being the most global system of all. We have barely started to understand the complexities of our global system, which is continuously signaling the actual and potential catastrophic public health threats arising from the alteration of ecological determinants—alterations that are more extensive and quicker in pace than in any other time in human history. Humanity not only has the capability to influence and create but also destroy life on the planet, and with this kind of power comes great responsibility (Oosthoek and Gills, 2008), especially under this age of environmental and climate mediated health risks now happening in the Anthropocene.

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CHAPTER 2

APPLYING ECOLOGICAL PRINCIPLES TO HUMAN HEALTH IN THE ERA OF THE ANTHROPOCENE

Our planet has been evolving ever since it became cool enough for life to start around 4 billion years ago, and the ecosphere is the thin layer of the surface of this Earth in which life is possible. In fact, the ecosphere sustains life because of energy received from the sun and functions due to unique cycling processes. Earth is a complex, evolving planet that is characterized by continuous interaction with physical and biological systems, which constantly change over a wide range of space and time scales both natural and human-induced.

Global environmental change is not a new phenomenon, but the rates of change that have occurred in these systems since the arrival of the human species are faster than at any other time in the history of Earth, and many of these rapid changes are related to (1) our ever increasing need for natural resources and their retrieval, production, distribution, consumption, and disposal; (2) to short-term economic considerations; and (3) to the growth and distribution of the human population (Mackenzie, 1998). There is a broad scientific consensus that the environmental changes happening are predominantly arising from the effects of human anthropogenic activities, the same activities which have led us into this new epoch of the Anthropocene.

Ecological principles of human health have specifically focused on health concerns arising in relation to this new era of the Anthropocene and its global environmental and climate crises. Applying the evolving concepts of ecological principles of human health means enacting significant changes from traditional practices and will present new challenges in public health developments. Most changes begin by reflecting on the different stages of epidemiological transition toward the totality of environmental and climate mediated health risks, including the actual and potential transitional risks possibly arising from the underlying driving forces of ecological determinants of health and disease, as a concept of transition in health and its dynamics in human history *per se*. This 21st century is the first time in 2,500 centuries of human evolution, indeed the first in the 45 million centuries of our planet's evolution, where the technological and industrial activity of a single sentient species not only directly challenges its own survival and that of many other species, but also threatens the very fabric of much of the planet's ecosystem (Malone, 2018).

Ecology of Disease and Health, e.g. COVID-19

The term "ecology" derives from the ancient Greek words *oikos* ("house" or "place to live") and *logos* ("study of"), and means "science of the habitat". It designates a science that deals with the interrelationships between organisms and their surroundings. The term is said to date back to 1866 (Lawrence, 2000), when Ernst Heinrich Philipp August Haeckel (1834–1919), one of the world's best-known and most-read zoologists, named and defined a new science, "Oecologie". According to Egerton (2013), Haeckel had already absorbed Alexander von Humboldt's ecological perspective long before he read Darwin's work on evolution, though Humboldt's ecology lacked Darwin's concept of competition. Haeckel believed that nature, like a household, is a unified economic unit with each member working in an intimate relationship with the other members (Townsend and Mahoney, 2004). The "total relations of the animal to both its organic and its inorganic environment" implicitly defines ecology's roots in natural history and we can easily trace back the history of ecology to the beginning of human history on Planet Earth (Bodini and Klotz, 2011).

The term "human ecology" on the other hand was first used in 1921 by Robert Park and Ernest Burgess, sociologists at the Chicago School of Sociology, in reference to the study of the spatial and temporal organization and relations of human beings with respect to the "selective, distributive and accommodative forces of the environment", which focused on people-environment relations (Lawrence, 2000). By the 1930s ecology developed concepts of hierarchical levels of organization beyond individuals and populations, first in terms of the community, then with Arthur Tansley's concept of an "ecosystem", which was characterized not only by the components of a living system but by the interactions among those components. This term, "ecosystem", was coined by him in 1953.

Sir Arthur Tansley recognized the integration of a biotic community and its physical environment to be a fundamental unit of ecology, within a hierarchy of physical systems that spans the range from the atom to that of the universe. Raymond Lindeman's study in 1942 of energy flow through an aquatic ecosystem helped to introduce the modern concept of an ecosystem by demonstrating that the exchange of energy and matter between biotic and abiotic pools makes a community inseparable from its environment (Schowalter, 2013). This concept of "ecosystems" was eventually adopted by the texts of ecology of the 1950s and then later was designated as (more than the sum of) the various communities plus the inert atmosphere (Horwitz and Parkes, 2019).

The accumulation of knowledge surrounding this concept has also added to our understanding of diseases, which like all living organisms coexist and interact under these ecological principles. Indeed, such a critical lens led us to the concept of 'pathocenosis'. Introduced by the medical historian Mirko Drzen Grmek in 1969, the term is of significance as a new paradigm for human medicine, referring to an integrative concept that helps us to consider the status of health holistically and in all its complexity with relation to its environment (Gonzalez et al., 2010).

Grmek conceptualized this concept of pathocenosis modelled on the term "biocenosis", which was coined by the German zoologist Karl Möbius and employed in ecological literature written on the European mainland to designate what in English is usually called an "ecological community" (Sallares, 1991). As a historian of medicine, Grmek reaffirmed that the concept of pathocenosis is particularly useful for understanding the current emergence of infectious diseases, as their underlying mechanisms include interactions of infectious agents both with one another and with the environmental factors that are capable of modulating disease dynamics. A change in the pathocenosis, whether of "natural" or anthropic origin, can lead to the emergence and spread of diseases (Gonzalez et al., 2010). This important idea has been left behind for almost 40 years. The principal lesson of the pathocenotic concept is that disease prevention requires a global, comprehensive, and integrated approach (Gonzalez et al., 2010).

Another important theoretical advance was to use studies of ecology to inform our understandings of health and disease, as how we conceptualize disease and health has an influence on how we treat disease. Therefore reframing health with different alternative perspectives in turn encourages us to be open to considering health in holistic terms, as in evolving understandings of disease ecology (Anthamatten and Hazen, 2011). For instance, the idea of the 'ecobiosocial' conception of health, that conceptualizes health as a product of the interaction of environmental factors, biological factors, and social factors, in which human health reflects relations among various species in any local environment, as seen in the significant role of zoonotic diseases, the importance of animal reservoirs, and human/animal interaction patterns (Singer, 2016). Within these perspectives, humans are only viewed as one part of an integrated disease cycle, existing alongside infectious agents, disease vectors, and other animal hosts, as well as the environmental conditions that are required for effective transmission of a disease (Anthamatten and Hazen, 2011). The complex nature of this human-animal interface is constantly influenced by the effects of climate change, as well as anthropogenic and natural factors, including geoclimatic change. The latter most markedly affects zoonotic diseases transmitted by arthropod vectors (Naicker, 2011). Globalization and climate change, as one of the determining factors for the ecology of infectious diseases and their emergence and re-emergence, continue to have a significant impact on human development and wellbeing. Especially whenever the emergence of new diseases may go undetected and discovery of outbreaks could be suppressed for strategic reasons. Hence, all these conditions combined could lead to an increase in the risk of pandemics (Bouzid, 2017).

However, historically, medicine was taught in undergraduate teaching schools with what Bomford calls the five common causes of disease at that time in the 1950s: (i) inborn and inherited abnormalities; (ii) excess of a chemical agent in the environment; (iii) deficiency of a chemical substance; (iv) infection or infestation by viruses, bacteria, fungi, or animal parasites; and (v) physical trauma (Bomford, 1953). In this regard, Cohen (1953, p. 160) also states:

> "*The distinctive contribution of the nineteenth century, however, to the concept of disease was the recognition of its causes. Bacteria as the necessary and specific causes of such diseases as typhoid, tuberculosis, cholera, were unmasked; the significance of endocrine imbalance, of nutritional deficiencies, of genetic influences was soon recognized; the part played by social, occupational, and economic factors, and the psychological contribution to the etiology of disease were all made clearer.*"

Nevertheless, Cohen (1953) believed that "we are in a position to appraise the present status of the two concepts of disease which we earlier recognized as pervading the history of medicine in the past 3,000 years" and that understanding the history of medicine "is a worth-while pursuit, for a knowledge of the history of ideas has a moderating influence". This latter statement is true and can be seen in the growing public perception of the seriousness of environmental problems since the 1960s. The definitions and interpretations of human ecology—including the way to use ecological knowledge—have varied considerably, from the preservation of natural resources, ecosystems, and the biosphere, to achieving a viable life on Earth (Lawrence, 2000). It is important that realizations for ecological approaches to human health consider human beings as part of this broader ecosystem, as well as part of a broader cycle of disease that is focused on interactions between humans and environments in ways that either support or damage our health (Anthamatten and Hazen, 2011).

This is a major transformation in the understanding of health and disease that emphasizes the shift from a simplistic, reductionist cause-and-effect view of the medical model to a complex, holistic, interactive, hierarchic systems view known as an ecologic model, as public health lies within the broad field of human ecology and incorporates the study of interactions of man and human society with the environment and culture (Hancock, 1985). It is becoming increasingly clear that population growth and economic development are leading to rapid changes in our global ecosystems. The Millennium Ecosystem Assessment has established the scientific basis for the actions needed to enhance the conservation and sustainable use of those systems, so that they can continue to supply the services that underpin all aspects of human life (Corvalán et al., MEA Programs and WHO, 2005).

The science of ecology is based on knowledge of the interconnectedness of the components of an ecosystem (Philp, 2001), and at present, ecology is a key science that can contribute to solving the big global problems of humankind (Bodini and Klotz, 2011) and help maintain all aspects of human life. Ecology is the science that seeks to describe and explain the relationship between living organisms and their environment; it is a relatively young science and formal experiments on communities and ecosystems as a result are confined to the last 100 years. Ecological processes that take place over large areas tend to happen very slowly and encompass processes operating from the microscopic to the planetary level. The fossil record helps us to appreciate the current scale of change with regard to major environmental change in the planet's history. We have learned that fossilized carbon has been being released at an accelerating rate over the last 200 years and as such humanity has been slowly altering the chemistry of the atmosphere (Beeby and Brennan, 2008).

Recognition of anthropogenic effects on atmospheric conditions, especially contributions of greenhouse gas and pollutant concentrations to global warming, has renewed interest in how natural and altered communities control fluxes of energy and matter that modify abiotic conditions (Schowalter, 2013). In 1997, a time of accelerating rates of change, Vitousek et al.'s paper on "Human domination of Earth's ecosystems" was published and concluded that the world is in our hands – and how we handle it will determine its composition and dynamics, and our fate, in fact, this is only beginning to be realized in science and conservation (Curtin and Allen, 2018). It affirmed that for global change science requires a transdisciplinary synthesis, one emblematic of a complexity-based perspective that seeks a union of overarching interacting patterns and processes to address the significant challenges occurring globally.

It is anticipated that global environmental and climate change will have a wide range of complex impacts upon the occurrence of diseases, including infectious disease, in human populations. This now may be the fourth great transitional period in the long process of human cultural evolution that reflects the impacts of demographic, environmental, technological and other rapid changes in human ecology, which then further affirms infectious disease transmission should be viewed within this ecological framework (Patz et al., 2003). Especially, the number of newly recognized diseases affecting humans, domestic animals and wildlife has increased in recent decades and many of these diseases "emerge" when environmental conditions change and alter contact rates between species, which could have drastic effects and impacts on pathogen transmission and host health in many disease systems (Ladeau and Han, 2016). In many ways this summarizes how disease ecology derives from fundamental ecological principles.

As a recent ongoing example, back in late December 2019, a SARS-CoV–like coronavirus, the 2019 novel coronavirus, emerged in the city of Wuhan in the Hubei Province of China and spread rapidly across mainland China and across other parts of the world (To et al., 2020). This form of coronavirus is a potential zoonotic disease with person-to-person transmission which may occur through droplet or contact transmission (Wu, Chen and Chan, 2020). As usual diseases are named by the WHO in the International Classification of Diseases (ICD) with implication to enable that discussion on disease prevention, spread, transmissibility, severity and treatment; the WHO officially announced "COVID-19" as the name of this new emerging disease on 11 February 2020 (WHO, 2021a). This ongoing outbreak of COVID-19 is a highly infectious disease, and the WHO declared a global pandemic public health emergency a month later on the 11th of March 2020, as there are more than 118,000 cases in 114 countries, and 4,291 people lost their lives on that day alone—with thousands more fighting for their lives in hospitals (WHO, 2020b).

As according to *The Dictionary of Epidemiology*, a pandemic is an epidemic occurring worldwide or over a wide area, crossing boundaries of several countries, and usually affecting a large number of people (Porta, 2014) by infecting more than 100,000 people in 100 countries. At the time of my writing, this form of coronavirus is becoming unstoppable and has already reached over 5.4 million infected cases globally as of May 26th 2020 (WHO, 2020c). Therefore a coordinated global response is desperately needed to prepare health systems to meet this unprecedented challenge (Remuzzi and Remuzzi, 2020).

The WHO (2020d) has further indicated that SARS-CoV-2 caused COVID-19 was first identified in humans in December 2019 and that the virus is believed to be ancestrally linked to bats, despite its origin and intermediate host(s) of this virus not yet having been identified. These coronaviruses are a large family of viruses, some causing illness in people and others that circulate among animals, including camels, Himalayan palm civet cats and bats; however, rarely, animal coronaviruses can evolve and infect people and then spread between people such as has been seen with MERS and SARS (CDC, 2020). According to phylogenetic data that further implicates this SARS-CoV-2 as being of zoonotic origin, the rapid spread suggests ongoing person-to-person transmission (Ghinai et al., 2020).

In addition, since June 2020, 214 human cases of COVID-19 have been identified in Denmark with SARS-CoV-2 variants associated with farmed minks, including 12 cases with a unique variant, as reported on 5 November (WHO, 2020d). As of December 2020, eight countries, namely Denmark, Lithuania, Netherlands, Spain, Sweden, Italy, and Greece and the US have reported COVID-19 in framed mink to the World Organisation for Animal Health (OIE) (WHO, 2020f). This highlights that mink outbreaks are a “spillover” from the human pandemic. It means mink can be infected by SARS-CoV-2 and they can also transmit the virus to humans (ECDC, 2020). This risk of reservoir establishment with unforeseeable consequences has been the basis for the decisions to cull mink farms; because SARS-CoV-2 could potentially be introduced to escaped and wild mustelids or other wildlife, especially when this SARS-CoV-2 and the human-animal one interface (Koopmans, 2021). An analogy could be made with influenza pandemics, such as avian and swine influenza viruses, which continue to evolve in their animal hosts, constituting a permanent pandemic threat (Koopmans, 2021).

As Guègan (2019) has stated, even wild animals can be affected by human action on the environment and other attributes of ecosystems, and can be exposed to detrimental pathogens associated with neighboring livestock or human individuals. Thus, understanding the complex interactions between infectious diseases, their hosts, and the environment in time and space requires an ecological understanding of numerous linkages such as population dynamics of disease transmission and their interactions. This includes the role of biodiversity in the life cycles and spread of multi-host diseases. Statistics show that over 60% of these parasitic species are of zoonotic origin, meaning that they originate from other wild or domesticated animals. The spread of domestic animals outside of their domestication centers also contributes to the spread of zoonotic diseases, for instance: anthrax is from *Bacillus anthracis* and, according to genetic analyses, diversified more than 17,000 years ago and then spread across the world with the dispersal of domestic livestock (Morand and Lajaunie, 2018).

In fact, identifying a causal pathogen or characterizing a novel condition necessitates attention to its specific properties, meaning statistical risk factors or disease ecology translates into conceptualizing diseases, including emerging diseases (Zuckerman et al., 2014). As Mike Davis (2005) stated:

> *"Human-induced environmental shocks – overseas tourism, wetland destruction, a corporate "Livestock Revolution", and a Third World urbanization with the attendant growth of mega slums – are responsible for turning influenza's extraordinary Darwinian mutability into one of the most dangerous biological forces on our besieged planet." (Quoted in Giles-Vernick and Craddock, 2015, p. 22).*

The human health impacts of accelerating environmental change through emerging risks at the human–animal–ecosystems interface (HAEI) must recognize the zoonotic nature of many emerging infectious diseases (EIDs) (Ogden, AbdelMalik and Pulliam, 2017). Current global changes (climate change, land use change, and biological invasion, to name a few) are shaking up the epidemiological environment, in which these changes are responsible for new occurrences and distributions of infectious disease epidemics, as well as the emergence of new infections through the modification of biotic and abiotic factors (Morand and Lajaunie, 2018). Over 75% of EIDs affecting humans are, or were originally, zoonoses (infectious diseases transmitted from animals to humans), particularly those maintained by wild animals. They are transmitted by various routes including via direct contact, food, drinking water, recreational water and arthropod vectors (Ogden et al., 2017).

Looking back over the relatively short span of a quarter of a century, the world appears to have witnessed the proliferation of an unusually large number of what are referred to as “new and emerging diseases” – that is, infectious diseases that are newly appearing in populations or that have been known for some time but are rapidly increasing in incidence or in geographic range. Examples include West Nile virus, Lyme disease, HIV-AIDS, antibiotic-resistant tuberculosis, the Ebola virus, influenza A/H1N1, SARS, MERS (Giles-Vernick and Craddock, 2015), and now COVID-19.

Principally, when a virus is widely circulating in a population and causing many infections, the likelihood of the virus mutating increases (WHO, 2021b). Insofar, SARS-CoV-2 has accumulated mutations since its emergence in the human population in 2019, with which an average a genome from a virus collected in October 2020 had around 20 accumulated mutations compared to the first strain sequenced in January 2020 from Wuhan province (ECDC, 2020). On 14 December 2020, authorities of the UK and Northern Ireland reported to the WHO that a new SARS-CoV-2 variant was identified through viral genomic sequencing (WHO, 2020g). And this new variant of SARS-CoV-2 (Alpha or B.1.1.7) was first detected in September 2020, and in November 2020 around a quarter of cases in London were the new variant, and that reached nearly two-thirds of cases in mid-December (Gallagher, 2020). A total of 1108 cases of this new variant had appeared in the UK as of 13 December 2020 (WHO, 2020g).

Despite viruses mutating all the time, often with no impact, this new variant of SARS-CoV-2 appears to be more transmissible than other variants, meaning it spreads more easily has a greater potential for catastrophe, subjecting us to a more contagious virus spreading with exponential growth (Tufekci, 2021). Driven by this new variant’s increased infectiousness, the UK reported more than 50,000 cases a day in the last few days of December 2020 and the first few days of 2021; this particular variant of SARS-CoV-2 has been estimated to be up to 70% more transmissible than the previously circulating form of this virus (Kirby, 2021). And as of January 6, 2021 this new variant has been reported across 32 different countries (New York Times, 2021). As expected, multiple variants of SARS-CoV-2 have been documented globally throughout this pandemic (CDC, 2021). Currently, the variants of concern are including Alpha, Beta, Gamma, Delta, and Omicron, within which Omicron becomes dominant COVID-19 strain. The WHO warns of a ‘tsunami’ of COVID-19 cases. And according to the dashboard of the WHO, there have been over 281million confirmed cases of COVID-19 globally, including 5.4 million deaths reported as of 27 December 2021.

> "A dangerous virus emerges. It spreads rapidly around the world." ……
>
> "This isn't the first time WHO has responded to a pandemic, and it won't be the last – but COVID-19 is the most challenging crisis we have ever faced."
>
> (WHO, 2020e)

Horton (2021) states that every dichotomy in global health has been challenged by this pandemic, and this era is truly one marked by a universal experience, a universal predicament, and the need for universal solutions. Scientists have been warning for at least a generation about the potential impact of EID in a world experiencing climate change, and despite climate change not causing emerging diseases, it does however provide opportunities that set the state for pathogens to explore new fitness spaces (Brooks, Hoberg and Boeger, 2019). Societies start and end with the collective security of the planet, and climate stabilisation must be the cornerstone of the 2020s and beyond. COVID-19 has revealed the fragility of civilizations built on social injustices, short-term policies, and a dangerous disregard for the environment (Lancet, 2021). A new understanding of preparedness for healthcare systems will need to prioritise resilience and sustainability to overcome the collective challenges of shifting demographics, climate change, and increased demand (Lancet, 2021).

Environmental Factors for Human Health

Since the first Earth Day in 1970, George Perkins Marsh's *Man and Nature* has remained a classic text, with each new crisis rekindling its relevance. *Man and Nature* was indeed "the fountain-head of the conservation movement" (Lowenthal, 2000). We have now polluted air, water and land and have depleted potentially sustainable resources such as forests, soil micronutrients and marine life at rates that nature cannot replace (Cole, 2019). Indeed, the US Global Research Program has documented how the various effects of climate change on aquatic ecosystems can interact and ripple through trophic levels in unpredictable ways. However, over the ages, human societies have degraded and changed local ecosystems, resulting in important consequences for humans given that ecosystems provide us with "nature's goods and services" (McMichael, 2003).

It is worth noting that the Lalonde Report in 1974 was one of the first documents to emphasize the important role of environmental factors in shaping human health, and was a call to broaden the scope of improving public health beyond the traditional biomedical model (Dakubo, 2011). Over a decade later, the WHO then released the Ottawa Charter for Health Promotion in 1986 which expressed a new view of health and reiterated the importance of incorporating ecological factors in health promotion strategies. This Ottawa Charter acknowledged that ecology, caring, and holism were essential issues in developing strategies for health promotion, emphasizing the interrelations of health improvement and stable ecosystems through sustainable use of natural resources for protection of the environment.

To backtrack a little, in 1972 the United Nations Conference on the Human Environment declared one of the major concerns to be the depletion of natural resources (McMichael et al., 2003). Continuing with this area of concern ever since, the WHO has encouraged the conservation of natural resources throughout the world as a global responsibility, and emphasized incorporating the protection of both the natural and built environments into health promotion strategies. This line of thinking formed a significant part of the Ottawa Charter, which was the first document to delineate an agenda for a new public health by locating it within the context of new ecological thinking (WHO, 1986). Since then there have been many other subsequent initiatives continuing expressively similar ecological sentiments to health promotion, including:

i. The Brundtland Report in 1987;
ii. The Earth Summit in Rio in 1992 – which aimed at focusing attention on the intricate interconnections and interdependencies between the environment, health, and sustainable development;
iii. Health for All by the Year 2000 strategy;
iv. The United Nations Millennium Development Goals, as presented in The Millennium Ecosystem Assessment Report 2005 and the 2010 Climate Change Summit in Copenhagen. They all draw attention to the linkages between environment and human health, and the need for broader ecological approaches that span beyond the health sector; and
v. The UN SDGs in 2013, which subsequently reinforced the significance of those commitments.

Echoing the 1986 Ottawa Charter for Health Promotion in all of its aspects, the United Nations (UN) 2030 Agenda for Sustainable Development contains a broad range of expertise aimed at better understanding the causes, consequences and potential solutions related to the grand challenges of our time. An international research cooperative originating from the 2012 World Universities Network for Planetary Health, it was drawn together with a Statement of Principles for Planetary Health and further affirms the urgent need to consider the health of people, places, and the planet as indistinguishable. This is particularly stressed in its Canmore Declaration, which in 2018 came together for its 7th meeting in Canmore, Canada (Prescott et al., 2018).

All of these initiatives have reinforced the significance of the health concerns arising in relation to those associated environmental factors, including ecosystems health, the impacts of climate change, and environmental sustainability. As the development of science, technology, and industrialization which began in the eighteenth century fundamentally changed human-environment interaction with drastic consequences for our global health. The human disease spectrum has since then undergone great changes, especially with the emergence of the concept of ecological health. With those changes have come changes in attitude, deeply rooted in people's minds. Relying on the concept of praying not to be sick began to turn gradually towards the prevention of disease, and to actively cure it. Later, society came to recognize the "Right of life and health" as our basic right of citizens, in which the state should have the obligation of maintaining the health of its residents. Accompanying this was the idea that health is not only a personal problem, but rather that the daily interactions of the individual with the surrounding environment and the social environment are all closely related to it too (Li, 2014).

This is especially so today, as humanity is pushing against the limits of the eco-environment and is exceeding the planetary boundaries (PBs) in several critical areas already. Therefore when humanity trespasses on these PBs, meaning that human pressures on the environment become greater than the ability of the Earth's natural systems to absorb those human pressures, the result is a major change in the function of the Earth's ecosystems (Sachs, 2015). As synthesized from the conclusion of the Lancet Commission on Planetary Health, the health of human civilization is dependent upon the long-term stability of the Earth's natural systems, and countering the threat arising to natural ecosystems posed by environmental degradation, climate change, biodiversity losses, and the associated over-exploitation of natural resources (Nelson et al., 2019).

The resultant consequence of globalization and production outsourcing, pollution and pollution-related disease have become planetary problems, and the concept of planetary health is based on the scientific understanding that human health and human civilisation depend on flourishing natural systems and also the wise stewardship of those natural systems (Landrigan et al., 2017). Scientifically, the adverse transitional impacts from the interrelationships of planetary health for the global eco-environment that are inextricably linked with our health and environmental sustainability, including pollution, pose a massive challenge to planetary health. This is detailed in the Rockefeller Foundation-Lancet Commission on Planetary Health, whose 2015 report also described how human activity is changing the global environment, increasing the risk of disease, and threatening the conditions that, ultimately, sustain all life on Earth (Landrigan et al., 2017). For planetary health we have to build novel coalitions to achieve meaningful and lasting change; urgent and transformative actions are needed to protect present and future generations (Whitmee et al., 2015). Humanity is now living far beyond its means, as our society has long been built on the myth of endless growth by borrowing so freely from the future (Wijkman and Rockström, 2012). In this context, planetary health means the ambitious task of emphasizing interconnections between human health and environmental changes, in doing so enabling holistic thinking about overlapping challenges and designing integrated solutions for present and future generations (Pongsiri et al., 2019).

The WHO estimates that 23–25% of the Global Burden of Disease could be avoided by improving ecosystem management (IUCN, 2018). There is evidence that many different aspects of the environment—biological (biotic), physical (abiotic), social, cultural, and technological factors—affect the health status of the human population as well as other species within the same ecosystems. In turn, the planetary boundaries (PBs) concept rests on three branches: (1) Earth systems and sustainability science; (2) the scale of human action in relation to the capacity of the planet to sustain it; and (3) shocks and abrupt change in socio-ecological systems from local to global scales (Mohajan, 2015).

This PB framework represents a significant advance in specifying the ecological constraints on human development, thus it is essential to advance our understanding of such interactions between different PBs for humanity to be sustainable. We must respect the natural biocapacity of these ecological constraints on what we can do on and with our planet (Clift et al., 2017). To achieve such dramatic change will require a global transformation, and it is vital for the global community to recognize that human and planetary health are two sides of the one climate coin, and that together they present a critical road for co-mitigation (Demaio and Rockström, 2015). The scientific impact of this PB framework is based on biological, physical and chemical structures, and ultimately is important for sustainability. It is perfectly understandable that the result of these complex tensions is the practical relevance for maintaining ecological principles in a transition to human health.

Sooner or later (the timing is difficult to predict), the cumulative effects of resource scarcity, eco-environmental deterioration, climate change that will impose poor public health, all of which will eventually lead to the shrinkage of economies. For this reason, the dependence of many security determinants on a healthy environmental support system that imposes limits on growth has led to the notion of environmental security as the "ultimate security" (Lautensach, 2015). Li (2016b) has indicated, global population growth is expected to reach more than 9 billion by 2050, which raises even more eco-environmental concerns, including the fact that further climate change will be placing greater pressure on our planet's finite natural resources. In addition, the food system of the future must meet the nutritional requirements for the health of our future generations, as currently our global dietary trends are causing a problem from both public health and sustainability perspectives. Neither medicine nor public health gives much coherent attention to the status of the larger ecological systems on which people's health depends, to the extent that ecological health is a new necessity for medicine and public health (Guenther and Vittori, 2008).

Reflections from Different Stages of Epidemiological Transition

Since the earliest days of mankind, cultures around the world have sought the elusive understanding of what it means to be healthy; the subsequent definition has evolved many times, often reflecting the specific beliefs and the levels of scientific and medical understandings of that particular era. Understanding these changes provides a context for another new definition that is needed in the present age (Badash et al., 2017). Disease ecologies have focused on the impact of the natural environment on disease, ranging from naturally occurring elements and minerals to the effects of climate, latitude, and elevation (Oppong and Harold, 2014). Concerning global environmental and climate changes are constantly imposing a dynamism on the planet, an endless process of change in the Earth system. A close look at the ecology of diseases can lead to recommendations for public health strategies for reducing the burden of the illnesses or infections emanating from those adverse impacts.

In this regard, epidemiology can be used simply as an analytical tool for studying diseases and their determinants, and therefore the reflections from different stages of epidemiological transition can also steer public health decision making, and aid in developing and evaluating interventions to control and prevent health problems. The word "epidemiology" was first used in the 1700s to describe the science and methods used to study epidemics, and later expanded to the study of factors affecting the health and illness of populations. In fact, epidemiology is a science that affects all of us every day of our lives, serving as the foundation of interventions made in the interest of public health and preventive medicine (Fos, 2011).

Harper and Armelagos (2010) stated that the epidemiological transition model provides a means for understanding the evolution and spread of emerging diseases, as well as the changing relationship between humans and their diseases. The purpose of the different stages of epidemiological transition is in fact to indicate health trends as proxies for mortality data at large. In this sense, the health transition could be just another name for the mortality transition. However, as Augé and Herzlich (1995) stated, illness poses a problem which requires interpretation and it must have a meaning if humans are to have any hope of overcoming it. Also, a described illness acts as a social signifier in which it is the subject of discourses that continually call into question the environment in the broadest sense. These discourses are varying according to the historical period and the social and professional situation of those who pronounce them. As key development with deeper and continual scientific understandings, health transitions at different epidemiologic transitional stages should also focus on in terms of their underlying causes or consequential determinants that have caused particular ill-health and/or diseases. As Li (2018b) postulates that different stages of epidemiological and health transitions are in fact reflections of the collective picture of changes in morbidity and mortality, as well as projections of the underlying causes of health threats arising from changing situations. That is to say, understanding the changing processes at different stages in epidemiological transition (ET) would enhance the arising and associated evolving concepts of health and diseases.

Death rates or mortality alone cannot be sufficient enough to describe the burdens of disease, as patterns of morbidity could be rather different from the causes of mortality. Instead, the worthwhile question should be "What existing evidence is available to explain the changing causality in the patterns of morbidity of diseases in addition to just those indicators of mortality?" Omran's ET theory is embedded with four different stages and was first introduced almost five decades ago. As of 1971, it was one the first attempts to account for the extraordinary advances in healthcare made in industrialized countries since the 18th century.

Meanwhile, the emphasis on ET research has also changed over the past five decades, with an increasing tendency to study the wide-ranging aspects of the determinants of mortality, including risk factors, lifestyle changes, socio-economics, and macro factors such as climate change

(Santosa et al., 2014). As we are now facing the global environmental and climate crisis in the 21st century, the additional major throes contributing to morbidity and mortality have been overtaken by human anthropogenic causes. This is especially so as time goes on, given that new levels of scientific and medical understandings continuously advance our concepts of health and disease in relation to the consequences of different driving forces and underlying determinants of a particular era.

In fact, eco-environmental and climate impacts are most important factor in the interaction of agents and hosts under this epidemiological or ecological triad that can also be influenced by multilevel and multinature determinants. These pathways are not unidirectional and eco-environmental factors could be an outcome of these multiple drivers and pressures (Li, 2017a). Despite other factors that could also be possibly influencing the occurrence of disease, as refer to concepts derived from different models of disease causation, e.g., the epidemiological tetrad; multifactorial causation; webs of causation; and BEINGS models of causation that include biological, behavioral, environmental, immunological, nutritional, genetic, social, and spiritual factors. More importantly, the growing amount and availability of scientific evidence that shows good planetary health must be our pressing concern as this ongoing global environmental and climate crisis, including its dynamics and consequential mediating health threats which could be drastic and catastrophic at the global-scale.

Reflections on different stages of ET and its associated public health developments are essential information for developing our scientific understanding of the changing needs for the current state of transition in public health. Therefore, a renewed paradigm with viable conceptual models are required to counter the arising health-related problems that accumulated over time with associated underlying determinants. For the past several decades, the model of epidemiologic transitions has served as a guiding framework for understanding relationships between patterns of human health and disease as well as economic development. The theory has become paradigmatic in public health, as it provides a model for the dynamics amongst economic, social, demographic, and ecological factors as well as the evolution and spread of disease as resultant effects (Zuckerman et al., 2014).

Omran also proposes and outlines three basic models of the epidemiologic transition, which are a function of peculiar variations in the pattern, the pace, the determinants and the consequences of population change (McKeown, 2009). For instance, the history and experiences across different countries can lead to differences in the pace of Omran's described epidemiologic transition stages, notwithstanding that the context of characteristics could be very diverse and tends to vary from different developmental situations in different countries, nations or even regions. Omran's theory of ET has focused on the primary causes of morbidity and mortality as indicated from the first three transitional phases (see below), in which the complex change in patterns of health and disease based on the interactions between these patterns and their demographic, economic and sociologic determinants and their consequences are also incorporated (Li, 2018a). The following Figure 2-1 summarizes the changing models of public health throughout different stages of epidemiological transition, particularly extended with the proposed Ecological Public Health Model as the fifth stage of ET due to the changing underlying determinants during this Age of global environmental and climate mediated health risks in the Anthropocene. This paradigm in transition further extended together with "The Triple New Priorities" towards planetary health, which is specifically formulated as integral part of 'knowledge-to-action'. And the details will be further elaborated in chapter 5.

Stages of ET	**Underlying Determinants**	**Models of Public Health**
1. The Age of Pestilence & Famine* (~100 centuries ago)	• Poor sanitary & contaminations • Poor use of ecological resources & lack of social & economic capitals • Domestication of animals bringing other disease vectors • Public health emerges	(1) Sanitary Environmental: The environment is a threat to health.
2. The Age of Receding Pandemics* (~200 yrs ago)	• Increased economic growth • Improved use of ecological resources & food safety • Public health developments • Basic social services provided	(2) Social Behavioral: Health is a function of knowledge and behavior patterns.
3. The Age of Degenerative and Man-Made Disease* (~late 20 century)	• Improved medical care & social determinants • Public health movements e.g. vaccination programmes	(3) Bio-Medical: Health improvement requires understanding of biological causation.
4. The Age of Delayed Degenerative Diseases**	• Prevalence of one or more diseases means a relatively long period of morbidity with increase in average life expectancy • Health promotion & primary health care emphasized	(4) Techno-Economic: Economic and technological growth is the prime elevator of health. Life-styles, etc.

The Age of Environmental & Climate Mediated Health Risks	• A. Global drivers • B. Global change • C. Ecological determinants • D. Other health determinants • E. Public Health in Transition	(5) Ecological Public Health: Health depends on the successful coexistence of the natural world and social relationships.
Planetary Health for Healthy Eco-environments in the new epoch of the Anthropocene	• Planetary boundaries and limits • Ecosystems services functioning • Earth's carrying capacities	(6) Ecological public health paradigm in transition with "The Triple New Priorities".

Figure 2-1: Paradigm shifts of epidemiological and public health in transitions with the changing underlying determinants during this age of environmental and climate mediated health risks in the Anthropocene (adapted and modified from Li, 2018a). Model of Ecological Public Health is proposed as the fifth stage of ET under this Age of Environmental and Climate mediated health risks, together with its paradigm in transition is being continually extended across this new epoch of the Anthropocene.

Public health in transition can be seen as revolutions for the changes that are embraced with paradigmatic shifts onto our renewed conceptualization of the transitional changes upon revealing paradigmatic limitations from the previous four stages of ET. And therefore, this book proposes this Model of Ecological Public Health as the fifth stage of ET, together with its paradigm in transition being extended continually across this new epoch of the Anthropocene, which further unfolds the importance of scientific understandings towards planetary health for healthy eco-environments, especially for our sustainable health developments *per se*. This is indeed a stark contrast of the traditional healthcare professionals' role in the functions of healthcare setting, as which is being established intensely based on 'Bio-medical' Model of disease-oriented focuses from the past few stages of epidemiological transition (Li, 2018b). Perhaps, historically the idea that disease is caused by specific disease agents led disease to be viewed in terms of a simple cause and effect, with one cause, such as a pathogen or toxin, seen as leading to a particular set of symptoms. This is an approach known as the "doctrine of specific etiology", which is heavily based on the biomedical perspective seeking connections between specific causative agents and particular symptoms in a "reductionist view of health", rather than considering broader influences on health (Anthamatten and Hazen, 2011).

However, health has its historic, cultural and social foundations and the field of public health has been influenced by the socio-historical context of globalization for the past 25 to 30 years (Li, 2018a). Evidence points to a broad view of the determinants of population health, which requires an ecological view of health that shifts in the ecology of human living in relation to both the natural and social environments, accounting for much of the ebb and flow of diseases over time (McMichael and Beaglehole, 2003).

Moving beyond Omran's original formulation with the modifications of the transit process of health transition can help to broaden the epidemiologist's understanding of the complex, multiple dimensions of health and disease over time, framing them as components of broader health trends attributable to longer-term and ultimate causes in the Anthropocene. Environmental conceptualizations of ecological health serve as evolving concepts of transitions in health and its dynamics; they are associated with planetary health and global eco-environments, which in turn can help the predictions of future epidemiologic trends. This conceptual insight regarding epidemiologic transitions provides a scientific basis to serve as a guiding framework for the significant unfolding relationships between patterns of human health and disease and economic development for the past several decades. This insight translates into conceptualizing diseases, including emerging diseases, as singular entities attributable to more immediate and predominantly proximate causes (Zuckerman et al., 2014).

In fact, most of these changes occur in relation to substantial changes affecting standards of living as well as ways of life. There are many underlying causes, influencing factors, and determinants arising and accumulating in the different stages of epidemiological transition, which in turn form the significant patterns of health transition in human history. The entire health transition process is likely to first lead to a divergence in mortality then be followed by a phase of convergence that could lead to homogenization until a new major advance occurs. Thus this process breaks down into successive stages, and includes a specific divergence-convergence sub-process as well (Vallin and Meslé, 2004). In this way, a health transition presents different changes in the health status of populations, moving from trends of disease patterns dominated or replaced by other different and significant health risks that arise during and through the transit process of changes. The significant accumulative effects are likely to be a matter of concern in terms of the divergence-based trends of determinants that continuously impose adverse health effects globally. Li (2018a) reinforces that environmental and climate mediated health risks have increasingly become a priority for health implications in the 21st century, which is the latest epoch of ET and continues to provide insights into the transitional nature of public health (Li, 2018a).

Especially, these large-scale global environmental hazards then form the major ecological determinants having harmful consequential effects on our human health. They exist in conjunction with the burdens from ecosystem disruption and loss of ecosystem functions, which all together lead to the prime concerns in ecological public health developments (Li, 2017a). A broad array of systems and interrelated determinants of health exist, acting either synergistically or antagonistically, with substantial implications for public health (Zuckerman et al., 2014). As Montuelle and Graillot (2017) indicated, urban, agricultural and industrial developments have generated many pollutant emissions—which are often a complex mixture of substances and highly variable in nature—and environmental factors that impose acute or chronic effects. These directly or indirectly (via the domino effect) affect or stress a multitude of environments. For instance, on aquatic environments (nutrients, pesticide residues, heavy metals, pharmaceutical residues, etc.), in which they cause physiological and/or genetic effects (multigenerational and transmittable) in a thematic known as stress ecology.

Environmental public health like this can be very broad, concerning the overall "health of the planet" and climate change, sustainable development, and the built environment, or it can focus on specific, non-communicable environmental hazards—for instance those of a chemical, physical or biological nature (Abelsohn, Frank and Eyles, 2009). It is now well recognized that existing medical science is further complicated by the evolving concepts of health with the emergence of complicated factors stemming from the scientific advancements that strengthening up our understanding of the complex crises of the 21st century.

Ecological and Global Determinants of Health and Disease

Human health and diseases are always determined by many complex factors, a fact which has been solidified as concepts of diseases have evolved and developed at different stages throughout the history of public health developments (Li, 2017a). From the formerly prevalent miasmatic paradigm and the emergence of germ theory in the 19th century, to the 20th century and its revolutions in quantum theory (Schroeder, Thompson, Frith and Pencheon, 2013), advances in biomedical understanding have been translated into medical interventions, which in turn have led to marked improvements in the outcomes of many diseases (Schettler, 2006). However advances in biomedicine alone cannot provide solutions to the long term health needs of humanity (Schroeder et al., 2013). The long-term good health of populations depends on the continued stability and functioning of the biosphere's ecological and physical systems, often referred to as life-support systems; but we have ignored this long-established historical truth at our peril (McMichael, 2003).

As humans, we are not separate from the environments in which we live, and we are indeed integrated with them through the air we breathe, the water we drink, the food we eat and the waste we produce. Many cells within us come from bacteria, viruses or other microorganisms with which we coexist, and which also help or hinder our interaction with the wider, external environment. As a result we are an integral part of this wider biosphere of Earth that also primarily determines the health of our planet (Cole, 2019). Over the past 11,000 years during the Holocene epoch, human activity has become the dominant influence on many of Earth's systems (Merritts, Menking and de Wet, 2014). Simply, the environment in which we live is a major determinant of health and well-being (Barton and Grant, 2006), mankind is now the major actor implicated in its own environmental alterations: "sapiens alters his ecosystem, while the ecosystem also shapes him in return" […] and "the dominant cause of most environment changes and the recent acceleration could have major impacts on human health" (Marck et al., 2017, p. 4). Humans continually interact with each of these habitats, not as passive recipients but as active shapers of the natural, built, and social environments, within which we make further environmental modifications ranging from deforestation, the construction of dams, and road building, to farming and mining, the latter of which have been associated with a higher prevalence of disease (Oppong and Harold, 2014).

Engaging health with sustainability involves shifts in human perception and consciousness, on the one hand in terms of addressing the interplay of practices based on ecological understanding, and on the other in terms of reconceptualizing ecosystems not as resources for human consumption but as relational participants within the social-ecological equation (Williams, 2017). We are not owners but tenants, with needs and rights as well as obligations for this planet, which, though once uninhabitable, became habitable and so provided nurture and habitat for all its teeming creatures—yet it is not unlimited in its resources (Rhodes, 2012). Our environment is the totality of what we live in, natural or constructed, spatial, social and temporal, however it is clear that our current way of life and reliance on resources are not sustainable (Fleming, Tenkate and Gould, 2009).

Ecological crises are created as climate science and the Earth's climate have continued to evolve over recent decades, with increasing evidence of the risks of human-induced anthropogenic influences on global eco-environmental and climate change. With knowledge of past climates to qualify the nature of ongoing changes came the realization that Earth's climate might be sensitive to the atmospheric concentration of gases that create a damaging greenhouse effect containing a diverse mix of greenhouse gases, including carbon dioxide, methane, nitrous oxide, and water vapor, as well as some industrial chemicals of synthetic halocarbons such as chlorofluorocarbons (CFCs), hydrofluorocarbons (HFCs), sulfur hexafluoride (SF_6), perfluorocarbons (PFCs), and halons (Le Treut et al., 2007). Human activities, particularly the burning of fossil fuels, have increased the concentration of GHGs in the atmosphere dramatically over the last century, which has forced increased warming in the lower atmosphere and has consequences for human health (WHO, 2009).

In comparison, if Earth had no atmosphere, it would be a frozen planet without life. As it stands, gases including water vapor, carbon dioxide, methane and nitrous oxides in the atmosphere temporarily trap some of the energy from the sun and convert it to heat, which maintains an average surface temperature on Earth that is capable of sustaining life (WHO, 2009). In 1824, Jean-Baptiste Joseph Fourier (1768-1830), the great French mathematician and physicist first discovered the basic concept of how the Earth's temperature is determined. Later in 1862, John Tyndall speculated how water vapor, carbon dioxide and the ozone are related to climate change, which is what we now call the greenhouse effect.

In many respects, the intensity of global warming's effect depends on the concentration of two major GHGs, water vapor and carbon dioxide; as the atmosphere warms, the water vapor in the atmosphere tends to increase, which intensifies the greenhouse effect, meaning it is a self-reinforcing cycle in this respect (Le Treut et al., 2007). The emissions of the main GHGs that lead to human-induced climate change are increasing each year, and the threats to the planet are growing. Especially CO_2 stays up in the atmosphere for a long time and perhaps lasts for centuries (Sachs, 2015). As Tong (2008) postulated, the major current environmental problems have had a substantial effect on human health; these problems include human-induced climate change and stratospheric ozone depletion, with the most serious potential consequence being the erosion of Earth's life-support systems, which would in turn threaten the ecological support systems on which our human life depends.

The essential links between the well-being of human health and the eco-environments in which we live have indeed been well recognized, and yet over the past 150 years developing and industrialized nations have lost sight of this connection as we have over farmed, over fished and dumped increasing quantities of industrial and human wastes. This increasing and relentless abuse of the ecosystem has depleted our natural resources and amounts to the global destruction of our own life support systems (Nicholson and Stephenson, 2004). It is a point of fact that many of the world's environmental problems are related to the wastes produced by human activities that pollute and degrade air, water, and land (Merritts et al., 2014). Examples include:

1. In parts of northern and western Africa, large areas of land have been denuded of most vegetation, and famine occurred repeatedly in the 20th century.
2. Environmental degradation due to (i) overpopulation, (ii) overconsumption, and (iii) pollution per unit of resource used. For instance, "pollution per unit of resource used" could refer to the increased use of coal for energy at a time of rapid industrial growth, resulting in substantial air pollution problems.

There is a broad scientific consensus that environmental degradation is caused by human anthropogenic activities and that it constitutes a profound and unprecedented challenge in human history. There is also no scientific uncertainty that the global environmental and climate crisis is occurring more rapidly than predicted. This new scientific name of "*Anthropocene*" comes from Greek roots: "*anthropos*" – meaning humankind, and "*cene*" – meaning epoch or period of Earth's history (Sachs, 2015).

It is true to say that global environmental changes and climate mediated health risks are now representative of the new epoch in health transition, with many underlying determinants involved in this health transition process. As Li (2018a) has previously elaborated, concepts of health are indeed defined in a very broad sense, with which we set forth the boundaries in relation to the particular health issues and determinants. Many of the key determinants of health and disease provide insights into the fundamental problems in the health transition that we are undergoing. Some of the different determinants of health such as biological, psychosocial, environmental, and socio-economic factors, health behavior practices, medical advancements, and the influential factors arising from ecological and global health determinants which are well recognized as growing intensely, are summarized in Figure 2-2.

Global Ecological Hazards: - Climate change - Stratospheric ozone depletion - Land degradation & occupation - Loss of biodiversity - Changes in hydrological systems - Deforestation - Intensification of food production systems (agriculture and livestock) - Soil contamination & acidification - Ocean acidification - Biogeochemical flows disturbances (Nitrogen & phosphorus cycles) - Eutrophication - Freshwater depletion - Acid rain - Anthropogenic pollution: air, water, soil, chemicals, POPs, plastics, landfills, incinerations - Food web contaminations **Ecological Factors:** - Ecological footprints - Changing ecosystems - Human demographics & behavior - Human-Animal-Ecosystem-Interface (HAEI) - Genetic and biological factors - Microbial adaptation & changes - Susceptibility to infection - Antimicrobial resistance	**Global Health Determinants:** - Ecological hazard determinants - Planetary health (i.e., limits of planetary boundaries) - Eco-environments & service functioning of ecosystems - Biotic & abiotic factors **Health-related Determinants:** - Biological - Physical - Social - Socio-economic - Biopsychosocial - Health practice behavior - Cultural & belief-based practices - Health literacy & Lifestyles - Medical advancements - Healthcare services & systems - Public health services - Public health movements **Social, Political & Economic Factors:** - Globalization & urbanizations - Economic growth - Poverty & social inequity - Food security - Nutritional transition - Intent to harm

Figure 2-2: Ecological and global health determinants.

Ecological and global determinants on health and disease should not be limited to current conceptions of disease causation, as that may underestimate the true impacts of their resultant consequential effects and disruptions to human health in more indirect, complex, and potentially non-linear processes both locally and globally. The interrelatedness of those underlying determinants, together with their complex interplay with health and diseases, is an extremely difficult concept to be unified, excluded or even concluded.

Ecological public health threats have escalated from different types of ecological and global health determinants, such as land degradation, loss of biodiversity, burning fossil fuel, greenhouse gas emissions, declining freshwater resources, pollutions, ocean acidification, deforestations, agriculture and food production systems, over-exploitation of fisheries etc., and all of which have impacted on the service functioning of ecosystems. This book emphasizes the importance of ecological public health for nursing and health professionals and is meant to presciently warn this sector of the actual and potential threats, which will eventually impose an enormous burden on the healthcare systems. The professional ways of safeguarding our human health in this era of the Anthropocene—under these transitional mediating health threats posed by global environmental and climate crises—are the ultimate aims of ecological public health movements. Their focus is on the changing needs toward sustainable health developments by generating the necessary insights to tackle and challenge this new epoch of epidemiological and health transition. A renewed ecological and determinants approach for tackling the transitional health risks is, therefore, absolutely indispensable.

In general, the different phenomena of patterns in health transition could be varied across different countries, and therefore a dual phenomenon could be the resultant effects from the changing underlying determinants in divergence-based influences. However, the identified diverging underlying determinants which prevail across different countries only serve as reference criteria for the explanation of health progress at a particular period of time across particular countries and/or the world at different stages of epidemiological transition, as they depend on the changes of diverging trends of determinants during the historical processes in health transition, as aforementioned in Figure 2-1. Yet again, and crucially, it shows how the paradigm shifts of epidemiological and public health in transition happen in association with the changing underlying determinants. The significance of the changing ecological and global health determinants is shown by their scientific justifications, their conceptual understandings and scientific engagements with them, as illustrated under this age of environmental and climate mediated health risks. Henceforth, my newly proposed ecological public health paradigm in transition, yet again further unfolds the importance of these scientific understandings towards planetary health for healthy eco-environments in this new epoch of the Anthropocene.

The 2005 Millennium Ecosystem Assessment was the first global implementation program of the Ecosystem Services Approach, which aimed at providing strong scientific understanding for how ecosystems affect human welfare and how they can be sustainably managed (Brebbia and Zubi, 2012). It is therefore worthwhile to reinforce such a perspective of planetary health for eco-environments in this new era of the Anthropocene as part of the new challenge through empowering this proposed paradigm of ecological public health globally. The modern concept of "ecosystem services" has progressed significantly in recent decades, and is not just conceived primarily as societal dependence on nature, but also incorporates economic dimensions and provides support to human wellbeing and sustainable development (Brebbia and Zubir, 2012).

Halbert L. Dunn (1896-1975) maintained that a high-level of wellness is a concept of vitality and thus a product of the sustainability of the Earth's natural systems. In this regard he called for a universal philosophy of living (Prescott, Logan and Katz, 2019). Given the growing recognition of the influential factors arising from ecological and global health determinants, there is an acceptance that different combinations of public health approaches are required. It must, however, be recognized that the health consequences of these determinants, as in accordance with the Millennium Ecosystem Assessment, are not only already visible but are likely to grow worse over the next 50 years (Tarkowski, 2009). Our ecological footprint indicates the extent to which humanity is using nature's resources faster than the ecosystems services can regenerate; in other words, we are exceeding the carrying capacity of the Earth. This also shows to what extent humans dominate the biosphere at the expense of other species through influences on biodiversity (Sinha and Choudhary, 2008). The greatest challenge is recreating ecosystems: raising the importance of the conservation of biodiversity is a fundamental issue in humanity's relationship with nature, and brings a new, and for many a more tangible way of valuing biodiversity (Harris, 2012).

This context allows us to further reiterate how public health paradigm shifts and developments with movements towards ecological approaches in relation to these complex patterns of sustainable health in transition will be required for the momentous demands supporting eco-environmental sustainability. Thus, applying ecological principles to human health is meant to spark these momentous demands in support of our eco-environmental sustainability across future generations. Especially, these planetary phenomena pose a serious and urgent threat to human health, well-being and sustainability. Human activities have degraded the Earth's ecosystems and threatened basic life support services to such a degree. With the resultant effects of climate change, severe weather patterns, environmental degradation, desertification, ocean acidification, zoonotic disease outbreaks, biodiversity loss and in particular air pollution (Rabinowitz et al., 2018). This further elicits the importance of planetary health for global and eco-environments, as these aspects are closely interlinked with the ecological and global health determinants in this new era of the Anthropocene. Henceforth, the importance of applying ecological principles to human health is not just presciently a statement of intention, but utterly essential and indispensable for action.

Applying Ecological Principles to Human Health

Over 200 years ago, Charles Erasmus Darwin (1809-1882) famously argued that the value of what is known today as an evolutionary approach would be to "unravel the theory of diseases". He also declared that one of the key principles of evolutionary medicine is that selection acts on fitness, not health or longevity. This yet again reflects how our evolutionary history does not cause disease, but rather impacts on our susceptibility to the risks of disease in particular environments. That we are now living in novel environments, compared to those in which we evolved, leads us to consider these evolutionary principles in conjunction with population genetics and describe several pathways by which evolutionary processes can affect disease risks as part of the insights into determinants of health and disease (Gluckman et al., 2011).

John Graunt (1620-1674) described human population in quantitative terms, and developed his approach to human population by measuring birth rates, death rates, sex ratios, and age structure, and making use of such parameters to predict the evolution of the population of London (Bodini and Klotz, 2011). Later, the famous work of Thomas Robert Malthus (1766-1834) in "An Essay on the Principle of Population" in 1798, in fact formulated a general theory of the dynamics of human populations and has, in essence, been regarded as a biological law ever since. In more recent times it has also been regarded as part of human ecology, in addition to Darwin's credit for the first modern in-depth analysis of biological and environmental interaction with man's place in nature (Kartman, 1967). Malthus conceived of man as acting like other organisms which tend to reproduce up to the limit of the means of subsistence, inevitably ending in famine, disease, and general disaster. This has been referred to as the "ecological fallacy" or the "ecological dilemma". The fallacy presents a view of man as completely enmeshed by and dependent upon the natural system. The dilemma suggests that the circumstance of man is at the same time a part of nature, and yet beyond nature (Kartman, 1967).

As Wilcox and Jessop (2012) illustrated, population ecology began in earnest in the early 19th century, after Thomas Malthus published his famous volume, in which he focused attention on the problem of population regulation and the limits to population growth imposed by the environment. The ideas of Malthus inspired several generations of scientists whose work ultimately provided the foundation of modern population ecology as well as scholars and popular authors writing about the environmental carrying capacity. Such work regards the population size that can be supported in a given area, within the limits of available food, habitat, water, and other needed resources.

This is especially so, as today's human population has increased from about 200 million 2000 years ago to almost 7.5 billion, a multiple of almost 40. Actually, it has already doubled since about 1970, when its rate of annual increase peaked at over 2%. Despite the growth rate having fallen since then, world population still rises by over 80 million per annum (Bulter, 2016). Population growth is putting heavy stresses on a fragile environment, so food needs are outstripping food production. As Malthus in his work warned, if humanity were able to raise its living standards, then the population would expand accordingly, until the rise of population would put strains on the food supply and thereby reverse the gain in living standards. In fact, he is posing the basic challenge of food security for a growing population (Sachs, 2015). The increase in human population (and of energy use and invention) has also been made possible by the transformation of the biosphere to meet human wants and needs (Bulter, 2016). Especially when considering patterns of production, consumption, and waste handling, together with their consequential effects on the biosphere, this global human enterprise is now becoming less sustainable (Boischio et al., 2009).

Ecological and demographic chaos threatens us all and the medical and healthcare professions must embrace this new challenge, and aim to reverse the ecological clock, now poised almost at midnight for many of the species and people on this planet (Butler, 1994). It is estimated about one billion people will become environmental refugees by 2050 in the aftermath of earthquakes, hurricanes, droughts, famines, and floods (Wang, 2009).

Ecological theory maintains that small populations of a living organism introduced into a suitable new environment will at first increase exponentially, as natural selection programs all living organisms to maximize evolutionary fitness (Sallares, 1991). However, as the population increases it will gradually encounter more and more environmental resistance to continued growth as the available resources are used up; by then the rate of increase will diminish gradually until density-dependent intraspecific competition brings fertility and mortality to the equilibrial population density, symbolized as "K" (Sallares, 1991), in which "K" simply means Earth's carrying capacity.

Human ecology is indeed an integral part of the determinants of health in transition, as the state of public health also reflects the "carrying capacity" of the environment. Again, by this term we mean the maximum number the Earth can possibly support. Salk (2017) described an epochal transition and reasoned that the increase of population growth could not go on forever and that growth would likely slow and reach a plateau as a sigmoid curve ("s-curve"), with its midpoint as the point of inflection between two distinct portions: an upward facing, accelerating curve called Epoch A, and a downward facing, decelerating curve called Epoch B (Salk, 2017). In Epoch A, there are few perceptible limits; there are values of unrestricted growth and expansion; there is the exploitation of both natural and human resources for consumption; and independence and short-range thinking tend to predominate. On the other hand, in Epoch B, resources are limited and growth is slowing; a high value is placed on conservation, sustainability, interdependence and long-range thinking; and these apparently shifting value systems occur alongside shifts in population dynamics (Salk, 2019). A graphical representation of this is shown in Figure 2-3.

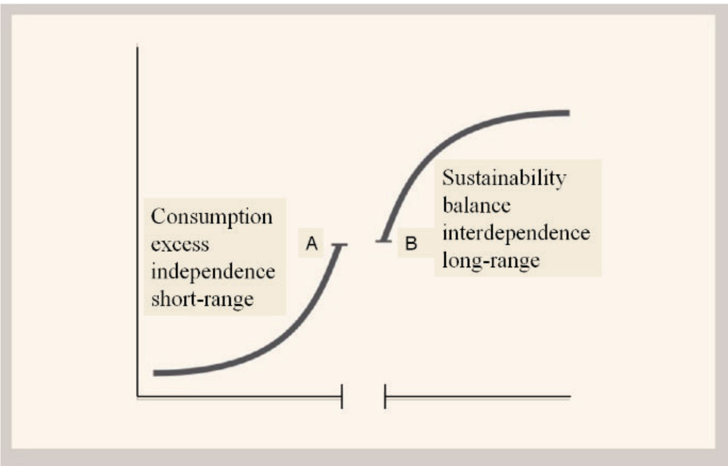

Figure 2-3: Shifting value systems with shifts in population dynamics. Used with permission from: Jonas Salk and Jonathan Salk (2018), *A New Reality: Human Evolution for a Sustainable Future.* Stratford, CT: City Point Press.

During these times of rapid and escalating social, political and environmental shifts in which human-driven activity is critically harming the planet's ecosystems, we are collectively faced with deep and urgent questions concerning how we will live within the Earth's carrying capacity. The fundamental question is whether this planet of ours can continue to feed not only the 7 billion of us, but the added 75 million people born annually as well. Despite this, most demographers conclude that world population will stabilize at around 10 billion, though others project a smaller number (Rhodes, 2012). In view of this context, what can we learn from nature is that living systems have six key features, which are: (i) interdependence, (ii) diversity, (iii) resilience, (iv) adaptability, (v) unpredictability, and (vi) limits, upon which the prime concerns for ecological coexistence depend.

Thus, the paradigm of any conceptual framework for ecological thinking within these prime concerns for ecological public health has to be focused on these interrelationships of sustainability for our environments and Planet Earth for all human health, and with regard to our planet as a whole. The paradigm of this conceptual framework for applying ecological principles to human health is the furtherance of the interrelationships of sustainability of our environments in relation to the changing ecological and global determinants of health and disease, which are in turn understood as sources of actual and potential environmental and climate mediated health risks. Whereas, the concept of clinical ecology means practicing medicine with planetary health in mind; in other words, we can define clinical ecology as a healthcare approach that considers the interconnected vitality of person, place, and planet (Nelson et al., 2019). Moreover, healthcare practice with the concept of clinical ecology reinforces the undeniable reality that human health and the vitality of natural and anthropogenic ecosystems cannot be separated (Nelson et al., 2019).

Given our understanding of the Anthropocene, it is crucial for us not to forget that it is the choices our societies make and that will determine the future of the planet, and consequently, that of our species. Ultimately, planetary health needs to be at the center of these choices (Lancet, 2019). Only the achievement of the highest attainable planetary health in terms of maintaining healthy global eco-environments that is the ultimate goal for sustainable health, wellbeing, and equity worldwide through judicious attention to both the human systems—political, economic, and social that shape the future of medical and health humanity—and together with the Earth's natural systems that define the safe eco-environmental limits, and only within which humanity can flourish. This latter requirement includes integrating policies to address the social, economic, and environmental determinants of health (Whitmee et al., 2015), as which comprise the ongoing and future health transitions of the 21st century.

The precautionary principle suggests that human societies are unwise to drive Earth systems substantially away from a Holocene-like condition, as this has profound implications for global sustainability (Steffen et al., 2015). Ecological health is used both for human health and to describe the state of the environment, which includes our eco-environments that can sustain the planet and maintain a healthy habitat for all forms of beings. It drives for planetary boundaries and limits within the proposed safe operating space as defined in Figure 1-1, the “Limits of Planetary Boundaries”.

A critical point for maintaining a productive and effective ecosystem is that the confluence of threats must be countered with a congruence of benefits (Guenther and Vittori, 2008). It is therefore necessary to learn more about the complex relationship of how ecological, environmental, medical or even social sciences can contribute to improving human health (Morand and Lajaunie, 2018). According to the Four Laws of Ecology in Barry Commoner’s *The Closing Circle* (1971), “planetary health is the systematic application of human health, from global to local scales” (quoted in Frumkin, 2017):

1. “Everything is connected to everything else.
2. Everything must go somewhere.
3. Nature knows best.
4. There is no such thing as a free lunch.”

As according to the scientific understandings, “Everything has a limit” should perhaps be added as a “fifth law”. With these laws and their justifications in mind, then, we come to the facts that: (a) planetary boundaries have limits, (b) ecosystem services have limits to their biocapacities in order to function effectively, and (c) Earth’s carrying capacity is not limitless. In fact, all of these dangers represent our prime concerns of planetary health for global eco-environments. All these laws and declarations relate scientifically to ecological principles that mostly deal with “time”, “species”, “place”, “disturbance”, and the “landscape”, all of which have particular implications for land use and can assure—if judiciously maintained—that the fundamental processes of Earth’s ecosystems are sustained within levels of organization acceptable to ecology. We must then remember that ecology is the study of organisms’ interactions with the abiotic and biotic components of their environment—with their biosphere, ecosystem, community, and population. An ecosystem is all of the living, biotic things in an area interacting with all of the abiotic parts of the environment. Thus, the relationship of the biophysical aspects of ecosystem health to societal well-being is evident. A sign of a productive ecosystem is its ability to produce continuous goods and services (such as clean water and air), productive habitats, and intact coastlines, of which all provide direct benefits to our society (The World Bank, 2006).

From a history of science perspective, humans have been driven to develop concepts, theories, and models of reasoning to facilitate the understanding and study of concepts of disease causation, as well as how to maintain health. Yet again, it is worth re-emphasizing that ecological processes that take place over large areas tend to happen very slowly and encompass processes operating from the microscopic to the planetary level, in which the fossil record helps us to appreciate the current scale of change with regard to other major environmental changes in the planet's history. This area of study shows planetary health's diverse historical background and its foundational principle that human health is irrevocably coupled to the health of natural systems within the Earth's biosphere, in which the condition of the environment and the health of humans, animals, and the planet itself, have been meaningfully engaging with the living systems on which we depend (Horwitz and Parkes, 2019). Li (2017a) further reinforced this point, stating that the magnitudes and blueprint of ecological transition, epidemiological transition and health transition have indicated that the changes in patterns of illness within a human population, which elucidate how human health is being affected or impeded within ecology of food and related environments on human health. In this context, Figure 2-4 summarizes the timeline of historical developments and certain turning points with regard to the evolving concepts of disease and health in terms of their association with progressive knowledge of ecological principles in relation to human health.

Timeline of historical developments concerning ecological principles in relation to human health
Miasmic theory is a term derived from the Greek word for stain or defilement that has been around for over 2,000 years and was popularized in the 17^{th} century. Our ancestors believed that ill-effects of the environment were conveyed by miasmas.
Ca. 460-370 BCE The Hippocratic Corpus entitled "On Airs, Waters, and Places" was an early proponent of environmental determinism. Hippocrates is regarded as the "Father of Western Medicine".
1674-76 Anton van Leeuwenhoek observed single-celled organisms; he was the first to see, discover and describe bacteria.

Thomas Robert Malthus (1766-1834) The relationship between human population growth and the growth of resources was explored in his publication "An Essay on the Principle of Population" in 1798.
Alexander von Humboldt (1769-1859) The Prussian geographer and naturalist in his works on botanical geography laid the foundation for biogeography. He is considered the "Father of Ecology", as he was the first to take on the study of the relationship between organisms and their environment.
Charles Darwin (1809-1882) Darwin developed the concept of natural selection. Life greatly affects the global environment and the environment constrains life and can drive natural selection, and all of these interrelations are manifestations of a basic ecologic process, competition, which in its "pure" form is an impersonal striving for advantage.
Herbert Spencer (1820-1903) Spencer elaborated the "principle of continuity" – the theory that homogeneous organisms are unstable, that they develop from simple to more complex and heterogeneous forms, and that such evolution constitutes a norm of progress.
In 1838, Matthias Schleiden's methods lead him to propose the cell theory for plants. He was the first to recognize the importance of cells as fundamental units of life.
In 1850— "The Age of Modern Medicine" begins in 1850s.
In 1854 Cholera outbreak: Jon Snow publishes a Broad Street map and demonstrates that cholera bacteria were transmitted in contaminated drinking water.
In 1855, Rudolf Virchow published his now-famous aphorism *omnis cellula e cellula* ("every cell stems from another cell"). He also stated that all diseases involve changes in normal cells.
In 1856, Louis Pasteur discovers microbial fermentation while studying the causes of spoilage in beer and wine. In 1864, he proposed germ theory, furthering knowledge of bacteria.
Ronald Ross (1857-1932) In 1892, he confirmed that mosquitoes are connected with the propagation of disease by demonstrating the life-cycle of the parasites of malaria in mosquitoes, and provided substantial input to the development of ecology as a science.
Karl August Möbius (1825-1908) Möbius was a German zoologist who was a pioneer in the studies of "biocenosis", or living community. He argued that plants and animals live together in an interactive community, which is central to the science of ecology, and an idea which was crucial to the origins of the conservation movement.
Vito Volterra (1860-1940) and James Lotka (1880-1949) The Lotka-Volterra competition model is a general framework that can model the dynamics of ecological systems with predator-prey interactions, competition, disease, and mutualism.

Georgyi Frantsevitch Gause (1910-1986) He elaborated the "Principle of competitive exclusion" or Gause's Law of competitive exclusion (or just Gause's Law). It is the notion that two species that compete for the exact same resources cannot stably coexist. He argued that ecological differentiation is the necessary condition for coexistence.
Ernst Haeckel (1834-1919) The German zoologist Ernst Haeckel in 1866 coined the term ecology, stating: "By ecology we mean the body of knowledge concerning the economy of nature – the investigation of the total relations of the animal both to its inorganic and to its organic environment".
Authur Tansley (1871-1955) The term ecosystem was originally defined by Tansley in 1935 as a biotic community (or biocenosis) along with its physical environment (or biotope). In ecological studies, biocenosis is the emphasis on relationships between species in an area.
Victor Ernest Shelford (1877-1968) Shelford extended the ecological concept and its theory, making a crucial step toward creating a fuller concept of the ecosystem.
Charles Elton (1900-1992) A British ecologist, Elton's contribution was to "scientific natural history", or "the science of super-individual complexes". His book *Animal Ecology* in 1927, gave us the first ideas of "food chains" and "food webs".
Raymond Lindeman (1915-1942) Lindeman's pioneering work on the linkages among nutrient cycling, productivity, energy flow, and nutritional efficiency laid the foundations for modern ecosystem ecology.
Eugene Odum (1913-2002) Eugene Odum's first textbook on ecology was published in 1953, and some saw it as the "radical science", in which ecosystems were recognized as units that regulate the flow of energy, increase efficiency of energy transfers among biotic compartments, and regulate the circulation of material between the abiotic environment and the living things acting within it. It was known as the "new ecology" or "systems ecology".
The "One Medicine" approach first appeared when Calvin Schwabe, a veterinary epidemiologist at the University of California, Davis, introduced the term in his book *Veterinary medicine and human health*. In the 1980s this led to a public health approach within a multidisciplinary framework called One Health. The approach involves collaborating disciplines working towards optimal health for the planet – for its people, animals, and environment. During the 1980s the concept of sustainable development grew, requiring health to be inclusive for people, animals and ecosystems.
In 2005, the UN's Millennium Ecosystem Assessment Report stated that human activity was putting such a strain on the natural functions of Earth that the ability of the planet's ecosystems to sustain future generations could no longer be taken for granted.

Planetary ailments impacting on human health, such as climate change, are famously described in the *Lancet* as the biggest global public health threat of the 21st century.

Figure 2-4: Timeline of historical developments with progressive knowledge of ecological principles in relation to human health. (Walton, 2019; Bodini and Klotz, 2011; Horwitz and Parkes, 2019; Golley, 1988; Hardin, 1960; Schellnhuber, Crutzen, Clark, Claussen and Held, 2004; Kartman, 1967).

Despite ecology not being considered an important science until the 1960s, the increasing human population, the exploitation of natural resources and the degradation of the environment have awakened people to the importance of studying such problems scientifically. To us ecology should never deviate from its principle of holism, which acknowledges the (eco)system, including what processes it uses, and what it does (structure, process and function) as well as how components are distributed and how the whole is organized. Public health transition is also driven by underlying determinants of health, together with our understandings in the concepts of disease that reflect from different stages of epidemiological transition. In this new epoch of the Anthropocene, our renewed conceptualization of the transitional changes can be reinforced by referencing the timeline of historical developments in understanding ecological principles and their relations to human health, as briefly summarized in Figure 2-4. Yet in this connection, public health in transition can also be seen as a revolution for the changes with paradigm shifts, as the driving forces relating to the underlying determinants of health (as in Figure 2-1) are being revealed, as which is closely associated with the concepts of disease. On that basis, ecology seeks to make sense of a complex and uncertain world (Horwitz and Parkes, 2019). Henceforth, applying ecological principles to human health is meant to be an ultimate approach in support of sustainable concepts in health developments, as our conceptualization of disease and health is changing and being affected under the different driving forces of ongoing global and ecological health determinants.

In fact, concepts of disease have always been the subject of a vast concern as disease is a central notion to healthcare. Consequently, it is important to understand the process of its causation. Epidemiology is the study of the determinants of diseases from different perspectives, including the identifications of the causes and/or mechanistic causes of a particular disease, while disease ecology is more focused on studying the underlying principles that influence the spatio-temporal patterns of diseases. The conceptual theories and interrelationships amongst different interactions arising from the evolving forms of our scientific understandings and epistemological knowledge in relation to ecological principles and human health have continued to prevail. Because evolutionary theory represents a milestone for ecological thought and for all concepts that form the background of ecology, when it comes to conceptualizing these ecological principles with regard to human health, the vastly complex and diverse landscape that comprises these accumulative conceptual theories and scientific reviews has been specifically chosen given the particular interrelated dimensions of its attributes. Evolutionary theory in relation to ecological principles will continue to play a significant role in adapting to transitions in health.

The global environmental and climate crisis is, of course, closely interlinked with the ecological effects of biodiversity loss, environmental pollution, freshwater depletion and food security that are already undermining health and wellbeing developments globally. Indeed, the state of environmental degradation and climate change is the most alarming transition and is intimately connected to our health developments. The reciprocity and intimacy required for maintaining the interdependency of both planetary health and human health necessitates the evolution and broadening of existing concepts in order to understand the relationship between ecological principles and human health. The basic premise of ecological thinking is that human health and its determinants are interrelated, and that different determinants of health lead to different patterns in the burdens of diseases. In fact, those underlying determinants are acting as driving forces that mediate many health risks both locally and globally, causing the changing patterns in health transition. These patterns are constantly and continuously influenced by determinants in transition at different paces across different countries, as well as across generations.

It is believed that understanding the global underlying drives and ecological determinants of health is necessary to develop, implement, and evaluate the effectiveness of interventions designed to improve health. Gebbie, Rosenstock and Hernandez (2003) re-emphasize that sustainability of population health must take a broad view of determinants and an ecological view of health to account for much of the ebb and flow of diseases over time in the shifting ecology of human living in relation to both natural and social environments. Professor Tony McMichael (1942-2014) in his work alerted many to the health implications of climate change and argued that these impacts required consideration not only in terms of the nature of the change, but its complex interactions with place, society and economy. Such complexity is further deepened by spatial variation, not only in the effects of climate change but also in the nature of environments with consequential effects on populations (Butler, Dixon and Capon, 2015).

Yet the surge of environmentalism over the last half century is patent. And environmental impacts are increasingly seen as global and interrelated, complex and unknowable, long-lasting and perhaps irreversible consequences. None of these perspectives are wholly new—some even echo Marsh's *Man and Nature* (Lowenthal, 2000). Marsh, the American scholar-diplomat who published the first comprehensive study of human environmental impacts in 1864, called his work *Man and Nature; or, Physical Geography as Modified by Human Action*. In this work, he states (quoted in Lowenthal, 2000):

> *"The Earth is fast becoming an unfit home for its noblest inhabitant, and another era of equal human crime and human improvidence . . . would reduce it to such a condition of impoverished productiveness, of shattered surface, of climatic excess, as to threaten the depravation, barbarism, and perhaps even extinction of the species."*

The excerpt also refers back to Marsh's 1847 lecture that predicted human-induced climate change and warned of the potential dangers of the mismanagement of natural resources (Hickman, 2011). Nonetheless, only since the 1950s have the global environmental and climate mediated crises been given more intense attention, especially concerning the ecological footprints of socio-economic trends and Earth system trends (as in Figure 1-2). These factors as indicators, together with the limits of planetary boundaries (as in Figure 1-1), led to the affirmation of the Great Acceleration that was then dated back in the 1950s, and the ensuing changeover into the new epoch of the Anthropocene at that time. Though the debate about whether global environmental change is real is now over, in its wake is the realization that it is happening more rapidly than predicted, and these changes constitute a profound challenge to human health, both as a direct threat and as a promoter of other risks (Schwartz et al., 2006).

Our future depends on sustainability. In 2001, McMichael illustrated that the cumulative impact of our activities on the self-renewing ecological systems of the planet has been clearly established as unsustainable, and therefore supporting global ecological integrity in public health addresses a key question in 21st century public health in general (Brown et al., 2013). In this regard, the concept of a health transition has been used to describe the dynamics involved in this period of human history that refer to historical trends in demographic, epidemiological and nutritional changes in human populations in the context of economic, socio-cultural and political changes (Defo, 2014). The concept of a health transition is, in fact a more precise term to describe the full ranges of such a dynamic process, referring to an overall epidemiological, demographic and nutritional transition. The possible global driving forces of underlying determinants that interacting with the evolving concepts of health in transition during this age of environmental and climate mediated health risks are summarized in Figure 2-5.

Socio-economic trends (Also see Figure 1-2)	**Earth system trends** (Also see Figure 1-2)	**Nine critical planetary boundaries** (Also see Figure 1-1)
- Population - Real GDP - Foreign direct investment - Urban population - Primary energy use - Fertilizer consumption - Large dams - Water use - Paper production - Transportation - Telecommunications - International tourism	- Carbon dioxide - Nitrous oxide - Methane - Stratospheric ozone - Surface temperature - Ocean acidification - Marine fish capture - Shrimp aquaculture - Nitrogen in coastal zones - Tropical forest loss - Domesticated land - Terrestrial biosphere degradation	- Climate change - Biosphere integrity (genetic & functional diversity) - Land-system change - Freshwater use - Biogeochemical flows (phosphorus & nitrogen cycles) - Ocean acidification - Atmospheric aerosol loading - Stratospheric ozone depletion - Novel entities (chemical pollution)

Figure 2-5: The possible global driving forces of underlying determinants.

Substantial transitional changes have been identified from the impacts of ecological changes on eco-environments and the climate, and human health is intricately connected to the vitality of natural systems with the Earth's biosphere. This includes the principles of what is now termed "planetary health", with a broad spectrum of health implications resulting from anthropogenic threats to our life within the biosphere. These possible driving forces of underlying determinants are continuously interacting with those ecological and global health determinants (as summarized in Figure 2-2), to further impose mediating effects as the core drivers propelling an epidemiological transition with resultant effects on the health transition. As the health of human beings, societies, ecosystems and the planetary life support system is fundamentally interconnected and interdependent, in which sustainability as a process of interactions with pace and time and its subsequent intensity projects a need to integrate ecological, social, cultural, economic and psychological (spiritual) considerations into a flexible and responsive strategy to facilitate the transition as a learning journey (Wahl, 2016). This in fact, echoes and re-emphasizes the Canmore Declaration's notion that public health, biopsychosocial medicine, and planetary health are one-and-the-same (Prescott, Logan and Katz, 2019).

> *"Sustainability is impossible if social or economic benefits are maximized at the expense of ecosystem processes that produce the services. We need to protect biodiversity as insurance against the loss of critical ecosystem services."*
>
> (Schowalter, 2013, p. 305)

This is no easy challenge, but—as Stephen Boyden noted back in 1986—the whole question of the dynamic interrelationship in the modern world between human populations and their environments really is a complicated one, and the subject is very difficult. It is very much easier to be a good specialist in one of the traditional academic disciplines than it is to be a good human ecologist (Wakefield-Rann and Fam, 2018). There have been for several years, however, growing concerns about the discrete, isolated approaches to managing the social, environmental, and economic components of natural resources, with more emphasis placed on the economic component to the detriment of the other two (Dakubo, 2011). Human activities increasingly influence the Earth's climate and ecosystems with humans acting as the dominant driver of change to the Earth's systems; this, in turn, raises the concern that further pressure could destabilize critical biophysical systems and trigger abrupt or irreversible environmental changes that would be deleterious or even catastrophic for human well-being (Rockström et al., 2009). Therefore, the WHO reinforces that: "*human beings are at the centre of concerns for sustainable development. They are entitled to a healthy and productive life in harmony with nature*" (Watts et al., 2012, p. 1). Henceforth, giving rise to an ecosystem approach to natural resource management with increasing calls for sustainable development and the preservation of the environment must be our emphasis and the important role of ecological factors in shaping human health cannot be ignored (Dakubo, 2011). As an analogy with a simplified view, for instance, all living things require a certain amount of water and the availability of water, terrestrially, to flourish within certain temperature tolerances for aspects of their life cycle; this is due to the essential connection of temperature and water to life. Thus it is not difficult to see how important climate is in determining where different species, and assemblages thereof (ecosystems), can be found as a confluence of forces (Cowie, 2013).

Conclusion

Health manifestations could be perhaps oversimplified as mere vehicles of disease, with mere common causes of disease from bio-medical models only. But an equally important causation which we do not comprehend, or comprehend but dimly, is that ecological principles attribute to our human health along with those of serious deteriorates or disruptions of eco-environments. With the litany of ecological alterations that are occurring and which have been accelerating considerably since the mid-twentieth century, human activity has pushed the Earth's ecosystem beyond the boundaries of its natural ability, which has caused profound changes in and on the planet. Soon these are likely to be presented to us in the form of a decrease in well-being (Lambin, 2012).

Both this changing new era and our entrance into the Anthropocene encapsulate the evidence that the entirety of Planet Earth is interacting in intricate physical, chemical, and biological ways. The shocking impact of our activities on our planet have become so profound as to cause a multidimensional predicament that requires a new way of thinking to contend with the current unsustainable transitions in health.

The effective integration of ecological understanding with ecology of disease and sustainable health requirements in relation to ecosystems and planetary health is a key challenge to human health in this era of the Anthropocene. The driving forces of ecological and global health determinants constitute the multi-scale magnitude of the practical relevance reflecting from different stages of epidemiological transition for public health orientations and concepts in transition; these are further discussed in Chapter 6, together with my proposed new waves of public health movements towards planetary health for global eco-environments.

It is clear, then, that a perspective focused on planetary health and global eco-environments is needed to keep abreast of the totality of this predicament. A starting point for the intended purposes of action is to consider the implications of this view of ecological health as a series of related time-effects for an ecological public health paradigm in transition. Ecological principles applied to human health are indeed serving as a significant and integral part of the changing demands in the healthcare environment, and must continue to do so on a long-term basis in response to sustainable developments in health.

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CHAPTER 3

PUBLIC HEALTH IMPACTS IN THE AGE OF ENVIRONMENTAL AND CLIMATE MEDIATED HEALTH RISKS

Global environmental threats are not just caused by economic development, but also the related human activities, including lifestyles that produce serious disturbances to Earth's ecosystems. This includes habitat destruction and fragmentation, climate change, overexploitation of natural resources, invasion of exotic species and massive influxes of pollutants, degrading the habitat of species and simplifying their biodiversity. These disturbances threaten natural communities, driving the loss of species and their interactions (Garay-Narváez et al., 2013). Climate change can also be a driver for disease migration. As for over 170 years, scientists have studied the complicated relationship between the weather, climate, and human health (Portier et al., 2010). Climate change affects human health through complex processes mediated by disturbances of ecological systems; additionally it can also intensify the propensity of diseases that can change the species range of disease vectors and further affect a human population (Cowie, 2013).

The new stage of epidemiological transition in this age of environmental and climate mediated health risks depicts the public's health globally in its broadest possible context, as global environmental and climate changes encompass serious forms of widespread health threats worldwide and imposes transitional risks to our health outcomes through a mediating process both directly and indirectly. Climate change can therefore affect human health in two main ways: firstly, by changing the severity or frequency of health problems that are affected by climate or weather factors; and, secondly, by creating unprecedented or unanticipated health problems or health threats in places where they have not previously occurred (US Global Change Research Program, 2018). As a constantly changing field, ecological knowledge of public health requires evidence-based information and regular scientific updates, even more so in the context of a world with a globalized society under this process of epidemiological transition. Therefore, ecological public health is always a complex science helping in the decisions, actions and interventional changes accommodating sustainable health needs under such particular process of health transition during this new age.

As the World Health Organization (WHO, 2017) illustrates, we need global defenses against universal transboundary threats to health, like climate change, air pollution and antimicrobial resistance—all of which are sounding the alarm with regard to our health. In particular, climate change is the defining issue of the 21st century, and its threats are evolving and multiplying. Especially, climate change is endangering the stability of the planet's ecological systems and poses untoward risks to the continued survival of humans, as it has increasing effects on the global burden of disease, which could create enormous costs to society (Leffers and Butterfield, 2018). To illustrate this point further, human life is dependent on the dynamics of Planet Earth's climate system, in which climate change has far-reaching consequences: its adverse effects touch on all life-support systems. Fundamentally, it simply affects our human health and survival (Githeko, Lindsay, Confalonieri and Patz, 2000).

Climate change directly affects five components of the environment: water, air, the weather, oceans, and ecosystems; these in turn affect human health (Portier et al., 2010). As the IPCC's 2018 report points out, the impacts of climate threats affect a range of natural and human systems, such as terrestrial, coastal and marine ecosystems and their services; agricultural production; infrastructure; the built environment; human health; and other socio-economic systems. And many subsequent impacts may also be triggered by combinations of those factors, including "impact cascades" through secondary consequences of changed systems (Allen et al., 2018). With the growth of population and industry in particular comes the ever-increasing demand for those resources as fuel, land, and clean freshwater. Environmental degradation is already the obvious and nearly inevitable result of such demands, and the question which concerns us is: does Earth have a finite "carrying capacity" (Merritts, Menking and de Wet, 2014) to sustain our human population with those resources of clean air, clean water, and adequate nourishment for our sustainable existence? And perhaps more pertinently, do the consequences of the further growth of human population, the increasing use of those resources (e.g., minerals, fertilizers, and water), the consumption of energy, and the production of waste, mean that we have moved beyond that carrying capacity?

Back in 1861, the natural philosopher John Tyndall made the prediction, little noted at the time, that anthropogenic emissions of carbon dioxide would trap the radiative energy of the sun within the Earth's atmosphere and raise surface temperatures. Since then global warming has been accelerating at a rate far greater than we predicted even a century ago (Staropoli, 2002). Major human activities related primarily to the burning of fossil fuels and changes in land cover (such as deforestation) are continuously changing the concentration of atmospheric constituents or properties of the Earth's surface that help to absorb or scatter radiant energy, so if current warming trends continue, heat waves, floods, and droughts and their attendant physical effects are likely to become more frequent and severe (Patz and Khaliq, 2002).

As temperatures rise and conditions deteriorate significantly, climate change will test the resilience of many societies around the world (Stern, 2008). The causes of this climate change are increasingly well understood and the conclusion is that most of the warming observed over the last 50 years is likely to be attributable to human activities as illustrated and affirmed by the IPCC since 2001 (McMichael et al., 2004). Human health is sensitive to temporal and geographical variations in weather (short-term fluctuations in meteorological conditions) and climate (longer-term averages of weather conditions), with the effects of climate change on health more easily estimated (McMichael et al., 2004). Climate change typically acts in conjunction with other environmental changes, and health risks are in fact influenced by both "natural climate variability", and also by "human-induced" climate change through human anthropogenic activities that increase GHGs such as stratospheric ozone depletion and land clearing. As our planet becomes increasingly dominated by human activities, the health of humans, animals (domestic and wild), plants (cultivated and wild), or of social and ecological systems and processes, is being affected enormously and relentlessly at a rate of change which continues to escalate on a global scale (Cumming and Cumming, 2015).

There were 12.6 million deaths (23% of all deaths worldwide) in 2012 attributable to modifiable environmental factors according to the WHO's estimations. Many of these could have been influenced by climate change or were related to the driving forces of climate change (Li, 2017b), together with other global environmental mediated health risks directly and indirectly imposing onto our human health that even causes greater rising concerns. As the WHO (2019) also indicates that the known avoidable environmental risks cause about one quarter of all deaths and the disease burden worldwide, amounting to at least a steady 13 million deaths each year. There are totally 101 diseases or injuries out of 133 considered in the Global Burden of Disease project that have significant links with the environment (Cole, 2019). It is believed that climate change during the next century and beyond may even exacerbate many of those health threats faced by human populations (Burns, 2002). Figure 3-1 shows the possible profound effects of direct and indirect public health impacts during this age of environmental and climate mediated health risks (Li, 2018b).

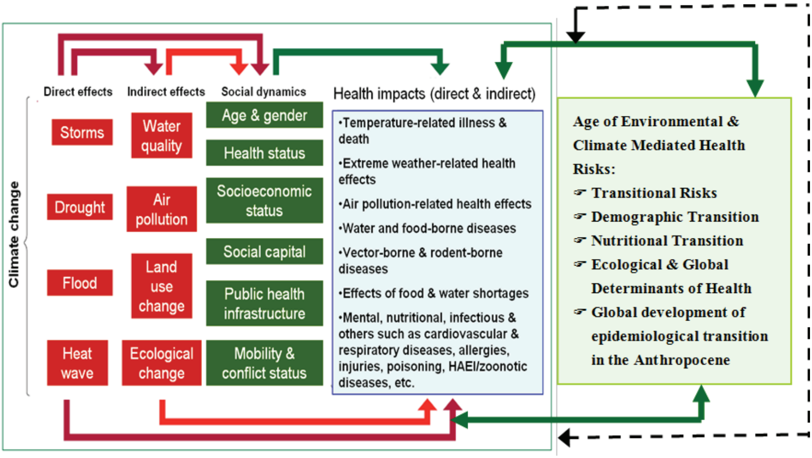

Figure 3-1: The possible profound effects of public health impacts in the age of environmental and climate mediated health risks (Adapted & revised from Li, 2018b).

Climate change is one of the vital indicators of health and well-being; its overwhelmingly negative effects (existing and potential) and their impacts are therefore the main culprit of the health-related threats that are arising from global environmental and climate mediated health risks. The complexity of the changes in this new epoch of epidemiological transition has such a profound effect on public health that it becomes potentially, actually and catastrophically interlinked with those mediating threats largely due to this global environmental and climate crisis. Therefore, a broad conception and understanding pertaining to the driving forces of those underlying ecological determinants is of significance. In this view, the application of this ecological perspective will be critical if a sustainable future is to be achieved, as an awareness of the shifts in the ecology of human living in relation to both natural and social environments, which requires an ecological view of health (McMichael and Beaglehole, 2003). In addition to disasters such as earthquakes, instances such as famines, epidemics, and severe weather events can usually be traced to anthropogenic environmental change—i.e., (a) to various combinations of climate change, declines in ecosystem health and in resource availability, and (b) to other manifestations of the global environmental crises including pollution, resource scarcity, and the rapid loss of biodiversity (Lautensach, 2015).

> *"Climate change will force humans to negotiate with their changing environment as never before to find ways to reshape it both for short-term protection and long-term alleviation of health consequences."*
>
> *Portier et al., 2010*

The need for sound science becomes more critical than ever, as climate change endangers human health with environmental consequences and adverse changes become more intense, imbued with the massive potential to harm a lot of people. The following articulates the unprecedented global environmental and climate crisis in the Anthropocene caused by humans and its consequential effects on human health, so as to recognize the infinity linkages and complexity of certain adverse mediating effects and public health risks.

Temperature-Related Morbidity and Mortality

Global temperatures are rising at unprecedented levels and it is believed that a temperature increase of 2^0C above the pre-industrial period level could have catastrophic effects. Insofar, the hottest year on record was in 2016 since measurements began in 1880 and global temperatures have already risen by more than 1^0C. However, in Europe this average is already 1.4^0C higher and the change is particularly pronounced in the winter (rather than the summer months), which projected increases as high as 8 to 10°C in some European regions by 2080 (ECDC, 2012).

As temperature plays a crucial role in mortality rates, a similar relation links temperature and survival rates, with an optimum value between 20 and 26˚C. Major temperature elevations during current climate changes may have unfavorable impacts on our capacity to reach our functional maxima and absolute physical limits (Marck et al., 2017). Especially, our physiological traits will be affected by such temperature changes. Heat-waves or heat stress induced mortality of food source species, ecological keystone species, and disease vectors and reservoirs are other examples of this primary temperature-related effects (WHO, CBD and UNEP, 2015).

One of the most severe environmental hazards to public health is extreme heat, which has numerous impacts on vital social systems including food, water, energy, and infrastructure; furthermore, these extreme heat events are projected to intensify in frequency and severity due to climate change, with even greater impacts in urban areas, due to heat-island effects and further aggravation by air pollution as well (Howe et al., 2019). Back in the summer of 2003, for example, Europe was struck by a heat wave that led to the deaths of over 20,000 people, over half of which occurred in France. As global warming continues, the frequency of heat waves is expected to increase heat-related mortality, as well as other adverse effects such as: the potential to alter disease transmission; food insecurity due to droughts or severe weather that damages crops; water scarcity that leads to further outbreaks of disease (e.g. cholera) as people are forced to drink water contaminated with sewage; warmer temperatures exacerbating air quality problems; and the formation and development of a tropospheric ozone formed from compounds in car exhausts, which may increase respiratory distress (Merritts et al., 2014). Examples of excess mortality attributed to the 2003 hot summer or heat wave period in Europe are shown in Figure 3-2 (Haines et al., 2006).

Excess mortality attributed to the 2003 hot summer or heatwave period in Europe			
Places	Number of deaths	Percentage increase	Period
England and Wales	2091	17	4-13 August
Italy	3,134	15	1 June-15 August
France	14,802	60	1-20 August
Portugal	1,854	40	In August
Spain	4,151	11	In July and August
Switzerland	975	6.9	In June-September
Netherlands	1,400-2,200	3-5	1-24 August
Germany	1,410	--	In summer

Figure 3-2: Excess mortality attributed to the heatwave period in 2003 (adapted from Haines et al., 2006, p. 588).

There is growing evidence that rising greenhouse gas concentrations are increasingly affecting some characteristics (e.g., likelihood and severity) of heat waves, and projections of future climate change indicate that heat will become an increasing problem, as global warming will exacerbate extreme heat hazards in areas that already experience extreme heat. These hazards will also spread to areas with little prior experience of health-threatening heat, which depend not only on exposure, but also on behavioral responses in relation to the perceived risk of those extreme heats (Howe et al., 2019). The health outcomes of prolonged heat exposure include heat exhaustion, heat cramps, heat stroke, and death; all of these maladies are likely to increase in response to climate change (Portier et al., 2010). When humans live above a certain temperature threshold, mortality rises side by side with temperature (alongside illness and injury), as heat stress strongly correlates with exacerbations of lung disease—such as asthma and emphysema—as well as dehydration and injurious electrolyte abnormalities. The approximate estimated death rate increase per 1^0C (1.8^0F) increase in temperature is (Lemery and Auerbach, 2017, p. 22):

- 2.8 to 4.0% for elders with chronic conditions
- 4.0% for persons with diabetes
- 3.8% for persons with a previous heart attack
- 3.7% for persons with chronic lung disease
- 2.8% for persons with heart failure

Increased frequency, intensity, and/or duration of heat waves in combination with black-asphalt roads and other dark surfaces, buildings, and industrial activities in cities can also create an urban heat island effect, especially where urban areas are relatively lacking in trees, as their absence leads to less of the cooling effect associated with evapotranspiration (Levy and Patz, 2015). Crucially, the IPCC in 2018 estimated that global warming of roughly 1.5^0C is expected between 2030 and 2052 with devastating implications for worldwide populations (Allen et al., 2018).

Extreme Weather-Related Health Effects

Human health is undeniably sensitive to shifts in weather patterns and other aspects of climate change. In line with current trends, average global temperatures could rise by 2-3°C within the next fifty years or so leading to many severe impacts, often mediated by water, including more frequent droughts and floods (Stern, 2008). Moreover, melting glaciers will also increase the risk of floods during the wet season and strongly reduce dry-season water supplies to one-sixth of the world's population, predominantly in the Indian sub-continent, parts of China, and the Andes in South America (Stern, 2008). Additionally, one notion of flooding in the field of microbiology views the world as being covered by a "fecal veneer," in which our planet is blanketed by layers of infectious filth, which also overwhelm sewage systems, contaminate drinking water, and spread infectious diseases (Lemery and Auerbach, 2017). There is a high correlation between waterborne illness outbreaks such as diarrheal disease and high temperatures, as hot weather favors bacteria— entamoeba, protozoa, etc.—plus warmer temperatures and extreme weather events encourage the growth of mycotoxin-producing fungi, including *Aspergillus, Claviceps, Stachybotrys,* and *Fusarium spp*. Exposure to mycotoxins could induce further transitional health risks, including (WHO, 2009):

1. The pathogenesis of cancers, ergotism, and birth defects;
2. *Aspergillus* can produce aflatoxin, a potent mycotoxin that has caused much death and disease in Africa and Asia (to which young children are among the most vulnerable); and
3. Extreme weather events such as droughts, which could weaken seed kernels of plants that allow greater fungal contamination. On the other hand, flooding causes moist conditions and could also promote fungal growth.

And such shifts are already exacerbating health problems, with direct effects of changes in temperature and precipitation including the occurrence of heatwaves, floods, droughts, and wildfires, in addition to other indirect effects, for instance the damage done through ecological disruptions such as crop failure and shifting patterns of disease vectors (Smith et al., 2014). And increases in the incidence and intensity of extreme weather events may adversely affect people's health immediately during the event or later following the event (Portier, 2010). For example, there were 95 named tropical cyclones in 2018, well above the 1981-2010 average of 82 (NOAA, 2019). Extremes in weather also lead to severe storms, tornadoes or high-intensity hurricanes and typhoons, flooding and storm-related flood surges, mega-droughts, and changing weather patterns, such as heavy precipitation or reduced precipitation. Climate change threatens all aspects of the basic elements of life for people around the world—access to water, food, health, and use of land and the environment.

Sea Level Rise

Sea levels rise much more incrementally and slowly than temperatures, but will continue to do so over a long period. By around 2050 sea-water flooding and coastal protection could become a problem. For regions in Southeast Asia, small islands and many conurbations: Tokyo, Shanghai, Hong Kong, Calcutta, Karachi, Buenos Aires, London, and New York—predictions range of sea level rise are between 10 and 88cm by 2100

(Godard, 2008). There will be serious risks with increasing pressures for coastal protection in those places (Stern, 2008). As sea level rise is a special type of climatic disaster that can cause inundation (Li, 2017a); e.g., the small Pacific Island states, including Kiribati, Fiji, and the Cook Islands, might experience impaired agriculture and freshwater sources along with population displacement within fifty years (Nicholson and Stephenson, 2004). In addition, the melting or collapse of ice sheets would also raise sea levels and eventually threaten at least 4 million km^2 of land, which today is home to 5% of the world's population. By the middle of the century, 200 million more people may become permanently displaced due to rising sea levels, heavier floods, and more intense droughts, according to one estimate.

Sea levels are the highest ever measured. The global average sea level has risen by about 8.1 cm over the past 26 years, when satellite altimetry records began. The global sea level is rising at an average rate of 3.1 cm per decade (NOAA, 2019). If global warming results in a temperature rise of 3 or 4°C (or more), rising sea levels will mean dozens to hundreds of millions more people will face flooding each year. A warmer planet directly threatens planetary glaciers, particularly those of Greenland and Antarctica, where 2.1% of all the water on Earth exists in a frozen state. At the current rate of glacier melting and water transfer to the oceans, sea levels globally could rise between three and five feet by the end of the twenty-first century (Lemery and Auerbach, 2017).

Stratospheric Ozone Depletion

The stratospheric ozone is a layer of the atmosphere around 10 to 40 km above us, and this layer's biological importance is in its ability to absorb much of the incoming solar electromagnetic radiation and the harmful effects of ultraviolet (UV-B) radiation. It was also important for the evolution of life on the continents after it developed (Langematz, 2019). The layer is regarded as "good" ozone, acting as a shield to protect life on Earth, which is in contrast to the tropospheric ozone (the layer of air closest to the Earth's surface, thus also called "ground-level ozone"). The stratospheric ozone layer can be destroyed in catalytic chemical cycles involving reactive, so-called ozone depleting substances (ODSs), which include chlorine, bromine, hydrogen and nitrogen compounds from source gases emitted at the Earth's surface by industry. They are then transported into the stratosphere (Langematz, 2019).

Over the past few decades, the release of human-made halocarbons such as chlorofluorocarbons (CFCs) into the atmosphere has resulted in significant stratospheric ozone depletion and the much-publicized hole in the ozone layer over the Antarctic. As the IPCC has documented glacier retreat, sea-ice diminution, earlier bird nesting, earlier flowering, and altered timing of insect migration as evidence of these effects (Nicholson and Stephenson, 2004). These effects from exposure to UV radiation arise from UV-induced immune suppression and photocarcinognesis that will damage to our skin. Other risks include several eye diseases as that can also cause moderate or severe visual impairment such as cataracts and age-related macular degeneration that is beyond the repair capabilities of the body (EEAP, 2019). Statistics showed that age-related macular degeneration was the cause of 7% of blindness worldwide in 2010. And the major environmental risk factor for both melanoma and non-melanoma skin cancers has been estimated to be 14% greater (2 million people) in terms of its worldwide incidence by 2030 (Lucas et al., 2015). Chronic exposure to solar UV radiation can also lead to having photoaged skin that is wrinkled, leathery, shows loss of elasticity, which is often associated with the development of squamous cell carcinoma (Lucas et al., 2015). Apart from those adverse effects on human health from UVB radiation, other environmental related effects include (EPA, 2019a):

1) Effects on plants – it affects the physiological and developmental processes of plants by indirect changes in the plant's form: such as how nutrients are distributed within the plant, the timing of developmental phases and secondary metabolism. This, in turn has implications for plant competitive balance, herbivory, plant diseases, and biogeochemical cycles as well.
2) Effects on marine ecosystems: it causes damage to the early developmental stages of fish, shrimp, crab, amphibians, and other marine animals. The most severe effects are decreased reproductive capacity and impaired larval development. Scientists have also found a direct reduction in phytoplankton production that further affects aquatic food webs. As phytoplankton is the base of the food chain, this will have rippling effects throughout food webs.

Desertification

The earliest agricultural civilizations developed in the fertile valleys of the Nile (Egypt), Tigris/Euphrates (Mesopotamia), Indus (Harappan), and Yellow Rivers (China); even with relatively crude technologies, those civilizations were capable of sufficient overexploitation of vegetation and soil resources to cause desertification, i.e., ecosystem deterioration through overuse and that leads to desert-like conditions (Schowalter, 2013). This is the result of human activities and decisions such as overgrazing that could remove moisture and nutrients from the soil beyond a reparable point and accelerate such conversion of dry environments into desertified ones (WIT, 2009).

Desertification is, in fact, a global phenomenon of land degradation that reduces the natural potential of ecosystems; it has already affected about two-thirds of countries of the world and one-third of the Earth's land surface (FAO, 2019). Desertification has been described as the greatest environmental challenge, as human activities pollute or degrade the quality of soils, which can in turn affect our human health through complex pathways. The potential impacts of desertification on health include (WHO, 2019c; WIT, 2009):

- ☞ higher threats of malnutrition from reduced agricultural productivity and water supplies;
- ☞ an increase in populations migration;
- ☞ an increase in water- and food-borne diseases due to lack of clean water;
- ☞ an increase in acute and chronic respiratory diseases caused by atmospheric dust from wind erosion and other air pollutants;
- ☞ the spread (and change of ecological range) of infectious diseases; and
- ☞ an increase in forest and bush fires.

Precipitation

Life on Earth is critically dependent upon the continuous cycling of water between oceans, continents and the atmosphere. Precipitation (including rain, snow and hail) is the primary mechanism for transporting water from the atmosphere back to the Earth's surface, which involves the continuous circulation of water in the Earth-atmosphere system (Levin and Cotton, 2009). Precipitation is an important component of the hydrological cycle that replenishes water for the Earth; without precipitation, this planet would be an enormous desert. Thus, changes in precipitation regimes and the frequency of extreme weather events, such as floods, droughts, severe ice/snow storms, monsoon fluctuations, and hurricanes are of great potential importance to life on the planet (Levin and Cotton, 2009). Precipitation, evaporation, transpiration, condensation and runoff are all part of the hydrological cycle, and if the hydrological cycle is being influenced by natural and anthropogenic changes in atmospheric aerosols this might have important implications for precipitation, which in turn could comeback to climate change(s) (Levin and Cotton, 2009).

The potential changes in precipitation efficiency is adding to the perturbation of the hydrological cycle in the tropics, which is caused by deforestation and desertification, as the tropical forests are extremely efficient in returning precipitation back to the atmosphere in the form of water vapor. Without them, there will be a much greater risk of periodic fires or wildfires when there is less evapotranspiration and precipitation, especially with a consecutively lengthening of dry season and hotter conditions (Crutzen and Brauch, 2016). In fact, higher temperatures together with reduced precipitation can impose desertification and lead to wildfires and dust storms, all of which affects our respiratory health (Luber and Lemery, 2015).

Globally, fire activity during 2018 was the lowest since record-keeping of it began in 1997, with a combined burned area of about 500 million hectares (Blunden and Arndt, 2019). Regionally, South America and the northern hemisphere of Africa each experienced their lowest fire year, while North America and Australia had fire emissions that were higher than normal (NOAA, 2019). Humans encroach on forests, notably in what is known as the wildland-urban interface, and when a dry forest goes up in flames or “dry lightning” that causes the fire, it possibly spews embers and fireballs, and overruns the terrain and dwellings with a ferocity unmatched by any other natural disaster (Lemery and Auerbach, 2017). Wildfires also emit fine particles and ozone precursors that in turn increase the risk of premature death and adverse chronic and acute cardiovascular and respiratory health outcomes (US Global Change Research Program, 2018), including seasonal allergies (e.g., hay fever) and respiratory afflictions such as asthma, which are exacerbated by allergenic pollen. Respiratory allergies and diseases may become more prevalent because of increased human exposure to pollen (due to altered growing seasons), and molds (from extreme or more frequent precipitation) (Portier et al., 2010).

Extreme weather events and changes in temperature and precipitation patterns can directly damage or destroy crops and other food supplies, and the intensity of extreme precipitation events is projected to increase with future warming (Portier et al., 2010). According to the IPCC, an increase in the average global temperature is very likely to lead to changes in precipitation and atmospheric moisture, including shifts towards more extreme precipitation during storms. There is a clear association between increases in precipitation and outbreaks of waterborne disease through effects on water temperature and precipitation frequency and intensity, which are pathogen and pollutant specific due to climate change altering in the frequency of extreme precipitation (Portier et al., 2010).

Ground Level Ozone – Photochemical Smog

The most important pollutants that play a role in the formation of tropospheric ozone (ground level ozone) include nitrogen oxides (NO_x) and volatile organic compounds (VOCs) as well as, to a lesser but still significant extent, methane and carbon monoxide (Amann et al., 2008). Fossil fuel burning increases concentration of nitrogen oxide in the atmosphere, which increases levels of ozone at the surface as the pace of photochemical reactions forming ozone in the atmosphere depends on the presence of sunlight/solar radiation and rising temperatures through photochemistry. Ground level ozone (GLO) is toxic to plants at concentrations as low as 30 ppb (parts per billion), but these effects are rarely included in future predictions (Stern, 2008). GLO is a highly oxidative compound formed in the lower atmosphere from gases that originate to a large extent from anthropogenic sources, and which, because of its highly reactive chemical properties, is harmful to vegetation, materials and human health as well (WHO, 2008).

Rising surface ozone can aggravate asthma, heighten the risk of pneumonia, and cause permanent lung damage. These adverse impacts upon human health include not only the exacerbation of existing conditions but also the creation of long-lasting outcomes, for instance repeated exposure can lead to the permanent scarring of lung tissue. The contribution of elevated ozone concentrations also imposed detrimental effects to people's health during the aforementioned heatwave of August 2003. And France was the country most affected, with around 15,000 excess deaths (WHO, 2008). The overall health risks from GLO may also cause developmental harm, reproductive harm, asthma attacks, wheezing and coughing, shortness of breath, cardiovascular harm, susceptibility to infections, lung tissue redness, swelling, and even premature death (Li, 2018a). GLO is also a major product of the reactions involved in the generation of the atmospheric pollution known as photochemical smog.

Water- and Food-Borne Diseases

A complex web of relationships between climatic-environmental determinants and food-/water-borne diseases has been linked to ambient temperature and precipitation. As the replication cycles of food-borne microorganisms will be accelerated with elevated temperatures, and the extended summer seasons may increase the chance of mistakes in food handling (ECDC, 2012). Increases in water temperature, precipitation frequency and severity, evaporation-transpiration rates, and changes in coastal ecosystem health could also increase the incidence of water contamination with harmful pathogens and chemicals, and thus food sources may also become contaminated. The result would likely be increased human exposure to food- and water-borne diseases with increasing ocean-related pathogens and biotoxins (Portier et al., 2010).

Additionally, excessive bursts of precipitation could cause sanitary sewer overflow and promote the emergence and spread of infectious diseases, ranging in severity from mild gastroenteritis to life-threatening ailments from cholera, dysentery, and hepatitis (Lu and Peng, 2017). And, infectious disease agents, together with the transport and fate of chemicals such as heavy metals and organic compounds in the environment, will be affected by such changing water flows as well (Schuster-Wallace, Dickin and Metcalfe, 2014). Furthermore, according to the WHO, in 2014, water-borne disease caused 1.5 million deaths (De Paula, 2018). In addition, sources of environmental contaminants can enter into the webs of our food chain and cause possible human health hazards via food chain contamination (details shown in Figure 4-3 in Chapter 4).

Vector-Borne and Rodent-Borne Diseases

Compounding upon the impact of our progressively more intimate interactions with fragmented environments is the fact that human activity modifies environmental systems (often detrimentally), and the resulting environmental repercussions then impact humans. This has given rise to an era of disease emergence and re-emergence at unprecedented rates (Galvani et al., 2016) due to the interactions of climate factors with many other drivers, such as changing land-use patterns (US Global Change Research Program, 2018).

Natural geological determinants of disease primarily relate to the larval stage of vector-borne diseases, when soils and surface water availability factor into insect breeding site availability and quality, which are important but complex issues (National Academy of Sciences, 2007). Vector-borne diseases are among the most well studied of the diseases associated with climate change, owing to their large disease burden, widespread occurrence, and high sensitivity to climatic factors. Epidemics of vector-borne disease have the capacity to overwhelm health systems and as a result may also significantly disrupt health security and cause wider socio-economic impacts around the world (Campbell-Lendrum et al., 2015). Furthermore, globalization has led to over eight million people travelling via airplane every day, which has enabled such disease outbreaks to disseminate rapidly and pose a threat far beyond their areas of origin (Galvani et al., 2016). From the mid-1990s onwards, scholars of international politics have been speculating that emerging and re-emerging infectious diseases may also constitute a threat to international security; especially as processes of "globalization" are often linked to the diffusion of pathogens in the modern era, given that trade is directly associated with the inter-continental diffusion of pathogens and with their vectors of transmission (Price-Smith, 2009).

By 2100, it is estimated that average global temperatures will have risen by 1.0–3.5ºC, increasing the likelihood of many vector-borne diseases in new areas (Githeko et al., 2000). The increasing emergence of the zoonotic Nipah virus and rodent-borne Hanta virus as human pathogens has been traced to extreme weather events that forced animal hosts to leave their ecological niches and invade human settlements (WHO, 2017). Climate change and global warming are directly associated with the spread of insect pests and infection disease vectors, which can expand the distribution of infectious diseases—especially those transmitted by mosquitoes and other vectors. It can invite more emergence of others. Predominantly, vector-borne diseases carried by mosquitoes, such as malaria, dengue, Zika virus, West Nile virus, and Chikungunya, can be related to droughts as well (Lemery and Auerbach, 2017). Because insects and rodents respond quickly to changes in temperature and moisture by migrating and increasing numbers, thus the reproduction and survival of blood-feeding vector organisms, such as mosquitoes and ticks, are greatly affected by climate and other ecological factors, including: (i) enhanced infection prevalence, (ii) prolonged transmission seasons, and (iii) extended range. A vector-borne disease is any condition that is caused by an infectious microbe transmitted to people by blood-sucking arthropods, such as mosquitoes, sandflies, ticks, and snails, which can cause diseases, including parasitic infections. Examples of the global burden caused by parasitic infections can be found in Figure 3-3 in the coming pages.

From EIDs to Epidemics and Global Pandemics (e.g. COVID-19): Infectious and HAEI/Zoonotic Diseases

Serious disease outbreaks are becoming more common. This trend can be attributed to a number of interrelated factors, such as population growth and demographic change, globalization, and increased mobility. Such factors have led to increasingly changing interactions between humans, disease vectors and animal hosts, directly affecting the vulnerability of human populations by increasing human-animal or human-vector contact. This is especially so given climate change, which adds another dimension as a risk multiplier, driving further changes to vector ecology (Estrada et al., 2016). In this regard, health threats from the human-animal-ecosystems interface (HAEI) result in zoonotic diseases (zoonoses), or HAEI zoonotic diseases, which are of increasing concerns for public health. Emerging pathogens are transmitted through contact with animals, food, water and contaminated environments, as is being increasingly evidenced with numerous examples of emerging health threats of zoonoses through water-borne, food-borne, vector-borne and air-borne diseases, especially together with antimicrobial resistance in some pathogens (Li, 2017a).

Statistically, the epidemiological transition of new emerging infectious diseases (EIDs) or the re-emergence of “old” ones arising from the HAEI that still represent significant public health risks, be they endemic, epidemic or potential pandemic events. There are over two hundred HAEI zoonotic diseases which have been described and indicated by the World Health Organization (Li, 2017a). And, over 60% of infectious diseases impacting humans are zoonotic in origin and zoonoses are on the rise globally, accounting for over 75% of emerging diseases. There are clear associations and underlying linkages between climate, ecosystems, and infectious disease agents, particularly in the different ways that climate can influence the emergence and transmission of infectious disease agents.

HAEI zoonotic diseases can also be transmitted from animals to humans by either contact with animals or by vectors that can carry zoonotic pathogens from animals to humans such as avian flu. These shared infectious agents cross species boundaries and cause great suffering to human and non-human animals; and, especially as host ranges expand into more densely populated human areas, the potential for increasing opportunities for “bi-directional pathogen transmission”, or the transmission of pathogens between humans and wildlife as well as between wildlife and humans, also increases (Deem, Lane-deGraaf and Rayhel, 2019). It is estimated that some 60% of emerging infectious diseases reported globally are zoonoses, from which about one billion cases of illness and millions of deaths occur every year (WHO, 2020c). Higher temperatures tend to accelerate microbial growth and survival, which can alter the distribution and abundance of disease vectors; in addition to the changing precipitation patterns and more extreme rainfall events cause contamination of water sources through flooding, which also affect the ecology and behavior of vectors (Luber and Lemery, 2015).

Climate and its impacts on vector-borne and zoonotic diseases have contributed to the spread of several infectious diseases, included arthropod-borne viral diseases such as Dengue Fever, Chikungunya and Zika, and to parasitic diseases such as Malaria and Chagas Disease. It has also been deemed important as part of larger pandemics or in local processes involving autochthonous pathogens (Bouzid, 2017). Evidence has further reaffirmed that the pathogens and parasites responsible for most tropical diseases of poverty are predominantly transmitted through environmental pathways and highly influenced by ecological factors (Garchitorena et al., 2017). The first such shift involved a change in settlement patterns 10,000 years ago as hunter-gatherers adapted to agrarian-village living based on herded food and agriculture, through which new ecological opportunities were created for the spread of disease. This shift enabled countless novel strains of bacteria/viruses to make the jump from domesticated herd animals and rodents to relatively stationary human beings (Giles-Vernick and Craddock, 2015). It is also worth noting that historically, since the early emergence of agriculture and livestock herding around 10,000 years ago, three great transitions in human/microbe relationships are readily recognizable (Patz et al., 2003, p. 104):

1. *"Early human settlements enabled enzootic infective species to enter Homo sapiens.*
2. *Early Eurasian civilizations came into military and commercial contact around 2000 years ago, swapping dominant infections.*
3. *European expansionism over the past five centuries caused [the] transoceanic spread of often lethal infectious diseases."*

Infection remains a major cause of human morbidity and mortality: it has an ever-lasting influence and remains an ever-present threat. The threat of emerging diseases from wildlife and vectors is a continuous, dynamic process, which will most likely accelerate due to human population growth and more extensive environmental change. Pathogens change and so do the environments and the hosts, resulting in deleterious side effects that include environmental degradation and the diminished viability of the biosphere in general and human health in particular (National Academy of Sciences, 2007).

Human ecology is concerned with the coevolution of complex cultural–economic–technological systems and physical–chemical–living systems, and the effects of their often-unpredictable emergent properties on the health of humans and ecosystems (Wakefield-Rann and Fam, 2018). The following Figure 3-3 is a simplified illustration to point out that many human pathogens in tropical regions, including those that cause the burden of neglected tropical diseases (NTDs), spend part of their life cycle outside the human host, where environmental conditions drive their ecology and transmission (as shown in the upper panel). Ecosystem and disease dynamics, on the other hand, influence key forms of capital necessary for the economic development of at-risk human communities (as indicated in the lower panel). And this Figure 3-3 is meant to represent the dynamics of NTDs and other tropical diseases related to poverty across a wide spectrum of transmission strategies. It examines human-to-human contagious diseases in relation to economic activities and how resources affect those same dynamics by altering vulnerability to disease and introducing land-use change to affecting ecosystems. It is also intended to help investigate the environmental drivers of joint poverty–disease dynamics, with the ultimate goal being the identification of sustainable solutions for human and planetary health by showing coupled natural and human systems as feedback loops between ecosystems, infectious diseases, and economic development (Garchitorena et al., 2017).

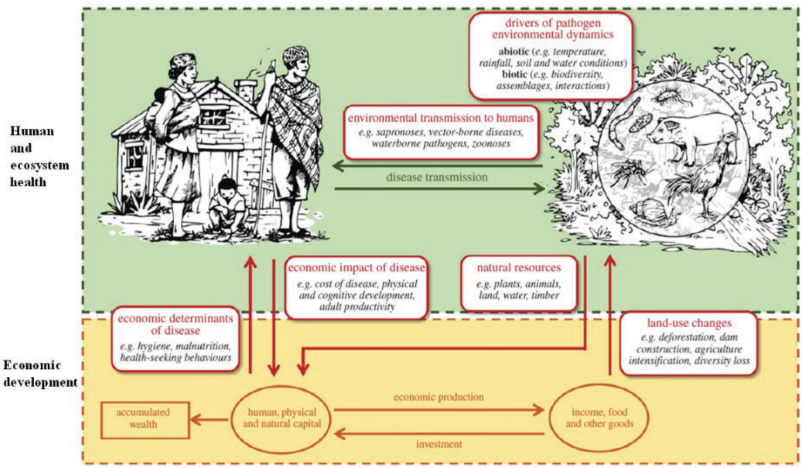

Figure 3-3: Coupled natural and human systems: feedback between ecosystems, infectious diseases and economic development. (Used with permission from Garchitorena et al., 2017.)

Land-use change for the purpose of economic development (e.g., expansion of road networks, dams and agricultural land conversion) can further affect environmentally transmitted parasites and pathogens through impacts on the physicochemical conditions of water and soil. This is done via their ecological community composition, e.g., loss of biodiversity, or inter- and intra-species interactions, e.g., predation and migration (Garchitorena et al., 2017). The magnitude and direction of altered disease incidence are due to the particular ecosystems change, type of land use change, and disease-specific transmission dynamics, as well as the susceptibility of human populations (Patz et al., 2005).

The distribution and incidence of zoonotic diseases relate, in part, to their degree of climate sensitivity and, seemingly, travel, tourism and trade are also the major human factors impacting the epidemiology of zoonotic diseases (Naicker, 2011). Going further, to understand the nature of epidemic and endemic diseases with the emerging pathogens is essential, as infectious diseases are a product of the pathogen, vector, host, and environmental interactions. Thus, the scale of ecological change may be leading to disease emergence or reemergence (Patz et al., 2005). These endemic infectious diseases are in fact responsible for over one billion human cases per year, leading to millions of deaths annually (WHO, CBD and UNEP, 2015). With the rise of global migration, international trade, and global environmental challenges such as climate change, it is not surprising that the interactions between humans and other animals are shifting, and therefore that zoonotic parasitic infections are of specific interest. It is vital to consider these shifting interactions, especially with the concept of One Health as a part of the public health discipline within the past decade (Pisarski, 2019). Building on traditional systems in disease ecology and epidemiology, a general infectious disease model that accounts for direct and environmental pathways of disease transmission routes such as food-borne, vector-borne and water-borne pathways, which are associated with different parasitic infections in the global disease burden. Figure 3-4 shows the global burden of parasitic infections.

Global burden of parasitic infections		
Parasitic infections	**Transmission routes**	**Diseases burden**
Food-borne		
Soil-transmitted helminthiases	Environmental. Ingestion of eggs and larvae or penetration of the skin	875 million children at risk
Food-borne trematodiases	Food-borne. Consumption of contaminated fish, seafood or vegetables	Unclear; more than 56 million in 2005
Taeniasis/cisticerosis	Food-borne or faecal–oral. Consumption of pork or ingestion of parasite eggs	Unclear; responsible for 1.5 million epilepsy cases
Vector-borne		
Lymphatic filariasis	Vector-borne. Mosquito bites (Anopheles spp., Culex supp. and Aedes spp.)	More than 120 million infected

Onchocerciasis	Vector-borne. Bites of blackflies (Simulium spp.)	37 million infected
Chagas disease	Vector-borne. Faeces of haematophagous triatomines	7 million infected
Leishmaniasis	Vector-borne. Bites of sandflies (Phlebotormus supp.)	1.3 million cases/year
Dengue, and Chikungunya	Vector-borne. Mosquito bites (Aedes supp.) with different viruses (Flavirideae flavirvirus in Dengue) & (Togaviridae alphavirus in Chikungunya)	390 million Dengue infections/year
Malaria	*Malaria is the world's most serious vector-borne disease, as about 40% of the world's population currently lives in malaria-endemic areas	**207 million cases and 627,000 deaths
Water-borne		
Schistosomiasis	Water-borne. Direct entry into skin after asexual multiplication in snail hosts	240 million infected

Figure 3-4: Global burden of parasitic infections (adapted from: Garchitorena et al., 2017; *WHO, 2009; **Campbell-Lendrum et al., 2015).

In sum, over 75% of the EIDs affecting humans are, or were originally, zoonoses (Ogden, AbdelMalik and Pulliam, 2017). The WHO (in 2015) published and prioritized the top five to ten emerging pathogens likely to cause severe outbreaks in the near future with potential to generate a public health emergency, and for which no, or insufficient, preventive and curative solutions exist. Their list includes: Crimean Congo hemorrhagic fever, Filovirus diseases (i.e., Ebola virus and Marburg), Lassa fever, MERS and SARS Coronavirus diseases, Nipah and Rift Valley fever, as well as other diseases with epidemic potential such as HIV/AIDs, Tuberculosis, Malaria, Dengue, and Avian influenza. Despite Zika virus not being on the list of the top ten emerging pathogens, its major source of transmission is still via mosquitoes of the genus *Aedes.* In fact, case reports have also shown direct transmission through sexual contact, mother-to-fetus transfer, and blood transfusion. The virus is now endemic throughout large portions of the Western Hemisphere with 2.2 billion people currently at risk (Lemery and Auerbach, 2017). In fact, the disease is frightening because it has profound adverse consequences, most notably devastating microcephaly births (abnormally small head with severe developmental delay) and the neurologic disorder known as Guillain-Barré syndrome (GBS), a disorder in which one's immune system attacks parts of the nervous system, causing severe weakness and ascending paralysis (Lemery and Auerbach, 2017).

EIDs are often unpredictable, and understanding new emerging and re-emerging infectious diseases is an increasingly important topic, as a true pathogen is an infectious agent that causes disease in virtually any susceptible host. From Ebola in West Africa to Zika in South America to MERS in the Middle East as well as SARS Coronavirus diseases, together with a bird flu called H7N9 avian influenza in China, dangerous outbreaks are on the rise around the world. The number of new diseases per decade has increased nearly fourfold over the past 60 years, and since 1980, the number of outbreaks per year has more than tripled (Walsh, 2017). Infections that have recently appeared within a population or those whose incidence or geographic range have increased in the past 30 years and could increase in the near future, include HIV infections, SARS, Lyme disease, hantavirus, Dengue fever, West Nile virus, Chikungunya virus, Zika virus, and those influenza viruses.

Historically, there were three influenza pandemics in the 20th century, in 1918, 1957 and 1968, which resulted in 50 million, 1 million and more than 0.5 million deaths, respectively. Nowadays the concerns over the pandemic potential of H5N1 avian influenza still remain high (Vandegrift et al., 2010). With hindsight, it also became clear that highly pathogenic avian influenza (HPAI) versions of H7N9 were also detected in chickens and in human cases back in December 2016 and January 2017 (Lycett, Duchatel and Digard, 2019). In the same vein, we now know today that the deadly Spanish flu of 1918 resulted from the introduction in the human population of H1N1 influenza viruses; that was then replaced by H2N2 in the Asian influenza pandemic in 1957; that was then replaced by the Hong Kong influenza pandemic of H3N2 viruses in 1968; and the subsequent changes in this respect continues, including (Giles-Vernick and Craddock, 2015):

- In 1977, the H1N1 virus that had circulated in the early 1950s caused the so-called Russian influenza epidemic or pandemic. Though, it was much less severe than other pandemics because many people had already encountered this virus earlier in life and had protective antibodies.
- In 1997 came the avian flu outbreak in Hong Kong. It was caused by the highly pathogenic H5N1 virus that was transmitted from poultry to humans and were responsible for human infections.

The human infections caused by that highly pathogenic H5N1 subtype avian influenza in Hong Kong during 1997 evidentially demonstrated the capability of direct human infection without passing through an intermediate host. The spreading of outbreaks in poultry from December 2003 to mid-July 2005 then occurred in nine countries (Cambodia, China, Indonesia, Japan, the Republic of Korea, the Lao People's Democratic Republic, Malaysia, Thailand, and Vietnam); thus this Avian influenza (H5N1) has recently been recognized as a new EID that may pose a threat to international public health (Riedel, 2006). From 2003 to 2009, dispersion of this H5N1 highly pathogenic avian influenza (HPAI) virus led to epizootics in about 60 countries on three continents, as the continuing spread of H5N1 viruses into poultry populations on several continents also became associated with a growing number of human "spill-over" infections, after which came heightened interest in pandemic prediction (Taubenberger and Morens, 2009). The significance arises

> *"[b]ecause of the inherent unpredictability of influenza viruses [...] The associated risks to both animal and human health are still unknowable to a certain extent, and therefore a public health risk is assumed to exist whenever influenza viruses are circulating in certain animal populations, especially those in direct contact with humans, as well as those antimicrobial resistance pathogens and antibiotic-resistant bacteria" (Li, 2017a, p. 9007).*

Scientifically, amongst the four main influenza types, A, B, C and D, Type A influenza viruses are known to infect a wide variety of birds and mammals (Lycett, Duchatel and Digard, 2019). It is now well established that the reservoir for all influenza A viruses is aquatic birds, which contain the genetic diversity of all known influenza A viruses, namely, all the different influenza A viruses that can be distinguished on the basis of their two surface glycoproteins: hemagglutinin (HA) and neuraminidase (NA). In total there are sixteen species of hemagglutinin and nine species of neuraminidase known today, lending their letters (H and N) as specific numbers assigned to the current nomenclature of influenza subtypes (Giles-Vernick and Craddock, 2015). The hemagglutinin of the human influenza virus has been replaced by a bird hemagglutinin termed H5 in what we call bird flu. The resultant mortality in humans hospitalized with H5 bird flu is high (Oldstone, 2010). As early as 2009, H5N1 was already endemic through South Eastern Asia, which had spread through Eurasia and Africa, and was then established in domestic bird populations. It had caused several hundred human deaths with estimated case fatality ratios of around 30–80% depending on the country (Lycett, Duchatel and Digard, 2019).

> *"However, the H5 bird virus that infected humans has not yet undergone significant transmission from one human to others. When or if that happens, then another serious pandemic of influenza is likely to occur" (Oldstone, 2010, p. 12).*

As with the H1N1 avian influenza epidemics, the coronavirus epidemics of SARS and MERS are prime examples of how a species-spanning approach has helped to avert pandemics (Deem, Lane-deGraaf and Rayhel, 2019). For instance, in 2009, the H1N1 'swine flu' pandemic was a result of reassortment between different strains of influenza avian virus that had been circulating in swine for at least 10 years, but these precursor swine strains all had segments tracing back to avian origins some 30 years previously (Lycett, Duchatel and Digard, 2019). Statistically, Influenza A virus infections result in ~500,000 human deaths per year and many more sub-lethal infections as well. Most crucially, these avian viruses have contributed genetic material to most human viruses, including subtypes H5N1 and H1N1 (Vandegrift et al., 2010). Prior to the ongoing COVID-19 pandemic, it had been a little over a decade since the world had experienced its last pandemic, i.e., the 2009 surge of H1N1 swine flu. Between the spring of 2009 and the spring of 2010, the virus infected as many as 1.4 billion people across the globe and killed between 151,700 and 575,400 people, according to the Centers for Disease Protection and Control. This 2009 flu pandemic was the second H1N1 pandemic the world had seen, as the first being the 1918 Spanish flu, which is still the deadliest pandemic in history. Scientifically, the 2009 pandemic was caused by a new strain of H1N1 that originated in Mexico in the spring of 2009 before spreading to the rest of the world in June of that year. There were enough cases that the World Health Organization declared the swine flu outbreak a pandemic (Hickok, 2020).

It is important to recognize that emerging zoonotic disease outbreaks are increasing, with the majority of recent major human infectious disease outbreaks and the worldwide emerging diseases such as SARS, Nipah virus, and HIV/AIDS originating in animals. For instance, SARS is caused by the SARS Coronavirus (SARS-CoV-1) that can infect animals and humans, and is currently not known to be circulating among people, but it could still be circulating in animal hosts (such as bats and Himalayan palm civets) and may thus re-emerge in humans (WHO, 2014). The most recent example is of course back in December 2019, with a significant zoonotic infectious disease outbreak of COVID-19 (SARS-CoV-2) in Wuhan, China. It reportedly had some link to a large seafood and animal market, suggesting animal-to-person spread; however, many patients then reportedly to have not had exposure to animal markets, thus the occurrence of person-to-person spread became clear.

At the time of this writing, it is still unclear how easily or sustainably COVID-19 (SARS-CoV-2) is spreading between people. While a full scientific understanding of this disease's transmission modes has yet to be attained, compared to the previous SARS-CoV-1 in which we know the biochemical and molecular properties, it is likely this novel coronavirus will allow for indirect methods of transmission, including fomites and aerosols, in addition to respiratory droplet transmission (Galbadage, Peterson and Gunasekera, 2020).

We can also see other zoonotic EIDs in human populations, including Rift Valley Fever, Q Fever, SARS, and MERS associated with the ever increasing domestic-wild animal links (Deem, Lane-deGraaf and Rayhel, 2019). And now of course, COVID-19 is the latest example of new EIDs spreading out across the world. The Lancet were right to predict that this current outbreak of COVID-19 was likely spread to most, if not all, countries, and that it is not benign (Lancet, 2020). COVID-19 is thought to be zoonotic in origin but has since mutated or otherwise adapted in ways that allow human pathogenicity, but the animal reservoir is not yet fully known, and human-to-human transmission is widespread (Perlman, 2020).

The world is still in the middle of this current COVID-19 pandemic and public health crisis globally. It is still spreading rapidly at the time of this writing. People all over the world have become more vigilant in terms of the best practices which can be employed during the pandemic in the modern era. We can also learn from the past that outbreaks are nearly constant, though not every outbreak reaches pandemic level. In epidemiology, the increasing adoption of and reliance upon socio-ecological models has also opened up a spectrum of possibilities for investigations of disease risk that include social, cultural, political, and economic factors, as well as how these factors have changed over time. Epidemiologists are gradually recognizing that addressing patterns of health-states might yield greater insights into more upstream, shared determinants and therefore have a profound impact upon population health (Zuckerman et al., 2014).

The human population has continued to grow and expand geographically, building new cities and acquiring more and more new diseases; pathogens also expand geographically, leading to new distributions of established diversity, which in turn sets the stage for the emergence of new specialized diversity (Brooks, Hoberg and Boeger, 2019). Therefore, 21st century physicians need awareness of the complex linkages between human activities and global health risks resulting from pollution, climate change, and disease outbreaks due to emerging and re-emerging infections (Sethuraman, 2020). And insofar as pandemics have occurred throughout history and appear to be increasing in frequency—particularly because of the increasing emergence of viral disease from animals—this is no less the case today, with the variety of pandemic threats still being driven by the great diversity of pathogens and their interactions with humans (Jamison et al., 2018). In particular, the human ecological footprint has had a disproportionate influence on the distribution of diversity on the planet for the past 12,000 years (Brooks et al., 2019).

Outbreaks of pandemics across international borders such as cholera, bubonic plague, smallpox, and influenza are some of the most brutal killers in human history. It is likely that perceptions of what is threatening, what is desirable socially, and how much risk can be tolerated are all conditioned by culture; consequently, both culture as a whole and the cultural mores in any given society in which an individual is born (or adopts as their own) are critical to sustainability and health in many ways (Guidotti, 2015). Supposing that cultural reorientations, as they are often referred to, were to be closely examined through a historical lens, including the history of medicine, there are very few phenomena throughout human history which have shaped our societies and cultures more than the catastrophic outbreak of a pandemic (Huremović, 2019).

Historical information indicates that there may have been at least 13 pandemics over the past 500 years (1509 to 2009), or approximately one pandemic every 38 years (Taubenberger and Morens, 2009). The following table, Figure 3-5, summarizes the notable events with a selective timeline of epidemics and global pandemics.

Time period	**Events**	**Type/Pre-human host**	**Estimated mortality (M=million)**
1347-1351	Bubonic plague (Black Death)	Yersinia pestis bacteria/ Rats, fleas	200M
1520s	New world smallpox outbreak	Variola major virus	56M
1665	Great plague of London	Yersinia pestis bacteria / Rats, fleas	100,000
1629-1631	Italian plague	Yersinia pestis bacteria / Rates, fleas	1M
1817-1923 1881*	Cholera pandemics (1-6 times) *Fifth cholera pandemic	Vibrio cholerae bacteria	 *1.5M

1885	Third plague (China & India)	Yersinia pestis bacteria / Rats, fleas	12M
1889-1890	Russian Flu	Believed to be H2N2 (avian origin)	1M
1918-1919	Spanish Flu pandemic	A strain of influenza A, H1N1 virus / Pigs	40-50M
1957-1958	Asian Flu pandemic	H2N2 virus	0.7-1.5M
1968-1970	Hong Kong Flu pandemic	H3N2 virus	1M
1981-onward	HIV/AIDS	Virus / Chimpanzees	36.7M
2003	SARS pandemic	Coronavirus / Bats, Himalayan palm civets	>740
2009-2010	Swine Flu pandemic	H1N1 virus / Pigs (also previously in avian origin)	1.4 billion infected & 151,700 – 575,400 deaths
2012-2019	MERS	Coronavirus / Bats, camels	2494 infected & 858 deaths
2014-2016	Ebola epidemic	Ebolavirus / Wild animals	28,616 infected & >11,000 deaths
2018	Ebola epidemic	Ebolavirus / Wild animals	3462 infected & 2262 deaths
2019-	COVID-19 pandemic	Coronavirus / Unknown (possibly pangolins)	>281 M infected & >5.4M deaths (as at 27/12/2021)

Figure 3-5: Timeline of notable epidemics and global pandemics (adapted and modified from: WHO, 2021; CDC, 2019; Jamison et al., 2018; Huremović, 2019).

Pandemics are large-scale outbreaks of infectious disease that can greatly increase morbidity and mortality over a wide geographic area and cause significant economic, social, and political disruptions (Jamison et al., 2018). Global warming and the risk of severe pandemics pose particular challenges to long-term economic growth. A "recovery" of climate is not a scientific concept, since the climate does not respond like a pendulum that swings back after it has been pushed in one direction, and there is a very high probability of the warming exceeding 2°C unless global emissions peak and start to decline rapidly in 2020. Otherwise, the global mean air-temperature is projected to warm by 2°C-7°C above pre-industrial averages by 2100 (Allison et al., 2011). The progress of causal pathways between climate change and health outcomes are operated in both direct and indirect mechanisms; human infectious diseases, for example, are affected by both mechanisms, and thus their interactions and the estimates of exposure to climate health risks are particularly complex, especially given that temperature affects the survival rates of pathogens (Lu and Peng, 2017).

Additionally, the hyper-urbanization of domesticated animals, combined with the use of antibiotic growth factors, is contributing to increases in selective conditions for the entry of zoonotic pathogens from animals to human populations. Given today's means of subsistence, including human settlements that have consolidated to the point that the majority of the global population now lives in urban environments with ample opportunities for ongoing disease transmission and the emergence and reemergence of infectious diseases, so understanding these relationships and the pathological consequences of interspecies interactions has substantial implications for public health (Zuckerman et al., 2014). Finally, the wide array of subsistence practices that increase exposure between humans and animals increases the probability that nonhuman pathogens will, through a series of evolutionary steps, evolve the ability to infect humans, and later, evolve the capacity for sustained transmission within and between human populations.

It is clear that all life modifies other life at some level, and that we are all connected within the so-called "web of life". Humans are, of course no exception, and indeed have been modifying the environment since the first bipedal footsteps of *Homo sapiens* (Deem, Lane-deGraaf and Rayhel, 2019). Historically, the influence of the environment on human health dates back to antiquity, when human life expectancy was shorter than today as a result of the hostile environment in which we lived. EIDs have been a health hazard faced by humanity since human beings first appeared, as diseases spread from person to person or from animals to humans, often through water, food or insect vectors, and so transmission may be directly affected by environmental changes (Bouzid, 2017). Approximately 2500 years ago, Hippocrates' treatise "On Airs, Water and Places" described the importance of these environments in the spread of diseases and made an association between human infections and the characteristics of climate, soil, water, diet and living conditions (Bouzid, 2017). And nowadays, our human influences on the planet's atmosphere, hydrosphere, and biosphere are of such magnitudes, which consequentially would lead to the potential for human activities to foster more dispersal of viruses, bacteria, fungi and protists into novel locations. As Gillings and Paulsen (2014, p. 5) write:

> *"[C]hanges in microbial dispersal and disease incidence broadly correspond with phases of the Anthropocene: the evolution of zoonotic diseases and inadvertent spread of soil organisms that accompanied the rise of agriculture; the transport of organisms by sea during the age of exploration, hastened by the development of mechanized transport in the industrial revolution; and culminating in the rapid mass transit systems and consequent rise in international tourism that accompanied the Great Acceleration".*

Despite this, the last 50 years have seen unprecedented improvements in human health, as measured by most conventional metrics. However, this human flourishing has been at the cost of extensive degradation to the Earth's ecological and biogeochemical systems. The impacts of the transformations in these systems include negative effects concerning accelerating climatic disruption, land degradation, growing water scarcity, fisheries degradation, pollution, and biodiversity loss—all of which have already begun to negatively impact human health. As Sorrell points out, nature is revealing to us the interdependence of environmental, animal and human health and emphasizing that our resources are finite (in Walton, 2019).

As we are now living in the age of the Anthropocene, this implies the rate of change we affect the planet is ever more evident, with environmental harm and resource over-extraction leading to new health hazards for all life (Deem, et al., 2019), including the West Nile virus, SARS, Nipah and Hendra viruses, Ebola, avian influenza, H1N1, zika and yellow fever (Rabinowitz, Pappaioanou, Bardosh and Conti, 2018), in addition to the ongoing COVID-19 outbreaks. If this current pandemic is a crisis about life itself, what tentative conclusions might we draw from its effect so far on human society? Perhaps, it is our tasks to understand what this disease means to the lives of those it has afflicted, and to use that understanding not only to change our perspective on the world but also to change the world itself. As Horton (2020) states:

> *"The idea of the Anthropocene places human activity as the dominant influence on the future of life on our planet. Although this newest of geological eras is supposed to underline the harm our species is doing to fragile planetary systems, paradoxically it also asserts our supremacy. Severe acute respiratory syndrome Coronavirus 2 (SARS-CoV-2) has*

revealed the hubris of this view. Our species has many reasons to be self-critical about the effects of our way of life on planetary sustainability."

Evidence suggests that the likelihood of pandemics has increased over the past century because of increased global travel and integration, urbanization, changes in land use, and greater exploitation of the natural environment (Jamison et al., 2018). Ecological changes are still the major predisposing factors of those health threats that lead to the arising EIDs, re-emerging infectious diseases and zoonoses under this process of ecological transition. There are numerous examples of their emerging and reemerging, in addition to the resurgence of various infectious diseases that are linked, in part, to the ecology of vector habitats, climatic changes, disruptive patterns of land use, and changes to the hydrological environment. They can also cause disturbances in rodent ecology due to the human-induced disturbances to our environments and food systems, such as air pollution, water pollution, misuse of antibiotics and growth hormones, overfishing, abuse of chemical usages, food fraud, and overlooking animal/poultry welfare. In fact, all of these have raised the already considerable worries and concerns in public health (Li, 2017a).

EIDs as Time Bombs

EIDs will, however, remain a key, global public health challenge in a globalized world where demographic, climatic, and other environmental changes are altering the interactions between hosts and pathogens in ways that increase spillover from animals to humans and spread globally (Ogden, AbdelMalik and Pulliam, 2017). Spillovers have always occurred, but the rapid environmental change wreaked by humans in recent years has accelerated the spread (Walsh, 2017). Human industrial activities, agricultural practices, and consumption patterns have also played a major role through generating greenhouse gases that exacerbate climate change, including the fact that (DeLaet and DeLaet, 2012):

"The increase in average temperatures and the resultant shift in weather patterns have significantly disrupted the ecological balance in local, regional, and global ecosystems. As a result, pathogens that previously had been isolated in particular ecosystems are now expanding their range and exposing human beings to new or reemerging illnesses."

Although most EIDs are initially considered "spillovers" from the established animal reservoir, many of these infections are also called "dead-end" infections because they die out eventually when effective human-to-human transmission cannot be established, however which is often applied retrospectively through observations (Riedel, 2006). The impact of infectious diseases on human populations has influenced the history of the world, not just because of their devastating physical, economic, cultural, political and social consequences, but also because of the alarm caused by their potential global spread and resulting health impacts (Bouzid, 2017).

Catastrophes, calamities, and disasters have certain characteristics. As the WHO (2003) has illustrated, today there is an apparent increase in many infectious diseases, including some newly-circulating ones such as HIV/AIDS, hantavirus, hepatitis C, and SARS. The increase reflects the combined impacts of rapid demographic, environmental, social, technological and other changes in our ways-of-living, and the WHO has concluded that changes in infectious disease transmission patterns are likely major consequences of climate change. For instance, influenza virus transmission in wild and domestic animals and humans is intimately connected, thus any anthropogenic change—including human population growth, land use, climate change, globalization of trade, agricultural intensification, and changes in vaccine technology—may also alter the evolution and transmission of influenza viruses (Vandegrift et al., 2010).

Furthermore, there are vector-borne diseases of zoonotic concern, as there also are infectious diseases whose transmission involves animal hosts (such as in avian flu). These diseases can be transmitted from animals/poultries to humans by either contact with the animals or through vectors that carry zoonotic pathogens from animals to humans. There is an estimated over 75% of EIDs of humans that have evolved from exposure to zoonotic pathogens, as the land-use changes that affect a host of indirect links between infectious disease and environmental conditions are mediated through changes in ecosystems resulting from human activities. Subsequently, connectivity across the HAEI for zoonoses and vector-transmitted anthroponoses that are dependent on the ecology of non-human animals will be especially sensitive to such effects and the resultant ecological changes (Patz et al., 2003).

Historically, infectious agents have been in existence since long before humanity, as many of the clinical descriptions presented in the Hippocratic Collection, the *Corpus Hippocraticum*, relate. They are still the archetypes of the natural history of certain infectious diseases and their collective interplay with the environment, climate, and society; the writings are still influential 25 centuries after its publication (Pappas, Kiriaze and Falagas, 2008). Foreseeing issues and potential threats should be a matter of standard practice in public health, while morbidity and mortality are certainly prime considerations with regard to the threats posed by infectious outbreaks in the modern days. Thus, we have two goals: "*The first is to prevent. When that is not possible, the second is to minimize disease and extended disability*" (Osterholm and Olshaker, 2017). Insofar as our having achieved this, there are significant gaps and challenges which exist in global pandemic preparedness, as this analogy harkens:

> *"A Chinese proverb says that the best time to plant a tree was 20 years ago, and the second-best time is today. High-functioning community health platforms are the trees that we wish our ancestors had planted in every community many years ago. Future generations cannot afford to have us spend the next 20 years attending to local epidemics and global pandemics that could have been snuffed out and quickly controlled if all local communities had been performing all of the essential public health functions and engaging their communities in building a culture of health" (Jamison et al., 2018, p. 281).*

Crucially, there are challenging complexities in historical processes, scientific and historical explanations are not alternatives; any historical change is strongly influenced by happenstance, whereas historical happenstance may well play a big role in humans' ability to selectively borrow ideas from other societies. In other words, we could guide the evolution of our own culture through historical example. The value of extreme examples is that they often reveal processes in a more pure and stark form than less extreme cases (Richerson, Mulder and Vila, 2001).

> "Diseases are more easily prevented than cured and the first step to their prevention is the discovery of their exciting causes".
>
> William Farr
>
> (Source: www.ph.ucla.edu/epi/snow.html)

Anthropogenic Pollution and the Time Bomb of Plastic Waste

Anthropogenic pollution is caused due to human activities from different sources of environmental pollutions, such as: the burning of fossil fuels, deforestation, mining, sewage, industrial effluent, pesticides, fertilizers, food-production systems, and heavy metals. In addition, there is also marine environment pollution and plastic pollution, which are continuously inducing rapid environmental degradation and climate crises to the disequilibrium of planetary sustainability. It is obvious that anthropogenic activities increasingly provoke deleterious impacts in aquatic ecosystems; these impacts include (Häder et al., 2020):

- corals reefs impacted by sewage reaching the ocean through underground aquifers;
- crude oil spills resulting in mortality of sub-lethal damage in many marine organisms;
- Patagonian coastal zones showing high concentrations of heavy metals; and
- riverine and eolic inputs of terrigenous material affecting marine phytoplankton (the tiny, plant-like producers of the plankton community, which include bacteria and algae to form the base of aquatic food webs).

Concurrently, anthropogenic pollutants such as nutrients and heavy metals, together with natural variables such as temperatures, salinity and geographic distance are affecting mesozooplankton communities in marine ecosystems, which could eventually pose far-reaching consequences for marine food webs. The zooplankton inhabiting coastal ecosystems are key components in food webs, acting as an important trophic link between marine primary producers and higher trophic levels. Thus a decline in the biodiversity of zooplankton could decrease the survival rates of higher trophic organisms such as fish (Gao et al., 2019). Devastatingly, the additional disruptive anthropogenic threat of about 8 million tons of plastic enters the oceans every year, further affecting marine life (Häder et al., 2020).

The rise of plastics, along with their deleterious ecological effects, is one key story of the Great Acceleration. It echoes the philosopher Roland Barthes' idea in 1957 that "the whole world can be plasticized, and even life itself" with the rise of plastics (Ronda, 2018). Historically, the first synthetic plastic, Bakelite, was produced in 1907, marking the beginning of the global plastics industry. It was not until the 1950s though that its rapid production was being realized; since then the annual production of plastics has increased nearly 200-fold to 381 million tons in 2015 (Ritchie and Roser, 2018). The planetary-scale ubiquity and ever-increasing production of new and improved plastics makes plastic-contaminant interactions as of great interest to toxicologists and ecologists (Carbery, O'Connor and Thavamani, 2018). Toxic pollutants can also be released into the environment during incineration of plastics waste, which contains NO_x, VOCs, CO, PM, polycyclic aromatic hydrocarbons (PAHs), Dioxins and Furans, PCBs, CO_2, methane, aldehydes, etc., that will possibly cause human health risks to neurological systems, respiratory systems, cardiovascular systems, digestive systems, hepatic systems, and reproductive systems. Figure 3-6 shows some of the examples of plastic posing distinct risks to human health at every stage of its life cycle.

Plastic life cycles	Risks to human health
Transforming fossil fuel into plastic resins and additives releases carcinogenic and other highly toxic substances into the air.	Documented effects of exposure to these substances include impairment of the nervous system, reproductive and developmental problems, cancer, leukemia, and genetic impacts like low birth weight.
All plastic waste management technologies (including incineration, co-incineration, gasification, and pyrolysis) result in the release of toxic metals such as lead and mercury, organic substances (dioxins and furans), acid gases, and other toxic substances to the air, water, and soils.	Toxins from those emissions, fly ash, and slag in a burn pile can travel long distances and deposit in soil and water, eventually entering human bodies after being accumulated in the tissues of plants and animals via food webs.
Microplastics entering the human body via direct exposures through contact, ingestion, or inhalation.	Inflammation, genotoxicity, oxidative stress, apoptosis, and necrosis, with further health outcomes, including: cancer, cardiovascular diseases, inflammatory bowel disease, diabetes, rheumatoid arthritis, chronic inflammation, autoimmune conditions, neurodegenerative diseases, stroke, etc.
Plastic in the food chain transfer with potential impacts and movement of plastic and microplastics through terrestrial environments, marine ecosystems, and food chains.	Adverse effects of human health from food chain contaminants (also see Fig. 3-7 human health risks resulting from bioaccumulation and biomagnifications of microplastics and Fig. 4-6 exposure to food contaminants via food chain).

Figure 3-6: Examples of plastic posing distinct risks to human health at every stage of its life cycle (adapted and modified from Kistler, 2019).

In recent years, the presence of plastic debris called microplastics, defined as fragments smaller than 5 mm has been reported in diverse aquatic ecosystems with a few reports suggesting that plastic fragments in the size range <100 nm, referred to as nanoplastics (NPs), together with the microplastics (MPs) in terrestrial ecosystems and the soil are an increasingly emerging health threat (Revel, Châtel and Mouneyrac, 2018). Recent research identified that soils in agricultural and urban areas are expected to represent major environmental reservoirs of micro(nano)plastics, possibly comprehensively larger than the marine one (Hurley and Nizzetto, 2018). Additionally, soils exhibit several potential exposure pathways for micro/nanoplastics to organisms and human health, including contamination of groundwater aquifers. Traditionally, most microplastics studies have focused on the marine environment; however, recent research has identified the significance of microplastics in terrestrial ecosystems and the potential for soil microplastic contamination has also been reviewed. Rillig (2012) illustrated that microplastics could be spread further by becoming air-borne (for example from landfills, or other surface deposits) and then enter terrestrial systems and the soil through atmospheric deposition, and those microplastics could also result from abrasion of plastic debris at soil surfaces (where UV light could render the material brittle) or inside the soil profile.

It is therefore, important to address that microplastic pollution can come from a variety of sources, including everyday items like plastic bottles or disposable contact lenses. According to Gasperi et al. (2018), more than 90 million metric tons of textile fibers were produced in 2016 containing fibrous microplastics after degradation of those fibers. Some of these fibrous MPs could be inhaled. Most of them are likely to be subjected to mucociliary clearance; however, some may persist in the lung causing localized biological responses, including inflammation, especially in individuals with compromised clearance mechanisms. Associated contaminants such as Polycyclic Aromatic Hydrocarbons (PAHs) could desorb and lead to genotoxicity while the plastic itself and its additives (dyes, plasticizers) could lead to health effects including reproductive toxicity, carcinogenicity and mutagenicity (Gasperi et al., 2018).

Plastic represents more than 80% of the waste in the oceans and causes incalculable and irreparable damage to marine ecosystems. The UNEP estimates that by 2050, there will be more plastic in the oceans than fish (Rocha-Santos, 2018). There has been a considerable increase in research on the ecological consequences of microplastics and nanoplastics that can potentially be ingested by aquatic organisms, thus entering the food chain and posing a threat to environmental health and human health (da Costa et al., 2016; Rocha-Santos, 2018). It is now a matter of fact that plastic litter has become one of the most serious threats to the marine environment from different trophic levels. There is an abundance of evidence for the trophic transfer of microplastics and contaminants within marine food webs, as over 690 marine species have already been impacted by plastic debris (Carbery et al., 2018).

One of the most devastating elements of this pollution is that plastics take thousands of years to decay; as a result, most marine species and wildlife are becoming intoxicated. Consequently those toxins from the breakdown of plastics (micro/nanoplastics) have been able to enter our food chain. Plastic pollution has been detected in all major marine environments worldwide, from shorelines and surface waters down to the deepest parts of the ocean, including the bottom of the Mariana Trench (WWF, 2018). Plastic pollution of oceanic and coastal habitats is now recognized worldwide as an important health threat and a potential hazard that impacts food webs through ingestion and bioaccumulation of particles and toxic chemicals that are likely influencing ecosystem processes as well (Vegter et al., 2014). The following diagram, Figure 3-7, shows human health risks resulting from the bioaccumulation and biomagnification of microplastic and chemical contaminants, illustrating how their toxicity can possibly enter into the human body via food chain transfer.

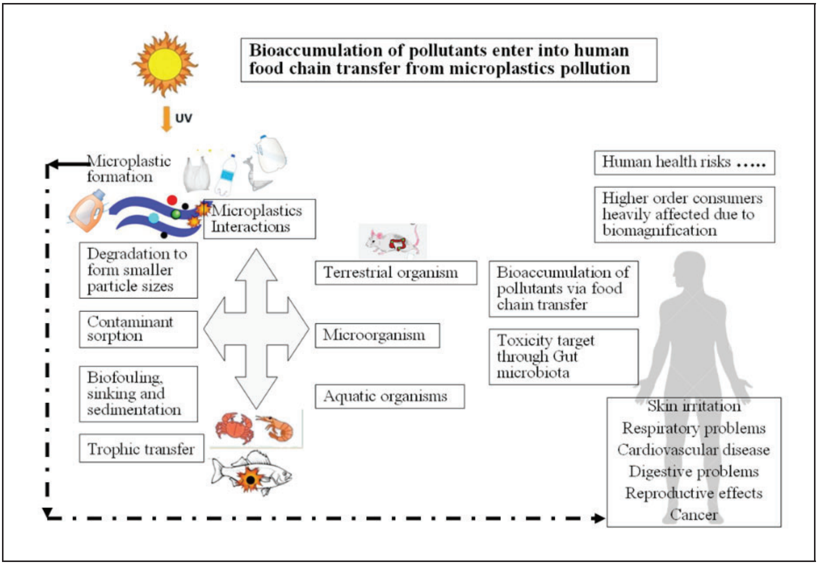

Figure 3-7: Human health risks resulting from bioaccumulation and biomagnification of microplastics with toxicity through gut microbiota, possibly entering into the human body via food chain transfer.

Under the grave consequences of using and discarding such massive amounts of plastic waste, thus education and awareness strategies are an indispensable requirement, alongside creating and spreading messages aimed at modifying human behaviors related to the manufacture, purchase, use and single use of plastic products (Vegter et al., 2014).

Conclusion

Human health directly depends upon the environment in a broad way, as our human condition is tied to natural systems in and on this planet, which are interrelated and interconnected with each other. Public health impacts in this Age of environmental and climate crisis will have serious effects not just on the eco-environments or human health but on human life itself, affecting the entire world's conditions for sustainable health developments and healthy living. From the rising costs of extreme weather, such as floods, droughts, storms and heat waves; stratospheric ozone depletion; rising sea levels; desertification, GLO pollution to the time bombs of EIDs and anthropogenic pollutions, etc. The current conceptions of disease may underestimate the true impact of "upstream" environmental changes that will result in more indirect, complex, and potentially nonlinear processes, as global environmental change contributes to ecosystem degradation, species loss, and possibly greater difficulties in food production. These will create a cascading cycle with environmental scarcity, conflict, social disruption, and population morbidity and mortality on a global-scale (Schwartz et al., 2006).

The important role of environmental and climatic conditions in fostering healthy communities cannot be overstated; we need clean air, water and natural resources for sustainable health developments. The ecological perspective provides useful conceptual understandings of the wide range of influential factors that are continuously affecting our health and wellbeing from the multiple dimensions of those mediated health risks of the global environmental and climate crisis. The consequential public health risks can be substantial, from both direct and indirect impacts that affecting our sustainable health developments as well as the sustainability of healthcare systems, including from those newly EIDs and re-emerging infectious diseases.

The global environmental and climate mediated health risks threaten our human health in such wide-ranging ways, including a significant ecological public health concern with the health consequences of transitional epidemiological risks such as emerging and re-emerging infectious diseases leading to actual and potential endemic, epidemic, and pandemic threats. More importantly, these ecological calamities imposed by all those anthropogenic human activities could directly and/or indirectly magnify the actual and potential hazardous health risks, which would also further amplify during this age of environmental and climate crises in the Anthropocene.

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CHAPTER 4

TRANSITIONAL RISKS: ECOLOGICAL DETERMINANTS OF GLOBAL PUBLIC HEALTH

The human environment is located at the Earth's surface and is heavily dependent on soil, on water, and on the atmospheric continuum that moderates all of our activities, as well as the physical, chemical, and biological properties of each of these components and their interactions; they are absolutely vital for human life (Brusseau, Pepper and Gerba, 2019). Humanity has become a serious threat to its own future well-being, and perhaps even its survival, as the result of unprecedented human-caused harm to the natural environment and large-scale economic activity are also resulting in multiple kinds of damage to our planet and its climate (Sachs, 2015). The frequency and severity of these environmental and climate mediated threats have risen dramatically along with the reshaping of the Earth's physical systems (i.e., affecting Earth's climate, chemistry, and biology), which has had massive overall impacts that is likely lead to greater transitional risks (Li, 2017b). Our knowledge of Earth has increased since the dawn of humankind, has refined over the millennia into a fixed understanding; much of that progress has been revealed through the study of Earth itself. This has now become the study of change, as the air, the oceans, and the land are changing, perhaps at a pace unequaled in our planet's recent past (Hazen, 2012), especially with the striking concerns of global public health threats in this contemporary era.

Human health in the Anthropocene provides strong evidence of humanity's impact on Earth. It represents a time of uncertainty and unprecedented biophysical change (De Paula, 2018). As humans we can no longer live by disassociating ourselves from the health of the planetary system that sustains us, nor can we ignore the fact that human and ecosystems health is interdependent. It is a significant and emerging threats with increasingly growing concerns about how eco-environments and climate change will affect people around the world. As the potential implications of the quality access to safety food, clean air and freshwater is the basic tenets for our well-beings, and to maintain our sustainable health developments. It is an imperative to address the challenges that we are facing the global ecological calamities, which will eventually impose and mediate the transitional health risks onto our human well-beings both directly and indirectly. Henceforth, the areas of concern is meant to spark supports for sustainable health developments with the health transition to an 'ideal Age of Sustainability' through new waves of ecological public health movements towards planetary health for a better global eco-environments. Therefore, understandings of the possible transitional risks and mediating health threats are absolutely indispensable.

In actual fact, these are the global public health threats now and in the future. Our revolutionary way of thinking seeks to promote ecological views of sustainable health that are: (1) garnered from the varying influences of ecological determinants of health and disease; and (2) supported by our evolving scientific understandings of these concepts and their relations to health. Fundamentally, public health effects stem from what we eat, what we drink and what we breathe; this can include anthropogenic contaminants which have accelerated deteriorations of air and water quality, or the increased pollution of soil, which can then have an effect on the food chain. Both of these examples represent highly anthropogenically devastated eco-environments. Additionally, we emit waste as a product of our consumption activities, including air and water pollutants, toxic materials, greenhouse gases, and excess nutrients, together with some waste such as untreated sewage (and many other accumulating pollutants) that threaten our human health continuously. For all these reasons, the relationship of human health to ecosystems health is gaining increasing attention because ecological imbalances are a major source of present day human health vulnerabilities (The World Bank, 2006).

The greatest environmental mediating effects arise from: climate change, ocean acidification, soil contamination, stratospheric ozone depletion, loss of biodiversity, atmospheric aerosol loading, eutrophication from nitrogen and/or phosphorus biogeochemical cycles, global freshwater depletion, land conversion/occupation, and chemical and persistent organic pollutions, all of which are transforming our planetary boundaries and pushing them to or beyond their limits. These transitional risks include pollutants and pathogens in the air, water, soil and in food that make us face significant dangers, along with the current trajectory of health threats from those risk-based vulnerabilities. Predictably, the globalization of environmental degradation may take various forms, including (Blewitt, 2018):

- ☞ The exploitation and destruction of the global commons – the atmosphere, the marine environment and hydrological cycles.
- ☞ Demographic expansion, exponential economic growth, and consumption of global raw materials, all of which lead to increases in pollution; and
- ☞ Transboundary pollution involving the transmission of pollutants through the air, soil and water across political borders so that their environmentally degrading impact occurs throughout the world in many countries.

Pollution is, in fact, the world's largest environmental cause of disease and premature deaths, for instance in 2015 diseases caused by pollution numbered 9 million (Li, 2018a). In particular, environmental pollution via the contamination of air, water and soil by human activity is the largest cause of disease and death (Landrigan and Fuller, 2015). Traditionally, the concerns of environmental epidemiology have included the contamination of air, water and food. Nowadays, its focus is expanding to include predisposing factors such as climate change and other large-scale environmental impacts related to globalization and urbanization, with these anthropogenic activities being culpable for the further aggravation of a significant number of adverse health outcomes (Li, 2017a). An estimated 12.6 million people have died as a result of environmental risk factors such as air, water and soil pollution, chemical exposures, climate change, and ultraviolet radiation—factors which also contribute to more than 100 different diseases and injuries—as the WHO warned back in March 2016 (WHO, 2016). These accumulating hazards unquestionably will influence a transition toward sustainability.

In general, health transitions can explain the shifts in the composition of diseases in populations, and health needs usually change due to health and epidemiological transitions, which in turn can be influenced by many complex factors and determinants (both directly and indirectly). The concept of health transitions has a wider framework that includes not only epidemiological characteristics but also the ways in which societies respond to this changing health situation. This is especially so when the health and disease patterns of a society evolve in diverse ways as a response to broader demographic, socio-economic, technological, political, cultural and biological changes (Santosa et al., 2014). Yet again, ecological determinants on health and disease should not be limited to current conceptions of disease causation, as that may underestimate the true impact of their resultant consequential effects and disruptions to human health globally in more indirect, complex, and potentially non-linear processes.

This is especially so, as climate change is of overarching importance as it impinges on many other global eco-environmental issues. One example is food production, which continues to be an area of contention. This includes the use of agri-chemicals, irrigation, the application of biotechnology, soil erosion, the pollution of watercourses, changing food consumption patterns, and all of which could pose health-related problems (Harris, 2012). In fact, since the time of Hippocrates, climate has been acknowledged as having a wide range of impacts on health. In reality, climate change will continue to be experienced against a background of other global changes such as population growth, urbanization, land use changes and the depletion of freshwater resources—all of which could also magnify its impacts (Haines et al., 2006). All of this further implies the future of global public health is increasingly under threat, with a growing non-communicable disease burden, expanding nutritional vulnerability, water- and food-borne diseases, vector-borne zoonoses, HAEI and new EIDs and re-emerging infectious disease exposures, as well as susceptibility to displacement. These factors exist in addition to rapid global environmental change manifested in large-scale biodiversity loss, resource scarcity, changing biogeochemical flows, various forms of pollution, and climate change, together with their impact on food and water availability. We are currently on a trajectory towards a planet that is heading to be 4ºC warmer than pre-industrial levels, which indicates the alarming ecological crisis on this planet. These ecological changes are becoming increasingly strong determinants of health and are affecting the wide-range habitability of vast regions of the world, include the virulence of infectious diseases or the security of our food systems (Zywert and Quilley, 2020). These ecological changes serve to reinforce the essentialities of planetary health, thus the connections between human-caused disruptions of Earth's natural systems and the resulting impacts on human health are a central concern (Veidis et al., 2019).

Moreover, the greatest transitional mediating threats are continually interacting with all of these arising determinants in transition, including demographic and nutritional transitions under this new changing global context of epidemiological and health transition in the Anthropocene. Public health impacts are also being continuously affected by the current unprecedented environmental and climate mediated health risks, through the global contamination of air, water, soil, food and the food chain. The greatest transitional mediating health threats in the Anthropocene with its impacts on our public health are summarized in Figure 4-1.

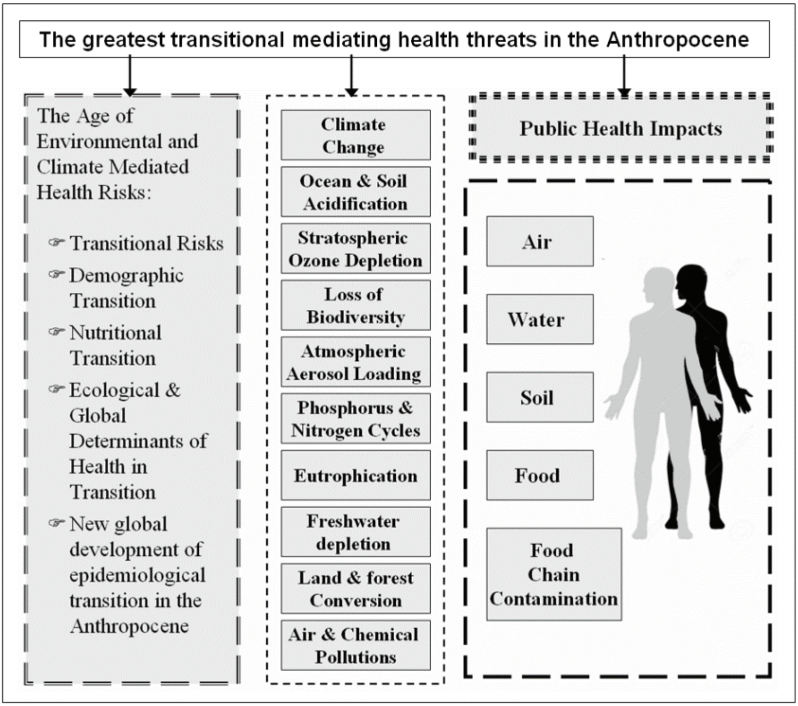

Figure 4-1: The greatest transitional mediating health threats in the Anthropocene.

Water, air, and soil are the three natural resources that we cannot live without, and ecosystem services can be classified into categories according to them. In the same vein, Hippocrates conceived hygiene as "an influence of atmosphere, soil, and water on human health", citing that "every disease has its own nature and arises from external causes". In fact, Hippocrates was the first to regard disease as a natural, rather than a supernatural phenomenon, encouraging doctors to look at the physical causes of illness and to use objective observation and critical deductive reasoning (Pappas, Kiriaze and Falagas, 2008). As pollutants interact with the environment, they undergo physical, chemical and biological processes, in which the subsequent changes that occur within the environment determine the ultimate impact of the pollutant on the environment, and concomitantly on humans and other organisms. These subsequent impacts then reverberate throughout the environment, leading to impaired soil, water, and air quality, which further damages our habitats, as well as causing stress to wildlife populations (Brusseau, Pepper and Gerba, 2019). The increasing incidences of air pollution, water pollution, land and soil pollution, solid and hazardous waste pollution, deforestation, soil erosion, silting, and flooding are evidential illustrations of environmental quality deterioration that slowly, but steadily, pose a threat to human security (Malik, Grohmann and Akhtar, 2014). The pollution of air, water, and soil has attracted particular interest, because of its direct adverse impact on landscapes, ecosystems, cultural heritage and human health (van der Perk, 2014). For all these reasons, we are going to look at our basic needs in relation to the arising ecological calamities, and assessing their multiple resultant adverse public health impacts and mediating harmful threats.

Air

The universal dependence of humanity on fossil fuels, which has changed the way human beings live and breathe on this planet, has also been a catastrophe for human health and the Earth's environment (Saxena and Naik, 2018). The concerns around ambient air pollution are growing steadily as it is nowadays one of the most crucial contributors to our deteriorating health status worldwide. It is a great danger to the life of billions of people worldwide, and can be counted as attributive cause to numerous adverse health outcomes such as cardiovascular diseases (CVDs), respiratory diseases, birth outcomes, neurological diseases and psychiatric diseases (Bazyar et al., 2019). Its long-term effects can include chronic respiratory diseases, lung cancer, heart disease and even damage to the brain, nerve, liver or kidney. An estimated 1.4 billion urban residents in the world breathe air that fails to meet the WHO's air quality standard (Zeneli, Daci, Pacarizi and Daci-Ajvazi, 2011). The WHO (2018) estimates that around 7 million people die every year from exposure to fine particles in polluted air. In a report entitled "Ten Years in Public Health", this organization reinforced that air pollution, with its multiple toxic compounds, penetrates deep into the lungs and also the bloodstream, causing inflammation and a gradual narrowing of the arteries, similar to the well-known damage caused by tobacco smoke. It is estimated that more than one-third of all deaths from strokes, lung cancer, and chronic lung disease are associated with exposure to air pollution (WHO, 2017). Air pollution alone is one of the largest risks to health, causing seven million preventable deaths per year, with more than 90% of people worldwide still breathing polluted air (WHO, 2019).

The air we breathe is a heterogeneous composite mixture of gases, airborne solids, liquids, and aerosols. Aerosols are small airborne particles released together to the atmosphere by both natural and human activities with mixtures of liquids and gases, or liquids and various chemical compounds (including solids). They exert a strong influence on the climate system, hydrological cycle, and atmospheric chemical processes, and have multiple adverse effects on organism health (Butz et al., 2018). Air pollution is a mixture of air pollutants in gaseous forms, particles in suspension, plus different ionizing radiation, in which the gases form as: oxidized and reduced forms of carbon (CO_2, CO, CH_4) or of nitrogen (NO_2, NO, N_2O_4, NH_3, NH^{4+}), SO_2, O_3, C_6H_6 vapours, Hg, volatile phenols, Cls, etc., and in particulate forms such as: PM_{10} and $PM_{2.5}$ particulate matter, heavy metals with a toxic effect (Pb, Ni, Cd, As), polycyclic aromatic hydrocarbons (PAHs), etc. (Khallaf, 2011). Ambient particulate pollution is hazardous to human health due to the resultant surface absorption of many harmful contaminants, for example: heavy metals (lead, cadmium, and mercury) and organic compounds (PAHs, PCBs, dioxin and furans). They include:

- Fine particulate particles that can reach the lungs and are deposited in the alveoli. These are associated with increased risk of cardiovascular and lung diseases.
- Ultrafine particles which are deposited deeply into the lungs and may pass into the bloodstream by different transfer routes and mechanisms. They are then distributed into other bodily organs, including the brain (with potential neurotoxic effects).

While hundreds of anthropogenic air pollutants are toxic, including six ubiquitous air pollutants exist that are regulated by the governments in most countries due to their significant harmful impacts on human health and the environment (Saxena and Naik, 2018). The emission of air pollutants from anthropogenic activities has now surpassed those from natural emissions. To be more specific, there are some air pollutants designated under the Clean Air Act of 1971, which are more strongly suspected to be harmful to public health and the environment in comparison with other primary and secondary pollutants; these are termed criteria pollutants. They are: nitrogen dioxide (NO_2), sulphur dioxide (SO_2), particulate matter (PM), Lead (Pb), carbon monoxide (CO) and ozone (O_3) (Saxena and Sonwani, 2019).

In 2013, the International Agency for Research on Cancer (IARC) of the WHO stated that the air we breathe has become polluted with a mixture of cancer-causing substances and we now know that outdoor air pollution is not only a major risk to health in general, but also a leading environmental cause of cancer deaths. Subsequently, it was announced that outdoor air pollution has been classified as carcinogenic to humans (and was placed in 'Group 1') (IARC [WHO], 2013).

The WHO (2017) states that air pollution is the deadliest form of environmental degradation, supplying abundant evidence which shows that exposure to air pollution either indoors or outdoors is a significant cause of respiratory disease, including lung cancer. It is also one of the main drivers of climate change (from fossil fuel combustion), and is now causing major health problems. Air pollution kills more than six million people a year, of which the majority, according to a study focused on 2014, was attributable to household pollution:

> *"The World Health Organization reports that over four million people die prematurely from illness attributable to household air pollution from cooking with solid fuels. More than 50% of premature deaths among children less than 5 years of age are due to pneumonia caused by particulate matter (soot) inhaled from household air pollution. It is estimated that 3.8 million premature deaths annually from non-communicable diseases (including stroke, ischaemic heart disease, lung cancer and COPD) are attributable to exposure to household air pollution" (WHO, CBD and UNEP, 2015, p .64).*

In actual point of fact, a wide range of hazards and environmental pollutants have been linked to the increased risk of morbidity and mortality from many diseases, including organ disturbances, cancers, and other chronic diseases. These in turn have various adverse health effects such as perinatal disorders, infant mortality, respiratory disorders, allergies, malignancies, cardiovascular disorders, increase in oxidative stress, endothelial dysfunction, mental disorders, and various other harmful effects as well (Kelishadi, 2012). Human activity, especially the burning of fossil fuels, is a major source of nitrogen oxides (NO_x), which is not only a GHG itself (in the form of nitrous oxide), but also contributes to depletion of the stratospheric ozone. And, as Roy and Braathen's study of 2017 illustrated, nitrogen compounds also represent a significant part of urban pollution with fine particles ($PM_{2.5}$), of which the health cost in terms of premature deaths is estimated at USD 1.8 trillion in Organisation for Economic Co-operation and Development (OECD) countries and USD 3.0 trillion in the BRIICS countries (Brazil, Russia, India, Indonesia, China and South Africa) (OECD, 2018). Further striking facts have also indicated that globally 93% of all children and 630 million children under the age of 5 are exposed to air pollution levels above the WHO air quality guidelines (WHO, 2019b). These guidelines are shown in Figure 4-2.

World Health Organization air quality guidelines	
Particulate matter with a diameter of 2.5µm or less ($PM_{2.5}$)	10 µg µg/m^3 (annual mean) 25 µg/m^3 (24 h mean)
Particulate matter with a diameter of 10 µm or less (PM_{10})	20 µg/m^3 (annual mean) 50 µg/m^3 (24 h mean)
Ozone	100 µg/m^3 (8 h mean)
Nitrogen dioxide	40 µg/m^3 (annual mean) 200 µg/m^3 (1 h mean)
Sulfur dioxide	20 µg/m^3 (24 h mean) 500 µg/m^3 (10 min mean)
Carbon monoxide	60 mg/m^3 (30 min mean) 30 mg/m^3 (1 h mean) 10 mg/m^3 (8 h mean)

Figure 4-2: World Health Organization air quality guidelines (WHO, 2010).

Many of the diseases that are linked to immune system dysfunction can be affected by several environmental factors such as poor air quality (Ghorani-Azarn, Riahi-Zanjani and Balali-Mood, 2016). Furthermore, poor air quality is especially dangerous to children because they are physically active, breathe more per unit of their body weight, and have immature and developing lungs susceptible to damage (WHO, 2009). Hedley (2009) compiled evidence from different reliable studies and inferred biological plausibility that indicated systemic multi-organ involvement in the injuries caused by breathing polluted air. His findings were as follows:

- Cardiovascular disease
  - Formation of arterial plaques (atherosclerosis)
  - Coronary artery disease
  - Heart attacks (myocardial infarction)
  - Irregular heart rhythm (arrythmias)
  - Loss of heart rate variability
  - Stiffening of arterial walls (arteriosclerosis)
  - High blood pressure (hypertension)
  - Alteration of clotting factors increasing the coagulability of blood
  - Stroke (cerebral thrombosis)
- Respiratory disease
  - Inflammation of nasal, sinus, throat and tracheal airways with acute or chronic symptoms
  - Lower respiratory tract inflammation and infection causing bronchitis and pneumonia
  - Chronic airways damage causing chronic obstructive pulmonary disease (chronic bronchitis and emphysema of COAD)

    - Initiation and/or exacerbation of asthma
    - Reduction of lung growth and function in young people
- Interactions between inflammation, respiratory and vascular effects from air pollution
    - Exposure to particulates and other air pollutants causing a specific decline in lung function which can, for example, be measured as a test of the forced expiratory volume of air achieved in one second (FEV_1)
    - There is a strong association between reduced lung function based on this type of measurement and cerebrovascular disease measured as stroke
- Damage to the central nervous system
- Evidence has also been accumulating that air pollution causes either a change toward a downward trend in life expectancy or otherwise limits the expected increases in life span
- Harm to the unborn fetus

There is incontrovertible evidence from all over the world that air pollution causes damage to our body tissues, especially the eyes, nasal passages, lungs, blood vessels and heart—of which the increased health risks are cardiopulmonary problems and lung cancer—as well as damage to unborn infants through the blood circulation of a pregnant mother (Hedley, McGhee and Wong, 2006). Studies by the CDC indicated that an average of 200 industrial chemicals and pollutants were found in the cord blood, demonstrating how penetrable and vulnerable the placenta is and how a mother's current and sometimes even lifelong exposure to toxic chemicals are shared with her fetus by easily crossing the placenta and resulting in pre-polluted babies (ANA, 2007).

There are numerous scientific studies which have increasingly recognized that many childhood diseases are, in fact, caused by environmental hazards, thus health professionals need to be aware of the environmental causes of childhood morbidity and mortality, and must equip themselves for these new challenges in child health, as the time between conception and birth is one of the most vulnerable life stages, during which the environment may have tremendous immediate and lasting effects on health (Li, 2018b). Epidemiological evidence overwhelmingly suggests that prenatal exposure to certain forms of air pollution can harm the child, affecting birth outcomes and infant mortality (WHO, et al., 2015). The following image, Figure 4-3, summarizes air pollution risks to fetal growth and the prenatal origin of respiratory diseases in relation to different trimester gestational stages of fetal growth, which associated with morphological abnormalities and functional defects in their later developmental stages (Li, 2018b).

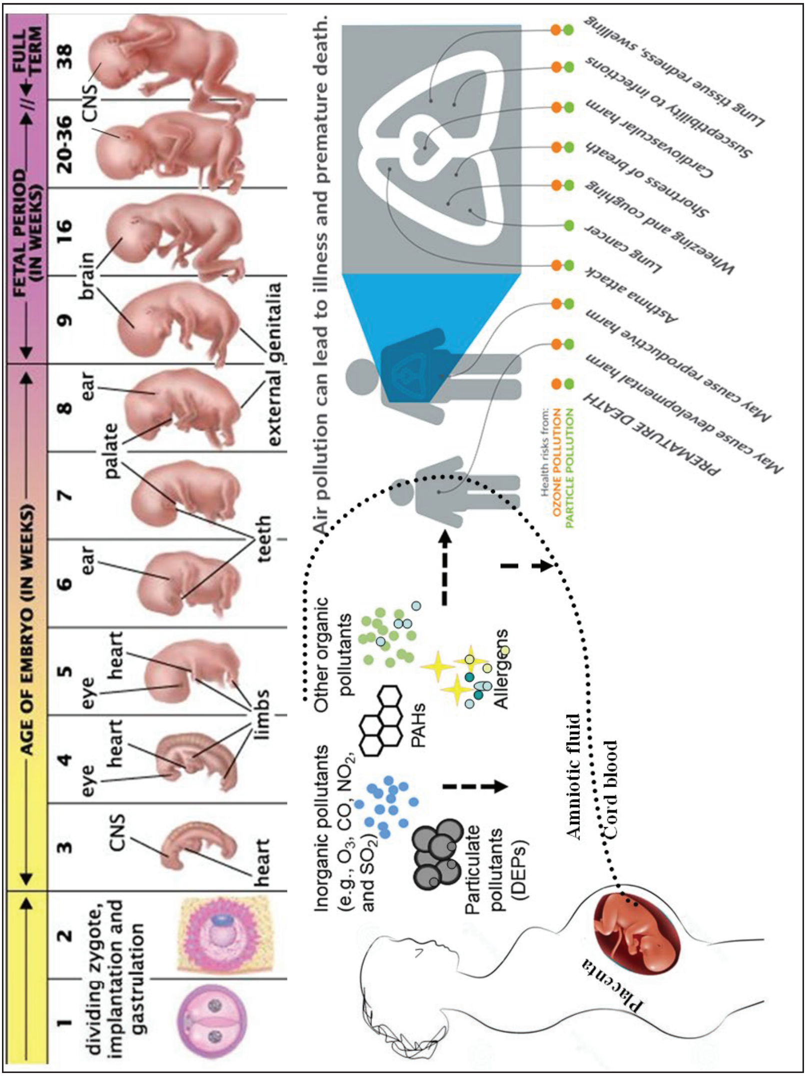

Figure 4-3: Air pollution risks to fetal growth and prenatal origin of respiratory diseases – (PAHs [polycyclic aromatic hydrocarbons] and DEPs [diesel exhaust particles]). (Adapted & modified from Li, 2018a; Li, 2018b; American Lung Association, 2017.)

Evidence is also accumulating that poorer growth during the fetal period is an important risk factor that responsible for adverse health later in life with regard to diseases such as coronary heart disease, stroke, type 2 diabetes and hypertension. We are now beginning to understand how air pollution exerts its effects on pregnant women and their fetuses (Malmqvist et al., 2017). The number of studies linking maternal exposure to air pollutants—including particulates—during pregnancy to various birth outcomes is steadily increasing, and is of particular interest owing to the crucial time span of biological development, especially during the prenatal state of fetal growth. As such, air pollution has the potential to have long-term consequences on our overall health (Kelly and Fussell, 2015). If the tip of the iceberg represents the premature deaths caused by health problems, then beneath it under the surface is a huge burden of ill-health and all the risks of future illnesses that are initiated or exacerbated by exposure to air pollutants. Figure 4-4 shows the concept of the pyramidal effects of the disease burden arising from pollutant exposure as explained by using the iceberg theory.

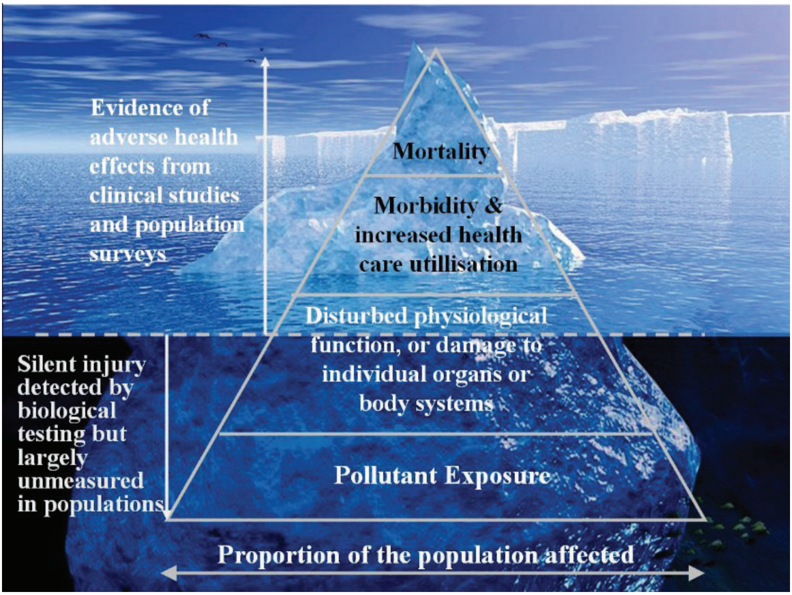

Figure 4-4: The concept of pyramidal effects of the disease burden arising from pollutant exposure, explained using the iceberg theory (adapted and modified from Hedley, 2009).

Within this concept of a "pyramid of effects" indicating bad health outcomes only the tip of the iceberg is visible and much of the burden placed on the future of community health and the economy is hidden (Hedley, 2009). This concept of a "pyramid of effects" is similar to the iceberg theory, or what is sometimes known as the "theory of omission", that was coined by the American writer Ernest Hemingway (1899-1961). In this concept of the pyramid of effects, as postulated by Professor A. J. Hedley, mortality, morbidity, and increased healthcare utilization appear only on a small part of the iceberg. Beneath the water, much of the disease burden is hidden, and very often the proportion of the population being affected could be drastic.

Disease emergence is complex and in many cases poorly understood; however, the role of environmental change is critical (Aguirre, Ostfeld and Daszak, 2012). For example, ambient particulate matter $PM_{2\cdot5}$ exposure is now considered a major risk factor for chronic obstructive pulmonary disease (COPD), as well as a leading risk factor for death worldwide. It was also the fifth most common cause of death and premature mortality and disability. At least half of the COPD burden in adulthood is believed to be caused by poor lung growth rather than accelerated decline in lung function; therefore high air pollution concentrations could be priming an epidemic of chronic respiratory disease, especially in children and adolescents whose lungs are still developing (Lancet, 2019). These examples also illustrate our increasingly growing awareness of the complex interrelationship between the health of all forms of species, including humans and the environment.

Most importantly those harmful effects emphasize epidemiological evidence that childhood exposure to some pollutants also appears to increase the risk of developing health problems in later life, including chronic non-communicable diseases in adulthood such as COPD and asthma (WHO, CBD and UNEP, 2015; Kelishadi, 2012). Recent health statistics reflect that COPD requires urgent attention as the global prevalence of the disease increased by 44% from 1990 to 2015, and in 2017 alone 3.2 million people died from it worldwide (Dransfield, Stolz and Kleinert, 2019, p. 1786).

Air pollution is therefore one of the greatest environmental risks to human health. Building through the industrialization of the 19th century and especially during the "Great Acceleration" of the 20th century, the primary emission, secondary formation, and concentration of air pollutants like ozone, nitrogen, sulfur oxides, soot, and a wide range of other reactive trace gases and aerosols have greatly increased. Air pollutants can act as adjuvants and alter the immunogenicity of allergenic proteins, while climate change affects the atmospheric abundance and human exposure to bioaerosols and aeroallergens that can induce and enhance chemical modifications of allergens, increase oxidative stress in the human body, and skew the immune system toward allergic reactions (Reinmuth-Selzle et al., 2017). Air pollution and climate change are potential drivers for the increasing burden of allergic diseases such as allergic rhinitis, atopic asthma, eczema (atopic dermatitis), and food allergies, and all of which have strongly increased in recent decades (Reinmuth-Selzle et al., 2017).

Other major air pollutants, classified as carcinogen and mutagen compounds, which are thought to be responsible for the incidence and progression of cancer in humans include: VOCs such as benzene, toluene, ethylbenzene, and xylene; PAHs such as acenaphthene, acenaphthylene, anthracene, benzopyrene; and other organic pollutants such as dioxins, all of which are unwanted chemical pollutants that almost totally being produced by industrial processes and human activity. The main toxic effects of exposure to such air pollutants are principally respiratory, cardiovascular, ophthalmologic, dermatologic, neuropsychiatric, hematologic, immunologic, and reproductive in nature. A multitude of researchers came together to create a Global Exposure Mortality Model, in which they used to compare different global risk factors; the model showed that ambient air pollution is a leading cause of excess mortality and loss of life expectancy (LLE). In particular, such pollution was found to contribute significantly to cardiovascular diseases (CVDs): cerebrovascular disease, COPD, ischaemic heart disease, lung cancer, lower respiratory infections, and also non-communicable diseases (Lelieveld, 2020). Globally, ambient air pollution accounts for health effects ranging from increased hospital admissions to increased risk of premature death, including (WHO, 2020a):

- 29% of all deaths and disease from lung cancer
- 17% of all deaths and disease from acute lower respiratory infection
- 24% of all deaths from stroke
- 25% of all deaths and disease from ischaemic heart disease
- 43% of all deaths and disease from COPD

Another adverse mediating effect of atmospheric pollution is the production of photochemical smog, which refers to the mix of natural atmospheric chemicals with anthropogenic emissions derived mainly from fossil fuel burning that produced in the presence of solar radiation. Smog can be extremely toxic and harmful to humans, animals, plants and to nature as a whole, especially in high concentrations (Kumar, Narwal and Sethi, 2017). The chemical reactions in this type of smog are aided by radiant energy from the sun, hence the term "photochemical"; the mixtures produced by these reactions lead to the generation of reddish, yellow-brown, and gray hazes in the sky, and which can be detrimental to living organisms and ecosystems. Carbon monoxide, sulfur and nitrogen oxides, lead, toxic hydrocarbons (organic compounds of hydrogen and carbon) such as benzene and toluene, and particulates can be major contributors to smog. Ozone is also a major product of the reactions involved in the generation of smog (MacKenzie, 1998; Crutzen and Brauch, 2016).

Additionally, air pollution from sulphur/sulfur dioxide (SO_2) and nitrogen oxides (NO_x) and ozone to some extent are the primary causes of acid rain, which is one of the most serious environmental problems. Acid rain refers to a mixture of deposited material from the atmosphere containing higher than normal amounts of nitric and sulfuric acids that originate from human activities such as the combustion of burnable waste or fossil fuels in thermal power plants and automobiles (Bhargava and Bhargava, 2013). It is due to the interaction of these acids with other constituents of the atmosphere that protons are released, causing an increase in the soil acidity. The lowering of soil pH mobilizes and leaches away nutrient cations, and increases the indirect effect of toxic heavy metals, such as Al, Cd, Zn, Pb, Hg, Mn and Fe, which are liberated from soil when it becomes acidified. These mobilized contaminants can also dissolve in soil and water, making their way to groundwater that is drunk by humans and/or contaminating the food (fish, meat, and vegetables) eaten by humans (Bhargava and Bhargava, 2013). People can inhale the pollutants of SO_2 and NO_x as that can cause acid rain, as well as sulfate and nitrate particles in the air, which are harmful to humans (EPA, 2019b). In addition, N_2O emission is currently the single most important ozone-depleting agent, and is expected to remain the largest throughout the twenty-first century (Erisman et al., 2013).

Ecologically, air pollution can cause serious environmental damage to the groundwater, soil, and air, which then has a serious toxicological impact on human health and the environment, including all the destructive effects of the atmosphere and/or deterioration of the ecosystem such as acid rain, temperature inversion, and global climate change (Ghorani-Azarn, et al., 2016). Using a conventional deterministic risk assessment, we can estimate the potential carcinogenic and non-carcinogenic risks from worst-case inhalation, ingestion, and dermal contact exposure to chemicals of potential concern in the air, food, water, and soil for susceptible populations in polluted areas. Results show that inhalation is a major exposure pathway for volatile organic compounds (VOCs) and particulate matters with impregnated toxic heavy metals, and that this subtle and potential source of exposure may pose significant public health hazards. Because of the intricacy of incremental degradation of human health from long-term chronic exposure, hence, too often they remain largely unidentified (Olawoyin, 2018).

In fact, the sheer range of air pollution reflects a central alarm of the Anthropocene, namely that human influence, through atmospheric compositional change, is profoundly interfering with the biological state of the environment. The results of this are adverse effects on ecosystems and agricultural crops, changing biogeochemical cycles, and induced public health risks (Lelieveld, 2017). Diseases caused by pollution were responsible for an estimated 9 million premature deaths in 2015, and it also endangers planetary health, destroys ecosystems, and is intimately linked to global climate change as well. Pollution is, in fact the largest environmental cause of disease and premature death in the world today (Landrigan et al., 2017).

In this present era of the Anthropocene, massive pollution emissions have transformed atmospheric composition to the extent that biogeochemical cycles, air quality and climate have changed globally and in some parts profoundly (Lelieveld, 2017). Human activities have created forms of air pollution for millennia and the inhalation of products of combustion, as particles and gases from fuels, has long been recognized as a cause of ill-health and premature death (Hedley, 2009). The negative impact of air pollution on people's health has grown in significance with its increased health risk (Gu et al., 2019), and many of these toxic gases and fine particles entering the air pose health hazards such as cancer, genetic defects, and respiratory disease (Spellman, 2009). Airborne dust is another source of pollutants which can impact human health, especially when the particles are less than 10 microns in size (Brevik & Burgess, 2014). Such complexes of inorganic and biological particulate matter can travel long distances within the troposphere, even around the globe, in relatively short time spans, through the processes of advection, convection and turbulence.

Humans can breathe airborne dust containing toxicants into the lungs, where the toxicants may enter the bloodstream. And the main direct health effects of inhaled dust are irritation of the respiratory passages and diseases (e.g., lung cancer). However, airborne dust can carry additional materials, such as pathogens, harmful gases, organic chemicals, heavy metals, insects, pollen, and radioactive materials that can lead to other health problems (Brevik & Burgess, 2014). Its molecular and cell toxicity may also induce a variety of cancers in the long term. Other studies have shown that there are relationships between air pollution exposure and fetal head size in late pregnancy, fetal growth, and low birth weight.

> *"Animal and human studies have shown that inhalation of aerosols can affect mother and offspring health at the microvascular level, possibly through impairment of mitochondrial function." And "when inhaled, particles smaller than 1µm, corresponding well to the size range of anthropogenic air pollution, can penetrate the alveolar wall and enter the maternal bloodstream such that particles and inflammatory mediators may reach the placenta and the fetus" (Malmqvist et al., 2017).*

Perhaps the best way to combat pollution is first to identify its causes and sources; atmospheric pollution is, by its nature, more global in its impact, though, because of atmospheric dispersal and dilution, it is often less severe in its immediate effects (Rhodes, 2012). Yet again, much of the disease burden arising from pollutant exposure is very often hidden and the actual proportion of the population being affected could be drastic, as reinforced in the concept of pyramid effects as explained by using the iceberg theory as already shown in Figure 4-3. Ultimately, all pollution is global, and pollutions can affect air, water, soil, food and food chains. The direst of its effects often fall most harshly on the world's poorest people.

Water

Water covers much more of the Earth's surface than land does, and the continual movement of water across the Earth due to evaporation, condensation, or precipitation is called the hydrologic cycle (Brusseau, Pepper and Gerba, 2019). Within the Earth's hydrosphere, freshwater comprises less than 3% of the total water in the Earth system. Because most freshwater is held in glaciers and polar ice caps, only ~30% of freshwater reserves are available as surface water or groundwater for human use (National Academy of Sciences, 2007). The water footprint (WF) is a measure of humanity's appropriation of freshwater in volumes of water consumed and/or polluted under three categories: rainwater (green WF), ground and surface water (blue WF), and volumes of water polluted or being used (grey WF) (Hoekstra and Mekonnen, 2012), whereas black water is the wastewater from toilets or sewages (black WF). Blue water consumption consists of surface water from lakes, rivers, and groundwater. Strictly speaking, blue water merely used and returned within the same watershed is not blue water consumption, but blue water withdrawal. Polluted or used water can be expressed with a grey water footprint, while rainwater and soil moisture evaporated or incorporated into traded goods, especially in agriculture or forestry, is called green water consumption (Doka, 2015).

> *"Thousands have lived without love, not one without water."*
>
> *W.H. Auden (British poet)*

Freshwater resources are in decline in many parts of the world and about three billion people live in locations that are subject to varying degrees of water stress, partly because of depletion of aquifers, which cannot be replenished in human lifetimes (Haines, 2016). The Earth's freshwater resources are now subject to increasing pressure in the form of consumptive water use and pollution, as the study shows that about one-fifth of the global water footprint in the period 1996–2005 was not meant for domestic consumption but for export, and therefore such associated external water dependencies strengthen the argument to put the issue of water scarcity in a global context (Hoekstra and Mekonnen, 2012).

Not only is the agricultural sector the biggest consumer of global freshwater resources, with farming and livestock production using about 70% of the Earth's surface water supplies, it is also one of the most common types of water contamination (due to farm waste and fertilizer runoff) caused by excess nitrogen and phosphorus in water or air. This form of nutrient pollution is the leading cause of water degradation and can cause algal blooms, a toxic soup of blue-green algae that is harmful to people and wildlife. It also represents the biggest threat to water quality worldwide (Denchak, 2018). Therefore, it is critical for us to increase our understanding of the relationships, so as to improve our ability to predict ecological outcomes of those interacting threats, as well as to enhance the resilience of freshwater ecosystems. Especially, freshwater ecosystems continue to face impacts from numerous ongoing and emerging threats that often lead to unexpected ecological responses and novel ecosystems (Craig et al., 2017).

> *"Fresh water in particular, and lots of it, has always been essential to the viability and success of any civilization."*
>
> *Al Gore, 1992, p. 99.*

In 1993, the United Nations General Assembly designated March 22 as the first World Water Day to advocate for the sustainable management of freshwater resources. To this day, the occasion highlights the importance of freshwater as an annual observance, and explores how water and climate change are inextricably linked. Most crucially, freshwater habitats are absolute essential for human survival, as well as for plant and animal life. In addition, freshwater flow is important for sustaining biodiversity. And also the functions required for maintaining the state of the ecosystem. It is worth noting that excessive human induced freshwater withdrawal can affect freshwater ecosystems; as phosphorus is the primary contributor to freshwater eutrophication (Ryberg et al., 2018). This is because phosphorous is the predominant growth-limiting nutrient for freshwater ecosystems, while nitrogen is the primary contributor to marine eutrophication because nitrogen is, in many cases, the predominant growth-limiting nutrient for marine ecosystems (i.e., estuaries and coastal systems) (Ryberg et al., 2018).

Further eutrophication will be caused by misbalancing biogeochemical flows from either nitrogen or phosphorus cycles (or both), which would affect the functioning of key processes in the cycles of water, nitrogen, and carbon. Nitrogen and phosphorus cycles are essential nutrients for the survival of all living organisms, plants and animals, as well as for controlling the mass balance of ecosystems. That is why nitrogen flow and phosphorus flow are two parts of one single planetary boundary called "biogeochemical flows" as emphasized by Rockström et al. in 2015 (Doka, 2015). Despite nitrogen and phosphorus being essential nutrients for all living organisms, their abundant utilization for human prosperity contributes to several environmental impacts such as climate change, eutrophication, acidification and biodiversity loss, and has also raised environmental concerns regarding water scarcity and water pollution.

If the Well Goes Dry

"*Taken as a whole, our civilization has adapted over the last 9,000 years to the distinctive – and relatively constant – pattern by which the Earth continuously recycles water between the oceans and the land through evaporation and runoff, distributes it in the form of precipitation, river flow, and the movement of creeks and springs, then gathers and stores it in lakes, swaps, wetlands, underground aquifers, glaciers, clouds, forests – indeed, in all forms of life*."

Al Gore, 1992, p. 99.

This is especially so given the global growth of livestock systems, aquaculture, and crop production (with the intensive use of inputs such as pesticides and chemical fertilizers), all of which have expanded and intensified to meet increasing food demands related to population growth and mobility, as well as changes in dietary patterns (Mateo-Sagasta, Zadeh and Turral, 2018). The resultant effects of the over-application of nitrogen-based fertilizers in agriculture, as well as its concentration in domestic animal manure, is the eutrophication of surface waters and groundwater in many locations around the world (Sachs, 2015). Consequently, that nitrogen is now being converted from N_2 into reactive nitrogen (N_r), in addition to the microbiological production of Nitrous oxide (N_2O), a greenhouse gas and a source of nitrogen monoxide or nitric oxide (NO) in the stratosphere, where it is strongly involved in ozone chemistry. N_2O then enters into the atmosphere as Nitrogen dioxide (NO_2)that causes smog and local pollution (Schellnhuber et al., 2004).

Li (2017a) postulated that the ecological implications of human alterations to the nitrogen cycle from many human activities—such as burning fossil fuels, the application of nitrogen-based fertilizers, and other activities—could dramatically increase the amount of biologically available nitrogen in an ecosystem. And of course any large changes in the availability of nitrogen can lead to severe alterations of the nitrogen cycle in both aquatic and terrestrial ecosystems, which will have a significant environmental impact. Especially, we are now under increased pressure as the global demand grows and natural resources are depleted; climate change only serves to exacerbate this situation. Water scarcity is caused not only by the physical scarcity of the resource, but most importantly by the progressive deterioration of water quality in many basins, hence further reducing the quantity of water that is safe to use. Additionally, the exceedance of the effects on levels of N could impose more health impacts via different routes, as summarized in Figure 4-5 below:

Sources	**Routes**	**Health impacts**
NO_x and NH_3	Inhalation: - direct impacts of NO_2 - impacts via ozone (O_3) - impacts via PM	Asthma, respiratory disorder, inflammation of airways, reduced lung functions, bronchitis, cancers.
N_2O	Health impact due to: - global warming often enhanced by eutrophication - stratospheric ozone depletion	Enhancement of vectors for infectious disease (e.g., malaria) and frequency of infestations (e.g., algae blooms, insects).

Nitrate in drinking water and food:
Nitrate pollution of groundwater poses a recognized risk to human health. The WHO standard for drinking water is 50 mg NO_3 for short-term exposure, and 3 mg NO_3 for chronic effects.
A diet high in red meat is associated with the formation of nitrosamines through the additives (sodium nitrite) that increase the red color of the meat. The natural breakdown products of proteins can combine with nitrites to form compounds such as nitrosamines. There are many different types of nitrosamines, most of which are known carcinogens in test animals.

Figure 4-5: Exceedance of the effects levels of N that could further impose health impacts. (Adapted and modified from Erisman, et al., 2013.)

Toxic chemicals are increasingly important causes of pollution worldwide. Chemical pollution is a great growing global problem. The effects of chemical pollution on human health are poorly defined and its contribution to the global burden of disease is almost certainly underestimated (Landrigan et al., 2017). Many thousands of new chemicals have been invented in the past 50 years, and they are used in a vast array of products, which are also widely disseminated in the global environment (Landrigan and Fuller, 2015). Their direct pollution may contaminate streams, rivers, lakes, groundwater, or the oceans, but the linkage of each of these into a single interacting system in the water cycle adds to our vulnerability (Rhodes, 2012). As one of the most unique properties of water is its ability to dissolve other substances and to carry contaminants relatively long distances, it has shaped the nature of all living creatures on the planet (Brusseau, Pepper and Gerba, 2019). Types of water pollution include:

- "Discharge or disposal of polluting agents such as inadequately treated sewage, industrial or chemical waste
- Surface runoff of soil, fertilizer, pesticides, industrial solvents, detergents, petroleum or other harmful substances
- Accidental leakages or spills of hazardous materials" (Rhodes, 2012, p. 186)

In particular, soil and groundwater contamination occur when chemicals and wastewater seep through the soil from unlined ponds, pipes and drains, or from dumps and spills (Malik, Grohmann and Akhtar, 2014). And therefore, soil and food production is of significant concern under ecological public health *per se*, as they are part of the greatest transitional mediating health threats in the Anthropocene.

Soil and Food Production

The transitional risks emanating from the global environmental and climate crisis are continuously transmitting threats onto our public health, with human anthropogenic pressures characterized by major biophysical changes to Earth's planetary systems. These profound changes pose global ecological and biophysical threats to the air we breathe, water we drink, and food we eat, together with the soil that requires us to grow food—all of which are fundamental in maintaining our health and well-being. In actual fact, there are many ways that soil can adversely affect human health (Steffan et al., 2018).

As the human nutrient supply actually comes from soils, human developmental effects will be affected by the quality of soil. Especially under two major potential consequences: (i) malnutrition, particularly during the prenatal period and early childhood (because decreased food availability and nutritional content could have a marked multigenerational effect), and (ii) exposure to toxic contaminants, biotoxins, and particularly metals that could be contaminated in food (Steffan et al., 2018). In terrestrial soils, heavy metals can be toxic to microorganisms, thereby reducing ecosystem functions such as nutrient cycling and decomposition of organic materials (Schuler and Relyea, 2018). Furthermore, chemicals are the most common type of water contaminants from industries and farming activities, especially solvents and metals used in industrial production can pollute rivers and lakes. Pesticides used in farming also induce the other major cause of soil contamination (Suner, 2019).

Consequently, the unintended consequences of the intensification of agriculture plus the use of synthetic herbicides and pesticides as natural pest control that will not only further diminish biodiversity and increase vulnerabilities to pathogens, but also cause soil nutrient deficiencies. Then, energy inputs are required to compensate for those lost ecological services by using energy-intensive ammonia-based fertilizers that in fact further acidify the soil and kill much of its living biota (Singer, 2016). It is therefore worth noting that soil is not only a part of the ecosystem but also the main source of trace elements for plants in the form of micronutrients.

There are a mere 11 elements constituting 99.9% of the atoms in the human body. They are typically divided into major and minor elements, in which the four major elements, H, O, C, and N, make up approximately 99% of the human body, and the seven minor elements, Na, K, Ca, Mg, P, S, and Cl, make up another 0.9% of the body (Brevik and Burgess, 2014). When soils provide a healthy, nutrient-rich growth medium for plants, the resultant plant tissues contain most of the elements required for human life when consumed as our diet (Brevik and Burgess, 2014). Simply because the survival of man requires the maintenance of soil's productivity with its functions for filtering, buffering, storage, and transformation system to protect against the effects of trace element pollution if its biological activity are persevered (Kabata-Pendias and Mukherjee, 2007).

Exposure to heavy metals through soil contact is another major human health concern, as food contaminations from different routes of soil are increasingly intense. Heavy metals with the most toxicity for humans include lead, cadmium, mercury and arsenic. These heavy metals have been used by humans for thousands of years, and although the adverse health effects of heavy metals have been known for a long time, exposure to heavy metals continues and is even increasing (Järup, 2003). Heavy metals enter groundwater through numerous anthropogenic activities, including mining, agriculture, landfills, and urban developments; they also accumulate in roadside soils that can be mobilized by road salts such as sodium chloride (NaCl), magnesium chloride ($MgCl_2$), and calcium chloride ($CaCl_2$) into freshwater ecosystems. Toxicologically, these can interact through an increase in the bioavailable (especially free-ion) fraction with those heavy metals that could then increase the concentrations of heavy metals in food webs (Schuler and Relyea, 2018).

Furthermore, the indirect effect of acid rain on human health involves toxic heavy metals because they are liberated from the soil whenever it becomes acidified. Then these mobilized contaminants can dissolve in the soil with water and make their way to groundwater that is drunk by humans. They can also contaminate the food-webs of fish, meat, and vegetables that end up being eaten by humans (Singh and Agrawal, 2008). Climate change will also increase human exposure to those chemical contaminants in food, e.g., through elevated sea surface temperatures which will lead to greater accumulation of mercury in seafood, while increases in extreme weather events will introduce more contaminants into the food chain, together with rising carbon dioxide concentrations. As climate change will alter the incidence and distribution of pests, parasites and microbes, which then lead to increases in the use of pesticides and veterinary drugs (US Global Change Research Program, 2018).

Today, the emergence of air, water and soil pollution and eco-toxicity by persistent organic pollutants (POPs) are also the most significant health threats, especially when POPs can remain in the soil for a long period of time (up to several decades). These compounds are resistant to degradation both in the environment and in the human body and tend to bioaccumulate within the food chain and cause adverse health effects (Carpenter, 2011). Increasingly, the food chain is an important route and pathway for inducing possible human health hazards through exposure to food contaminants, as shown in Figure 4-6.

Food contaminants	Possible human health hazards
Metals/metalloids	
Lead	- complications in the nervous system and red blood cells - reduction in cognitive development and intellectual performance
Cadmium	- renal tubular dysfunction, associated with high risk of lung and breast cancer - osteomalacia and osteoporosis
Arsenic	- associated with dermal, respiratory, nervous, mutagenic & carcinogenic effects
Nickel	- associated with dermatotoxicity, lower body weight, and fetotoxicity among pregnant women
Mercury	- linked to cardiovascular, reproductive, and developmental toxicity, neurotoxicity, nephrotoxicity, immunotoxicity, and carcinogenicity
Mycotoxins	
Aflatoxin	- immunodeficiency - aflatoxicosis - primary hepatocellular carcinoma - liver cirrhosis
Ochratoxin	- nephropathy
Deoxynivalenol	- impaired intestinal integrity - impaired gut-associated immune system
Zearalenone	- hyperestrogenism and reproductive dysfunction
Fumonisins	- esophageal cancer and birth defects
Antimicrobials	
Tetracyclines	- impaired intestinal flora
Quinolones	- drug-resistant pathogens
Macrolides	- hypersensitivity and anaphylactic shock
Sulfonamides	- kidney damage and nephropathy

Polycyclic aromatic hydrocarbons (PAHs)	
Benzo[a]pyrene	- mutagenicity and carcinogenicity - DNA damage and oxidative stress - impaired male fertility - respiratory diseases - cognitive dysfunction among children
Pesticides	
Chlorpyrifos	- neurological symptoms
DDTs	- neurological symptoms - endocrine disruption
DDT and other OCPs	- infertility and fetal malformation
Dioxins and polychlorinated biphenyls	
Dioxins and PCBs	- language delay - disturbances in mental and motor development
PCBs	- neurological disorders
Microplastics/ Nanoplastics	- skin irritation, respiratory problems, cardiovascular disease - digestive problems, reproductive effects, cancer
Persistent organic pollutants (POPs)*	- cancer, immune system suppression, decrements in cognitive and neurobehavioral function, disruption of sex steroid and thyroid function - increase in the risk of chronic diseases, such as hypertension, cardiovascular disease, and diabetes

Figure 4-6: Exposure to food contaminants via the food chain and the possible human health hazards (adapted from Thompson and Darwish, 2019; and *Carpenter, 2011).

Soil is indeed one of the most significant essential commodities to human existence; for almost everything else we use (e.g., fuels, fabrics, fertilizers, metals, and other minerals) substitute materials can generally be found, but for soil and water, there are no substitutes. Water can perhaps be recycled; soil cannot (Rhodes, 2012). Sustainability in global food systems is one of the most relevant goals in this century as food production is one of the three consumption domains responsible for the largest share of environmental impact. At the same time, environmental sustainability is a fundamental determinant of human health (Rizzo et al., 2020).

The local climate plays a large part in determining the mineral components of soils (Rhodes, 2012), especially as the steady accumulation of atmospheric GHGs has warmed the planet and unleashed multiple threats to global sustainability including glacial melting, rising sea levels, ocean acidification, biodiversity loss, and extreme weather events, not to mention regional and international conflicts over increasingly scarce water and food supplies (Wakefield-Rann and Fam, 2018).

Global warming will have strong impacts on water availability in the developed world, especially under population pressures and water-intensive activities (such as irrigation), which already strain the water supplies in many regions—particularly those expecting to see falling supplies in food. Agriculture is of course highly sensitive to climate change; and in fact, many developed regions have existing water shortages that will be exacerbated by rising temperatures, which will increase evaporation and dry out land that is already dry. Such places include Southern Europe, California, South West Australia and the Middle East, places where higher temperatures and more severe droughts will cause serious problems to both water supply and agriculture (Stern, 2008).

Of paramount concern is the human adaptive capacity to a $1.5^{0}C$ warmer world. Such a capacity varies markedly for individual sectors and across sectors, i.e., in terms of water supply, public health, infrastructure, ecosystems and food supply. Thus, it is critical that we understand these connections (Allen et al., 2018). Figure 4-7 shows the interrelationship of the top panel with the range of temperatures projected at stabilization of concentration levels between 400 ppm and 750 ppm CO_2e at a long run equilibrium. The bottom panel illustrates the range of impacts expected from the eventual temperature change due to rising concentrations of CO_2 in relation to adverse effects on "Food and Water" (adapted from Stern, 2008).

This implies food production systems being affected, e.g., crop failure, reduced food production, and declining crop yields, especially in Africa. Such consequences are likely to leave hundreds of millions without the ability to produce or purchase sufficient food—particularly if the carbon fertilization effect is weaker than previously thought, as some recent studies suggest. At mid to high latitudes, crop yields may increase for moderate temperature rises (2 – 3°C), but then decline with greater amounts of warming (Stern, 2008).

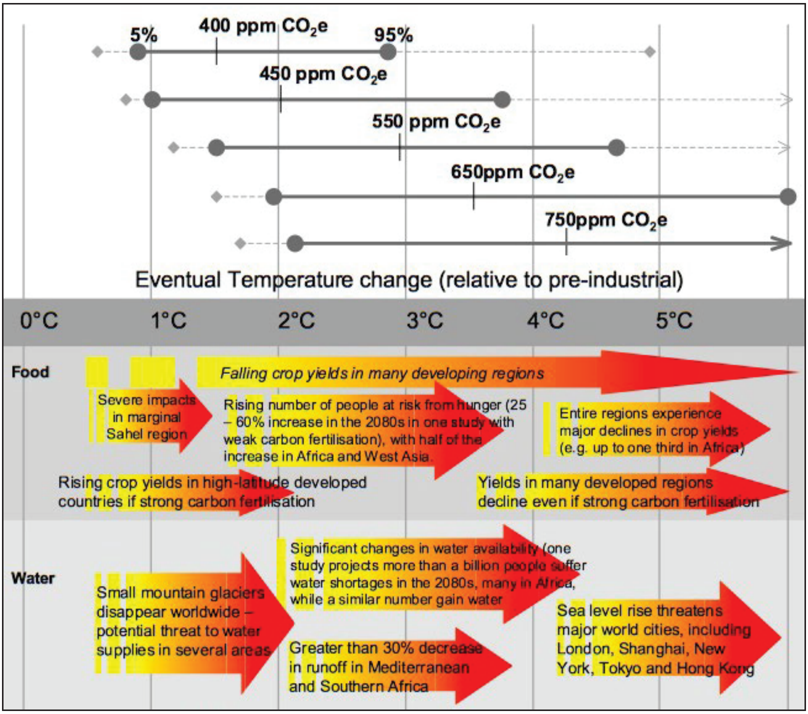

Figure 4-7: Stabilization levels and probability ranges of temperature increases associated with possible adverse effects onto "Food and Water" (adapted from Figure 13.4 in Stern, 2008, p. 294).

There is growing recognition of the additional stress on food insecurity affected by climate change. Drought-prone and long-term drying conditions (such as in Australia and in other subtropical regions around the world), higher temperatures, rising sea levels, increasing frequency of flooding, and the acidification of oceans all contribute to the impaired yield, quality and affordability of food in many countries (Friel, 2010). Well over half of the land area of Argentina has been diminished by erosion, while intensified farming practices in the United Kingdom have had a significant impact on soil erosion too (Rhodes, 2012). Another example in the degradation of Australia's fertile land is through salt intrusion (Raffaelli and Frid, 2010) due to creeping threats from dying coral reefs, as salt water from rising seas infiltrates damaged coral reefs and intrudes upon groundwater. As a result, the saltier groundwater impedes crop growth, and thus fosters malnutrition among the poor. It also leads to high blood pressure among those who use it for drinking water (Epstein and Ferber, 2011). Drinking water salinity is one of the most significant health risk indicators in raising blood pressure, and, as the WHO (2020d) have indicated, high blood pressure is a major risk factor for coronary heart disease and ischemic as well as hemorrhagic stroke. It is estimated to cause 7.5 million deaths worldwide annually, which comprises about 12.8% of the total of all deaths. This also accounts for 57 million disability adjusted life years (DALYS).

Freshwater bodies can receive salt through different pathways, for example through direct surface runoff from saline lands or subsurface drainage of saline waters to freshwater bodies. The latter may degrade water quality in freshwater bodies such as wetlands, streams, lakes, reservoirs and estuaries as a result of salt mobilization and concentration. Furthermore, human-induced salinization of freshwater bodies is now a challenge of growing concern with the extent of salts mobilized by agriculture and the consequent effects on human and ecosystem health (Mateo-Sagasta, Zadeh and Turral, 2018).

Example of the other greatest but poorly known threats that humans face from both heavy metals (as contained in the deterioration of vehicle parts) and road salts (put on icy roads to lowering the freezing temperature of water and melt the ice during winter) is their continuous movement and accumulation into groundwater systems through runoff from roads; which are then used for human consumption and agriculture (Schuler and Relyea, 2018). Microplastics in the aquatic phase are simply more obvious and visible compared to soil, however they have now been found in the soils of many terrestrial ecosystems. The decomposition rate of microplastics in soil is currently unknown, but the assumption is that this material is persistent and will thus accumulate, which could lead to soil drying, with potentially negative consequences for plant performance in terms of alterations to soil structure (Rillig et al., 2019).

In addition, the extensive use of antimicrobials means that these drugs are often found in the environment, including in waterways and soils (Li, 2017a). To summarize, a consequent loss of productivity is usually artificially mitigated through the systematic and intensive use of agrochemicals (pesticides, herbicides, fertilizers) in crop production and antibiotic and hormone use in livestock operations, leading to an increasing amount of anti-microbial compounds being released in our waste systems and soil as well (De Paula, 2018). Li (2017a) indicated that when our population grows and global consumption increases, nature may lose its capacity to withstand our ecological footprint and meet these growing demands. The risk of starvation, hunger, malnutrition, malnourishment, and water shortages are the rising challenges we face to supply our basic needs. Indeed, agriculture has been under pressure especially due to exponential population growth since the 19th century. Insofar as agro-systems have been simplified, agriculture intensification inherently trades short-term productivity against many ecological regulatory services (e.g., crop genetic diversity reduction in intensive settings is known to increase the risk for disease—i.e., the monocropping effect) by reducing crop and livestock species and genetic variability in intensive agriculture contexts, leading to a simplification or disruption of the local ecological functions (De Paula, 2018).

In fact, since the start of the 20th century, humans have doubled the input of chemically-reactive nitrogen in fertilizers used in the environment and this now poses serious threats to public and environmental health, with excessive nitrogen polluting the air, soil and water; this increases greenhouse gas emissions and impacts upon biodiversity and ecosystem functioning. Additionally, this reactive nitrogen stimulates the formation of ground level ozone and particles in the atmosphere and increases soil acidification. The transfer of nitrogen from terrestrial to coastal systems is also leading to algal blooms, causing a decline in the quality of aquatic ecosystems (OECD, 2018). This is another notable attribute of the immense challenges forced upon us: ecological perspectives on food and eco-environments, including aquaculture, agriculture and entire food systems must be employed.

Humans have become dominating drivers of change, and food production is the largest source of environmental degradation and has the greatest effect on the Earth system. The undeniable fact is that the human race is in the process of changing Planet Earth on a scale and with a rapidity that rivals the major changes of the planet that we have associated with previous geologic periods and epochs (DellaSala, Goldstein and Elias, 2018). The chemical signal for the Anthropocene began with the addition of chemical pollutants into the environment in the 1950s, including (DellaSala, Goldstein and Elias, 2018; Lewis and Maslin, 2018):

- A variety of inorganic pollutants that are exerting high levels of impact on geochemical cycles by increased anthropogenic fluxes for the major nutrient elements of carbon, nitrogen, and phosphorus (C, N, and P), as well as the trace metals silver, chromium, copper, nickel, lead, and zinc (Ag, Cr, Cu, Ni, Pb, and Zn).
- Artificial long-lived radioisotopes introduced into the environment during atmospheric nuclear weapons testing. These are classed as markers of the beginning of the Anthropocene, and include two

isotopes of plutonium: ^{239}Pu and ^{240}Pu. The presence of these two man-made plutonium isotopes has been marked since 1952.

- Factories and farming remove as much nitrogen from the atmosphere as all of Earth's natural processes do.
- We have manufactured so much plastic that it has made its way (in the form of tiny fibers) into almost all of the water we drink, as well as the food chain.
- Since the dawn of the Industrial Revolution, we have released 2.2 trillion metric tonnes of carbon dioxide into the atmosphere, increasing its levels by 44%. This is also acidifying the world's oceans and raising the Earth's temperature.

It is equally important to understand the effect of the physio-chemical and microbiological environment on human health from the concept of ecohealth and human ecology in the transition of these environmental health issues as there is a great deal of commonality between them. Both embrace the idea of a mutual influence between human health and environment from cross- or trans-disciplinary perspectives, within the respective field that reflects their historical and multi-origin background in the Anthropocene (Watanabe and Watanabe, 2019).

Global Demographic Transition

From the time that humans first began to inhabit the Earth, health and disease has been a part of life, and as the Earth's population continued to grow, many diseases began to occur (Fos, 2011). The world population reached one billion in 1800, and this modern expansion of the human population started rising at a slow but steadier pace to 2.5 billion in 1950; however, growth rates then accelerated to historically unprecedented levels (Bongaarts, 2009), with an estimated 7.7 billion people worldwide in 2019 (UN, 2019).

Malthus believed that it was necessary to slow the fertility of people so that the human population might find a way to avoid his principle of population, which in essence is the concern that fertility and overpopulation would lead to food shortages and a lack of other resources. Since then, the essence of his work are leading to the discipline of demography (Bogin, Cartmill and Brown, 2001). The theory of demographic transition was first formulated by the demographer Warren Thompson (1887-1973) in 1929, who described how societies originally with a high mortality and high birth rate, over time transform into those with decreasing mortality, followed by a decreasing birth rate (Bygbjerg and Meyrowitsch, 2007).

In 1929, Warren Thompson proposed that the change from a regime of high fertility and high mortality in pre-modern societies to one of low fertility and low mortality in modern societies that should be defined as demographic transition, an idea which did not become prominent until the 1960s (Lewis and MacPherson, 2013). Demography is the statistical study of populations that allows predictions to be made about how a population will change in its size or growth rate, its density and its dispersion, in which "density-dependent factors" are focused on biotic factors in the environment ("biotic environment") that have an increasing effect as population size increases, whereas "density-independent factors" are abiotic factors in the environment ("physical/abiotic environment") that affect populations regardless of their density. The "biotic environment" identifies the habitat of organisms other than humans, even though as an animal humanity is a member of the biota. The "physical environment" on the other hand is the non-living portion of the ecosystem, which includes the soil, the water and the atmosphere, all of which are natural environments (Sargent II, 1972).

Ecological sustainability could be indicated through safe operating planetary boundaries and limits, which would reflect the handling capacities within the natural eco-environment and humanity's activities *per se*. In this instance the balances of biotic and abiotic environments are symbolized by both the living and non-living things of an ecosystem. The symbolism within this picture and interactions amongst the varied components under the dynamics of an ecosystem that emphasize improving health occur within a constantly changing and interactive environment. Within such an environment, an ecological approach would work with the interaction of the multiple elements, as all the different aspects including the public health components, the drivers, enablers, and quality aspects, influence each other as part of a connected system (Nurse and Edmondson-Jones, 2007). Taking the degree at which the abiotic environment is capable of producing the biotic value gives us the ecosystem carrying capacity, in which the combined abiotic environment (abioticum) and biotic environment (bioticum) will both sequentially determine the habitat conditions of our planet (Vannevel and Goethals, 2020). The resultant interaction also comes from the impacts of global demographic transition, with consequential effects on nutrition and health.

Historically, the human population has grown rapidly because of the expansion of agriculture and industrial production as well as lower death rates from improvements in hygiene and medicine since the early decades of the Industrial Revolution. In the past century, with a huge boom in average wellbeing, industrialization, and urbanization, as well as rapid advances in health technologies (including medical advances such as antibiotics, vaccinations and vast improvements in public health and medical care), so that the population broke free of its ancient restraints. The world went from 3 billion in 1960 to 4 billion in 1974, 5 billion in 1987, 6 billion in 1999, and 7 billion in the year 2011. This is now the great challenge of world output that has soared around 240 times since 1800. The overall result is that the world's output per person, or GWP (Gross World Product) per capita grew, and alongside it so did threats to our environment (Sachs, 2015). Today's world is facing some of the most serious challenges in human history, including the rapid depletion of the Earth's resources, the ongoing degradation of land, water and air, as well as the loss of species and ecosystem biodiversity. It will continuously become increasingly difficult to support a prosperous, secure and equitable life for people on the planet (UNECE, 2016).

Human population growth has been difficult to predict accurately because it depends on a large number of variables, from advances in agriculture, sanitation, and medicine to the influences of culture, religion and medical practices (Merritts, Menking and de Wet, 2014). In the 19th and 20th centuries, with the remarkable advances in science, medicine, industry, agriculture, and technology, human disease has decreased. Whereas, the average human lifespan has increased, and this has resulted in the familiar explosive acceleration in world population growth in the past 150 to 200 years (Salk, 2019).

What is now clear is that the Industrial Revolution marked another significant transition for human health, intensifying urbanization, poverty, and anthropogenic pollutions. Early industrial cities incubated infectious diseases and exposed their populations to industrial toxins, while affluent countries began to see a rise in chronic and degenerative conditions due to longer lifespans and more frequent exposure to the environmental pollutants of industrialization (Zywert and Quilley, 2020). Despite improvements in public health in the early years of the twentieth century, there were a number of unwanted effects from increasing industrialization, population growth and urbanization (Cook, 2013). Urbanization is indeed a predictable outcome of industrialization and the demographic transition which accompanied with it. The following table (Figure 4-8) shows the changes in world and urban populations.

	Approx. 1992	Approx. 2012	Change from 1992
World population in billions	5.5 billion	7 billion	+ 26%
Urban population (as % of total population)	2.4 billion (43%)	3.5 billion (50%)	+ 45%

Figure 4-8: Changes in world and urban populations 1992 – 2012 (adapted from Hancock, Spady and Soskolne, 2015, p. 98).

Urban transitions are underway with an increasing resource intensity of energy, materials, and water required to produce a unit of goods and services. This implies the subtle impact on a broad spectrum of biotic interactions and the significant threats to biodiversity, with further increasing complexity in demands for widespread access to food, water, sanitation, modern energy, education, employment, etc. The question of concern, taking these aspects together, is "how can the aggregate effects of global urbanization help to transition society toward sustainability?" (Seto, Golden, Alberti and Turner II, 2017), especially when such multiple global change trends of urbanization are happening simultaneously. The United Nations predicts that by 2050 nearly three quarters of the world's population will live in urban areas; however, cities may not be sustainable with this population boom (Schneider et al., 2009). For this reason, the challenge of accelerating the transition to sustainability, then, is an urgent need (Seto et al., 2017).

The boom of population demands would outstrip cities' service capacities. This could result in a range of urban health hazards and associated health risks, such as substandard housing, crowding, air pollution, insufficient or contaminated drinking water, inadequate sanitation and solid waste disposal services, vector-borne diseases, industrial waste, increased motor vehicle traffic, stress on food production systems, etc. Therefore, the humanitarian and economic imperative to create livable and sustainable cities must drive us to seek synergistical interventions, which could successfully overcome the challenges of global urbanization and their impact on health (Moore, Gould and Keary, 2003). The issue of human population has been characterized as the most pressing social and scientific issue of all time, as many studies agree that overpopulation is a source of environmental problems. Indeed, ecosystem restoration cannot be achieved without dealing with the issue of human population and its influences (Fowler, 2005).

Nevertheless, the evolution of human nutrition in relation to demography and growth has been neglected. Given that food is central to human life, the most pressing nutritional problem of our time is still undernutrition and starvation, which afflict three-quarters of the world's children—nearly 2 billion people. The issue worsens in light of the human population outstripping the capacity of the Earth to provide food, water, and other resources. This notion is echoed in the report published by the Club of Rome in its oft-quoted book *The Limits of Growth*, in which five global trends are focused on: accelerating industrialization, rapid population growth, widespread malnutrition, depletion of nonrenewable resources, and a deteriorating environment (Bogin, Cartmill and Brown, 2001).

The Great Acceleration began gathering momentum in the mid-twentieth century and marks actual and potential catastrophic threats in terms of the human impacts on the biosphere, which have started to undermine the ecological bases of health on a global scale (Zywert and Quilley, 2020). How human actions are in fact transforming the Anthropocene is the necessary foundation for any serious effort to harness science and technology for the purposes of sustainability. The resulting intensification of pressures on an already stressed biosphere could be overwhelming. Examples include (Schellnhuber et al., 2004):

a. more nitrogen is now fixed synthetically and applied as a fertilizer in agriculture than is fixed naturally in all terrestrial ecosystems. In addition, its concentration in domestic animal manure has led to:
    - eutrophication of surface waters and groundwater in many locations around the world
    - the microbiological production of N_2O, and a source of NO in the stratosphere that is strongly involved in ozone chemistry
    - the release of NO into the atmosphere, including from fossil-fuel and biomass combustion, which is adding to rainwater acidity and giving rise to photochemical ozone ('smog') formation in extensive regions of the world
b. exploitation of fossil fuels that were generated over several hundred million years has resulted in a large pulse of air pollutants
c. the release of SO_2 to the atmosphere by coal and oil burning is at least two times larger than the sum of all natural emissions
d. oxidation of that SO_2 to sulfuric acid has led to acidification of precipitation and lakes, causing forest damage and fish death.

> The inevitability of impact … "We now see, far more than Marsh ever did, how malign, even catastrophic, our environmental impingement can be."
>
> (Lowenthal, 2000, p. 16)

In terms of our relation to the environment, modern hominids—including the agricultural societies discussed in the seminal text mentioned in the quotation above (George Perkins Marsh's *The Earth as Modified by Human Action* [1874])—are something of a pest from the perspective of the rest of the Earth's biota (Richerson, Mulder and Vila, 2001). The current rate of population increase is 1.2%, and with the current world population at over 7 billion that imposed a serious overpopulation problem. Especially, the WHO notes that 66% of the world's population is already malnourished (Pimentel, 2012). As the United Nations (2019) indicates, the global population could grow to around 8.5 billion in 2030, 9.7 billion in 2050, and 10.9 billion in 2100. That directly indicates the arising demands for food production will only be increasing for the world's future population.

Especially the intensification of food production is already becoming increasingly common in modern farming, which has become particularly susceptible to production diseases, with potentially negative consequences for farm animal welfare too. This also raises humane animal care and food safety concerns, especially from the perspective of production diseases in pig and poultry production systems (Clark et al., 2019). A number of elevated risks have been identified in relation to such intensive production systems, with most of the agreement surrounding issues of animal stress, the unnaturalness of the production method, and livestock disease, which has elevated perceptions of risk associated with prophylactic antibiotic usage, antibiotic resistance, antibiotic residues and food safety (Clark et al., 2019).

Additionally, this has been reinforced in the midst of our current transitional health risks: alongside it exist disrupting EIDs or re-emerging diseases (as the global human population continues to grow); the escalating extent of anthropogenic actions destabilizing a long-standing ecological balance, among a plethora of environmental problems; including extreme climate events which are also being intensified (Galvani et al., 2016). In view of the emissions trajectory of the world being as it is, the effects of climate change are likely to be worse than those anticipated by earlier reports of the IPCC (Adlong and Dietsch, 2015).

The extent to which we are exacerbating and accelerating through these global and ecological determinants of health in transition, plus with demographic and nutritional transition, are the primary concerns under this new global development of epidemiological transition in the Anthropocene. In this context, it is also worth noting that climatic changes influence human well-being, biology, health, and survival on six distinguishable time-scales when assessed historically (McMichael, 2012, p. 4732):

(i) influences on biological evolution (over millennia);
(ii) great transitions in human culture and ecology (at times of state-changes in climate);
(iii) long-term climatic changes (multicentury);
(iv) medium-term climatic changes (multidecade);
(v) Short-term climatic changes (multiyear); and
(vi) acute climatic/ weather events.

There are many ways that agricultural production, essential for human survival, is pushing the Earth system over one planetary boundary or another; it represents both a significant contributor to climate change and an increasing risk (Campbell et al., 2017). This is especially so as the size of the human population may be more than 10 billion by the end of this century (Sachs, 2015). In fact, global demographic "megatrends" (i.e., population growth, population ageing, migration, and urbanization) hold important implications for economic and social development as well as for environmental sustainability. Thus, population demographics are at the center of sustainable development (UN, 2019).

"We look at the concept [of the healthy city] historically and in relation to our changing view of the city and of health, and of what the concept may mean to different people. We then make a preliminary attempt to clarify just what are the dimensions and parameters of a healthy city, how we might assess the health, the competence, the 'goodness' of a city, and how we believe a city can become more healthy."

(WHO, 'Promoting Health in the Urban Context', 2000)

Discussing whether or not diseases play a role in human demography, Sallares (1991) notes that "*the beautifully written account of McNeill (1976), building on the insights into disease evolution of earlier researchers such as T. Cockburn (1963), is the most famous exposition of the idea that diseases have been a major factor in determining the course of human history*", in which it is ironically implied that diseases have served to constrain human populations throughout history.

Especially with rapid global urbanization, the importance of understanding relationships between the changing urban environment and human health and wellbeing is being increasingly recognized (Bai et al., 2012). As Bentley (2013) postulated, given that more than half the world's population now lives in cities with many pathways of environmental determinants of public health from urban environments to human health, there are many challenges to creating sustainable urbanism. Cities are indeed important determinants of future sustainability and are essential to addressing the complex challenges of urban health (Bai et al., 2012). As Santangelo, Rivkin and Johnson (2018) pointed out, the continued rapid expansion of urban environments globally has been associated with numerous changes to the biotic and abiotic environment and has often resulted in increased pollution, greater habitat fragmentation, and warmer temperatures, the last of which has also led to urban heat island effects.

An increased recognition of the interdependence of human and natural systems has provided the impetus for a broader definition of public health, encompassing the biological, economic and human dimensions of the system since these are linked inextricably with human health and well-being (Raffaelli and Frid, 2010). The environment is a variable that is associated with change (Garcilazo, 2011). This has given rise to an ecological or socio-ecological model which incorporates the state of health of cities and their people in the development of initiatives and processes promotive of health (WHO, 2000). Therefore, integrating ecological ethics into public health is of global responsibility and importance (Bentley, 2013).

Modern town planning originated in the 19th century in response to basic health problems (Barton and Grant, 2006) and had similar concerns as to the concept of the "first wave of public health" that focused on sanitary reform for clean water, sewers, drainage and growth of municipal power. It represented the 'structural' advancement in the waves of public health developments (also see "The Six Waves of Public Health: Ecological Civilization for Humanity" in Figure 6-3). Ironically, we have been literally building unhealthy conditions into our human habitat, in which the intervening planning has become largely divorced from health. It is a situation in which public health is being compromised by both the manner of human intervention in the natural world and the manner of development activity in our built environment (Barton and Grant, 2006).

Therefore, the achievement of global sustainable development goals subject to planetary boundaries will mostly be determined by cities as they drive cultures, economies, material use, and waste generation. Sustainable development requires adequate standards of living for both current and future generations while living within the planet's carrying capacity (Hoornweg et al., 2016). Due to this important fact, the number of studies examining evolution in urban environments has risen dramatically since 2010, as there is a pressing need to understand exactly how urbanization affects the evolutionary ecology of life. There is a close link between ecological change, urbanization and evolutionary change, and in which anthropogenic activities are often associated with the fastest rates of evolutionary change as cities can be considered large-scale, globally replicated "experiments" for examining evolution (Rivkin et al., 2019). Especially, urban environmental change represents an increasingly dominant and growing form of disturbance to Earth's natural ecosystems that affecting biodiversity and ecosystem services on a global scale (Santangelo, Rivkin and Johnson, 2018).

As refers to in the state of nature idolized by twentieth-century ecological reformers, human impact would dwindle until the environment regained stability (Lowenthal, 2000). In this context, Aldo Leopold's now famous definition of "land ethic": "A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community". Ironically, the major and most widespread global implication would be that unsustainable organizational practices and strategies would be inhibited by ecological pressures, and that such organizations may face a decline in population density or mortality (Clift et al., 2017).

However, when linked to the possibility of combining and recombining resources in order to maintain a competitive edge, another development appeared in the theory of dynamic capabilities. It is defined as the ability of a firm to integrate, build and reconfigure internal and external powers in order to respond to rapid change in environmental conditions (Garcilazo, 2011). Ecosystem health, or EcoHealth, is a systems-based approach to promoting health and wellbeing with a focus on social and ecological interactions, on conservation medicine, and on relationships between human and animal health as well as the environment (Walton, 2019).

Q: What would the health determinants of the 21st century be right now? And what are their implications for the future trends of public health?

It is therefore important to understand both the changing demands in the healthcare environment and the necessities for operating towards sustainable concepts in health developments. That reinforces the essentiality of our understandings of ecological views of health and also the concepts supported by global public health initiatives such as EcoHealth, One Health, and the most recent Planetary Health, all of which reflect and indicate a broader framework is required for the existential changing ecological and global determinants of health. This ecological public health interventional framework centers on epidemiological transition, health transition, the changing demands of the healthcare environment, sustainability development (including nutritional transition), planetary health and the limits of its boundaries, with implications of finding the right "balances". This further reinforces the synergistical empowerment of ecological public health education is of significance if we are to progress with ecological and systems thinking along the path of ecological public health interventions. As such, ecological public health education is absolutely indispensable for this paradigmatic shift in transition, which will be further discussed in Chapter 5.

Nutritional Transition

We must have food in adequate quantity, quality and variety to meet our energy and nutrient requirements for being healthy and active. More than one billion people worldwide were considered to be undernourished in 2009, and around a quarter of all children under 5 years of age suffer from acute or chronic symptoms of malnutrition (Li, 2016b). On the other hand, there are 1.1 billion people who are over-nourished and over-weight—almost rivalling the number of those under-fed. Just around a decade later, this updated figure has now gone up to 2.28 billion or more children and adults worldwide who are estimated to be overweight (Popkin, Corvalan and Grummer-Strawn, 2019).

In actual fact, diet-related obesity health issues, together with obesity-related non-communicable diseases (NCDs) come at a great cost to the global community and are arising in line with the current dietary trends from food production systems, which are causing further harm to our health and the environment. It is worth noting that diets are inextricably linked with human health and environmental sustainability.

These current unsustainable dietary trends between food, health and environment are now being recognized (Li, 2016b). Such trends and preferences are changing from mostly grains and carbohydrates to a greater consumption of meat, eggs, dairy, oil, fish, vegetables and fruit. In addition, different diets have different environmental footprints: for instance, a meat-based diet requires up to three times more phosphorus per year and per person compared to a vegetarian diet. And food losses and waste should also be reduced as much as possible to bring food production closer to actual demand and to minimize the waste of resources that associated with environmental impacts, as about one-quarter of food production is lost along the food supply chain through such waste (Mateo-Sagasta, Zadeh and Turral, 2018).

There are a wide variety of underlying and collective determinants of dietary practices and human health that have significant influences on the food production system, not to mention environmental consequences. The increasingly deteriorating quality of our environment poses threats that include increased exposure to infectious diseases, water scarcity, food scarcity, and natural disasters that accompanying changes to the ecosystem and human health (Li, 2016b). In addition, the rising CO_2 lowers the nutritional value of agriculturally important food crops such as wheat and rice, as rising levels of atmospheric CO_2 continue to reduce the concentrations of protein and essential minerals in most plant species (US Global Change Research Program, 2018).

Food systems have the potential to nurture human health and support environmental sustainability; however, they are currently threatening both. This reflects the need to develop and use sustainable food production practices that safeguard Earth system processes, on which food production and human wellbeing depend. This has become widely recognized in view of the growing body of evidential facts (Willett et al., 2019). In combination with world population growth projections, the increasing demand for agriculturally intensive animal foods, such as meat and dairy products, points to an approximate doubling in global meat consumption by the mid-21st century. This will have serious ramifications for climate change and local environments, in addition to causing concerns around food security and human health (Friel, 2010).

In fact, the relationship between food, environment, and human health has always been a complex issue with many interrelated factors. In the contemporary era, these factors include air pollution, water pollution, the misuse of antibiotics and growth hormones, over-fishing, abuse of chemical usages, food fraud, and overlooking food animals and poultry welfares, as well as other determinants of environmental contaminants, climate change and food-producing systems, etc. (Li, 2017a). New nutritional knowledge on the protective role of maintaining environmental sustainability, including its relation to the food production system, is of great significance. The FAO has indicated that livestock have a considerable impact on the environment, in terms of deforestation, overstocking land with grazing animals, which can cause soil erosion, desertification and the loss of plant biodiversity, together with the pollution of water supplies with their waste. Li elaborates on the situation (2016b):

1. *Despite livestock products providing one-third of humanity's protein intake, they are a contributing cause of obesity and also one of the top two or three most significant contributors to the most serious global environmental problems that have intensified negative impacts on our eco-environments and produced a substantial greenhouse gas source that is driving climate change, with further adverse effects on the food production systems themselves.*
2. *Meat consumption intensifies the negative impacts on our health and environmental sustainability in all aspects of human life and humanity's future survival prospects, including excessively high contributions to global greenhouse gas emissions, land and water pollution and depletion, as well as antimicrobial resistance problems—all of which are further imposing the vicious cycle on both our health and the environment.*
3. *As the WHO and FAO have further indicated, the global food system is broken, and the risks of undernutrition and being overweight are now problems affecting people worldwide. Food security and nutritional diets shift, together with their environmental consequences are also some of our greatest global challenges.*

Despite the shift from undernutrition to over-nutrition that has occurred in less than a generation (Popkin, 2007), the world's hunger is still a massive global concern, as there are over a billion people facing hunger and starvation, as well as being malnourished. As the global population continues to grow, this raises a significant challenge for nutritional transition as the food production systems are already under threat by climate change and other eco-environmental changes. They indeed represent the major contributor affecting climate change and thus impose further environmental harm on the planet. Humans especially require a higher quality diet and nutrient-dense foods, almost twice that of other primates of the same body size. Many studies show that the need for a high quality diet is a consequence of the human brain being several times larger than expected for a primate our size (Bogin, Cartmill and Brown, 2001). People in many parts of the world, however, are chronically near subsistence disaster in food production; whenever economic, political, or natural catastrophes occur, massive numbers of them are often pushed over the brink (Richerson, Mulder and Vila, 2001).

Malnutrition has historically been researched and addressed within two distinct silos, focusing either on undernutrition, food insecurity, and micronutrient deficiencies, or on the issues surrounding being overweight, on obesity, and dietary excess (Wells et al., 2019). Yet, the future direction requires to achieve the global goal of eradicating hunger and preventing malnutrition in all its forms (Lancet, 2019), providing a growing global population with healthy diets from sustainable food systems, is therefore an immediate challenge (Willett et al., 2019). Typically, malnutrition harms health throughout one's life course, and the emergence of malnutrition early in life is particularly harmful. A variety of physiological mechanisms propagate the effects of early-life malnutrition across the life course, and adolescent and adult malnutrition can transmit effects to the next generation. Scientifically, developmental responses to malnutrition in early life are shaped by ecological factors, and intergenerational cycles of malnutrition have proven difficult to disrupt through public health interventions (Wells et al., 2019). Hence, the proactive primary contribution of a major societal shift is required (Wells et al., 2019). Nutritional transition during this age of environmental and climate mediated health risks requires comprehensive change towards sustainable future and scaled up into the entire global food system through the empowerments of our scientific and epistemic understandings, together with synergistical ecological public health interventions.

For this reason, scientific targets for healthy diets and sustainable food systems should be integrated into a common framework within the safe operating space for food systems, so that creates the "win-win diets" (i.e., ones that are healthy and environmentally sustainable). Because food systems are a major driver of poor health and environmental degradation, global efforts are urgently needed to collectively transform diets and food production (Willett et al., 2019). Yet again, given that food is central to human life, and apparently the evolution of human nutrition in relation to demography and growth has been neglected. Nutritional transition historically reflects the shift in dietary consumption or practices required that coincide with economic, demographic, and epidemiological changes. Further to Professor Barry Popkin's five patterns of nutritional transition first postulated in 1993 (Popkin, 2011), I have further proposed "Pattern 6" as the extended new sixth stage of nutritional transition, which serves as a representation of the major concerns arising from this age of environmental and climate mediated health risks in the Anthropocene. Figure 4-9 shows "Pattern 6" added onto the timeline of the previous five patterns as the latest sixth stage of nutritional transition. This proposed "Pattern 6" further recognized the interrelationships between dietary trends and environmental impacts, and therefore they are of great significance for the current nutritional transition through—a. promotion sustainable diets; b. concern freshwater shortages; c. reduce food waste; and d. food animals and poultry welfares—in order to reduce environmental and climate mediated health risks as part of transitions towards sustainability developments for our eco-environments and human health.

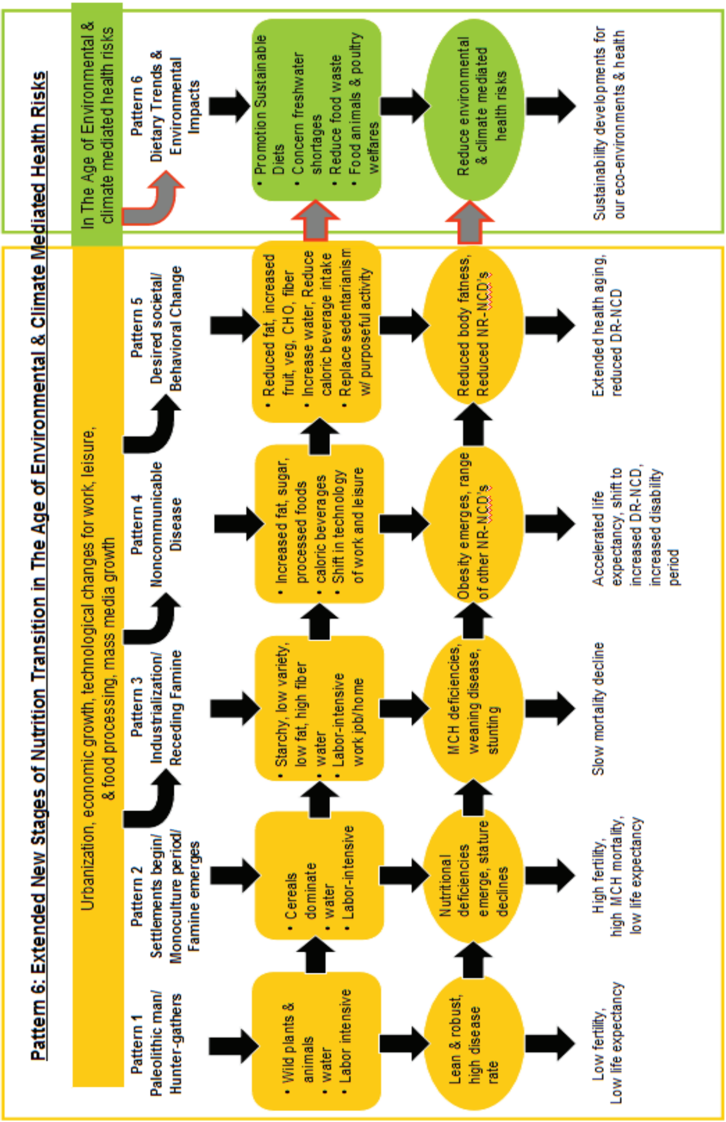

Figure 4-9: "Pattern 6"—The extended new stage of nutritional transition under this age of environmental and climate mediated health risks in the Anthropocene (used and modified with permission from Popkin 2011).

The newly extended stage of nutritional transition presented in "Pattern 6" shows the significance of sustainability developments for our eco-environments and nutritional health, demonstrating what is required for this age of global environmental and climate mediated health risks in the Anthropocene. The stage reflects the possible resultant effects of dietary trends and environmental impacts being interwoven intensively within a context of "sustainable diets". It represents the prime concern associated with both environmental sustainability and nutritional health, relying on new nutritional knowledge to work within the required scope. The fundamental focus is on how the complex sets of interactions amongst the range of underlying factors and conditions are challenges that need to be tackled. These include the epidemics of obesity and their related NCDs, in addition to the ecological dimensions of environmental sustainability and its impacts on the degradation of ecosystems, as well as other health threats like human animal-ecosystems interface (HAEI) and zoonotic diseases emanating from food producing systems (Li, 2016b). This extended new stage of nutritional transition further implies the potential and actual global public health impacts, as it links to important health outcomes with dynamic shifts in relation to ecological public health challenges in the Anthropocene.

Additionally, meat consumption (be it ruminants [cows, sheep and goats] or monogastric [chickens and pigs]) is an intrinsically inefficient process, because to obtain 1 calorie of beef from intensive farming, it takes 8-15 calories of vegetable food, which could have been consumed directly by humans, and a diet rich in meat also raises the following issues (Lambin, 2012, p. 33):

- *It requires the availability of two to four times more farmland than a vegetarian diet.*
- *Intensive animal farming also has a great impact on water resources, as large quantities of water are consumed, including irrigating the crop fields that feed food animals.*
- *The production of 1 kilogram (0.4 pounds) of beef emits seven times more greenhouse gases than the production of 1 kilogram of chicken, and fifty times more than of 1 kilogram of vegetables.*
- *Persistent organic pollutants such as pesticides and toxic products of industrial origin such as dioxins, furans, and polychlorobiphenyls (PCBs), accumulate in the fatty tissue of animals and enter into the human diet.*
- *Water pollution near industrial animal farms can be considerable due to the runoff of nitrogen, phosphates, antibiotics, hormones, arsenic, and pesticides into the ground-water.*

It must be understood that most farms are not equipped with sewer and water purification systems, and—as another example—a pig produces four times more excrement than a human being, and the slurry thus produced is spread over the fields, often in amounts that exceed the needs of the crops; all this leads to pollution of surface water, groundwater, and the air (Lambin, 2012). Therefore, dietary changes, waste prevention, and nutrient recycling are parts of the necessary transformation, as nutrient flows in the Earth system are instrumental to food security. Excessive flows of nutrients are linked with climate change and the loss of biodiversity, those being the three human-induced shifts that have led to over stepping our planetary boundaries.

As the global demand for food is rapidly increasing, the challenge of feeding the people is even more striking because it must be met when the critical biophysical boundaries for several Earth system processes (processes that determine elementary ecosystem services) have been transgressed or are on the verge of being transgressed (Kahiluoto et al., 2014). Professor Anthony McMichael, "one of the world's foremost authorities on the health effects of climate change, has worked with his colleagues to calculate how much global meat production should be reduced to prevent increased greenhouse gas emissions". And he has noted that overuse of nitrogen fertilizer on the soil allows some of it to aerosolize and become a greenhouse gas about 300 times more potent than CO_2 for warming the Earth. In addition, using coal also ruins our air quality and produces the contaminant sulfur dioxide, a mild acid that goes onto plants and into the soils and waterways, harming the plants as well as aquatic wildlife and contributing to habitat loss and loss of biodiversity (Parker and Shapiro, 2008).

Recent research has repeatedly suggested that anthropogenic nutrient flows may have transgressed the regulator capacity of the Earth, representing a major threat towards the irreversible loss of biodiversity and marine life in water, happening as a consequence of both eutrophication and climate change induced by nitrous oxide (Kahiluoto et al., 2014). Another major concern is that changes in microbial biodiversity and activities will affect the resilience of all other organisms, and hence their ability in respond to climate changes (Cavicchioli et al., 2019). The diversity of microorganisms underlies their role in maintaining a healthy global ecosystem: simply put, the microbial world constitutes the life support system of the biosphere, which when combined with local environmental factors, including soil type and light, greatly influences the complex network of microbial interactions that occur with other microorganisms, plants and animals (Cavicchioli et al., 2019). On top of all this, climate change can also reduce parasite resistance in livestock (WHO, 2009).

Food security and biodiversity conservation are closely interconnected challenges to be addressed in order to achieve a sustainable food system on a global scale. As food and energy crises multiply around the globe, it has become more evident that the twenty-first century will be shaped by ecological constraints (Wackernagel and Galli, 2012). Indirect health effects from global warming are also related to those ecological alternations and disruptions of food supply; one of the fundamental determinants is the availability of staple foods, predominantly cereal grains (WHO, 2009). Over time, traditional food production systems have given way to more intensive systems characterized by increased yields, monocultures, and a high level of pest control, together with inputs such as manure, fertilizers, feed, and agrochemicals (Cucurachi et al., 2019). As Cavicchioli et al. explain:

> *"Rice feeds half of the global population and rice paddies contribute ~20% of agricultural CH_4 emissions despite covering only ~10% of arable land. Anthropogenic climate change is predicted to double CH_4 emissions from rice production by the end of the century. Ruminant animals are the largest single source of anthropogenic CH_4 emissions, with a 19–48 times larger carbon footprint for ruminant meat production than plant-based high-protein foods. Even the production of meat from non-ruminant animals (such as pigs, poultry and fish) produces 3–10 times more CH_4 than high-protein plant foods" (*Cavicchioli et al., 2019).

As the production and consumption of food is one of the major determinants of environmental degradation at the global scale, the current global trends of population growth, increased affluence, and dietary choices are likely to worsen the impacts of food systems (Cucurachi et al., 2019). The idea of climate change and food security concerns impacts on availability, stability, access, utilization and food safety, which also raises implications for dietary patterns in relation to climate and nutritional alarm. And therefore, co-benefits of sustainable food production, sustainable dietary habits, and sustainable food consumption, together with food waste reduction, are good governance and ecological concerns to be promoted. Ultimately, the transition to sustainable food systems will require simultaneous action on behalf of the production and demand sides of dietary change. Such action would play a key role in achieving change (Scherer, Behrens and Tukker, 2019).

> "The integrity of ecosystems is fundamental to human well-being. As scientists we need to understand the links between biodiversity and the benefits that people enjoy from nature."
>
> (Raffaelli and Frid, 2010, p. 133)

Meeting the future needs of an increasing human population while remaining within the boundaries limits of our planet requires a transition towards the evolution of food systems in the direction of environmentally sustainable. In fact, food production and consumption are amongst the major drivers of environmental degradation with the evidence showing that the highest environmental impacts and biodiversity decline are due to the consumption of meat and dairy products, as reflected in the majority of the impact categories at endpoint level, whereas ecosystem quality and biodiversity are mainly affected by the consumption of pork and beef meat (Crenna, Sinkko and Sala, 2019).

The booming economy at the end of the twentieth century increased average incomes, enabling people to boost their intake of calorie-rich foods while shifting to a more sedentary lifestyle; thus the percentage of adults deemed overweight or obese increased in the UK from 12.9% in 1991 to 27.3% in 2004 (Popkin, 2007). Aside from acknowledging such statistics in hindsight, we must produce a long-term vision of how we can deliver a sustainable response to obesity (Popkin, 2010), as well as looking into global dietary trends and their impacts on environmental sustainability and planetary health for our global eco-environments. This also signifies understanding and combating non-fossil fuel-derived emissions such as those from land use change (change in carbon stocks of biomass and soils), methane from ruminants and certain agricultural practices and crops (e.g., flooded rice production), and also nitrous oxide from the application of fertilizers and animal waste to soil is of significance (Clift et al., 2017). Because these are major nitrogen threats to soil quality, for both agricultural soils and natural soils, as nitrogen reduces the diversity of vegetation primarily through eutrophication and soil acidification that may sooner or later lead to a decrease in crop and forest growth and leaching of components negatively affecting water quality, including its contamination with heavy metals (OECD, 2018).

All our food, in the end, relies one way or another on natural systems, including the complex ecological relationships that enable soils to support plant growth (WWF, 2018). The extensive use of pesticides and agrochemicals in agricultural systems cause an important part of public health concerns, as safe food production is a vital part of providing nutrient-dense food to meet consumer demand. Pesticides not only induce various diseases—there are more than 26 million human pesticide poisonings and about 220,000 deaths per year worldwide—but they can also affect biodiversity by killing weeds and insects, something which has negative impacts further up the food chain (Mateo-Sagasta, Zadeh and Turral, 2018). In addition, the process of food production and distribution is a multi-step system from farm to fork, with the potential of food contamination at any or even multiple stages en route, including food-borne pollution from chemical contamination by agriculture and aquaculture, food packaging, and disinfection (Garvey, 2019).

All of these could be accumulable pollutants with the potential to be biomagnified, that is to say, have their concentration increased within organisms as they are passed to higher levels in the food chain(s). Accumulable pollutants are transmitted through trophic interactions, being spread in the community depending on the structure of the food web (Garay-Narváez, et al., 2013). Another example is the mercury that comes from burning coal, which also ends up in the food chain and which threatens the development of the brain and nervous system (WHO, 2009).

What are the effects of releasing man-made chemicals into the environment?

How might these influence ecosystem health, and in turn, what impact could this have on global nitrogen cycling (for example, by changing the makeup of soil ecosystems)?

(Muñoz and Gladek, 2017)

As the world has now entered the "Anthropocene", an era in which human activities significantly impact Earth system functioning, including the profound, and almost omnipresent, impact of agriculture on the environment, two planetary boundaries—biosphere integrity and biogeochemical flows—have been fully transgressed, and agriculture has been the major driver of the transgression (Campbell et al., 2017). Reducing the environmental footprint of agriculture and food systems to stop them exceeding planetary boundaries, negatively influencing nitrogen and phosphorous flows, and causing loss of biodiversity, excess water consumption and GHG emissions, is utterly essential. This is especially so as the food-producing systems around the world are changing rapidly, with profound implications for diets and food consumption outcomes (Li, 2017a). As Li (2017a, p. 9009) states:

> "*Apparently, today's food system is on an unsustainable course with the problem beginning with and being driven by industrialized production of both crops and animals, due to reliance on the intensive use of nonrenewable and hard-to-renew resources—soil, antibiotics, freshwater and fossil fuels on one end and produced excess wastes and pollutions on the other (Wallinga 2009), plus further constraints with the confluence of population, economic development and environmental pressures resulting from increased globalization and industrialization that also pose an increasingly resource-constrained world (Johnston et al. 2014). For those reasons, eco-friendly food products and sustainable diets should be an integral part of the concept under the ecological public health model.*"

Otherwise, as in unified growth theory, we begin in a Malthusian world in which improvements in technology can raise living standards temporarily, reducing death rates, but in which population growth then puts pressure on agriculture which leads to starvation until equilibrium is reestablished (Canning, 2011).

> *'[…] soils that are degraded, aquifers that are depleted, and ecosystems that are destroyed in the name of raising incomes today can jeopardize the prospects for earning income tomorrow."*
>
> *The World Bank Report, 1992 (McMichael, 1994, p. xiii).*

The Planetary Boundaries (PB) framework represents a significant advance in specifying the ecological constraints on human development. As specified by Rockström's studies in 2009 and Steffen's studies in 2015, it conceptualizes the ecological limits of human development and the risks posed by unsustainable production and consumption. It is widely accepted that for human activities to be sustainable, we must respect such ecological constraints regarding what we can do on our planet (Clift et al., 2017). Impacts on the different system components act in synergistic ways that creating feedback and cascading effects on other components; those interactions may then push the Earth system towards multiple tipping points after which planetary health deteriorates at an increasing speed (Gupta et al., 2019). Climate change may also alter human exposure to chemicals that will vary widely according to their specific properties and chemical combinations, soil and water conditions, wind patterns, topography, land use, level of development, and human population characteristics (WHO, 2009).

Many pollinating species have declined in abundance, or are threatened by chemical use and agricultural expansion, putting the production of 75 percent of our food crops at risk (UN, 2019b). As Albert Einstein stated: “If the bee disappeared off the surface of the globe then man would only have four years of life left. No more bees, no more pollination, no more plants, no more animals, no more man” (quoted in Scholz, 2011, p. 17). Indeed honey bees appear in the fossil record at least by the end of the Oligocene, 25 million years ago, and pollination by insects is a critical ecosystem service that supports reproduction of a large proportion of plant species, especially in the tropics (Schowalter, 2013). As pollinators, bees play a part in every aspect of the ecosystem. They support the growth of trees, flowers, and other plants, which serve as food and shelter for creatures large and small. Bees contribute to complex, interconnected ecosystems that allow a diverse number of different species to co-exist. On the 20th December 2017, the United Nations General Assembly adopted a resolution declaring 20th May World Bee Day for acknowledging the role of bees and other pollinators for the ecosystem. It was also in honor of Anton Janša, the pioneer of modern apiculture, who was born on that day back in 1734 (FAO, 2018).

Once again, it is most probable that the promotion of a healthy sustainable diet should have far greater emphasis on prevention of the adverse health consequences of dietary-related NCDs, as well as on environmental sustainability. This is especially so, as Popkin (2002) suggested that the structure of the diet has shifted markedly as populations have urbanized. Major global dietary shifts across the globe corresponded with large increases in the consumption of caloric beverages and snacking, along with the increased intake of ultra-processed foods and use of precooked foods and refined carbohydrates, with a simultaneous reduction in the intake of fruits, vegetables and legumes (Popkin, 2011).

Under such circumstances, the extended new stage of nutritional transition detailed in Pattern 6 of Figure 4-9, which shows the necessity of dietary changes towards sustainability, must be our collective focus. Contained within this concept of a sustainable diet is in an attempt to foster opportunities for healthy practices, choices and lifestyle/behavior. And the ultimate concept of ecological public health also concerns all these very interwoven relationships of food, health and environmental sustainability as well (Li, 2016b). Sustainable food systems are indeed essential for meeting nutritional requirements, limiting environmental impacts, and reducing animal welfare loss. Within them lies significant room to reduce the intake of animal protein; thus alternative diets such as the Mediterranean, pescatarian, or vegetarian, offer those benefits, being characterized as they are by lower meat consumption and higher consumption of vegetables, fungi-based plants and fruits (Scherer, Behrens and Tukker, 2019).

Pesco-vegetarianism or pescatarianism is probably another future trend of dietary choice, provided eco-aquaculture practices are applied in the relevant food-producing systems. To address rising food demands, a major shift towards sustainable aquaculture is needed, as aquaculture makes use of 600 freshwater and marine species from all trophic levels (Whitmee et al., 2015). Rigorous governance of aquatic ecosystems is of significance for protecting marine biodiversity as well as ensuring ecosystem functions and continued future supply of wild seafood (Willett et al., 2019).

> *"Hurt not the Earth, neither the sea, nor the trees."*
>
> *Revelation **7:3**, the Holy Bible*

The growing academic recognition of environmental degradation and loss of biodiversity is directing international concern to sustainability in all its forms, including diets with linkages among agriculture, biodiversity, nutrition, food production, food consumption and the environment; thus health professionals should recognize the need for expanding their professional roles under this paradigm shift by reconceptualizing towards a holistic vision of global public health amongst humans, animals and the planet (Li, 2016b).

Currently, global dietary trends are a problem from both a public health and a sustainability perspective. The challenges of improving the food system in the 21st century will require systemic approaches that take full account of the social, economic, ecological and evolutionary factors that are currently under debate concerning consumption of a healthy and safe diet, food security, animal welfare, and preserving the environment and its resources. Therefore efforts to build the human capacity of workforces are needed beyond a single dimension. That is to say, education of this evolving role which integrates multiple parts of virtuous trends of dietary transition to all disciplines of nutritional health, medicine, nursing and other allied health fields, is indeed absolutely indispensable for supporting sustainable development in healthcare in the 21st century (Li, 2016b).

"Only after the last tree has been cut down,
Only after the last river has been poisoned,
Only after the last fish has been caught,
Only then will you find that money cannot be eaten."

Cree Indian Prophecy (Lambin, 2012)

Conclusion

Hippocrates, a Greek physician of the classical period, had already recognized that health and place are causally related and that environmental factors affect the distribution of disease. In fact, various ancient cultures dating back to the third century BC made reference to the relationship between environment and health, according to Chinese medical texts of the era (Davies, Bowman, Davies and Selinus, 2013). Hippocrates is often described as understanding that "health conditions, body types, and personalities are directly attributed to environmental factors, especially climate" as in the Hippocratic Corpus entitled "On Airs, Waters, and Places", which is an early proponent of environmental determinism (Anthamatten and Hazen, 2011).

Today, climate change threatens the basic elements of life for people around the world, including the potential implications for access to water, food, health and well-being, and use of land and the environment (Stern, 2008). In fact, most of the key environmental threats have profound cascading consequences on our air, water, soil, biodiversity, land and food. We exist as part of a web of living things, wholly dependent on a paper-thin envelope of soil, water, and air—without those, we perish, which is to the history of those life-support systems that we now turn (Rhodes, 2012).

All of these human impacts are so fundamental to the functioning of the Earth system that scientists have declared a new geological epoch of the Anthropocene that further reflects these impacts and changes. One of its key aspects is its global and pervasive nature, that is to say, its 'omnipresence'. Indeed, the manifold aspects of change go beyond just climate change, but affect biodiversity and global biogeochemical cycles (Dolman, 2019), together with anthropogenic pollutions and depletions in the quality of the air we breathe, water we drink and food we eat.

In the face of this reality—that our species is living on a finite planet with finite resources and a finite ecological carrying capacity—the continuing success of human society and social systems depends fundamentally on the preservation of the overall productivity, health, and long term sustainability of the ecosystems and environmental services that underpin and supply many of the most basic components of human welfare such as a healthy biodiversity, productive soils, clean water, and clean air (Environmental Pillar, 2012).

Sustainability involves Earth's ability to continue to supply our basic needs—food, soil, water, air, energy, and minerals (Rhodes, 2012). It is a perspective that is aware of the dominant threat to our health over the next century, aware of the ecological determinants of global public health effects of the transitional risks from those profound changes, and also aware of the need to be further translating and redefining our worldview to face up to the catastrophic problems of the Anthropocene. The conceptual diversity underpinning sustainability arises from the very basic needs of air, water, soil and food, as well as its understanding that these basic needs are in fact outcomes derived from complex interactions. The sustainable management of our eco-environments in relation to our health in the Anthropocene can only come through in-depth understanding of ecological principles. The subsequent challenges to our collective wellbeing require a paradigm shift towards emerging ecological public health movements.

We are living in an increasingly globalized world, using the past to inform the future, and as a result of this complex human impact on the Earth system throughout historical time, the human species has exhibited a tremendous ability to transform its environment. We now have the opportunity to alter (or possible adjust) our environment with a new approach moves towards integrative ecological public health paradigms as the intellectual foundation for understanding the transitional risks being imposed through the changing global ecological determinants under this age of environmental and climate mediated health risks in the Anthropocene.

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CHAPTER 5

A PARADIGM IN TRANSITION FOR ECOLOGICAL PUBLIC HEALTH IN THE ANTHROPOCENE

The Anthropocene is a reminder that the Holocene, during which complex human societies developed, was a stable and accommodating environment. However, the world is constantly changing and different approaches to public health have also needed to be adjusted in order to accommodate the transitional needs of arising situations. As we go any further into the Anthropocene, we are risk-driving the Earth system onto a trajectory toward more hostile states from which we cannot easily return, especially noticing the existential global environment shows clear signs of deterioration (Steffen et al., 2011). With the basic premise that ecological thinking, human health, and their determinants are interrelated, for this reason different determinants of health lead to different patterns in the burden of diseases (Li, 2017a).

Williams (2017) has investigated and questioned how we will live within the Earth's carrying capacity under this new epoch of the "Anthropocene", with its dire implications of ecosystem collapse for human wellbeing. Ironically the health sector has been slow to respond to the crises. Therefore, this inactivity, coupled with the increasing complexity of global, ecological, and human well-being issues, calls for the empowerment of health professionals and practitioners in order to address our beliefs about the nature of reality and its meanings of human-ecological well-being. An epistemological shift is therefore required to address the ecological determinants of global public health; as this will provide the basis for the necessary paradigm shift.

Yet again, most catastrophes, calamities, and disasters have certain characteristics that condition the response of public health developments and movements. Environmental ecological determinants on global climate change and public health are interlinked with the importance of all forms of sustainable developments, therefore the consideration of the natural environment as an important construct embedded in an ecological approach to health as the contemporary public health paradigm is urgently needed (Li, 2017b). Diseases are often construed as medical conditions that are associated with specific symptoms and signs, and disease concepts represent the relations among the symptoms, causes and treatments, which tend to focus on illness treatment over prevention. In contrast, as a result of the needs of ecological public health under this global environmental and climate crisis in the Anthropocene *per se*, proactive efforts of even greater concern to preserve our wellness through the support of sustainable health developments are the central focus on this paradigm in transition.

It is, therefore, highly recommended that we proactively shift this emphasis on sustainable health developments by helping people to take more responsibility for their own health. The ecological approach to health issues and ecological models of intervention have become distinctive features of disease prevention and health promotion through this concept of ecological public health. Therefore, endorsing the need for more complex theorization in order to capture fully the causal web of determinants and lead us to positive health behaviors and outcomes (Richard, Gauvin and Raine, 2011).

But it also means healthcare professionals and organizations should take a leadership role in making healthy, low-carbon lifestyles possible for everyone, and this is a challenge on which work has barely begun (SDU of NHS, 2009). There has never been a more pressing need for the intersection of nursing philosophy and ecology than at this current juncture of our planet's existence. Those in the field of nursing possess an understanding of humanity as interconnected and interdependent, seeing health as a set of holistic imperatives to procure wellbeing, and in fact these pillars are no longer optional extras in nurses' professional lives (Rosa et al., 2019).

What is needed "is not a slight reform of our present society, but a substantial reorientation of our whole civilization" (Naess 1989) (quoted in Keller, 2008). It has been highlighted that to sustain modern human society we will continue to need the resources of nature that, throughout history, have allowed us to thrive (WWF, 2018). Implementing ecological public health approaches to disease management and prevention, as well as to achieve wellness through sustainable health developments, is the current proposed paradigm shift, which would form the central basis of new waves for public health movements in order to support ecological integrity during the Anthropocene. This definitely requires health professionals' capacity building to foster and expand these sustainable orientations. The well-being and flourishing of human and non-human life on Earth have value in of themselves, i.e., have intrinsic value and inherent worth, as their value is independent of the usefulness of the non-human world, however, for human purposes.

Therefore, the reorientation of this parameter toward a perspective of health and well-being requires a deeper sense of the relations and infinity interlinkages of human and ecosystem health. Ecosystem health and environmental health are not exactly synonymous, as ecosystem health pertains to the sustainability of ecosystem functions in the presence of human activities; its focus is on the maintenance of ecological functions so as to avoid potential adverse effects on renewable resources (such as fisheries) and on human health (through disruption of food, or increased exposure to ecology of diseases). Its ultimate focus is on sustainable livelihoods and cultural survival (The World Bank, 2006).

During the 21st century, we are witnessing globalization not only of society and the economy, but also of environmental [and climate] change, as the degradation of any ecosystem affects societies and human health globally (Asakura et al., 2015). Given such a significant connection, sustainability has become a widely shared goal with different interactions involving economic, social and natural environmental factors (Hammond et al., 1995). The ecological approach is much broader than former ecological models and represents a unique way of looking at the world by involving more determinants at higher levels of influence, which has become the greater integration of the constitutive components of the ecological approach that offer promise for advancing knowledge (Richard, Gauvin and Raine, 2011). Seymour (2016) has revealed, humans are in many ways linked with the natural environment and our health benefits are associated with the sustainability of natural resources. Evidentially, the evidence also shows a tremendous increase in the kinds and numbers of diseases which are brought about directly by pollution and poisoning of mankind's environment (Li, 2018b). Therefore it is highly recommended that ecological health be integrated into pre-existing biopsychosocial medicine, given the fundamental importance of ecology to medicine (Li, 2018b). In this context, this is an accurate representation of the latest consistent trends towards emerging ecological public health education.

Thus only focusing on bio-medical human health is not enough, what we require is holistic systems thinking which would provide a sustainable platform for strengthening sustainable concepts in health developments as the primary means and foundations of an efficacious response to the changing demands of the healthcare environment. Sustainable healthcare education and planetary health literacy are required to recognize the health effects of environmental and climate change, in addition to the interrelated concepts between ecosystems and human health. They are the skills and knowledge needed to reduce the vicious cycle in the burden of healthcare systems. In fact, this issue is particularly relevant for unifying the codependent changing health demands, i.e., for articulating and connecting multiple concepts regarding the changing demands of sustainable health developments in relation to the environment as a whole. Such a holistic approach would be superior to looking at any single aspect in isolation.

Sustainable Health as the Challenge

Scientific understanding regarding the origins of disease has continuously advanced our knowledge and the necessary public health approaches and practices at different stages throughout the history of public health developments (Li, 2017b). The task of public health has always been to interpret and respond to the effects of major social and environmental change on human health, including the development of urbanism, industrialization, globalization and now planetary environmental changes. As the Australian scientist and professor Fran Baum has noted, if public health is to consider its full responsibility to the health of the public, it has no choice but to give major consideration to global sustainability (Brown et al., 2013). On that basis, these scientific advances should lead to the movements of public health in transition towards an ecological view of health as the relevant approach for disease prevention and wellness, and to one which considers the interrelationships in the concepts of disease and health that originating from the arising impacts of environmental and climate mediated health risks. Ill health in particular became a dire result of industrialization in the 19th and 20th centuries. Consequently, today ecological thinking has become central, simply because the interconnection of human and ecosystems health is now self-evident.

This is the modern manifestation of a long-established approach to knowledge, as ecological thinking helps public health by accepting the normality of complex interactions while also explaining the necessity of multiple rather than single interventions or actions (Rayner and Lang, 2015). Knowledge is one of the most strategic tools in reducing health problems in any environment as it allows us to understand what is harmful, why it is harmful, and possibly how to avoid such harm (Portier et al., 2010). The purpose of knowledge is action. Now more than ever, education has a critical role to play, not only in providing learners with the knowledge and skills to address these challenges, but also in promoting the values that will instill respect and responsibility towards others and the planet itself (UNECE, 2016). This idea endures because it captures the essence of the problems of environmental protection and development that confront the modern world, which also resonates with people's sense of sustainability in terms of population, urbanization, resources, health and governance (Holden et al., 2018). Hence, there is an urgent need for a new conception of health which cannot be dissociated from planetary boundaries, because the reality is that globalization, urbanization, climate change, biodiversity degradation and excessive use of chemicals are all fueling a crisis that threatens our existence intensively (De Paula, 2018).

Concepts of health and disease are significant to the developments of public health, as they influence its interventional strategies and measures of how to respond to changing health needs accordingly. In this regard, concepts of health and disease require the latest definitions, in addition to the knowledge from the historical perspective of its development, as such concepts possess accumulative value as time goes by, providing new insights, facts and evidence. This is the benefit of scientific advancement, as it unfolds our understandings, supplements or replaces old definitions, and/or makes suggestions for different ones entirely.

> Because we have polluted our eco-environments, the air we breathe, the food we eat and the water we drink, which in turn has imposed unprecedented effects on our public health with adverse ecological impacts and mediated health threats…
>
> ***Are we going to lose our capacity to sustain our life to the full potential of sustainable health developments under this new epoch of the Anthropocene?***

The emphasis on applying ecological principles to both human health and planetary health for global eco-environments underscores their interdependencies, and indeed is meant to provide a means for achieving broader goals of sustainable health developments. Reflections from different stages of epidemiological transition in association with public health developments are essential to unfold epistemological knowledge and understanding through scholastic dialogue. Such dialogue should call for professional organizations and all health professionals to add their voices and support the current changing needs for a paradigm shift under the throes of the Anthropocene. Indeed this is the greatest challenge for the ecological public health movements towards the 22nd century.

One of our concerns when identifying the concepts of disease and health from global and ecological determinants is helping us unfold a scientific understanding about how to further analyze those determinants and provide the basis for effective ecological public health developments, while incorporating synergistic strategies as part of the response and subsequent intervention to counter the increasing health threats in this new epoch. In this regard, the evolving concepts of health are therefore focused on the underlying causes of global ecological determinants of health, illness and disease from multiple perspectives. That focus has given rise to the relationship between ecological principles and human health, as well as the justifiable significance of planetary health for our global eco-environments. The 'ecological determinants of health and disease' is a broad term for such highly complex health issues that come from combinations of many disciplines. Brought together they then become a body of evidence with which to understand the unprecedented challenges for sustaining our life to its full potential towards sustainable health developments.

These ecological determinants emphasize the interdependent relations amongst environmental systems that can affect human health within and between different domains and levels, as well as interact along complex and dynamic pathways to produce health through the components of physical, biological and psychosocial environments. These environments include (adapted from Li, 2017a, pp. 9004 - 9005):

- *The physical: air, water, soil, housing, climate, geography, heat, light, noise, debris, radiation, etc.*
- *The biological: humans, viruses, microbial agents, insects, rodents, animals, plants, etc.*
- *The psychosocial: cultural values, customs, beliefs, habits, attitudes, morals, religion, education, lifestyles, community life, health services, social and political organizations, etc.*

Apart from the above categories, the other significant concerns of global ecological determinants include: climate change, stratospheric ozone depletion, land degradation, loss of biodiversity, changes in biogeochemical flows and eutrophication, anthropogenic pollutions, and freshwater depletion, together with stresses on food-producing systems.

These changes may lead to environmental scarcities, for instance, current patterns of water use are unsustainable, with rapidly declining levels in the quantity and quality of surface and ground water stores (Schwartz, Parker, Glass and Hu, 2006). This is part of a major challenge for ecological public health, in which actions have to be taken towards understanding the existing situations that includes the actual and potential health threats from global environmental and climate mediated risks. Will humanity get its comeuppance in the form of a future environmental crisis? The multiple crises of climate change, land degradation, freshwater scarcity, and loss of biodiversity continue to deepen, while the fact that

Earth's natural resources are finite becomes ever starker (Sachs, 2015). For this reason, the current focus on the ecological determinants of health is bolstered by a wide-range of scientific evidence regarding the many transitional health risks arising from those ecological and global health determinants. A summary of this is also presented in Figure 2-2. As seen in the Stern Review, published by Nicholas Stern (chair of the Grantham Research Institute on Climate Change and the Environment at the London School of Economics) in 2006, irreversible losses of ecosystems and extinction of a significant fraction of species will be affected by temperature change. Figure 5-1 details these projections:

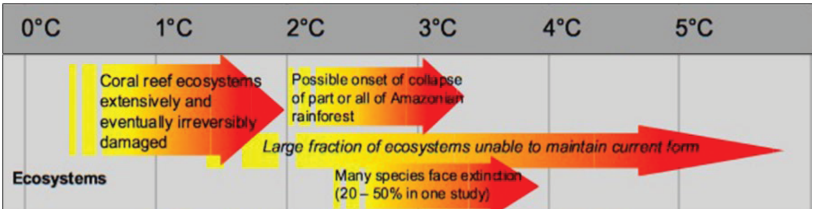

Figure 5-1: Ecosystems are being affected with temperature change, as projected in the Stern Review (Adapted from Figure 13.4 in Stern [2006, p. 294]).

It shows more catastrophic effects directly and/or indirectly arising from climate change, with combinations amongst some of the major ecological determinants. Godard's (2008) analysis of the report declares that the major and lasting actual and potential damage is in no way unavoidable, however, prevention through reducing, mitigating and/or slowing down these processes is one of the options remaining to us.

Therefore, we must focus on stabilizing the climate and treating the environment kindly for the development of our own civilizations. This focus must be supported by and grounded in the scientific understandings that: (i) humanity is the main driver of systemic change; (ii) we are seeing a dangerous deviation from the stable patterns of the previous epoch, the Holocene; and (iii) a new point of equilibrium in the Earth System must be reached by humanity (Franchini, Voila and Barros-Platiau, 2017). Transitions in health under the throes of this current epoch are the greatest challenges towards ecological public health and sustainable health developments. The growing urgency of this global environmental and climate crisis with increasing scientific evidence reflects how critical caring responses are required in all their crucial dimensions. The public health commitment to giving professional significance to current and future generations' health through this transition is therefore absolutely indispensable. The below pledges are specifically proposed to encompass these growing challenges and move us towards synergistical understandings of a paradigm in transition for ecological public health movements. They incorporate a knowledge-to-action mindset, deeming necessary:

1. A sustainable health development model that shows this interrelationship with its possible resultant dynamics under this new changing global context.
2. Conceptual engagement of transitions in health under the throes of the Anthropocene.
3. The Triple New Priorities for a Paradigm in Transition.
4. The "unfinished transformational agendas" for empowering the "triple new priorities" for this age of environmental and climate mediated health risks in the Anthropocene.
5. A paradigm in transition under the "Triple New Epochs" – the essence of the requirements for public health theory and practice in this new changing global context for sustainable concepts in health developments.
6. The proposed "Twelve Ecological Public Health Principles".
7. The necessity of ecological public health movements in the Anthropocene.

The predisposing and influential factors that affect the required sustainable health transition are of great significance, and deserve comprehensive review and analysis. The way forward is to entail scientific justifications from multiple perspectives ranging from various key concepts in transition to engage creative, innovative and knowledge-based approaches to the arising health-related problems on a theoretical and conceptual basis synergistically. This should be considered absolutely essential, otherwise, the growing burden of healthcare services in the health system will undoubtedly be driven to rise continuously in an unsustainable manner.

1. A Sustainable Health Development Model

Sustainable health is a common challenge for all of us. This is because our health and wellbeing would not able to be sustained under all of the actual and potential transitional risks imposed directly and/or indirectly by the unprecedented global environmental and climate change crisis of the Anthropocene. The best approach, therefore, must utilize integrative systems thinking, considering the rapidly changing healthcare boundaries due to the growing global environmental and climate mediated health risks. As one of the distinctive characteristics in the notion of public health, reliance is focused on its intrinsic orientation toward outcomes (Siegel and Merritt, 2019). Thus, a new focus on scientific thinking is needed concerning the ecological views of health. Such a focus would support the continuum of sustainable health developments by reducing the adverse impacts of the transitional risks. This is simply because sustainable healthcare would only be possible in parallel with sustainable health developments applied synergistically in transition. This prerequisite would favor a paradigmatic shift from a bio-medical disease-oriented model of health towards sustainable transitions in health.

Especially now that we are facing multiple environmental and climate mediated health threats, a conceptual key recognizing the interconnectedness needed to sustain and maintain our human health is the core focus. Such a conceptual key for a meaningful and context-specific focus is proposed in Figure 5-2, which gives a strong argument that a "Sustainable Development Health Model" can be adopted towards a sustainable future in healthcare by reducing transitional risks and optimizing sustainable health developments.

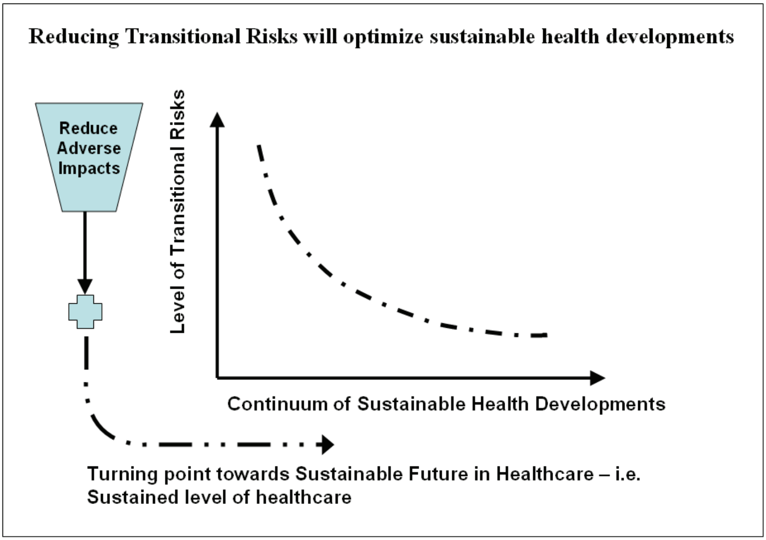

Figure 5-2: A sustainable health development model.

Its central idea is embedded within an integral part of ecological public health theory and practice in this new and changing global context, in that it indicates the adverse impacts of transitional risks and their correlation to the continuum of sustainable health developments. In this connection, the significant turning point towards future sustainable healthcare can only be achieved by reducing adverse impacts through lowering the level of transitional health risks. Figure 5-2 presents a sustainable health development model that shows this interrelationship with its possible resultant dynamics under this new changing global context of the Anthropocene.

2. Transitions in Health under the Throes of the Anthropocene

Perhaps, the question of greatest concern is what propels such transitions in health. The matter is certainly one of the greatest challenges for sustainable health development. Consequently, domains of learning and performance paths to empower and facilitate this direction are focused on in the following steps:

- ✓ *Knowledge obtained* – through evolving concepts of health with an understanding of the significance of applying ecological principles to human health
- ✓ *Synthesis generated* – for human health is interrelated with planetary health and global eco-environments
- ✓ *Analysis made* – to understand the importance of the ecological determinants of health and disease and their dynamics, as well as their impact on human survival
- ✓ *Comprehension developed* – challenges of ecological public health movements for sustainable transitions in health under the throes of the Anthropocene through the reflections from epidemiologic transition, specifically through encounters with transitional health risks imposed under the global environmental and climate crises

This context-dependent information contains some of the important steps and milestones for our scientific understandings from the arising mediated health risks we are facing (and will face) during the Anthropocene. Henceforth, the ecological nature of health must be recognized through this knowledge path, including ecology, as that provides a way of looking at any system by focusing on the interrelationships and the interdependencies both within and between the system under its broader environment for good human health to be optimized (Townsend and Mahoney, 2004). The following chart, Figure 5-

3, summarizes this conceptual engagement of transitions in health under the throes of the Anthropocene as the greatest challenges of ecological public health in terms of its supports for sustainable health developments to their full potential.

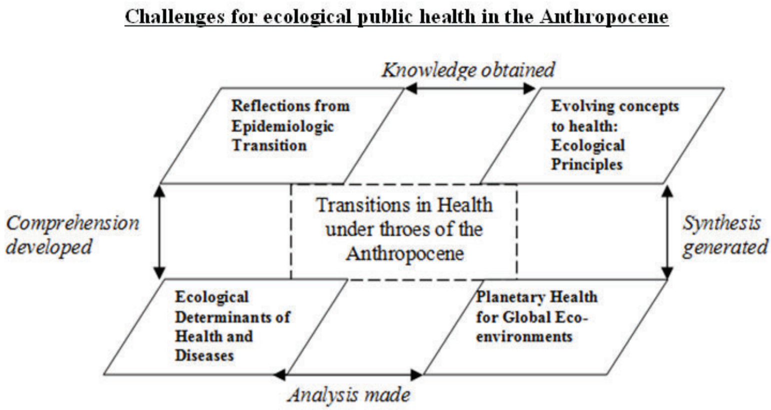

Figure 5-3: Transitions in health under the throes of the Anthropocene as the greatest challenges of ecological public health movements for sustainable health developments.

The underlying complex processes to sustain human health include understanding the changing demands in the healthcare environment and its concepts of healthcare reform for the ecological dimensions in maintaining our health fitness and wellness. Understanding the complex, direct and indirect links of the related concepts and their diffuse benefits begins from cure to care, and means recognizing the fundamental legacy-based value that serves as the turning point towards future sustainable healthcare. The other significant key means of achieving this is creating an educational platform with the necessary resources to prepare our changing health paradigm in transition, together with building professional capacities as the new priorities for this trend of demands.

3. 'Triple New Priorities' for a Paradigm in Transition

Health is crucial for sustainable human development, and insofar as sustainable health developments are concerned, the idea of proposing these "Triple New Priorities" is specifically formulated as part of a plan of action for this paradigm in transition. The "Triple New Priorities" are meant to encourage and support the paradigm in transition through the 'triple' emphasis on: (1) "Structures" for ecological public health education priority; (2) "Processes" to understand and recognize global environmental priority for planetary health; and (3) "Outcomes" targeting the prioritization of sustainable health developments. Figure 5-4 shows the interconnections as projected in a chart entitled "The Triple New Priorities for a Paradigm in Transition". From a knowledge-to-action perspective as the central focus of this framework seeking to make adaptive changes, and these 'triple new priorities' are proposed as essential supports and advocate for a paradigm in transition.

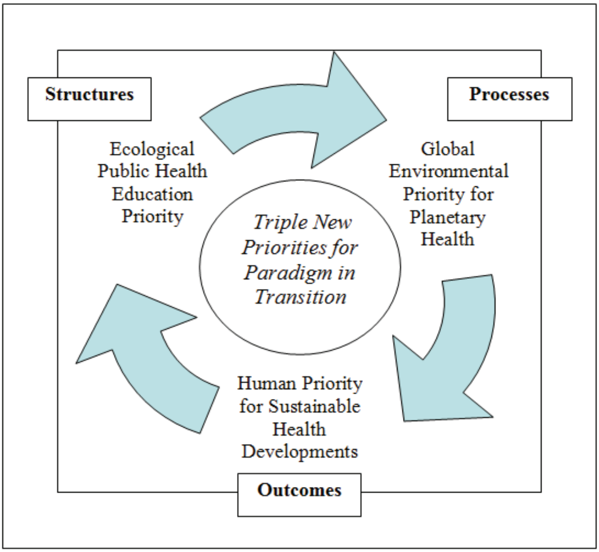

Figure 5-4: The Triple New Priorities for a paradigm in transition.

The totality of interrelations is attained through its 'structures', 'processes' and 'outcomes', operationalizing an awareness that is contained within scientific explanations of the complex old and new challenges facing current ecological public health developments. This is a shared vision for ecological public health education as in the 'structures' that required to sustain the 'processes' of change through empowering scientific understandings of global environmental priority for planetary health. It further aims to drive the quality 'outcomes' for sustainable health developments as an integral part of this transformational vision. This current proposal is not just a basis for scholastic dialogue but seeks to establish points of reference that convey how such a rapid and chaotic transformation to our global habitat happened, and the nature of its actual and potential health threats that our generations will inevitably face if we don't act. These "Triple New Priorities" seek to undergo a complementary process from knowledge-to-action to form part of the embracement of the "unfinished transformational agendas" which will make this shared vision a reality.

> "Knowledge implies the necessity for action. Concern, when based upon knowledge, is an empty emotion unless it becomes part of action."
>
> (Leo Kartman, 1967, p. 744)

4. Unfinished Transformational Agendas

Achieving the suggested unfinished transformational agendas and the "triple new priorities" represents the evolution of ecological public health needs. As the 21st century moves forward, nursing and health professionals must—by obligation and with renewed spirit—undertake such a journey towards the future necessity of our profession. A global paradigm shift depends on effective communication and public understandings to share the paramount task of shedding light on mental and societal models, value systems and individual behaviors, which are at the core of change, allowing humans and nature to coexist and thrive (Spinozzi and Mazzanti, 2018). As both human health and diseases are determined by many complex factors, concepts of health are indeed defined in a very broad sense, especially different focuses have different meanings or set forth different boundaries in a particular field of concern or in relation to the particular health issues and/or determinants in question. This has become more true as our understanding has developed regarding the correlation of the complex systems and factors involved, particularly given the ecological public health developments in conjunction with the ecological determinants of health in this 21st century (Li, 2017a).

Li (2018b) believes that environmental and climate mediated health risks have increasingly become a priority for our health given their extensive consequences. To build a sustainable future is therefore a central plank of public health. It entails reconnecting the value of the environment and public health for our sustainable benefits, as this ecological thinking helps public health by accepting the normality of complex interactions that must coexist, especially seeing sustainable health development is one of the most critical issues facing our global society. This age of environmental and climate mediated health risks is now emerging as the latest stage of epidemiological transition in the Anthropocene, in which the underlying determinants are the driving forces in these changing patterns of epidemiological and health transitions from multi-perspectives of public health models (Li, 2018a). Yet again, the preceding Figure 2-1 has shown the different paradigm shifts with the changing underlying determinants, hence Model of Ecological Public Health is proposed under the fifth stage of ET, together with its paradigm in transition continually extended across this new epoch of the Anthropocene.

Especially with the human population now exceeding 7 billion and the rapid growth per capita in consumption of goods and services, humanity's growing ecological footprint is altering the planet's land cover, rivers and oceans, climate system, biogeochemical cycles, so thus the functioning of its ecosystems. The resultant effects of this ecological alteration are readily understandable as the global scale of climate change signifies the alteration of Earth's biophysical and ecological systems at the planetary scale (Li, 2017b). In addition, major demographic transformations are taking place that present public health with more new challenges as we face the next decades of the 21st century.

As reference to the work of Professor Steffen and his associates in 2015 reaffirms, global climate change has been driven by society's excessive reliance on fossil fuels and the concurrent spikes in atmospheric GHGe triggered by several Industrial Revolutions in the eighteenth and nineteenth centuries (from about 1760 to sometime between 1820 and 1840), which, in turn, were magnified by the Great Acceleration of economic and urban development following World War II (Wakefield-Rann and Fam, 2018). Indeed, human activity is transforming nearly all of Earth's natural systems (Myers et al., 2013). Climate change and its catastrophic implications for human health represent an increasingly important issue for the healthcare sector; efforts to ensure the healthcare system takes a leadership role amongst such radical change are crucial (SDU of NHS, 2009).

Given the need to better understand the evidence-informed process of responding to climate change and its related health risks, scientists across disciplines, policymakers, global public health practitioner, nursing and all health professionals have a corresponding opportunity—perhaps even a moral imperative—to reconcile worldviews and collaboratively take societal action in working together to share knowledge and resources to build capacities within health systems and communities to address the pressing health concerns (Fielding et al., 2016). In this context, public health professionals are faced with many major challenges, including scientific and technological advances, globalization, demographic transition, and environmental changes (Gebbie, et al., 2003).

Given the enormous complexity of health challenges faced as the world continues to transition to the post-2015 era, no one dares to ignore the full contribution that nursing and health professions can make (Rosa, 2017). The ultimate goal of promoting global public health by applying ecological public health principles is to foster a holistic learning framework milieu to support environmental-sustainability concepts for the linkages of our health and environment, thereby signifying trends of demand in the ever-changing roles and professional practice (Li, 2016). Therefore, healthcare education should provide a knowledge base to prepare nurses for their role towards sustainable healthcare in future, as nurses are the largest group within the field and consequently play a critical role in promoting sustainable development for healthcare (Anaker, Nilsson, Holmner and Elf, 2015).

Global environmental and climate mediated health threats require serial actions synergistically to carry out knowledge-to-action strategies to tackle issues and guide us along the pathways towards sustainable health developments. Thus the emerging paradigm of ecological public health intends to spark mass action with a global campaign for the current unfinished transformational agendas. These proposed transformational agendas, as shown in Figure 5-5, reinforce: (1) sustainable health demands due to the changes of this age; (2) the importance of the role of nursing and health professionals and the necessity of their educational reform as a journey of professionalism; and (3) the support required for an emerging paradigm of ecological public health in this new era of the Anthropocene.

Ultimately, this is to address the importance of an emerging paradigm of ecological public health for the overarching goals of (a) promoting and tackling the threats imposed by this age of environmental and climate crises; (b) expanding the roles of nursing and health professionals throughout this necessary journey of professionalism in need; and (c) developing trends for the necessary ecological public health principles to be embedded into nursing and health studies curricula in order to reshape the significant concept of sustainable health developments under this new epoch of the Anthropocene. Furthermore, a holistic learning framework incorporating as part of these unfinished transformational agendas is utterly critical for such changing health needs; because building the professional capacity towards this direction is absolutely indispensable.

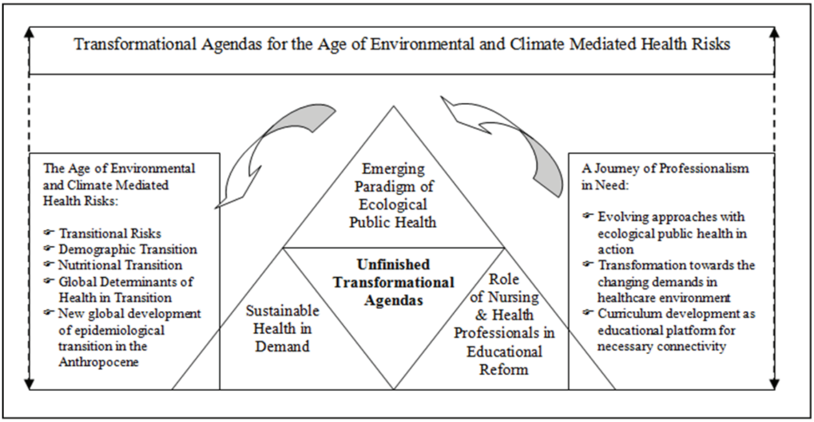

Figure 5-5: Transformational agendas for this age of environmental and climate mediated health risks in the Anthropocene.

In particular, sustainability is universally regarded as coalescing the idea that a building is a system unto itself, a part of other nested systems at multiple scales (Guenther and Vittori, 2008). Therefore, these proposed unfinished transformational agendas are acting, in turn, as the latest wave towards sustainable healthcare systems. They will be of compelling and pervasive relevance to the center stage of healthcare reform complementarily derived from multiple perspectives (revolutionary in their synergy and interfacing) for the next decade of changes, not only in terms of sharing professional development opportunities and obligatory responsibilities, but also in terms of their practical relevance for a paradigm in transition. Henceforth, an understanding of such massive and major determinants influencing the state of our common habitat on this Earth in relation to the professional roles in progression—which concern the fundamental concepts and principles of ecological systems with significant impact on planetary and global eco-environments, together with the consequential effects on human health arising from their interrelationships between epidemiological and ecological transitions—is indeed self-evident (Li, 2017a).

> *"Although valuable linkages do currently exist between the Earth science and public health communities, the limited extent of interdisciplinary cooperation has restricted the ability of scientists and public health workers to solve a range of complex environmental health problems, with the result that the considerable potential for increased knowledge at the interface of Earth science and public health has been only partially*

realized. The linkage of Earth science and public health is not about the relevance of Earth science knowledge to health, or vice versa—rather, the issue addressed here is the generally inadequate appreciation of the potential benefits of this interface and the consequent diminished priority that it is accorded" (National Academy of Sciences, 2007, p. 2).

We should therefore recognize and appreciate that there are five key contemporary predicaments also relevant to our argument which are often divorced from the daily work of healthcare professionals: material inequality, over-population with rising consumption, resource depletion, climate change and loss of biodiversity. In fact, these predicaments are intimately interwoven as integral parts of the global public health system as they play a central role in bringing all forms of life together. Henceforth, a new paradigm in transition is definitely required to tackle the broad changes emanating from these interrelationships: we therefore need a revolution in our health systems (Schroeder, Thompson, Frith and Pencheon, 2013), as the moves toward a sustained level of health will be the turning point for a sustainable future in healthcare (Also see Fig. 5-2).

Under such circumstances, a focus on human health outcomes will probably enable a holistic view to exploring global environmental and climate change-related health impacts, highlighting direct links with disease- or outcome-specific approaches. Most humans develop in a predictable fashion—growing from a fertilized egg to a fetus, newborn, toddler, child, etc., in a way that is fairly well understood—however, environmental effects can be a potent modifier, and people at different stages of life can respond very differently to environmental and climate changes (Portier et al., 2010).

In 2014, the WHO spelled out how human health is affected by changes or disturbances in biodiversity and ecosystem services, illustrating how the natural ecosystem's functioning is indispensable to the wellbeing of all people in the world. Indeed, every disturbance of the eco-environments will prime the subsequent alteration of disease patterns and our human exposure to both these patterns and the subsequent disease outbreaks; this in turn would most likely increase the burden on global public health (Li, 2017a), with possible adverse long-term consequences directly and/or indirectly impacting people across generations. Again, this entails serious implications as to the critical need to improve scientific understandings and implement synergistical strategies to respond, reshape or even reinterpret our changing health needs in terms of sustainable health developments *per se*. As the ecological variables, particularly those relating to the natural environment, cause massive changes or shifts in disease patterns, they invariably overshadow the impact of both medical healthcare and public health systems due to the mediating effects of transitional risks. It is worth remembering that these transitional risks also currently represent only the tip of the iceberg. The drastic consequences are likely to have direct adverse effects on public health globally and across generations, which represents a potential epidemiological time bomb. These are the resultant effects of a health transition that is continuously being affected by this age of global environmental, climate related and epidemiological factors (Li, 2017b). The epidemiological outcome of climate change on the global burden of mediating health threats and transitional risks is surely to be profound and challenging. Thus, ecological public health education reform derived from multiple perspectives collectively, collaboratively, and globally, is absolutely required in order to achieve the ultimate goals inherent to this paradigm in transition. And, to recognize the ongoing renewed public health theory and practice under this new changing global context for supporting sustainable concepts in health developments, which is further reinforced under the following proposed “Triple New Epochs”.

5. A Paradigm in Transition under the “Triple New Epochs”

Historically, the potential adverse health impacts of climate change have been discussed ever since Svante Arrhrenius broached the question of whether the Earth would warm as a result of fossil fuel combustion in 1896. However there was too limited an understanding of the relationships between atmospheric processes and human health impact at that time (Luber and Lemery, 2015). But our society is now confronting its most significant human-induced environmental problem in history with the scientific consensus that anthropogenic climate change is in fact occurring, and that the problems posed by environmental risks to our health and livelihoods of communities across the globe are daunting. Voluminous evidence shows that global climate change is currently having a profound impact on human health, and that it will continue in the future and across generations. It could also possibly act as a “risk multiplier” by amplifying both the exposures that bring about health risks and the vulnerabilities to these same exposures (Luber and Lemery, 2015).

Within this context, the most recent big idea to emerge in the history of the Anthropocene is the concerns of ‘sustainability’ in all respects. It represents the set of challenges posed by the urgent need to harness science and other forms of knowledge in promoting a worldwide transition that enhances human prosperity while protecting the Earth’s life-support systems. Achieving the goal of environmentally sustainable human development under the Anthropocene is no doubt essential for our species (Clark, Crutzen and Schellnhuber, 2004). All the time we can continue to observe dramatic changes in the ecology of the Earth, manifested by novel and potentially catastrophic health consequences through large-scale ecological drivers such as climate change, environmental pollution, disease emergence, and land use change (Aguirre, Ostfeld and Daszak, 2012), and all of which happen in an ever-accelerating process (Bulter, 2016). In recent years in the humanities, a transition in human affairs in response to changes in the Earth System triggered by humankind has been widely recognized, and this transition is about what can we do collectively to reshape our place in Earth's precious web of life in the 21st century and beyond (McLeod, 2018).

One of the utmost important and pressing tasks to adequately respond to the current ecological public health challenges is to prepare healthcare professionals to continue to improve ecological-related health. The extent of this success also depends in large part upon the quality and preparedness of our workforce of healthcare professionals, as well as their competencies on each of those interconnected components. This will be further encompassed by the state of knowledge and understanding of the cause-specific direct and indirect effects from all these underlying processes and their impacts on human health under the following proposed "Triple New Epochs": (1) the new epoch in the Anthropocene, that further propels (2) the new epoch of epidemiological transition in this age of environmental and climate mediated health risks, and therefore requires (3) a new epoch of educational reform through ecological public health education for nursing and health professionals towards future sustainable healthcare. This paradigm in transition under synergistical understandings through the 'triple new epochs' further reflects the necessity of renewed public health theory and practice in this new changing global context. A summary is offered below in Figure 5-6.

The development of scientific and epistemological knowledge with understandings through this synergistical and interwoven "triple new epochs" is not just about short-term health problems but rather dealing with the continuous adverse effects generated from the driving forces of those underlying determinants that are indeed acting as the long-term influential factors. Such resultant mediated adverse effects therefore require us to move into a renewed arena, thus my proposed Model of Ecological Public Health with professional focuses on: (a) the significant impacts of global ecological health determinants; (b) the evolving concept of health; and (c) the interrelations between (a) and (b) regarding the essentialities of planetary health and its eco-environments, in addition to the concepts of epidemiological, demographic, nutritional and health transitions as a whole. As such an approach is particularly relevant for the totality of these emerging challenges, we must recognize that all these aspects are dynamically interacting with each other and driving the growing global environmental and climate crisis. It is now a matter of evidential fact that a new phase of diverging trends of determinants has moved us into this new epoch of global environmental and climate mediated health risks in the Anthropocene.

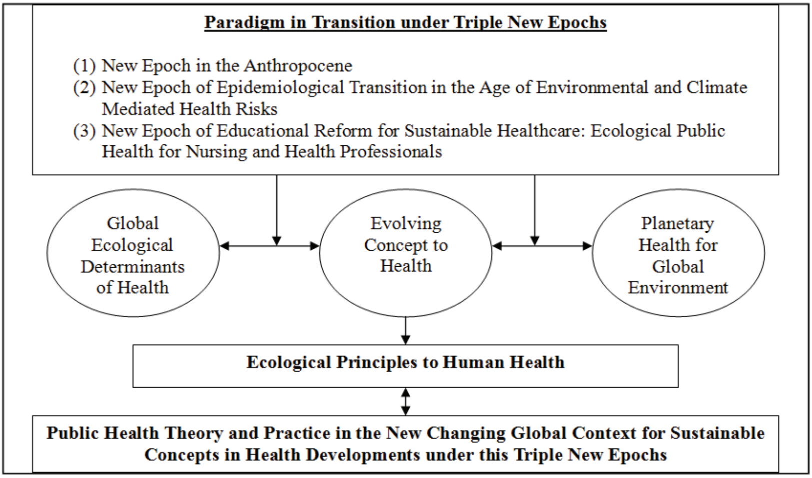

Figure 5-6: The Paradigm in Transition under the Triple New Epochs

Perhaps it is a difficult task to characterize what constitutes well-being and health. However, the evidential facts are the concrete truth and this is a significant reason for the emergence of our ecological views of health that have evolved. The way in which we have structured our societies has made possible major advances for the human species; ultimately, though, these actions are not sustainable and now we have reached the point where the non-sustainability of our actions is becoming the greatest threats to human health (Brousselle and Guerra, 2017). As human health in an era of global environmental change considers the different trajectories of changes, such as urbanization, agricultural intensification, climate change and the increasing pollution of air, water, soil, land and oceans as the vectors of human ill-health. All these factors have become intrinsically connected with the health of the planet in the unifying term "planetary health", which focuses on the significance of environmental sustainability and the impact of environmental degradation on human health (Foster, Cole, Farlow and Petrikova, 2019).

Climate change undermines these eco-environmental determinants of health, encapsulating the full range of acute to long-term transitional risks, including water-, vector- and food-borne infectious diseases; increased risks of EIDs and re-emgerging IDs, as well as increased risks of NCDs. The resultant effect of these adverse combinations with the existing challenges of communicable and non-communicable diseases is predicted to lead to the global burdens of disease being tripled, causing high morbidity and mortality, as well as threatening healthcare facilities and systems (WHO, 2018). We need to fully realize how these planetary ailments impact on human health, with climate change famously described in *The Lancet* as "the biggest global health threat of the 21st century".

> "Understanding environmental and ecological health is a prerequisite to protecting public health."
>
> (USGS Health Forum)

Despite the historical developments of public health and medicine being different, they have the same objective, in terms of improving (and maintaining) health and eliminating disease. As far back as 1920, Charles-Edward Amory Winslow, professor at Yale and a leading figure in the development of the concept of public health, put forth that:

> *"Public health is the science and art of preventing disease, prolonging life and promoting physical health and efficacy through organized community efforts for the sanitation of the environment, the control of communicable infections, the education of the individual in personal hygiene, the organization of medical and nursing services for the early diagnosis and preventive treatment of disease, and the development of social machinery which will ensure every individual in the community a standard of living adequate for the maintenance of health, so organizing these benefits in such a fashion as to enable every citizen to realize his birthright and longevity" (DeLaet and DeLaet, 2012, p. 4).*

However, only the sanitary paradigm was used to combat those problems in the "old" public health stage is insufficient, something probably due to the lack of scientific understanding regarding the ecological principles of human health at that point of time in the nineteenth century. A timeline and snapshot of public health developments further unfolds and reinforces our progress of scientific understandings concerning the importance of renewing ecological public health theory and its necessity under this new changing global context. Its evolution over time is worth exploring briefly:

1. The "old" public health was characterized by three phases:
   a. the sanitary phase (1840s–1870s), especially in the urban slums of European cities, which contained contaminated environments thought to be responsible for major disease epidemics
   b. the preventive phase (1870s–1930s), and
   c. the therapeutic phase (1930s–1970s).
2. A "new" public health emerged in the mid-1970s. The aim of this "new" public health was to shift the focus from an individual to a multi-causal, socio-ecological approach to health, taking into account the interaction of social, environmental, psychosocial and other factors in producing ill health.

After that, the UN's Millennium Ecosystem Assessment identified that severe detriments to population health were arising from global environmental deterioration, and healthcare would as a result play a prominent role in the Millennium Development Goals (Lautensach, 2015). These are the key milestones leading to the emergence of ecosystem approaches to public health thinking, research, and practice that can be traced as a changing process in the evolution of thinking from the "old" public health, through the "new" public health, and onto the "critical" new public health (Dakubo, 2011). Historically, the models of old or new public health were geared towards dealing with the greatest traditional health threats; today however, the greatest threats are intrinsically entangled between our human systems that are comprised of two basic components: (1) the human-created social system that we live within, and (2) the planetary Earth-systems—the habitat of global eco-environments for all forms of beings, including ourselves. Thus the global health challenges of the 21st century must be, in large part, public in nature (DeLaet and DeLaet, 2012). This is especially so, as we are now facing various unprecedented challenges in this new epoch with the realm of public health having shifted to the complex patterning of health and disease with profound implications for the momentous demands needed for achieving eco-environmental sustainability. Henceforth, studies of ecological public health trends under the changing "Triple new epochs" overwhelmingly rely on several different perspectives:

1. Concepts of transition in health, from scientific profiles of demographics to epidemiological and health transitions from different determinants of health across different periods of time in the history of public health developments.
2. Impacts of transitional changes from historical, current and emerging perspectives of ecological change in relation to concepts of disease with actual and potential risks, both direct and indirect.
3. Health consequences in the trends of population growth and urbanization as well as the effects of demographic and nutritional transition.
4. The driving forces of underlying determinants, especially scientific understandings of human-environmental systems from our interactions with the biophysical reality of human existence, as well as the consequential effects of ecological determinants. Both are considered integral parts of evolving concept of health and disease.
5. Planetary health for global and eco-environments in relation to human health in the Anthropocene as the ultimate emerging determinants for the sustainability of all beings across generations.

Thus, the movement of public health theory and practice towards this new changing global context for the evolution of ecological public health needs is absolutely indispensable. Parallel with this reasoning, the importance of public health movements is therefore on the parameters of maintenance of health, and sustainable health developments are then the ultimate ecological public health orientations and concepts in transition for this 21st century. And therefore, my further proposed public health orientations and concepts in transition are absolutely required, and will be further discussed with the new waves of public health movements towards planetary health for our global environments, as an integral part of public health theory and practice in this new changing global context in the next chapter.

Public health is indeed an incredibly broad conception of health that covers a wide range of potential and complicated topics, including the environmental factors, like roads, clean air, and clean water that contribute to the health of whole populations. In fact, the evolution of public health is a continuing process as a result of the severe climate and ecological changes that posing harsh and potentially devastating consequences to our health; these changes are indeed a large part of the threats to health now faced by the world (Tulchinsky and Varavikova, 2014). It has long been known, based upon on cumulative scientific studies, that historical developments of public health are always focused on searching for effective means of preventing diseases and promoting health, something which is applicable to the long-standing public health challenges in their developments at different stages of epidemiological transition throughout the changing health transitions.

The currently proposed "triple new epochs" reviews the necessity of this paradigm in transition, assessing how we reconceptualize disease and how we consider approaching interventions. In doing so it has an influence on our health. Therefore, evolving understanding in the concepts of health and disease is a significant aspect of forming suitable approaches and interventions. The relevant evidence points to the need for understandings of (i) global ecological determinants of health, and (ii) planetary health for the global environments; which in turn means evolving concepts of health as a new inception under this age of environmental and climate mediated health risks, representing the new epoch of epidemiologic transition in the 21st century. Therefore, a new ecological sense of public health is required to support the implied needs of this health transition and to achieve the sustainable concepts in health developments that are the ultimate focus of public health movements in transition during this age (Li, 2018a).

Yet again, there are many scientific investigations which have progressively refined our understanding of the eco-environments as ultimate determinants on human health. This further reflects how concepts of health and diseases are evolved at different stages throughout the history of public health developments, which in turn reinforces how understanding of paradigmatic shifts from multiple perspectives of public health developments in accordance with these changing needs is utterly essential (Li, 2018a). In this connection, we must not sacrifice our nursing sensibilities to lead and co-create the necessary changes, but bring a humanistic and scientifically rooted evidence-based contribution to the forefront through professional capacity building (Rosa, 2017).

Referring back to the last half century means encountering a number of transitions in how society has viewed the relationships between the environment, development, and knowledge in relation to the Anthropocene crisis, forcing humanity to manage consciously a transition toward the sustainable use of the Earth. This realization has gradually begun to sink in with the growing advocates of sustainability (Schellnhuber et al., 2004). Nowadays, one of the major emerging tensions in health transition is to maintain sustainable development for our health.

Sustainable development in health involves maintaining epistemological knowledge and scientific evidence in our concepts of disease (with all its underlying determinants of health), as well as the incorporation of all justifiable requirements for sustainable health and wellness in our living environments. The concept of sustainable health developments goes beyond the health systems, as there are many complex interacting and predisposing factors, together with mediating transitional risks that can affect our human health. Consequentially, we have to look into those complex influential factors in order to take precautions and reduce the level, intensity and severity of those mediated health risks.

Different public health perspectives have been continuously developing in accordance with our changing health needs as an integral part of interventional strategies for promoting human health. The structuring of streamlined and organized efforts is therefore required to evolve the approaches through educational reform and incorporate the concept of sustainable health developments with ecological public health principles as an integral part of renewed public health theory and practice. Specifically, we are now living in an age of rapid and unprecedented planetary change and our health, food and security all depend on the fundamental functioning of ecosystems through efficacious biodiversity. From medical treatments to food production, biodiversity is critical to society and people's well-being; thus to achieve climate and sustainable development commitments and to reverse the loss of nature and biodiversity is critical (Akerlof et al., 2010).

> "The systematic accumulation of knowledge is essential to progress in any profession … however, theory and practice must be constantly interactive. Theory without practice is empty and practice without theory is blind" (Cross, 1981).
>
> (Alligood, 2014, p. 2)

To incorporate and recognize the needs and perspectives of what is necessary today requires understanding the underlying determinants of the driving forces arising from this new epoch of epidemiological transition and its consequential effects. Importantly, knowledge should go with our understanding, recognitions and actions. As Pritchard, Millar and Haddock (2010) believe, the roles that knowledge and "thought with knowledge" play in our lives enable us to have a better understanding and recognitional abilities to characterize justification in relation to knowledge for our intentional actions.

Our initial goal is to better understand the necessity of ecological public health education in order to prepare the workforce of professionals for these changing health needs of essential practice as envisioned over time, and to foster evolving approaches for educational and healthcare reform. Advocacy for nursing and health professionals must also include anticipating and respecting diverse values, beliefs, and cultures on a knowledge-into-action basis in order to highlight the essentiality of global interdependence as a central focus for sustainable health developments across generations. If advocacy of this reform is counted as actualized support for sustainable health developments, public health must find evolving approaches to reach these continuing educational needs in action.

Applying fundamental ecological principles to human health with philosophical and practical reasoning and rationales to serve the evolving needs of public health paradigm and sustain our health development under this global eco-crisis is not just a statement of intentions, but rather represents a set of synergistic actions and interconnected holistic learning frameworks for the attainments of the “triple new priorities” and the “unfinished transformational agendas”. Such a framework shows the overview of ecological public health education should be comprehensive, integrated, and broadly-based to support the changing needs of the rapidly changing public health environment in the Anthropocene. A systematic dynamics of structural factors generated for conceptual progress, as reflected in all aforementioned proposals in this chapter, is meant to be in response to ensuring the completion of the paradigm in transition under these “triple new epochs”. As Li (2018b) envisioned:

> *“[T]he success of public health work depends largely upon the character of the educational program executed [and therefore] [...] health education reform is the key to the process of making this change, through both curriculum development and infusing the concepts of this paradigmatic shift as the holistic mapping of ecological public health principles for sustainable health development in our changing globalized society.”*

There is a need for opportunities and training to cultivate a strategic vision and address the major contemporary challenges that also come with ecological public health education; the deficiencies of embedding ecological public health principles into healthcare education will be adversely affecting the prospects of our sustainable health developments with much broader dimensions. Ecological public health education reform will definitely be a challenge. Thus, universities and health authorities have a pivotal role to play in support of such academic infrastructure, and to guide responses to this conceptual paradigm in transition for emerging ecological public health principles as the global reality for the 21st century.

6. The proposed "Twelve Ecological Public Health Principles"

Evidence of climate change and its impact continues to be accumulated, and it is frequently argued that the consequences of climate change are likely to result in an increased demand on health services, presenting new challenges for them. Strategies should be adopted to address these challenges accordingly (Nichols, et al., 2009). The mission of the public health sphere has long been to investigate and address the impacts of social and environmental change on the public's health; however, now that the ecosystems that support us are so endangered, the sustainability and integrity of our planet must be considered synonymous with the sustainability of humans (Fleming, Tenkate and Could, 2009). Perhaps more important is, yet again to further review its historical facts and their impacts on the current transition in health, which are summarized throughout the previous chapters, inter alia:

1. the limits of planetary boundaries in Figure 1-1;
2. the increasing human anthropogenic influences with indicators from graphical data of socio-economic trends and Earth system trends in Figure 1-2;
3. the global plastic production, use, and fate of polymer resins, synthetic fibers, and additives in Figure 1-4;
4. the exceedance of the effects levels of N_r for ecosystems or human population, and the contribution of N_r to the total effect, relative to other components or causes of the problem as shown in Figure 1-6;
5. the waves of extinctions: from the first mass extinction until now in the midst of the Earth's sixth mass extinction crisis as shown in Figure 1-7;
6. the paradigm shifts of epidemiological and public health in transitions (as in Figure 2-1) with the changing underlying determinants (e.g., the ecological and global health determinants in Figure 2-2) during this age of environmental and climate mediated health risks in the Anthropocene, together with the timeline of historical developments with progressive knowledge of ecological principles in relation to human health as shown in Figure 2-4; and
7. the arising concerns about the public health impacts as illustrated in Figure 3-1, combined with the greatest transitional mediating health threats in the Anthropocene as shown in Figure 4-1.

All of these historical facts reinforces transitions in health under the throes of the Anthropocene as the greatest challenges of ecological public health for sustainable health developments. And therefore, defining a set of ecological public health principles for human health with the changes of this health transition requires a new and emerging paradigm of ecological public health. The need for ecologically sustainable development in public health is an increasingly important environmental, scientific and moral challenge. A confluence of forces is being identified as the promising point for the latest epoch of epidemiological transition under this new age, out of which are unfolding such knowledge-based understandings of the adverse effects arising from the ecological and global health determinants that are affecting our human health, possibly across generations.

Concepts of disease and health are being increasingly recognized in relation to more complex interrelationships and dynamics where health and disease evolve in many diverse ways. Risk factors involved include biological, environmental, ecological, social, cultural and behavioral factors as well as the practices of modern medicine (Li, 2017b). In this vein, Gluckman et al. (2011) indicated that an understanding of the general principles of evolutionary medicine would assist in gaining a fuller understanding and appreciation of why the ultimate causes of human diseases arise; for instance, environmental influences in early life can adapt the fetal trajectory to affect traits in later life through the processes of developmental plasticity and molecular epigenetics. Henceforth, it is sensible to utilize these important ecological principles to promote health sustainability, as we are a part of, not apart from, the Earth's dynamic web of life. For that reason, ecological principles define the normative profiles that arise from evolving forms of understandings in our scientific and epistemological knowledge, in which the relevant differences and normative horizons bring all the vantage points of different perspectives to bear on our enduring understanding of the currently proposed concept of sustainable health developments under this new age in the Anthropocene.

The challenge is to accommodate those relevant differences, in terms of the impacts concerning human health, under the paradigms of ecological public health developments in the divergence and convergence journeys towards ecological public health principles. Ecological public health principles are no exception to this diversity especially under this new epoch, with additional focus on the new and continuing global experience of the current epidemiological transition of this age.

"Public health is the science of improving and protecting the health of entire communities by applying the principles of education, preventative medicine, control and monitoring of environmental dangers, and proper

sanitation. When people help keep the air, water, and land clean, the public is healthier" (Definition of Public Health, 2019).

Because public health tends to be about the big picture of society, it can threaten vested interests; however, it is a difficult time at present and the coming years hold many difficulties: as a result we must dare to reshape the big trends or adverse transitions that already frame the 21st century. The forces of public health must act in refocusing and shaping the conditions that enable good health to flourish (Lang and Rayner, 2012). Therefore, public health and practice in the new changing global context could be interpreted as the starting point of a new phase in the movements of ecological public health transition. My proposed Twelve Ecological Public Health Principles ("Twelve Principles") are specifically formulated for this journey of a paradigm in transition under the aforementioned "triple new epochs".

These twelve principles must propagate an exalted role as a genuine "science- value- and legacy-based" platform on an unshakable theoretical foundation for sustainable public health and attain the status of an art in their humanistic capacity for sustainable caring for the full potentials of well-being. It is exceedingly important to adopt these twelve principles when seeking to understand the key influential factors and their underlying determinants that concern sustainable health developments and the transitional health-related problems. Therefore, it should not be taken for granted that an integrative, coherent and holistic vision will emerge without focusing our efforts on putting forward this proposed principles as an integral part of educational reform and curriculum developments as capacity building for nursing and health professionals. Figure 5-7 presents this proposed "Twelve Ecological Public Health Principles": they are based on the changing needs for reshaping health and promote the new possibility for safeguarding ecological views with responsible actions and/or conduct for ecological public health education. This proposed "Twelve Ecological public health principles" will form the basis of the course of actions with which to overcome the limits in the current scope of public health, all the while retaining its strength. It will culminate, as it has done historically and continuously, in the transformation of understandings of our knowledge of the world in response to transitional health needs, connecting theoretically and practically with our ongoing existence on this planet.

1. Philosophy	To develop a sense of responsibility for ecological public health education and move towards a legacy-based value to sustain health.
2. Values	To enable an ecological and determinants approach for the necessary changes to prevent potential ecological harm and to optimize sustainable health developments.
3. Approaches	To support, guide and enable health professionals to expand their professional roles through a journey of professionalism focused on the unfinished transformational agendas.
4. Roles	To advocate sustainable health needs through ecological principles to human health, imperatively and proactively.
5. Functionalities	To take professional accountability in support of new waves of ecological public health orientations and movements.
6. Holistic conceptual framework	Integrative approaches applied in a balanced way for a conceptual paradigm in transition with focus on integrating ecological public health theory and practice in this new age.
7. Principles of practice	To act on the necessity of preventing destructive maladjustments to our biophysical and man-made environment on Earth, and to delineate a value-based legacy for sustainable healthcare through promotion, maintenance, and restoration of sustainable public health.
8. Journey of attributes	To form the basis of a future vision for humanism in caring, using an illness to wellness continuum proactively designed towards sustained health.
9. Ecological Harmony	Environmental ethics are a dynamic solution for striking a cosmic balance of ecological integrity and harmony with all life forms. This must be done within the virtues of ecological civilizations and a beneficial culture of health practice.
10. From Ego to Eco thinking	To anticipate a sustainable health transition through ecological views of health, i.e., planetary health for global environments and EcoHealth with understanding that nature is comprised of living systems and is vital for coexistence.
11. Sustainable health developments	To promote (a) effective and efficacious directions towards the realm of the paradigmatic shift and (b) re-orientation to connect with integrative "**O**ld", "**N**ew", and "**E**cological" public health perspectives of the "One World" concept with "**ONE**" vision for maintaining sustainable health developments across our future generations.
12. Sustainable healthcare	Value- and legacy-based healthcare with diverse scientific understandings that "prevention is better than curing", in which a healthy eco-environments is a basic need of sustainable caring and common good to sustain our health.

Figure 5-7: The Twelve Ecological Public Health Principles.

These twelve principles reflect the needed combinations of "science-value- and legacy-based" platform for sustainable health and sustainability developments across generations, encapsulating the necessities of a paradigm in transition under this age of global environmental and climate crisis in the Anthropocene. Especially given the global issues comprising the environmental and climate crisis, we are in a new era of public health. A new advocacy and public health movement is urgently needed as climate change is not just an environmental issue but a critical health issue with its global impacts and devastating effects harming people and the environment in many ways. There is no doubt that it will be the biggest environmental challenge that our generation has ever seen (Li, 2017b). Henceforth, ecological public health education with a specific focus on the importance of this proposed twelve principles for sustainable health developments across generations, for now and the future, is utterly indispensable.

As the role of public health is (a) to protect and promote health, (b) prevent disease and injury, and (c) reduce inequalities and adverse impacts on health, the transition to a sustainable, just and healthy future is entirely in line with this situational practice in the Anthropocene. This includes a developmental stage as an integral part for renewing public health theory and practice in this new changing global context. Our hope is to illuminate what is at stake in order to allow the crafting of humane and intelligent responses to living on this human-dominated planet; such responses must withstand intellectual scrutiny and have the capacity to alter our collective behavior in a sustained way (Lewis and Maslin, 2018). The WHO uses numerous data sources and epidemiological models to estimate the worldwide cause-of-death patterns and the general approach to a health transition framework, in which is the characterization and explanation of a set of long-term irreversible and/or substantial social, ecological, cultural, political, and behavioral changes with enduring global significance. In light of this view, ecological public health movements are the roadmap for our current paradigm in transition and a means of connecting us to the needs of this 21st century journey and its copious health threats.

The rationales and purposes of these principles are of significance for introducing the necessary developments towards a "One world concept with One vision", in which "ONE" represents an integration of "**O**ld", "**N**ew", and "**E**cological" public health perspectives, enhancing the notion of "**ONE**" integrated movements in the Anthropocene. The similarities and differences amongst these "**o**ld", "**n**ew" and "**e**cological" public health visions theoretically and empirically mark the disparities and divergent trends in the onset and pace of variations across different stages of epidemiological transition, as influential patterns of mortality and morbidity in association with different determinants of health in transition.

Ultimately, as Osofsky says, the field of planetary health is an optimistic one, as it makes the case that complex relationships between human modification of the environment and human health outcomes can be understood, and thus more thoughtfully and proactively addressed (Seltenrich, 2018). These can also be described as historical trends or the dynamics involved in human history (Defo, 2014). The inceptions of health, disease, and both direct and indirect impacts on well-being of health developments have been affecting, however which also advancing our scientific understandings of this new age of crisis in the Anthropocene.

Thus, the current proposed "unfinished transformational agendas" for empowering "the triple new priorities" under these "triple new epochs" are therefore utterly indispensable. This is a synergistical means that further reinforce the aforementioned notion of a "One world concept with One vision" by integrating "**O**ld", "**N**ew", and "**E**cological" models in order to enhance this latest developmental stage of ecological public health movements in the Anthropocene. This further requires many more innovative ideas of having ecological public health education, together with supports from authorities and universities to influence and advance curriculum developments through educational platforms for nursing and all health professionals. This in turn will also serve as the capacity building blocks for workforce training imbued with the evolutionary ideas of ecological public health movements in the Anthropocene.

7. The Necessity of Ecological Public Health Movements in the Anthropocene

The emergence of global environmental and climate change has encompassed several interconnected phenomena such as global warming, stratospheric ozone attenuation, desertification, resource depletion, species extinction, reduced biodiversity and ecosystem services, and has resulted in serious forms of widespread environmental pollutions. All these phenomena are mostly associated with anthropogenic human activity that is adversely affecting the biosphere of the Earth, and are closely interlinked with transitional risks to our health both directly and indirectly.

The World Health Organization has already announced that climate change is a significant and emerging threat to public health, plus the growing concern that human health is affected by changes or disturbances in biodiversity and ecosystem services (Li, 2017b). The impact of human activities on our planet's natural systems has been intensifying rapidly in the past several decades, something which has been termed "The Great Acceleration", with the extensive associated health effects impacting across nearly every dimension of human health (Myers, 2017). This is to be further discussed because in these times of such rapid and escalating social, political and environmental shifts in which human-driven activity is critically harming the planet's ecosystems (Williams, 2017), both the present and future anthropogenic damage to the biosphere pose important threats for human health and wellbeing (Tong, 2008).

Today's unprecedented global environmental changes, particularly climate change, ozone layer depletion, anthropogenic pollutions, land degradation and loss of biodiversity, reflect massive ecological disruptions, which in turn will have more profound, albeit longer-term effects upon the health of human populations (McMichael, 1994). Healthy ecosystems support many potential benefits to our existence, such as harvesting of renewable resources, recreation, and provision of drinking water. Natural systems provide a suite of "ecosystem services" including nutrition, purification of water, protection from natural hazards, and reduction of some infectious diseases. Myers et al. (2013) simply declared that "*Nature's goods and services are indeed the ultimate foundations of life and health*".

Thus, the acceleration of the breakdown of ecosystems is often conducive to an increase in human pathogens, recycling toxic substances, reduced yields, compromised food supplies, scarcity of potable water, and air pollution, all of which increase human health vulnerability (Rapport et al., 1998). In the current era, biodiversity is the worst affected component of our ecosystems (Gupta et al., 2019). And in fact, we are now in the midst of the Sixth Mass Extinction Crisis.

That in fact raises an important issue in ecological thinking, the term "human ecology", which implies the broadest possible view of human beings, both as individuals and as populations, in terms of the ecosystem, that is, the biologic, socioeconomic, political, cultural, and emotional complexes in their course of dynamic action and reaction. All of which in turn leads to the essential holism of human problems, including the tendency of industry to become more highly technical, and the introduction of new man-made hazards of a more diversified and complex nature of community health problems (Kartman, 1967). In human ecology, the environment is simply perceived as an ecosystem that is everything in a specified area: the air, soil, water, living organisms and physical structures, including everything built by humans. The living parts of an ecosystem are microorganisms, plants and animals (including humans), also known as its biological community (Marten, 2008). In ecology, "equilibrium" could describe a relatively stable stage of an ecosystem during evolution, but it is considered to be a “dynamic equilibrium,” because ecosystems must be complex dynamic systems to supply their services sustainably (Lu et al., 2015).

This is the epistemological justification for declaring that unsustainable consumption of natural resources imposes additional or new sets of health risks. That the profound impact of the rapidly growing world economy and population threatened to collide with the planet’s finite resources and fragile ecosystems was being first highlighted globally in 1972 at the UN Conference on the Human Environment in Stockholm. And the UN’s SDGs reflect more of the epidemiological transitions that have occurred in the last 20 years, seeking to address a much broader range of conditions that limiting human well-being as per determinants of health *per se*, hence the rights to healthy environments are then realized through addressing the underlying determinants of illness and inequity (Hawkes and Buse, 2016).

Health is indeed the central common thread running through all 17 of the UN’s SDGs, which are clearly related to nurses and concerned citizens at large; thus nurses and healthcare professionals are obligatorily working to echo and address the pressing challenges in these troubled times (Dossey, Beck, Oerther and Manjrekar, 2017). Ultimately, the Sustainable Development Agenda is calling for a global Culture of Health, with efforts to share accountability based on evolving needs (Rosa, 2017). The complex range of interactions between sustainability and wellbeing should be integrated within a wider cultural discourse, just as a literary scholar and an ecological economist also share the assumption that sustainable development and wellbeing are interrelated because they comprehend the duties as well as the rights of humankind to sustain and enjoy nature and culture (Spinozzi and Mazzanti, 2018).

Now the understanding of planetary boundaries presents the main ecological threats, including of course human-induced climate change (Sachs, 2015). And therefore, the reciprocity and intimacy required for maintaining the interdependency of both planetary health and human health necessitates broader and ever-evolving conceptual dimensions when seeking to understand the ecological principles related to human health and, as a result, counter the arising global environmental and climate mediated health risks.

And now, the foremost pressing issue in seeking sustainability and addressing human health issues from an ecological perspective is the need to take account of evolving concepts in the ecology of health, i.e., derive one’s understanding from the ecological conditions which comprise the state of ecosystems health. Earth is a large ecosystem made up of oxygen, water, plants, and animals (including the human species). The ecological equilibrium reached among these different elements and species is, today, the primary determinant of human health. Characterizing and addressing these threats requires a shared vision of paradigm shift. As such, we need to accept, understand, and influence the ecological relationships between humans and the natural environment, which is made up not only of resources, but of living entities. Protecting the health of future generations requires taking better care of Earth's natural systems (Myers, 2017), as they are inextricably interlinked and continually in dynamic interaction with each other to sustain health and wellbeing.

This means a fundamental change is required in how public health action should be envisioned (Brousselle and Guerra, 2017) from multi-perspectives of public health models (Li, 2018a). This is especially so, given this age of environmental and climate mediated health risks is now emerging as the latest stage of ET in the Anthropocene, in which the underlying determinants are the driving forces in these changing patterns of epidemiological and health transitions (Li, 2018a).

From these complex old and new challenges in public health developments that are reflecting from different stages of ET, which projected the underlying changes of our worldview towards the current concerns of sustainability from both material and immaterial dimensions of determinants *per se*. Yet, Fig. 2-1 summarizes these different paradigm shifts of epidemiological and public health models in transition, as in accordance with the changing underlying determinants of health *per se*.

Ecological approaches are becoming increasingly common to further our advocacy for ecological health behavior, as they produce a more comprehensive understanding of the many factors that affect health outcomes (Moran et al., 2016). One notable example concerns rapidly emerging theories of population-based ecological approaches, as there is major potential in changing entire systems to produce the ecological advantages needed to optimally enable people to adopt and maintain the health-protective behaviors as that are vital in promoting and sustaining developments in the new public health (DiClemente, Salazar & Crosby, 2013). Specifically, there are many scientific investigations which have progressively refined theories and unfolded our understandings of the influence of eco-environments on health. As we've noted, concepts of disease must evolve in diverse ways, in which environmental ecological determinants on global climate change and public health are closely interlinked with the importance of sustainable developments for all forms of beings in the planet (Li, 2018a).

In point of fact, the field of planetary health has emerged as a way to prevent further destabilization of the Earth systems and to avoid actions that would herald large-scale morbidity and mortality. Health professionals have to take up a role of raising awareness of such health risks (Walpole, Barna, Richardson and Rother, 2019). Ecological public health movements have indeed countered upon these changing health needs in relation to the possible and consequential underlying determinants that are leading to the throes of transitions in health under the Anthropocene. In this context, whether this shift comes under the term health transition, mortality transition or epidemiological transition need not be the entire focus of our arguments as such. As the impact of environmental and climate change on human society, especially greater susceptibility to disease world-wide that is the current focus of discussion, as which has already resulted in increasing morbidity and mortality. Therefore, its greater impact globally is in sharp public health concern as many scientific studies and reviews continuously publish reports warning of the impending catastrophic consequences of the arising health-related problems in the Anthropocene.

Ecological public health requires sustaining and maintaining a healthy Planet Earth for all forms of beings, something which can only be done within the safe operating planetary boundaries and by setting limits for humanity activities. As these are the sustainable boundaries for all life on Earth, ecological sustainability requires systems thinking to provide a sustainable platform for ecological health behavior in this new changing global context. Ecological public health is a unifying concept representing an ecological perspective in practice that addresses the interconnectivity and complexity of ecosystem services and demands a safe operating space within planetary boundaries for humanity to maintain the ecological integrity of the planet and civilizations towards our eco-environments.

For the past 10 years, the Sustainable Healthcare Education Network has experimented with ways of including planetary health literacy with learning objectives that link the relationship between ecosystems and human health to the skills needed to reduce the environmental impacts of health systems. That implies sustainable healthcare education applies planetary health concepts to medical education, which allows students to develop professional attitudes and skills to cope with the associated and arising complex problems (Walpole et al., 2019). Nursing and health professionals have to recognize that health is interrelated with both the daily lives of the individual and the conditions of the surrounding natural and social environment. They must also be aware that currently humanity is pushing against the natural limits of the eco-environments and that we are already exceeding the planetary boundaries in several critical ways.

Thus, the new waves of ecological public health movements towards planetary health for global environments require nursing and health professionals to keep abreast of the changing demands of ecological public health needs, which will be further discussed in the following chapters.

A critical risk is being posed to human health and survival, and healthcare experts have a responsibility to campaign for advocacy at all ranks to alleviate such crises (dos Santos et al., 2019). It is an [obligatory] opportunity to create emergent and evolutionary possibilities for nursing and healthcare in relation to planetary health by referencing to the UN 2030 Agenda for sustainable development (Rosa, 2017). The Lancet Commission also calls on health professionals to lead the response to the health threats of climate change with an international multidisciplinary approach, as health professionals have a vital part to play in tackling the public health impacts of climate change (Wang and Horton, 2015).

As a result, we are today uniquely positioned to educate and advocate for safeguarding the health of person, place and planet (Prescott and Logan, 2019). Ecological public health education for future sustainable healthcare in this new age is indeed absolutely essential, thus all healthcare professionals must further sustain this view for our ecological health. As human health cannot be uncoupled from the health of natural systems within the Earth's biosphere, the inclusion of the planetary health perspective within holistic and integrative medicine as a concept in relation to the health of humankind should definitely penetrate into the mainstream academic and medical discourse, especially given its relevance to contemporary and sustainable healthcare across generations under this new epoch of Anthropocene.

Conclusion

The discipline of public health is critical to this vision of transforming from public to planetary health in a way that nourishes and sustains the diversity of life with which we coexist and on which we depend (Horton et al., 2014). Public health professions today need to think and act ecologically with the recognition of this vital importance of a well-functioning natural environment—with its ecosystems and other biophysical processes—to sustaining human livelihoods and prosperity if they are to help reshape the conditions that enable good health to flourish (Tait, McMichael and Hanna, 2014). And therefore, "recognizing that 21st-century integrative medicine is, in fact, clinical ecology [and] can help clear an additional path as we attempt to exit the Anthropocene" (Nelson, et al., 2019).

The sustainability paradigm is values driven and is also a quietly revolutionary invitation to rethink this enterprise by considering medicine in its rightful place within a much bigger planetary system; thus realizing how these planetary ailments impact on human health is vital; understanding, as we do, that climate change is “the biggest global health threat of the 21st century” (Schroeder et al., 2013). In the long term, human health requires a healthy global ecosystem for climate stabilization, water purification, waste decomposition, pest control, seed dispersal, soil renewal, pollination, biodiversity, protection against solar radiation, etc., as there is no realistic way or current technology available to replace the declining natural ecosystem services that are essential to human health (Jameton and Pierce, 2001). Human impact on Earth extends over a vast majority of the planet and piles pressure on the planet’s resources, in addition to having consequences for climate and disease.

Consequentially, the concept of ecological public health should be widening in accordance with the arising threats and challenges of all health-related impacts as part of an integral global health strategy to promote ecological health and environmental literacy with ecological public health principles and education accordingly. This is especially so, as our human health can no longer be sustained if humans are depleting the natural resources and disrupting the ecosystems upon which our global life-supporting systems and our wellbeing are vitally and inherently based.

Therefore, all healthcare professionals must acknowledge those interrelationships between climate change, environmental sustainability, and the arising impacts on our health (Teherani, 2017). This convergence will pave the way for a transformation of sustainable health developments, together with professional spirits to uphold this paradigmatic shift towards greater ecological responsibility, and to provide the insight of practical relevance for a revolutionary humanistic duty in support of sustainable healthcare across generations.

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CHAPTER 6

PUBLIC HEALTH THEORY AND PRACTICE IN THE NEW CHANGING GLOBAL CONTEXT

Since the origin of public health, its theoretical concepts and practice from different waves of public health models have been gradually displaced by other new waves, as public health is concerned with the total system in response to evolving determinants of health in transition. In this new age of global environmental and climate mediated health risks in the Anthropocene, the ultimate concern of ecological principles in terms of sustainable health developments is to promote the concept of planetary health for global interdependence. The new challenges to public health in this global context need a reorientation towards the parallel inherence for future sustainable healthcare through optimization of sustainable health developments.

Especially the arising transitional risks and subsequent public health impacts are significantly interconnected and associated mostly with human anthropogenic activities that result in adversely affecting the biosphere of Planet Earth. The practical relevance of our global interdependencies is to shape the planet's underlying conditions to health and to form a caring philosophy focused on evolving concepts of health and the inherent worth of living beings as parts of the whole in a new ecological public health theory and practice in this changing global context.

A new vision for the ecological public health education emerging in the 21st century is resulting in approaching the nature of today's global public health challenges with new scientific thinking with an emphasis on sustainable health developments. It is a vital vision as a foundational response to the ecological and global determinants in transition that in turn impose the rapidly changing and expanding healthcare boundaries. As a result, it is essential that ecological public health concepts visualize and achieve long-term global targets correspondingly. There is increasing scientific evidence and knowledge detailing a vicious cycle of adverse health impacts under these global environmental and climate mediated risks, which impose a burden not just on our human health but also on entire healthcare systems. Paradigmatic shifts are required to recognize and appreciate the reality that ecological public health education is on the move towards such a long-term global target.

As scholars Louise Potvin and Catherine M. Jones stated: “There is a tendency to ignore that scientific facts alone cannot drive action; it is the normative lens through which scientifically established facts are read that ultimately dictates public action”. So, in this context, the fundamental intentionality for truly capturing the sustainable health and vitality of any human community requires a wide spectrum of action to create meaningful interventions (Prescott et al., 2018).

New Waves of Public Health Movements Towards Planetary Health for Global Eco-Environments

Public health has an important role in identifying the health impacts from the scientific evidence on the ecological changes causing the global environmental and climate crisis—a crisis which could bring about catastrophic public health threats and further impose disease burdens on a global-scale. A related opportunity is to adopt ecological thought that offers a rich entrance to understanding living systems: a relationality of connectedness, interdependence, and reciprocity to understand health in a complex and uncertain world, which indeed is coherent and foundational within many human knowledge systems but has been overlooked and poorly addressed in our current framing of how we consider health and well-being in society (Horwitz and Parkes, 2019).

In this context and beyond, ecological public health is absolutely indispensable to fulfill the intended purposes in addressing such implied needs as well as to make the necessary synergistic public health movements through collaborative and participatory efforts to tackle environmental and climate mediated health risks. The ecological determinants of public health and planetary health endeavor to convey the full range of their complexity in relation to health hazards and risks, with the possibility of forming a powerful and progressive new ecological public health synthesis. The combinations of upstream (macro) and downstream (micro) approaches to epistemological advances when unfolding our scientific understanding of the changing demands in the healthcare environment in the Anthropocene will significantly advance the ecological public health agenda. That leads to a new horizon for a new model as a projection for public health theory and practice in this new changing global context.

> The implication is that without theory, observation is blind and explanation is impossible.
>
> (Krieger, 2011, p. 3)

Put simply, planetary health is defined as the health of human civilization and the state of the natural systems on which it depends (Horton et al., 2014). Global population trends and increasing resource consumption have led to the current epoch of the Anthropocene. Despite the human population being healthier and better off than ever before, this achievement has involved exploiting the planet at an unprecedented rate and compromising global environmental health (IUCN, 2018). The WHO has stated that environmental health comprises those aspects of human health, including quality of life, that are determined by physical, chemical, biological, social and psychological problems in the environment; and the theory and practice of assessing, correcting, controlling, and preventing those factors in the environment can potentially and adversely affect the health of present and future generations (ANA, 2007).

The changing public health orientations and concepts in transition with different waves of public health models are continuously modified, expanded, and created anew to accommodate (1) different types of arising health problems; (2) their underlying causes and consequences; and (3) the complex changes and interactions that are leading to the health trends of transitions, and nowadays especially the actual and/or potential impacts on sustainable health developments. There are different developments and changes in the common defining stages of epidemiological transition (ET) in accordance with the different periods of time, circumstances, and arising conditions and situations of their respective environments. Our current period of climate change has resulted in ecosystems' intrinsic capacity for self-renewal to be damaged, with the prime implications becoming the greatest health risks in the 21st century. In this regard, environmental and climate mediated harm is indeed the most significant dimension worthy of inclusion in these complex parallels (Li, 2018a).

It is necessary to keep in mind that modern scientific knowledge has changed the concept of fundamentality as it occurred in response to the demands of its new form of management by referencing to the modern scientific understandings, in which the transformation from knowledge to information is the main change, and that is the basis for shaping cognitive competence as in accordance with its ability to generate new knowledge (Smokotin, Petrova and Gural, 2014). Epidemiology is used as a methodology and a scientific tool to search for the determinants that are causing and influencing the occurrence of disease and the consequent health impacts. Thus the evidence it provides indicates the reference-criterion to direct prompt with effective public health measures in a ‘knowledge-to-action’ manner to justify the relevance of its movements. Importantly, epidemiology is closely interwoven with the public health movement, and the roots of its evolution have been firmly implanted in an epidemiologic base (Terris, 1987). A wide range of public health models (as listed in Figure 2-1) have reflected the relevance of public health movements at different stages of ET in relation to health transition, which yet again reinforces that ensuring new waves of public health movements towards planetary health for global eco-environments means effective public health measures for this new epoch in the Anthropocene.

> “All things are connected. Whatever befalls the Earth befalls the children of the Earth.”
>
> Chief Seattle Quote, 1854 (Deem, Lane-deGraaf and Rayhel, 2019, p. 16)

In fact, there are a range of ways in which public health can contribute to sustainability—including the sustainability of the environment in which we live, the resources we use and the contribution we collectively and individually make to ecological sustainability—and the fundamental issue is that without the contribution of many disciplines to ecological sustainability we will see limited success (Fleming, Tenkate and Could, 2009). A holistic perception of reality, seeing things as a whole, requires interdisciplinary focus in knowing values and our connection to nature, and takes into account the evolutionary capacity of the human species (Dabrowski, 1995). We will not solve these issues using the same thinking that got us to this point in time; the magnitude of the threats to global public health requires a unified call to arms to immediately and aggressively pull the plug from the habits responsible for this global calamity (Guenther and Vittori, 2008).

There is no differentiation when citing the principles of “global public health” as the core beliefs of global public health emphasize health for all, with health seen as a public good that must be addressed (Upvall and Leffers, 2014). The vision is for a planet that nourishes and sustains the diversity of life with which we coexist, and on which we depend. It is heartening to know that the desire is to transform public health by taking it beyond personal, community, national, and regional levels, as planetary health is the ultimate goal (Patwardhan, Mutalik and Tillu, 2015). Complex links between the environment, climate, biodiversity and health will be so recognized and asserted through anew public health movements. As Thomas Logan wrote in 1895 (Morand and Lajaunie, 2018, p. 12):

> *"A knowledge of the etiology of diseases can best be attained by studying the affections of different localities in connection with every condition and circumstance calculated to operate prejudicially or otherwise upon the health of the inhabitants [...] and being also calculated to elucidate the relationship of diseases to climate, to the prevailing geological formations – the fauna, the vegetables, the minerals, the waters, which vary with the earth's crust".*

In fact, the consequential driving forces behind those underlying determinants are part and parcel of the process in these changing patterns of health transition that are intertwined with environmental sustainability. Subsequently, a critical point for the conceptual engagement of such transitions in health under the throes of the Anthropocene is the greatest challenge for sustainable health developments (see Figure 5-2). Thus, a wider framework includes not only epidemiological characteristics but also the ways in which societies respond to the changing health situations as "a dynamic process" whereby the health and disease patterns evolve in diverse ways as a response to those different determinants (Li, 2018a). In this respect, we argued further that the identification of determinants of this modern transition to a higher health status was needed, as both economic and social development may be drivers of health transitions (Lewis and MacPherson, 2013). In view of scientific advancements and understanding in this new era of the Anthropocene in relation to the global environmental and climate crisis, the changes of public health orientations and concepts in transition need to be promoted, and a new advocacy is urgently needed for this century, which looks both retrospectively at historical factors (i.e., from the past till the present), and prospectively towards the future through the "New Waves of Public Health Movements towards Planetary Health for Global Eco-environments".

The changes of public health orientations and concepts in transition are intended to ascertain wide-ranging frames of references in an attempt to obtain sustainable health developments. There is a progressive understanding and recognition that planetary health requires being cognizant of the interrelationships of its scientific justifications amongst multifaceted perspectives, together with generalizing epistemological advances and insights towards a new horizon. These paths will need to be influential in order to advance and empower such new waves of public health movements towards the ideal "Age of Sustained Health". Therefore, two approaches, namely (1) the ecological and determinants approach with ecological public health education, and (2) the sapiens approach (with determinants of the human spirit for an ecological civilization through my proposed "Concepts in Transition") should be adopted for strengthening up sustainable concepts in health developments. The contextual ideas of my proposed "New waves of public health movements towards planetary health for global eco-environments" are comprised, further elaborated on and discussed alongside critical reflections below in Figure 6-1.

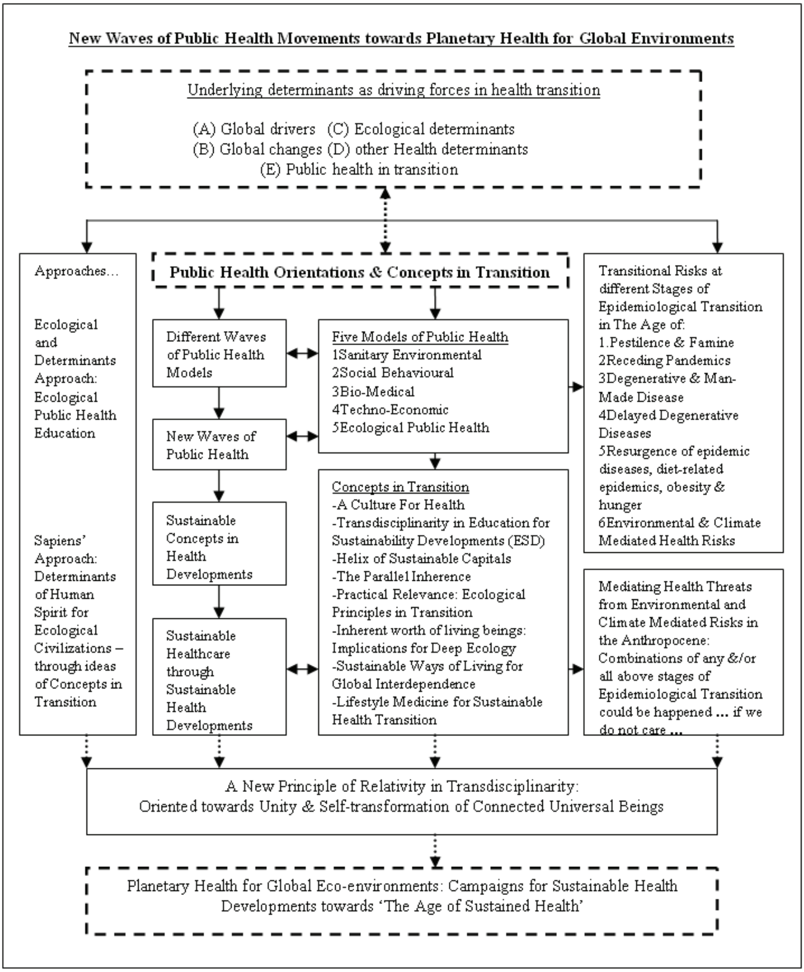

Figure 6-1: New waves of public health movements towards planetary health for global eco-environments.

Sustainable Concepts in Health Developments

It is crucial to develop an understanding of the accumulative processes that are still on-going as underlying driving forces adversely affecting sustainable health achievements under the unsustainable environment of the Anthropocene. Health and vitality are a product of the total lived experience over time, and our contemporary environment may be producing "altered (unhealthy) reactivity" vis à vis our evolutionary past; thus human health and vitality cannot be separated from the sustainable health and vitality of the Earth's natural ecosystems (Nelson, Prescott, Logan and Bland, 2019). Sustainable health developments depend on at least two basic components, human-created social systems and eco-environments, both of which we must optimize the functioning of to live healthily on this planet. The complexity of relevant conditions is one of the factors contributing to the ecological determinants of health, in conjunction with the harmful consequential effects of human-induced disturbances to our eco-environments and the burdens from ecosystem disruption, environmental hazards, and loss of ecosystem function. These are all areas of concern under the concept of ecological public health (Li, 2017a).

Planetary health provides a unifying concept wherein in response to changing conditions, planetary limits, and evolutionary pressure, things such as new values, new communities, and new modes of interacting will likely emerge and be integrated with developments in science, technology, economics, the arts, and international relations, resulting in our survival and enhanced health and well-being (Salk, 2019). And, as we've noted previously, planetary health is a unifying concept that extends to the planet's natural systems—the ecosystems and biodiversity upon which our own vitality depends—and therefore we argue that one simply cannot claim to be a "health" care professional without advocating forcefully for the planet, as there cannot be healthy people on an uninhabitable planet (Prescott, Logan and Katz, 2019). And therefore, the importance of these phenomena of health concepts in transition on the critical dimensions for achieving sustainable health developments is utterly indispensable.

Moreover, there is progressive understanding and continual recognition, reinforced with scientific justifications, that planetary health is the path to advance and empower the current proposed new waves of public health movements towards the ideal "Age of Sustained Health". Li (2018b) recognized that to build a sustainable future is a central plank of public health, and that reconnecting the value of the environment with public health is for our long-term benefit, as the burden of current healthcare systems means there are substantial struggles to keep up with the changing patterns of various diseases burden resulting both from a rapidly changing and degraded Earth and from the way people live as well. The intended purposes of those accumulative scientific understandings with learned knowledge should also be translated directly into ecological public health interventions, which are not just focused on disease preventions and wellness under the "bio-medical" public health model, but most importantly seek to optimize the conditions for sustainable health developments as the ultimate goal. In view of such significant dimensions of health concerns, Li (2017a) proposed that an ecological public health model be the ultimate focus of these transitional needs for an attempt to make positive movements and actions to counter these multiple influences on our health arising from ecological determinants.

Therefore, communicating the global environmental and climate crises plus the significance of ecological public health principles for education is our challenge in this new epoch, and is something that ought to be embedded with the humanist worldview. Despite the term "environment" being less than 400 years old, the advancement of environmental literacy, provided with scientific justifications of the concept and knowledge of the issues relevant to health and sustainability of the environment, is indeed closely related to human health (Scholz, 2011). This term "environment" signifies our understanding of the natural world which is inherently viewed from the multiple perspectives of human experience and habitation (Raffaelli and Frid, 2010). Despite this, most historical culture is conceived or perceived as that which places us apart from the eco-environments rather than as a participant in them.

Health literacy is, in fact, a precursor to health and the achievement of a culture of health, as health literacy is recognized as a social determinant of health based on its impact on health outcomes (Loan et al., 2018). In the 21st century, we face a scarcity of critical natural resources, the degradation of ecosystem services, and the erosion of the planet's capability to absorb our waste (Steffen et al., 2011). All those indications have now moved beyond the planetary boundaries, as in accordance with the defined safe operating space for humanity. Subsequently, this adverse situation will only worsen the vicious cycles affecting our habitation on this planet, including our human health. Consequentially, this further elicits how health and environmental literacy are of significance to bring science and society together. To do so is an epistemic necessity and one of the greatest challenges facing human survival. Under this circumstance, safeguarding human health means staying in the "safe operating space" within planetary boundaries by reducing our environmental footprints (Haines, 2019). The implications of these facts and the issue of how the Earth system is coping with such a wide variety of rapid, interacting and unprecedented changes—that affect not only human well-being, but most importantly the stability of the Earth system itself—are estimated to lead to one of the three outcomes (Steffen et al., 2004, p. 134):

1. stabilization at a new state of the system with its own characteristic patterns of variability;
2. relaxation of the system back to its previous state at a manageable rate; or
3. a more rapid catastrophic change of the system to its previous state or to a different state.

Perhaps, the most important aspect in sustainable development conceptually speaking is the idea of "human capital" and the ways to invest in human capital is simply to promote better health. The global strategy for health development advocated by the WHO implies that improving health requires action in three main areas: lifestyles, environment and the healthcare sector (IRMA of USA, 2018). In light of this view, health security is therefore intimately related to the sustainable management of the environment. It is linked to the fulfillment of the Millennium Development Goals (MDGs) and to the human security approach (UNDP, 1994) that has been adapted to changing conditions posed by climate change, population growth, urbanization and environmental deterioration (Spring, 2011). The SDGs for 2030 provide a veritable cornucopia of aspirations that reflecting historical and current concerns, and illustrating how we should be focused on a broader way of achieving an integrative balance to foster sustainable health developments and promote well-being for all ages.

Sustainable health development has been an agenda for public health academia since the United Nations approved their set of 17 SDGs that came into effect in 2016, with the aim of transforming our world to end poverty, protect the planet, and ensure prosperity (Takian and Akbari-Sari, 2016). The 2030 Agenda for Sustainable Development highlights the responsibility of every sector to contribute to the SDGs. It is an overarching agenda in which the SDGs are presented as "interlinked and integrated" evidence-based justifications derived from the consequential determinants that impact on our health, which represents a major conceptual shift in thinking on these foundations. The most promising avenue yet is to promote good health and well-being through ensuring that those determinants of illness are addressed, rather than limiting our vision to only ensuring access to illness-treatment or management (Hawkes and Buse, 2016). Sustainable concepts in health developments also characterize the interplay amongst these three areas as highlighted by the WHO: lifestyles, the environment, and the healthcare sector.

In our understanding, environmental footprints are tools that communicate human-driven pressure on the environment and, in some cases, the associated impacts (as indicated by planetary boundaries), and the related SDG targets are specifically intended to counter these related problems. Some examples are given in Figure 6-2.

Planetary Boundaries	**Related SDG targets (with specified *listed number*)**
Climate change	*13.2* Integrate climate change measures into national policies, strategies and planning.
Ocean acidification	*14.3* Minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels.
Stratospheric ozone depletion	*12.4* By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment.
Chemical pollution (novel entities)	*6.3* By 2030 improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater, and increasing recycling and safe reuse globally.
Bio-geochemical flows (nitrogen and phosphorus cycles)	*2.4* By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, help maintain ecosystems, strengthen capacity for adaptation to climate change, extreme weather, and other disasters and progressively improve land and soil quality. *14.1* By 2025, prevent and significantly reduce marine pollution of all kinds, particularly from land-based activities, including marine debris and nutrient pollution.
Biodiversity loss (change in biosphere integrity)	*15.5* Take urgent and significant action to reduce degradation of natural habitat, halt loss of biodiversity, and by 2020 protect and prevent the extinction of threatened species.
Land system change	*15.1* By 2020 ensure conservation, restoration and sustainable use of terrestrial and freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, in line with obligations under international agreements. *15.2* By 2020, promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests, and increase afforestation and reforestation globally.

	15.3 By 2020, combat desertification, and restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land-degradation nautral world.
Freshwater use	*6.3* As above-mentioned under chemical pollution. *6.4* By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity, and substantially reduce the number of people suffering from water scarcity.
Atmospheric aerosol loading	*3.9* By 2030 substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water, and soil pollution and contamination. *11.6* By 2030 reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality, municipal and other waste management.

Figure 6-2: Related SDG targets within planetary boundaries (adapted and modified from Häyhä, Cornell, Lucas and van Vuuren, 2018, p. 66; Lucas and Wilting, 2018).

In this connection, moving beyond a conceptual approach to advance actions for strengthening planetary health, and given that public appreciation of humanity's dependence on the state of natural systems is increasing, now is the time to move from conceptual narratives to decisive action with the agenda of SDGs that offers substantial opportunities to protect planetary health (Pongsiri et al., 2019).

An Ecological and Determinants Approach: Ecological Public Health Education

The traditional healthcare professional's role in terms of their function in the healthcare setting has been established (and based rather intensely) on a "bio-medical" model with a disease-oriented focus, particularly in past epidemiological transitions and prior epochs in need (Li, 2018b), according to a revision or an extension of Omran's theory discussed earlier. In fact, different transition frameworks have been applied insofar as theories can be used in diverse ways to achieve meaningful changes for public health objectives and to inform and guide interventions designed to reduce the health risk behaviors associated with morbidity and mortality. It is important to understand this range of potential theories so that they can be adjusted in accordance with transitions in health and determinants of health and diseases. As the determinants approach situates health and social problems in the broader social, structural and cultural conditions of our society and informs public health and health promotion approaches, it is strongly influenced by our learned knowledge derived from the determinants of health approach. In particular, the future of climate and ecology will be inextricably linked with new and potentially catastrophic patterns of health and illness in just a few generations' time (Keleher and MacDougall, 2015).

Together with the concept of a health transition introduced by John Caldwell in 1990, it was hoped that demographers would be encouraged to use their knowledge to preserve or restore health and extend life, which are matters also concerned with health trends from an epidemiological perspective on global transition, and which highlight the importance of knowledge in the production of health during development with a greater range of cultural, social and behavioral influences on health, especially child survival (Caldwell, 1992). In this context, Frenk and his associates also recognized the basic elements for developing a theory of health transition is due to the enormous potential of health transition theory to help us understand and transform society in the growing complexity of our times (Frenk, Bobadilla, Stern, Frejka and Lozano, 1991). This is also reflected in the nursing professions, where a transitions theory has guided nursing education and practice in current healthcare systems characterized by diversities and complexities (Im, 2018).

A sustainable level of healthcare can only be achieved by reducing transitional risks and, in turn, optimizing the continuum of sustainable health developments. In fact, many studies with justifiable and cogent reasons illustrate the needs for strengthening health promotion and disease prevention in a framework of sustainable health development with a focus that further echoes the 1987 Brundtland Report. From that perspective, sustainable health development is the most critical issue facing our global society nowadays, and ecological thinking helps public health by understanding the normality of complex interactions that must coexist. As Keleher and MacDougall (2015) stated, ecological public health emphasizes the essential interdependence of people's health with the health of the planet, which in turn is becoming the most powerful determinant of the health of people and civilizations. Thus, the ecological and determinants approach for ecological public health education proposed here is an opportunity to embark on a process of 'knowledge-to-action', which is the greatest global public health opportunity of the 21st century. Therefore, a newly emerging role for healthcare professionals is to integrate ecological public health education as a holistic vision and action agenda in support of these challenges (Li, 2018b).

This is one of the most significant parts of capacity building: to improve practices and infrastructure by creating new approaches, structures, or values that enhance existing abilities and sustain capabilities to promote health and engage in evidence-informed interventions (Bergeron et al., 2017). The recent evidence related to health risks from climate change suggests the need to build health resilience to climate hazards, and shows how we must: (a) raise awareness and understanding of the health risks from climate change; (b) develop the capacity of the health workforce to address climate risks; and (c) strengthen the management of environmental determinants of health through sustainable infrastructure (WHO, 2015). In this connection, it is also widely acknowledged that nursing scientists need to structure and target support from universities to develop an effective pipeline, and to bring in these new academic structures (Gimbel, Kohler, Mitchell and Emami, 2017), which is an essential parameter to promote nursing and healthcare professional engagement in ecological public health education. In this context, universities should take the pioneering role in the evolving trends of innovative-driven curriculum development as a platform and process for change; to nurture, cultivate and transform the necessary mentalities of perceptions and understandings towards this global direction of ecological sustainability in relation to sustainable public health development for a changing globalized society under this epidemiological and health transition in this age of environmental and climate crisis (Li, 2018b).

Goodman (2014) has reaffirmed that an urgent transformation in values and practices based on recognizing our interdependence and interconnectedness on a finite planet with a new vision to conserve and sustain ecosystems upon which we rely is absolutely necessary. Fragile ecosystems are subject not only to conflicts between short term rewards and long-term conservation goals, but are also subject to the vagary of human responses to environmental challenges (Galvani et al., 2016). A rapid shift of societies toward the UN SDGs could stabilize the Earth system, as the climate and the biosphere are two highly intertwined, aggregate components of the whole-Earth system—a single complex system—even though the evolution of those two components can be inferred somewhat independently from each other (Steffen et al., 2016). For instance, "Earth science describes a substantial component of this natural environment, encompassing the key terrestrial materials, associations, and processes that have both beneficial and adverse impacts on public health" (National Academy of Sciences, 2007). In a similar vein, there is the traditional juxtaposition of developments in medicine and public health from the evidence of transition, i.e., the "science of discovery" and the "science of delivery".

It is also as Omran postulated: The shifts in health and disease patterns that characterized the epidemiologic transition are closely associated with the demographic and socio-economic transition that constitute the modernization complex. For instance, the outbreaks of avian influenza alerted the world to new susceptibilities to epidemics due to population growth, unplanned urbanization, anti-microbial resistance, poverty, and lifestyle changes in communities (Santosa et al., 2014). In fact, urban areas are the fastest growing ecosystem on Earth with the development of cities leading to changes in many aspects of the environment, and today we are living in a time of unprecedented global change (Rivkin et al., 2019). The danger of such unprecedented global changes imposed so many challenges, including not only the current characteristics of epidemiological transition, but also the accumulative impacts of health transitions, possibly at a different pace across different regions, nations and countries.

The worldwide trend is toward urbanization, and as we expect the world's population to reach 8 billion by 2025 and 9 billion by 2040, apparently all of that increased population is expected to live in urban areas (Sachs, 2015). The power of urban evolutionary biology as a globally replicated experiment provides an unparalleled opportunity to understand how human altered environments affect evolutionary processes and patterns, which could also address existing gaps in our knowledge on the structure and function of ecological communities in cities (Santangelo, Rivkin and Johnson, 2018).

The varied effects of globalization as health prospects depend on trends in global environmental and climate conditions that rely upon the concepts of determinants of health in transition. A major transition in health is underway, and the profile of major causes of death and disease is being transformed continuously and globally. These broad-based transitional changes are interacting dynamically with different ecological determinants, which is putting public health at a substantive crossroads in the 21st century in terms of generating sustainable concepts in health development.

And this proposed ecological and determinants approach offers transformative effects in helping sustainable health developments with the potential to improve in gradual steps and/or perhaps quantum leaps our evolving public health needs. It is a milestone moment in which ecological public health education can and must play a critical role in achieving new pathways towards sustainable concepts in health. We must not squander this opportunity to recalibrate and initiate the significance of applying new waves of public health movements to this precarious situation. Therefore, this proposed new waves of ecological public health movements have to act upon the intended transformative effects under the notion of an epidemiological and health transition, and be implemented together with a significant Sapiens approach which appreciates and empowers the human spirit to build an ecological civilization.

A Sapiens Approach: Determinants of the Human Spirit for Ecological Civilizations

As Fam, Neuhauser and Gibbs (2018) revealed "even when we have excellent evidence-based research that addresses the main determinants of a problem, we may not be able to translate that knowledge into practical strategies that people can adopt in their social contexts". In order to strengthen and empower interventional and practical strategies, new waves of public health must be specifically developed as a 'Sapiens approach': a set of concepts for our transition that cater to the needs and enhancement of the human spirit and ecological civilization through a shared vision of our global interdependence. The approach includes:

a. A Culture for Health
b. Transdisciplinarity in Education for Sustainability Developments (ESDs)
c. A Helix of Sustainable Capitals
d. The Parallel Inherence
e. Practical Relevance: Ecological Principles in Transition
f. The Inherent Worth of Living Beings: Implications for Deep Ecology
g. Sustainable Ways of Living for Global Interdependence
h. Lifestyle Medicine for a Sustainable Health Transition

a. A Culture for Health

The emergence of human culture as a powerful new force in the biosphere, and the need for its effective control in the interests of humanity and the rest of the living world has implications for our global society. As Stephen Boyden recognized, the worldview and priorities of our current dominant culture are simply not compatible with the long-term survival of civilization. He subsequently proposed the need for a "cultural renaissance", a major transformation to an ecologically sustainable and equitable society upon human well-being and health (Boyden, 2004).

The concept of cultural anthropology was formulated in the mid-19th century by Sir Edward Burnett Tylor (1832-1917) and his contemporaries and followers in the field, who undertook the study of human diversity and the relations between humans as biological populations and as bearers of culture (Richerson, Mulder and Vila, 2001). The similarities to ecological public health are striking, though the latter takes the relevance of the interrelationship of human ecology further into the realm of the actual and potential impacts culture has on health-related issues, making it an integral part of this public health movements in transition. In 2015, the Lancet Commission on Planetary Health included "civilization" in their definition of planetary health, defining it as "the health of human civilization and the state of the natural systems on which it depends". The linkages between the rise and fall of human civilizations vis à vis natural systems (and environmental degradation) have been witnessed, retrospectively, over millennia; yet, it still remains difficult for humans to see these connections in a prospective way. However, it is clear that massive challenges remain, especially with regard to human behavioral change (Prescott et al., 2018).

Ecological knowledge and indigenous wisdom are about thriving together within regenerative cultures as an effective response to climate change. The word "regenerative" here signifies a commitment to the life processes inherent in ecological design; to becoming ecologically competent stewards of land, wildlife, soils, and waters; and to showing that we care enough to undergo a systems revolution leading to the art of seeing things whole, regarding both our actions and their likely consequences (Wahl, 2016). As David Orr argued, given the complexity of all systems and our inescapable ignorance, a systems perspective requires humility and precaution; however, cultures are not designed from the top down as much as they grow organically from the bottom up (Wahl, 2016). Thus, eco-literacy can be facilitated by learning from living systems i.e., from nature. By having greater interaction with the natural environment, there will be greater momentum to protect such areas; therefore to improve population health and ecology is to advocate and be connected to the local natural environment, which is critical to people's wellbeing (Kingsley et al., 2013).

The promotion of ecological health literacy and environmental ethics, then, via the proposed transdisciplinarity in education as a synergy of the ecological public health interventional approach and sustainable ways of living towards global interdependence under this environmental crisis is absolutely pivotal (Li, 2017b). As Prescott and Logan (2018) argue, tackling the "health of human civilization"—the primary task of planetary health—necessitates the acknowledgment that such a task is, in fact, a study of attitudes, intentions, emotions, ideals, values, and especially, behaviors. Our human civilization is at a crossroads and we need to change how we are affecting the ecosystems on which we depend by sharing the recognition that the physical environment and bio-ecological systems (the ecological determinants) are as important as socio-political and cultural systems for wellbeing (Tait, 2018). Recognizing that cultural change and re-integration are necessary components of a more sustainable and equitable society, transformational change with a true ethic and spirit of connectedness in values and mindset is the great challenge to be addressed (Hanlon et al., 2011).

> From the "crisis of perception" to the "systems view of life" …
> Our actions and how we create meaning are capable of creating conditions conducive to life.
>
> (Wahl, 2016)

There is ample historical evidence that public health efforts have been most successful when the socio-cultural context has been changed; this includes the creation of supportive environments, with the provision of living and working conditions that are safe, stimulating, satisfying, enjoyable and conducive to health-enhancing behaviors. This further re-emphasizes the need to identify and manage environmental barriers that might prohibit or inhibit optimal health (Cook, 2013). Importantly, behavioral change is also needed to improve human health and protect biodiversity. Human behavior, which is informed by differences in knowledge, values, social norms, power relationships, and practices, is at the core set of interlinkages between health and biodiversity, including challenges related to food, water, disease, medicine, and physical/mental well-being through the adaptation to and mitigation of climate change (WHO, CBD and UNEP, 2015).

The concept of "A Culture for Health" is derived from the fifth wave of public health development as described in a study by Davies et al. (2014), which is based on the increasing conceptual understanding of the contribution of individual behaviors and lifestyle choices to health outcomes and the subsequent shifts in accordance with the rising burden of chronic disease. The other four existing waves refer to "structural", "biomedical", "clinical", and "social" developments (Li, 2017b). Today a crisis of culture in this new era of the Anthropocene is another shifting concept that challenges many of our most deep-rooted and taken-for-granted cultural assumptions, as throughout recorded history humanity has regarded the continuity of nature as a given. The science and technology scholar Sheila Jasanoff warns that it could take "decades, even centuries to accommodate into a new revolutionary reframing of human-nature relationships", however, at this juncture, framing the right questions about what it means to be human in this radically different reality should be a priority (McLeod, 2018). Therefore, this pushes a necessary shift from the five waves of public health into the presently proposed six waves of public health culture, moving towards ecological civilization for humanity. The sixth wave is shown below in Figure 6-3.

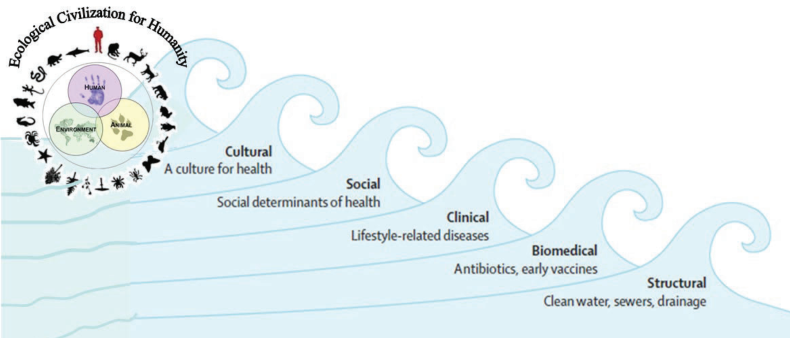

Figure 6-3: The Six Waves of Public Health Culture: An Ecological Civilization for Humanity (adapted and modified from Li, 2017b; Davies et al., 2014).

As for the benefits of eco-systemic sustainability, this shift further addresses the Anthropocene paradox that we need a fresh mode of thinking about our professional, social and cultural practices. The key to this fresh approach may well be the word "regenerative", with its meanings of revival and to grow again. Hence, we must seek more dynamic social forms with permeable boundaries that can respond rapidly and flexibly to emergent needs and opportunities (McLeod, 2018) to cultivate an ecological civilization for humanity. Therefore, we must apply our capacity for culture to the control of culture, and work our way towards this sixth wave of public health culture and an ecological phase of human history.

In this connection, an environmental conceptualization of health entails specific doctrines for nurturing an ecological understanding of environmental sustainability, just as "A Culture for Health" represents a parallel need for sustainable ways of living with an inherent global interdependency. These concepts are in phases which are both ecologically viable and humanly desirable, as promoting sustainable health and well-being can counteract the ecological unsustainability of human societies today. Furthermore, this change is an essential priority and pivotal requirement for the attainment of a "biosensitive" and sustainable society (Boyden, 2004). Despite ecologically sustainable development having become a universal concern and efforts to promote sustainable development being carried out on a variety of fronts, most people are very concerned about the environment and still feel overwhelmed by the complexity and scale of the problems (Marten, 2008). As Nicolescu (1997) described:

> *"The break between science and culture, which manifested itself over three centuries ago, is one of the most dangerous ones. On the one hand, there are the holders of pure, hard knowledge, on the other, the practitioners of ambiguous, soft knowledge. This break is inevitably reflected in the functioning of universities, which favor the accelerated development of scientific culture at the expense of the negation of the subject and the decline of meaning. Everything must be done in order to reunite these two artificially antagonistic cultures – scientific culture and literary or artistic culture – so that they will move beyond their assumed opposition to a new transdisciplinary culture, the preliminary condition for a transformation of mentalities."*

"A Culture for Health" starts with this reconciliation and the shift into the sixth wave of public health culture towards an ecological civilization for humanity. It could be a platform of connectivity to facilitate our practices in such areas as:

a) Transdisciplinarity in education for ecological public health literacy towards sustainable concepts in health developments
b) Sustainable diets
c) Waste reduction
d) A health belief model with accountable behaviors to promote environmentally sustainable practices and ways of living
e) Wise use of energy and natural resources
f) Demands for clean air, water, soil and food

With the overall focus being ecological harmony for all things, including nature, the necessity of realizing the fundamental ethical value of this and to take into account natural capitals and the management of natural resources in a sustainable way is again reinforced. This also coincidentally echoes Confucius' theory of environmental ethics of ecological harmony (Li, 2017a). Nurturing a favorable cultural attitude toward ecological values is a critical step in the embracement of transdisciplinarity in ESD (interchangeably known as "Ecologically

Sustainable Development"). Both transdisciplinarity in ESD and "A Culture for Health", as part of concepts in transition, which are meant to advance and expand the scope of our scientific and cultural understandings of all the glaring global environmental and climate mediated health risks.

b. Transdisciplinarity in Education for Sustainability Developments (ESDs)

The evolution of transdisciplinarity since the mid-1900s has allowed us to take a pragmatic approach in addressing the past failures of researchers and practitioners to identify complex problems and develop successful interventions. Transdisciplinarity is a reflection of radical changes in thinking about the nature of reality and of scientific inquiry into these parallels to seek practical solutions to important problems in society (Fam, Neuhauser and Gibbs, 2018). The overall goal of ESD is to develop the capacities of individuals and societies to work for sustainable futures (UNECE, 2005 & 2016):

> *"It is aimed at making people more knowledgeable, better informed, ethical, responsible, critical and willing to act for a healthy and productive life in harmony with nature, […] Education for sustainable development enables people to develop the knowledge, values and skills to participate in decisions about the ways we do things, individually and collectively, both locally and globally, that will improve the quality of life now without damaging the planet for the future".*

ESD continues to grow in importance on the world stage to confirm the role of education in sustainable development and to encourage the knowledge that change can indeed happen when all stakeholders work together with a commitment to a better world (UNECE, 2016). The epicenter of transdisciplinary learning is the role of the student, which is also a mechanism that promotes the levels of meta-cognition necessary for teachers and students to thoughtfully explore global sustainability issues through strategically targeted skill developments. Educators have the power to cultivate students' meta-cognitive skills in order to tackle many of the Earth's most challenging issues concerning global sustainability that future generations are likely to face (Smyth, 2017). Now more than ever, education has a critical role to play, not only in providing learners with the knowledge and skills to address these challenges, but also in promoting the values that will instill respect and responsibility towards others and the planet itself (UNECE, 2016).

This proposed evolving trend of transdisciplinary curriculum development on climate change and ecological public health is meant to act as a process of change and an innovative driver for cultivating the necessary mentalities of "trans-reality" regarding "sustainable ways of living for global interdependence". The trend represents a growing concern from multiple disciplines and the academic community towards the necessity of transdisciplinarity in education. Since a process of change requires educational innovation in many forms, true innovation in education will require a paradigm shift in terms of "concept", "format" and "methodology" (Ferrari, Cachia and Punie, 2009). In this respect, the proposed synergistic engagements include:

(a) The concept: a paradigm shift with
  i. a new principle of relativity in transdisciplinarity as the driving force; and
  ii. trans-reality on sustainable ways of living with the ordered overall movement for global interdependence as the outcome focus.
(b) The methodology: transdisciplinary curriculum development
  i. affecting the process of change through transdisciplinary curriculum development for the current proposed "journey of transformed transdisciplinarity".
(c) The format: knowledge integration and transformation in this era of globalized learning with the Delors Report's four pillars of a new kind of education
  i. "Learning to know",
  ii. "Learning to do",
  iii. "Learning to live together" and
  iv. "Learning to be".

This is a journey of transformed transdisciplinarity in education that is formed based on the complexity of reality, whereby "No level of Reality constitutes a privileged place from which one is able to understand all the other levels of Reality", and that is indeed the essence of "trans-reality" (Nicolescu, 2011). All actions that impact the environment come ultimately from individuals, thus a crucial ingredient for sustainable development is a well-informed public (Marten, 2008). One of our aims is to unify the conceptual links of the four pillars with sustainable ways of living and the shared vision of "trans-reality" for "the ordered overall movement" which acts on our responsibility to build sustainable futures (Li, 2017b). Socrates stated that connected to the soul of a person is not reason in general, but reason that is morally oriented, a "spirit of the people" that can undergo profound changes from which possibilities for forming a global culture arise (Petrova, Smokotin, Gural and Budenkova, 2014). Such a change is undoubtedly required under this age of environmental and climate crises in the Anthropocene.

A journey of transformed transdisciplinarity as a pedagogical framework for a new principle of relativity in transdisciplinarity requires communication in the process of change through (1) empowerment with an understanding of the relevant scientific-based information, and (2) engagement (cognitively, affectively and professionally) to move from knowledge to action. The following should be considered in this process:

a. Evolution of health education for promotion of sustainable health with proactive health advocates for sustainable global public health.
b. The rapid changing of healthcare boundaries with expansion of nurses' and health professionals' roles in 21st century global public health.
c. International collaborative action in nursing and health education for professional attributes of ESD.
d. A platform for sustainable healthcare systems through global campaigns for ecological health literacy in a context of shaping health through the power of all societies and cultures.
e. ESD for all health professionals with ecological public health principles.

As knowledge is legitimately derived from different value systems, different ethical bases, and different philosophical traditions, and in order to bridge different knowledge cultures towards solving a real-world problem, reframing a more deliberate approach requires transdisciplinarity and the increasing need to apply ecological concepts to understand and nurture sustainable human health (Aguirre, Ostfeld and Daszak, 2012). Education can make a critical difference to a range of health issues. For instance, education on a healthy lifestyle would ensure that people everywhere have the relevant information and awareness for sustainable development and lifestyles in harmony with nature, within which ensuring biodiversity would be valued, conserved, restored and wisely employed, as would maintaining ecosystem services, sustaining a healthy planet, and delivering the benefits essential for all people. Such an educational framework would be compliant with SDG12 that aims to "ensure sustainable consumption and production patterns" on a global scale (Leicht, Heiss and Byun, 2018). Indeed, education generally is deemed one of the most powerful tools explicitly underlined as a driver for change, but to realize this potential and to drive the transformational changes necessary for sustainable development, education systems need to be flexible, culturally sensitive, relevant, and suited to changing people's values and behaviors (Leicht, Heiss and Byun, 2018).

Theorizing transdisciplinarity as collaborative learning in practice is critical for addressing the complex environmental problems across multiple disciplines and to translate or disseminate experiences as a way to fill the knowledge-action gap. The practice would be an active and strategically planned process whereby new or existing knowledge, interventions, or practices are spread in society, as knowledge should not only be integrated across disciplines, it should also be implemented across societal sectors (Fam, Neuhauser and Gibbs, 2018). We should reposition for our sustainable futures in health development within the SDGs, and it is important to link our investments with the development of human capital, defined as the stock of knowledge, skills, attitudes, health, and other personal characteristics that enable individuals to realize their full potential as productive and responsible members of society (Bhutta et al., 2019). As the philosopher and theologian Ivan Illich explained about the beginnings of activism on the global environment, "What has changed is that our common sense has begun searching for a language to speak about the shadow our future throws"—because resistance to seeing the strategic threats often focuses on the lack of complete information or perfect understanding (Gore, 1992)—which echoes the importance of global campaigns for ecological health literacy.

Yet, the new waves of public health movements maps out alternative pathways that hold the genuine and realistic potential to improve ecological integrity through the two broad approaches: (1) an ecological and determinants approach with ecological public health education, and (2) a Sapiens approach focusing on educating and adapting the human spirit towards ecological civilizations through concepts in transition. Application of these approaches would facilitate a journey of transformed transdisciplinarity under a new principle of relativity in transdisciplinarity. This in turn could serve as a driving force to cultivate orientations of the necessary mentalities of "trans-reality" towards sustainable ways of living for a changing globalized society, and "A Culture for Health" recommended for empowerment of beneficial behaviors (Li, 2018a).

The idea of empowerment is to ensure that people are able to make informed choices about health, and to work out certain representations which hold good for the collective (Dew, 2012). As Li (2017b) has reinforced, the only viable education is an integral education of the human being, which entails both a new vision and a lived experience as a way of self-transformation, oriented towards knowledge of the self, the unity of knowledge, and the creation of a new art of living in the society. The concept of a new principle is therefore anticipated as a paradigm shift in reconciling effectiveness and affectivity through a journey of transformed transdisciplinarity as summarized in the third column in Figure 6-4.

DISCIPLINARY EDUCATION (DE)	TRANSDISCIPLINARY EDUCATION (TE)	TRANSFORMED TRANSDISCIPLINARITY (TT)
IN VITRO *One level of Reality*	*IN VIVO* *Several levels of Reality*	*IN SILICO* *Trans-Reality*
External world - Object	Correspondence between External world (Object) & Internal world (Subject)	No level of Reality constitutes a privileged place from which one is able to understand all the other levels of Reality
Accumulation of knowledge	Understanding	• Knowledge • Understanding • Being
Analytic intelligence	New type of intelligence - harmony between mind, feelings & body	Four pillars of a new kind of education*: - Learning to know - Learning to do - Learning to live together - Learning to be
Oriented towards power & possession	Oriented towards astonishment & sharing	Oriented towards unity & self-transformation of connected universal beings
Binary logic	Included middle logic	Open logic as permanent flexible evolutionary exigency
Exclusion of values	Inclusion of values	Contemporary values

Figure 6-4: A New Principle of Relativity in Transdisciplinarity (Li, 2017b, p. 7). (Adapted and modified from Nicolescu, 2011; Delors, 2013.)

This new principle of relativity in transdisciplinarity emphasizes how education for sustainability developments could act with an open logic as a permanent but flexible evolutionary exigency for achieving contemporary values. As Sachs (2015) recognized, sustainable development is a process, a way of solving problems peacefully and globally, using our science and technology, our know-how, and our shared global ethics to address our deep common needs. This is especially so when we are oriented towards unity and self-transformation as connected universal beings from a perspective of “learning to know, to do, to live together, and to be”. Perhaps through parsimony and sustainable ways to promote our systems thinking we can move *“Towards the aim of universality and towards a redefinition of values governing [our] own existence”* (Nicolescu, 1997).

c. A Helix of Sustainable Capitals

Envisioning the principal concept of ecological public health with a focus on the challenges of sustainable development in health is to increase the capacity to maintain all health-related helices as sustainable capitals. The sustainability relationship between human health and our environment with a focus on public health is comprised of three main components: environmental conservation, social responsibility, and economic development. In addition, the overall aim for sustainability is to promote healthy, viable, and equitable communities. The complex interaction between different components of the fields and systems in health illustrates the interconnections of how to produce sustainable health capitals as a shared set of goals within the model of a "Helix of Sustainable Capitals" as shown in Figure 6-5.

This proposed model is comprised of different components with the core interest of sustainable development in health, in which the interrelationships amongst critical infrastructures from four dimensions of capitals: Natural, Social, Economic, and Human & Health; within the three main interwoven aspects: environmental sustainability, a supportive society, and a prosperous economy. All these aspects are continuously interacting with each dimensions of those capitals dynamically, and their subsequent outcomes as projected through the conceptions derived from: (a) The Health Map; (b) the 3 Pillars; and (c) the 3 E's.

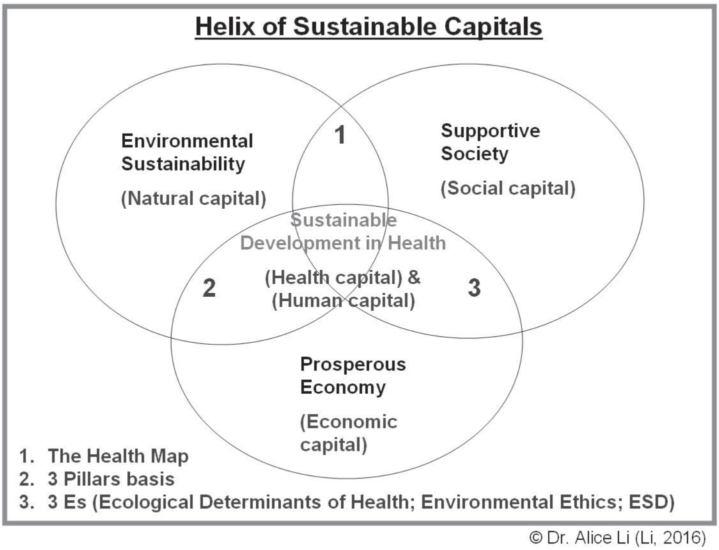

Figure 6-5: A Helix of Sustainable Capitals (Li, 2016).

This conceptual framework within the Helix of Sustainable Capitals Model constitutes components of:

- ✓ Four dimensions of capitals, namely:
  1. Natural capital
  2. Social capital
  3. Economic capital
  4. Human capital & Health capital
- ✓ The three main aspects:
  1. Environmental sustainability
  2. Supportive society
  3. Prosperous economy
- ✓ Theoretical- and knowledge-based conceptions:
  1. The Health Map
  2. The 3 Pillars
  3. The 3 E's:
     a. Ecological determinants of health
     b. Environmental ethics, and
     c. Education for Sustainable Developments

Whereas the "3 Pillars" represent: (i) a viable natural environment, (ii) a nurturing community, and (iii) an economy that intersected within their possible dynamics and/or limits for creating the path towards sustainable development with the 'balances' on sustainable natural and built environment for an equitable social environment, which allows to further cater the sustainable economic development. While the concept of the "3 E's" refers to a three-fold scientific and experiential knowledge on: (a) The **E**cological determinants of health, (b) **E**nvironmental Ethics, and (c) **E**SD, all of which illustrate determinants of health and well-being in human habitation are of significance and required to meet the roadmap of our "Health capital" and "Human capital" as the core concern. These conceptual insights represent *a priori reasoning* with theoretical and knowledge-based justifications to gain understanding of the associated threats arising from this age of global environmental and climate mediated health risks in the Anthropocene.

As McMichael and Beaglehole (2003) recognized, the sustained good health of any population requires a stable and productive natural environment, far more than just a utilitarian input or an incidental consequence of economic development. They affirmed that "*if the development process is not conducive to sustained and equitable improvements in health, then in a very fundamental sense it is not sustainable development*."

Simply, the existence of different determinants implies changing health situations. This further implies the significant influence of ecological determinants on our health transition, as well as the increased pressure on healthcare systems. Thus, determinants of health should be used as an evidential basis towards an organized response to interlink “vibrant and just society” with “prosperous economy”, as they can only come from the “flourishing environment”. This conceptualizes the fundamental building blocks for sustainable health developments in an attempt to support the roles and functions of public health, including the implications for the capacity in building healthy and sustainable communities for the people. Figure 6-6 conceptually reflects the importance of the complementary effects for the required capacity in strengthening up “*the balance*”.

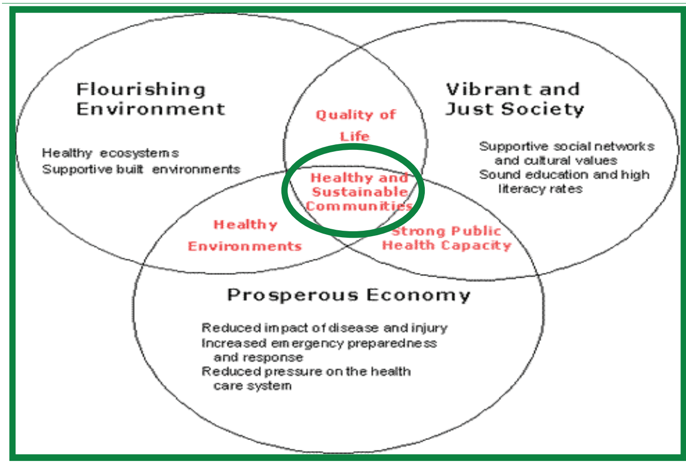

Figure 6-6: “The balance” – My lecture slide on capacity in building healthy and sustainable communities for contemporary value (Li, 2014b).

In the contemporary world, the culture of sustainability is required from a moral point of view if it is to be balanced against competing interests. As Guidotti (2015) recognized, the only social force powerful enough to conserve attitudes conducive to sustainability from one generation to another must be culture itself, and how profound ecological changes being provoked in social and cultural change is a critically important topic for these times of advocacy. To a great extent, global public health is rapidly transitioning worldwide and can bridge the gap to sustainability by (1) identifying the flourishing environment (e.g. healthy ecosystems, supportive built environments); (2) highlighting the vibrant and just society (e.g. supportive societal networks and cultural values, sound education and high literacy rates); and (3) a possible reference-criterion representing a prosperous economy (e.g. reduced impact of disease and injury, increased emergency preparedness and response, and reduced pressure on the healthcare system). All of these actions serve as the basic understanding of the complexity of the interrelationships needed for building healthy and sustainable communities with contemporary values (Li, 2014b).

With the realization that cultivating a Sapiens' approach means adapting the human spirit for ecological civilization through constructing a knowledge arch and a learning society as part of transdisciplinarity in education, comes the simple notion that a unity of knowledge is needed as the means of a liberation of reason and to evolve the necessary mentalities. This brings us back directly to the concept of new principle of relativity in transdisciplinarity as that redefines humanity as part of nature, which is meant to be the spark for the conceptual insight to build bridges to facilitate the transformation of society's contemporary values towards being connected universal beings on a common journey of humanistic transition for the concern of the global environment, for our health and for our safety (Li, 2017b).

While there is no absolute or precise theoretical parallel to this conceptual framework in principle, the guidance for a sensible course of action should be focused on the determinations of practical and realistic choice by empowering ecological health literacy towards the transitional changes occurring. This should be recognized as a parallel inherence and coherent priority in the course of action concerning ecological public health education, and as an integral part of health promotion towards sustainable health developments in our globalized societies.

d. The Parallel Inherence

The role and functionality of our "Ecological Public Health Principles" draw upon the historical roots and bases of public health developments, as they have always offered an alternative provision of priorities and empowerments in constant flux—as well as innovative ideas—in accordance with the changing health needs of the public. Such ingenuity will be necessary to understand and achieve large global-scale change and transformations in the maintenance of sustainable health developments. The parallel inherence under discussion, then, is derived from an ecological basis to promote the inherent worthiness of well-being cultivated for human health needs in this globalized society.

When we value and think about the interconnectedness of people and the planet we can see that the Earth has scarce resources for preserving life, so the necessity of changing or structuring our lives towards self-efficacy, without the need for endless consumption and growth, becomes clear (Parker and Shapiro, 2008). From ego to eco thinking means to anticipate a sustainable health transition through ecological views of health in relation to planetary health for global environments and EcoHealth. It also means an understanding of nature, of its living systems, and of its necessary features: (i) interdependence; (ii) diversity; (iii) resilience; (iv) adaptability; (v) unpredictability, and (vi) limits.

The impacts of globalization on human health are interlinked with all aspects of the determinants under a huge scope of unprecedented health impacts from all of the possible transitional risks. A new scientific paradigm is emerging with many conceptual affinities with pre-industrial attitudes toward nature, for instance, the concept of living in accordance with the "*Tao*" of nature complements the evolutionary and ecological axiom that human beings are part of nature and must conform human ways of living to natural processes and cycles (Callicott, 1997). In this connection, "environmental philosophy must recognize the values that are inherent objectively in nature independently of human wants, needs or desires" (Keller, 2008). This parallel inherence adds into the basis of an ecological paradigm with a shift to a broader ecological view of health in transition, and therefore our ecological footprints are interlinked with the "one health triad", which is symbolized by Figure 6-7.

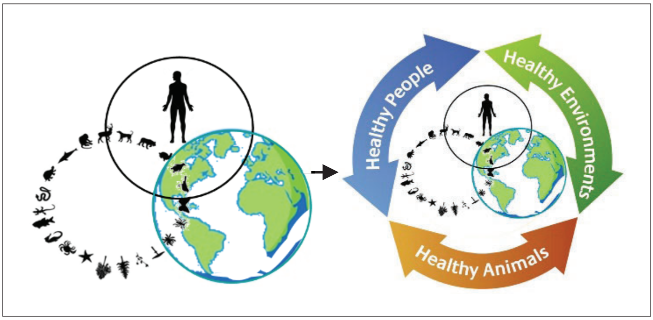

Figure 6-7: Ecological footprints interlinked within the one health triad.

We realize that viewing the health challenges of the twenty-first century through a One Health connection may be most evident when we combine abiotic and biotic factors in a planetary health approach; this requires an appreciation of the past, awareness of the present, and concern for the future; only then will we be able to gain a better understanding of, and solve, today's planetary health challenges that link humans, animals, and environments in harmony (Deem, Lane-deGraaf and Rayhel, 2019). This "planetary" vision for One Health facilitates going from "local to global", or more accurately "molecular to planetary", to address the health, well-being and sustainability of humans, animals and the environment (Rabinowitz, Pappaioanou, Bardosh and Conti, 2018).

> "Endless Forms Most Beautiful and Most Wonderful." – With these words Charles Darwin ended his great explanation of the history of life, *The Origin of Species*.
>
> (Alvarez, 2017, p. 117)

The realization that the human species is deeply embedded in the natural world and the survival of all species, including our own, is wholly dependent on a healthy planet and that is vital. However, our progress to date has come at a heavy price, giving us the "ecology paradox": "we have been mortgaging the health of future generations" (Lueddeke, 2019). It is beyond our capacity to return Planet Earth to its primeval state, however, our concerns for the existing parallel inherence under ecological principles in transition for sustainable concepts in our health developments can promote the concept of global interdependence through a body of knowledge—such as from "Ego" to "Eco" thinking—to resituate humans to be eco-centric. We must gain understandings of:

1. Ecosystems and planetary health in relation to human health and sustainable health developments;
2. The application of ecological principles to human health for a better balance and harmony between people and nature (in order to reduce the intensive human use of the natural environment and the impact it has on other beings and their habitats). To achieve this, we must fully realize that societies are complex and are interrelated fundamentally with the natural world.
3. Emerging ecological public health as the paradigmatic shift towards concepts of One Health, EcoHealth, and planetary health for our global environments.
4. Reciprocal maintenance as 'the overall guiding principle' in the need to create supportive environments through sustainable ways of living that form an ecological translation of "A Culture for Health".

5. New waves of public health movements with concepts in transition towards interconnectedness to promote global interdependence for sustainable healthy coexistence.

Indeed, a new understanding of the nature of health is necessary to meet the demands of life (Bircher and Hahn, 2017). A great deal of supporting evidence elucidates how human health is being affected, with changes in patterns of health and the burden of diseases coming from holistic spectrums of determinants, including the magnitudes and blueprint of ecological transition, rather than just a disease-centered model with only a biomedical focus.

As health is a dynamic equilibrium between man and his environment and disease arises when the maladjustment of the human organism to the environment occurs. This is one of the most simple and fundamental ecological concepts of health and disease, and as the WHO has re-emphasized ecosystem services are indispensable to the wellbeing of all people in the world. Planetary health is a new approach to public health that incorporates the notion that healthy people need a healthy society and, importantly, well-functioning ecosystem processes (Tait, 2018). An ecological public health paradigm shift to positive models for healthy coexistence, well-being and sustainability of these interconnected ecosystems is essential. Figure 6-8 shows the interrelatedness of these relationships, portraying "From Ego to Eco" thinking in visual form. Embracing the above dynamics as a way of thinking would resituate humans to a more eco-centric way of life.

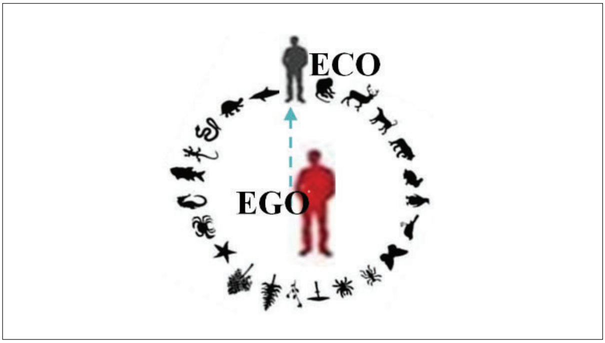

Figure 6-8: From Ego to Eco thinking: resituating humans towards eco-centricity.

Health is a universal development concern, and nature threads the very fabric of human lives—unfortunately, we do not fully understand how ecosystem services (such as human health benefits) can be secured by conserving natural capital (Bauch, Birkenbach, Pattanayak and Sills, 2015). Since the founding work conducted by Costanza and Daly in the late 1980s, there have been many studies highlighting that ignorance of the value of natural capital in decisions on land use and resource allocation. It has most likely resulted in degradation and destruction of this natural capital and eventually will prove very costly for society (Brebbia and Zubi, 2012). In sum, environmental impact on the planet affects human health and serious consequences are resulting from humanity's expanding footprint (IUCN, 2018).

Consistently, the pathways under discussion here, the "Helix of Sustainable Capitals", the "One Health Triad" and "From ego to eco thinking" to name just a few, are interwoven with each other, and produce positive effects on natural capital. Figure 6-9 represents the parallel inherence in transition in the form of the Borromean Knot: three interlocking rings symbolizing "ego to eco thinking" and the "one health triad" engaged with the framework of the "Helix" through a parallel inherence in transition. The three interlocking, but separate, rings of the knot symbolize concern for global change, biological diversity, and sustainable ecological systems respectively. The integrity of the whole requires the integrity of each part, and the breaking of any link can damage the whole system (MacKenzie, 1998). Ecological public health principles are further derived in line with the spirit of these interlocking symbols, specifically in the employment of the vision of "ego to eco thinking" as the projection for enhancing natural capitals for environmental sustainability, which are then interwoven with the "Helix of Sustainable Capitals" as the prime parameter for the parallel inherence in transition.

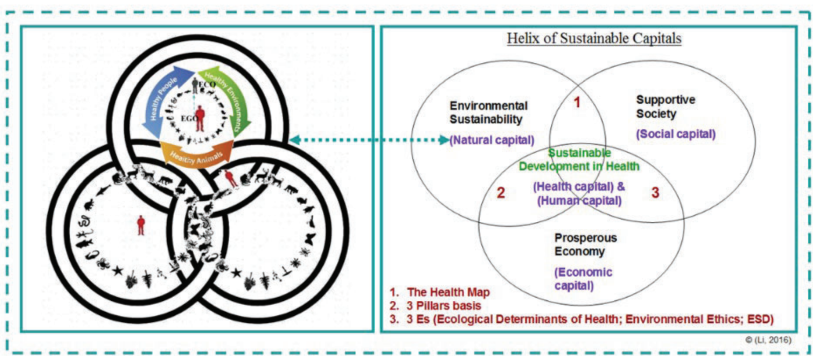

Figure 6-9: The parallel inherence in transition: From Ego to Eco thinking.

The basic idea is that societal systems are dynamic, and inevitably cause disturbances between different capitals, however, given the developments of environmental accounting, ecosystem services functioning, and the related notion of "natural value", the cornerstone forming linkages between environmental and economic valuation, and therefore the valuation of natural capital gains is receiving growing attention (Vannevel and Goethals, 2020). The issue that ecosystem approaches to human health address is no less than humanity's place in its environment, which is tied to the overall development of ecology and the emergence of these ecohealth-related concerns. The inextricable links between ecohealth and humans are reflected largely based on a holistic vision, in which all elements of nature interact toward a dynamic equilibrium for the endurance of sustainable development in human communities and for human health.

Accepting the value of harmony with nature is the only way to deepen our "ecological wisdom" of how nature works, and attaining our "self-realization" of every species is fundamentally biocentric or ecocentric and results in the realization that they have equal rights to live and flourish (Li, 2017a). Ecologically, sustainable development may only be possible once we have grasped the fundamental interdependence of human society and the natural environment. A whole-system perspective of human-environment interaction under the science of human ecology would sharpen our perception of interrelationships of how people and the environment function together (Marten, 2008).

As a caveat to these issues of concern, ecological principles in public health truly preserve and bring together the "inherent value" of nature and of its usefulness to humanistic needs. Our "values are what we believe in, what we hold dear, what binds us to others of our kind; values are the foundation of morality" (Last, 1998). Health is indeed crucial for sustainable human development, both as an inalienable human right and as an essential contributor to the economic growth of society through productive employment, reduced expenditure on illness care, and greater social cohesion by promoting good health at all ages. The benefits of sustainable health development extend across generations (Li, 2018b). The value of "human capital", then, is inseparable from "health capital".

Yet, human health and diseases are determined by many complex factors; concepts of health and diseases are as a result continuously evolving into ecological determinants under the advancement of scientific understanding. To attain the critically needed sustainable health developments for transitional needs towards global sustainability, sustainable knowledge is required for the changing demands. This, in other words, is the parallel inherence, a stepping stone of health needs. Put at its simplest, learning to know in exact parallel with increasing awareness of the worsening global environmental and climate change crisis, we must embrace the changing health transition with ecological views of health as the practical basis with which to understand and safeguard the significant ecological principles in transition.

e. Practical Relevance: Ecological Principles in Transition

Public health professionals have a major role to play in addressing these complex health challenges, but to do so effectively they must have a framework for action (Gebbie, Rosenstock and Hernandez, 2003). The admonition in line with the necessary practical relevance is that the notion represents the evolving concepts of health with ecological principles to human health and that is clearly predicated for sustainable health transition, in which our sustained health depends upon on many respects. One of the utmost important and pressing respects is to adequately respond to the current ecological public health challenges, and to prepare healthcare professionals to continue improving and promoting ecological-related health to the public, as part of professional competencies developments; and to facilitate this ecological paradigm in transition as the greatest challenges for public health theory and practice in this new and changing global context in the 21st century.

This consideration leads to ecological factors being one of the leading and predisposing factors of the core conceptual framework, with coherent values on planetary health and eco-environmental literacy serving as effective means for strengthening the interventional practices with skills competence (knowledge-attitudes-skills) through “knowledge-in-action”. This may mean that the new waves of public health have generated, in a practical sense, the operational framework of ecological thinking as a catalyst for cultivating the required “problem-to-outcome oriented” solutions. This framework can then be integrated into the process of unifying the conceptual engagements with empirical justifications in relation to: (1) the transition in health we are currently undergoing during this new epidemiological age of global environmental and climate crises; (2) the emerging paradigm of ecological public health education as a part of knowledge-to-action synergistical strategies; and (3) anew public health theory and practice for the new changing global context. This illustrated ecological public health is one of the “problem-to-outcome oriented” focuses of those arising problems—an identifier for generating “knowledge-to-action” and implementing it as “knowledge-in-action” through the current proposed new waves of public health movements in the Anthropocene.

Facing these challenges is utterly essential and obligatory to keep abreast of the necessary expansion of professional capacities. Achieving all of the above would provide vital insight and further understanding into the changing demands of the healthcare environment with regard to sustainability. Such transformational changes are required for understanding the ecological and global determinants of health as being indicative of our changing needs, in terms of the sustainable developments in health that impact the central concept of sustainable healthcare. This is a multifaceted spectrum for reconceptualizing a creative and specific healthcare environment by ensuring that evolving approaches within ecological public health principles are used by healthcare professionals and that the rapidly changing healthcare boundaries are at the center of their focus. It also represents a change in focus from the micro level upstream to the macro level, which is responsible for mediating the impacts of health threats. Without this change in focus there could be catastrophic domino effects on the health transition, including demographic, nutritional and other transitional risks arising under this new epoch.

Ecological principles in transition have a practical relevance since they seek to aid the complex human being, through an integrative theory, to reconcile the interrelationship and interdependence between themself and their living context to achieve this projected sustainable health-oriented caring. As ecological care recognizes that human existence must be understood within a web of relationships (Dahlberg, Ranheim and Dahlberg, 2016), in this sense, sustainable healthcare could only be realistically achieved through the support of sustainable developments in health as *a priori* reasoning *per se*. This could be an important issue of ecological thinking, i.e., whether our human health in this world is seen as static or as being nurtured in order to master our own life on this Earth, as either way humankind is undoubtedly an integral part of this eco-environments. In the same vein, Heraclitus of Ephesus (c.540-480 BC) expressed by the phrase *panta rhei* a state of flux or change that was also subject to the same “laws as nature” (Scholz, 2011). People are members of entire ecological systems that are also within the wholeness of health and on which our lives depend; thus, making the healthcare system bigger by steadily increasing healthcare expenditures is not going to change the trajectory documented by the Millennium Assessment or the changing patterns of disease (Guenther and Vittori, 2008).

From a theoretical perspective, knowledge of these interrelations is essential to gain an insight into the accumulative processes leading to the causes of these changes in the current health transition, which are being driven through the dynamics of its underlying determinants with consequential effects on sustainable health developments. The central tenet of practical relevance as derived from ecological principles in transition is therefore specifically meant to serve as an attribute to understand and advance the subsequent changing demands for the sustainable healthcare environment, from which we have to step back to further analyze a few fundamental changes in the worldview of the healthcare environment and its demands. The key messages which started to differentiate our systems thinking about the interrelationship between public health and healthcare under this new global context were characterized by a composition of important groundwork. This groundwork was formed of, inter alia:

1. a fundamental basis and its philosophy of human caring
2. transitions in health under evolving concepts of disease and health
3. different epidemiological stages and their transitional needs and mediated health risks as reflected and implied therewith
4. different models of public health associated with different related interventional strategies
5. changing aspects of challenges for nursing and public health professionals in this age of environmental and climate crisis in the Anthropocene
6. principles to foster a holistic health framework towards sustainable health developments
7. the role of health, medical, nursing and public health councils in their authority to guide directions for professionalism and their assurance for the attainment of professional competencies through educational needs and developments
8. curriculum developments and reform as a way forward for developing joint collaborative action and support from universities
9. transdisciplinarity in education for a new kind of education ahead
10. global campaigns for synergistical ecological public health literacy
11. concepts of healthcare reform towards sustainable dimensions of caring for optimal wellness and sustained health
12. synergistic strategies to approach system-wide problems (including from different levels – Marco, Meso, Micro and Cross-levels)

This in turn leads to the generation of the public health orientations and concepts in transition as summarized in Figure 6-1. In light of the environmental and climate mediated health risks under this era of the

Anthropocene, direct and indirect public health impacts will definitely stretch the healthcare boundaries and make increasing demands for the practical relevance of healthcare transformation. As a result, public health theory and practice in this new changing global context must continue to search for alternative new waves of this parallel inherence in response to the need for practical relevance in sustainable healthcare through optimal sustainable health developments.

From this perspective, sustainable health development is emerging as the viable basis to acknowledge and to integrate the practical relevance of ecological principles in transition for effective responses to this period of unprecedented change. As Professor John Last (1998) stated, “What could be more beneficent than spreading information about risks to health and actions that can be taken to reduce these risks?” He also understood that “health education encourages all to take greater responsibility for their own health”. Our advances in terms of emphasizing ecological public health education are highly important in response to such potentially catastrophic mediating health threats. It is our professional obligations to make a concerted effort to combat this new changing global context.

f. The Inherent Worth of Living Beings: Implications for Deep Ecology

Thoughts for quality of life from a deep ecological perspective are based in the belief that humans must radically change their relationship to nature with the inherent value of contact with the natural environment. In 1984, Professor Edward O. Wilson, an American biologist at Harvard University, proposed the concept of biophilia, from the ancient Greek *bios* means “life” and *philos* meaning “beloved” or “friend”. This concept refers to the psychological well-being that people experience during close interaction with the natural environment, as human dependency on nature contains aesthetic, emotional, cognitive, and spiritual satisfaction—and more widely, a quest for the meaning of life (Lambin, 2012). Within the interrelationship between humans and nature it should be recognized that nature is an integral part of the environment and does not exist solely for its usefulness to human beings. Deep ecology is focused on this environmental philosophy and its concerns for ecological science.

The phrase “deep ecology” was coined by the Norwegian philosopher Arne Naess in 1973. Its first principle promotes a biocentric egalitarianism that combines the biocentric, biospherical, and ecological with equality and egalitarianism; it holds that biota have equal intrinsic value with “the equal right to live and blossom” and that this “is an intuitively clear and obvious value axiom" (Keller, 2008). These constitute an interconnected system within which each organism gives rise to and supports the other, whilst the entire system is, what Naess would call, an "ecosophy"—an evolving but consistent philosophy of being, thinking and acting in the world, that embodies ecological wisdom and harmony. It emphasizes the interdependent value of human and non-human life as well as the importance of the ecosystem and natural processes (Keller, 2008).

> *This is a new, ecological age, and its universal religion will probably become like [Gerd Heinrich's], that of nature on a global scale. Our moral choices will be informed by that vision of the whole, which is greater than all of us humans combined. Individually, we are like cells of a giant organism, the earth's biosphere.*
>
> Bernd Heinrich, 2007 (Egerton, 2019)

This, yet again, coincidentally echoes the Confucian theory of environmental ethics and ecological harmony, in which a more holistic relationship with the Earth is an utmost essential (Li, 2017a). The notion of sustainability applies to all species and ecosystems and to the biosphere, wherein humans take on sustainable roles in systems that can sustainably maintain or support not only our species, but also others, to ensure the health of all involved (Fowler, 2005). Li (2017a) has pointed out that if humankind is to co-exist with Planet Earth, this ecological approach and maintaining its roots of historical heterogeneity are the key to taking care of the natural world. As Zhou (2008) claimed:

> "*Humans can find much resourceful and valuable wisdom in Confucianism [and] in the hope that Confucianism can benefit the ecological civilization, with the theory of 'the unity of nature and man' stressing the harmonious development of man and nature, which is not merely a humanist thinking principle but also the actualization of such a principle in the activities of treating nature kindly and preserving the natural environment."*

Thus, taking into account an inherent worth of the living being is an approach that places high value on harmonious and sustainable relationships between the needs of human livelihoods, ecosystems and human health. These are key tenets of deep ecology. This idea is also in accord with a sustainability approach that strives for a good balance between homocentric and eco-centric perspectives (Asakura et al., 2015).

> "*Where do they finally see the light of day in the shape of 'latent side effects', how can they be limited and distributed away so that they neither hamper the modernization process nor exceed the limits of that which is 'tolerable' – ecologically, medically, psychologically and socially*?"
>
> Ulrich Beck (Featherstone, 1992, p. 19)

A deeper understanding of us and a transformation of our value system might be required as today's generations have responsibilities for the welfare of future generations; humans have a responsibility toward the natural world for the sake of both nature and us. This holistic self-concept can help individuals to accept an extended sense of responsibility through an appreciation of connectedness with others and the natural world (Jameton and Pierce, 2001). The intrinsic value and inherent worth of living beings should therefore lead to the world not being perceived as merely a natural resource to be freely exploited by humans, as the ethical views of deep ecology hold that a whole system is superior to any of its parts (Devall and Sessions, 1985). As Jarrin (2007) described:

> *"Like Nightingale's conceptualization of man, an integral conceptualization of human beings recognizes that the physical body is not the essence or "eternal dimension" of human nature but rather the "vehicle" of the eternal spirit as it performs its work in the world. This eternal spirit is in every sentient being and also spiritually connects everyone through the ultimate source of life. In addition to this spiritual connection, there are immensely important social and ecological connections between and among living creatures. In this way, the physical body, while animated with life, cannot be separated from the social and ecological webs (or "systems," or "networks") that form life on our planet."*

A philosophical conceptualization about ecology and its relation to public health could be viewed as the science of man-made systems in their relation to the biophysical environment, within which public health is a system of principles for action and a guide to planned activity (Kartman, 1967).

> "… a "global unity of purpose" requiring joint action between human and animal health and the ecosystem – [is] the key to creating an environment where people from all walks of life work together to ensure the sustainability of the needs for human survival, and of those of the planet."
>
> David L. Heymann (Lueddeke, 2019)

In point of fact, an ecological basis to promote the inherent worthiness of well-being cultivation for human health needs in our globalized society by enhancing public health literacy in accordance with much broader dimensions of health determinants that would truly preserve our ways of thinking, feeling, our spirituality, as well as the choices in the course of actions towards a relatively holistic approach of sustainable health developments, is one of the basic premises for global ecological public health. As Albert Einstein famously pointed out, we cannot solve a problem with the same mindset that created it: we need a new way of thinking if humanity is to survive (Gabrysch, 2018).

As we enter the Anthropocene, and strive to embrace an ecosocial approach that can address the global ecological changes humans are creating, the implications for population health are then focused on the transformation in societies, economies, and ways of life to achieve One Planet living that represents a key challenge for the 21st century (Hancock, Capon, Dooris and Patrick, 2017). We cannot defeat nature as we are a part of it, thus we need to fundamentally rethink our relationship with the planet, combining philosophical, ethical, literary, medical, and other perspectives, ideally creating a positive vision in support of the transformation of human societies globally (Gabrysch, 2018).

The faculty of reason generates or creates concepts and principles from a deep ecological perspective that for the projected quality of life on this planet, as we understand the planetary system sustains us with a systematic purpose and also for practical natural reasons. In this respect, it has to be put this in mind by reference to evidence that we lay the foundations to be connected with our universal interactions, which are dependent upon either an *a priori* principle or "reason" to generate the relevant ecological public health principles. Then, "reason" can support those principles of practical relevance relating to the inherent worth of living beings and the "eco-existence" of all forms of beings for our globalized interdependence. The complexity of epidemiological transition in terms of the significance of the environmental conceptualization of health leads to immense challenges forced on the ecological dimensions for healthful practices and choices of our lifestyle behavior as the proactive approach and significant parameter in support of sustainable global interdependence (Li, 2017b).

One challenge now is the ease by which it is possible to miss the point about the fundamental connections with the natural world (Horwitz and Parkes, 2019). Yet, reciprocal maintenance is the overall guiding principle in the need to create supportive environments. It implies ecological empowerment as an important struggle for humanity and believes that strategies of connection with the natural world should stem from redefining the person in the environment to include the natural world (Norton, 2009). An alternative to the current healthcare system is needed to take account of the nuanced and pluralistic understandings of human-ecological issues as the given primacy of epistemology of our shared ecological public health future. The three identified critical capacities for the empowerment of health professionals and practitioners working with the ecological determinants of health include (Williams, 2017):

> *"(1) the ability to distinguish between different epistemologies and interests which underlie various empowerment approaches; (2) the discerning engagement of empowerment practices with sustainability approaches; and (3) understanding the respective relevance of indigenous, participatory worldviews and critical post-modernist approaches to empowerment practices."*

As Saari stated, "The individual's fundamental identity comes, not just from experiences with the body, though those are certainly not excluded, but from experiences in all of the contexts in which that person participates" (Norton, 2009). The link with the environment is direct in the sense of biospherical relationships both on account of the (past) history invested in them and on account of the (future) history that they foreshadow, and "it is for this reason that destruction of the natural world carries with it so much more than the destruction of our means of subsistence" (Brady and Phemister, 2012). However, anthropogenic human activities have already pushed the biosphere beyond its natural state and the science of ecology shows that ecosystems can absorb only limited change by humans or other dissonant influences, in which the actions of modern civilization threaten global ecological well-being. Today we are facing the greatest challenges with an increasing complex way of living, especially so when the world trend is towards urbanizations. Thus, achieving sustainability and an ecological civilization in this new era of the Anthropocene is causing a great deal of concern, as the human-dominated ecological systems from the earliest civilizations to the present, which characterized the formation of complex civilizations, as well as their resultant risks.

And the risks of civilization are developed from the intermingling of continuity and discontinuity of both wealth and risk productions, especially when the productive forces have lost their innocence in the reflexivity of modernization processes (Featherstone, 1992). However, modernization is a world trend, and there are different modernization theories with different interpretations of the human civilization process, namely: the tool-making revolutions, the agricultural revolution, the industrial revolution and the knowledge revolution (He, 2014). And the process of the transformation from an industrial to a knowledge civilization necessary includes the transformation from an industrial to a knowledge economy, society and culture, from material to ecological culture and so on (He, 2014). As human communities use more resources, they generate contaminants, such as air and water pollution and GHG emissions, along with increasing quantities of waste. Whereas, over-consumption uses up or severely depletes supplies of non-renewable resources such as fossil fuels, as well as depletes renewable resources such as fisheries and forests because we use them up faster than they can replenish themselves.

As we are facing the crises of this predicament, thus ecological thinking within the concerns for ecological public health is the current synergistical intervention, as the interrelationships of sustainability of our environments and our planet have resultant impacts for all human health. This deep ecology approach has the same aims as achieving a fundamental ecological transformation of our sociocultural systems, with collective actions and lifestyles by expanding the self beyond the boundaries of our narrow ego through the process of caring identification towards the planet as a whole (Drengson and Inoue, 1995). In this connection, sustainable ways of living for global interdependence are the practical solutions that entail also a respect for the inherent worth of living beings in support of socio-ecological transformation towards sustainability.

g. Sustainable Ways of Living for Global Interdependence

As opposed to other species who use organic structures directly to make a living (e.g., lions who kill prey with their teeth or monkeys grinding hard seeds with their teeth), but humans are unique. This fact has important consequences as humans have to make a living by extracting resources from the environment, and therefore using the term “human ecology” actually expresses a broad ambition to understand human behavior (Richerson, Mulder and Vila, 2001). According to Boyden, the concept of biosensitivity is a parallel evolution from the socio-ecological approach via human ecology. Principally, an understanding of the importance of “life” and the place of humans in the broad web of living things is in fact the key factors, as that embracing these tenets which then brings about the cultural transformation required for an ecologically and socially sustainable human society (Tait, 2018).

Humans are subject to very similar ecological and evolutionary processes as to any other species, and we have to understand how diverse parts of the system operate together to produce behavior, thus our interconnectedness is being recognized because societies are complex and interrelated. Having said that, our high level of ignorance of the causes of human behavior is not reassuring, as there is no guarantee that human collectives can act according to simple norms of rationality; or how absurd cultural norms can arise through simple systematic processes involving with positive feedback (Richerson, Mulder and Vila, 2001). In an era where the health of the Earth's biodiversity is on the line, whatever shape the visions of "a better life" under planetary health might take, the mandatory component will require a place of symbiosis (Greek: syn/m = together; way of living together); a place where global mutualism ensures each person can achieve their fullest potential, and that such efforts are prioritized in the context of supporting the biodiversity upon which that mutualism is reliant for our health of civilization (Prescott and Logan, 2018). Culture or civilization, taken in its wide ethnographic sense, is that complex whole which includes knowledge, belief, art, morals, law, custom, and any other capabilities and habits acquired by man as a member of society, and the human race has always been, and still is, steadily advancing in civilization (Tylor, 1871).

As Luciano Carrino (2014) suggests, the idea of "human" development focuses on the individual's abilities and freedoms but leaves in the shadow behind the collective responsibility and the functioning of societies—as a development needs to be "sustainable". Given that sustainability does not represent well as its destructive impact on the environment which leaves behind in the governance issues of societies, something that requires a deeply change of people's lifestyles (Missoni, Pacileo and Tediosi, 2019) with mentality of "trans-reality". We therefore need to have a new approach of transdisciplinarity in education for sustainable development that will enable us to navigate by:

- ✓ linking human health and wellbeing to ecology and ecosystem approaches,
- ✓ identifying the interconnectedness of environmental, socio-cultural and economic factors, and
- ✓ applying the current proposed twelve ecological public health principles together with new waves of public health movements towards planetary health to make Earth habitable for sustainable health developments.

Sustainability is described as the balance between supporting the quality of life for a human population and the continued functioning of its environmental support structures, namely ecosystems. For the ecosystems offer the overall benefits resulting from the regulation of both natural and anthropogenic processes (Spring, 2011) to all forms of life on this planet. As Naess states, from an ecological point of view “the right of all forms (of lives) to live is a universal right” (Brady and Phemister, 2012). Thus, part of the UN’s Millennium Developments Goals supports the right to clean air, safe potable water, adequate nutrition, shelter, the safe processing of wastes, and adequate healthcare (Lautensach, 2015). However, awareness alone might not sufficiently reflect that the Earth is in crisis and that we are possibly affecting all forms of life on the planet. Hence the current focus on these complex problems requires multi-faceted public health actions based on the Sapiens approach.

- Thinking: Beyond Concern to Attitudes; Beliefs; Values ….
  - Because it’s going to hurt me.
  - Because it’s going to hurt lots of people.
  - Because it’s going to hurt nature.

(Parker & Shapiro, 2008, pp. 129 & 157).

Historically, environmental threats are also shifting from ‘traditional’ threats, which are apparently now largely under control in the more affluent areas, especially within developed nations, while ‘modern’ threats on the other hand, are arising as a result of overconsumption and pollution associated with unsustainable over development, especially in those well developed industrialized nations (Nicholson and Stephenson, 2004). Further reflecting unsustainable consumption of natural resources, that is itself inflicting a new set of environmental hazards, Figure 6-10 shows the risks of this transition to ‘modern’ hazards (Moore, Smith and Connolly, 2013).

‘Modern’ environmental hazards
• Water pollution (populated areas, industry, and intensive agriculture) • Air pollution (transport, energy generation, and industry) • Solid and hazardous waste accumulation • Chemical and radiation hazards (introduction of industrial and agricultural technologies) • Infectious disease hazards (emerging and re-emerging) • Major ecological change in ‘closed’ systems (deforestation, land degradation, ozone depletion, transboundary pollution, and climate change)

Figure 6-10: Modern environmental hazards and risks in transition (adapted from Moore, Smith & Connolly, 2013 pp. 358-9).

It is argued that the field of public health education now has greater significance since the "new" public health is a common effort by epidemiologists and educators promoting the principles of human ecology as the necessary basis for preventive public health action. In this regard, human ecology and public health must accept the concept of change as sacred morality by applying this notion to the field of human disease, which will in turn fundamentally change problems of the public's health through planning and manipulating ways and means for modifying the biosocial environment (Kartman, 1967). And as it is presently, we need education in the obvious more than in investigation of the obscure (Kartman, 1967). The very recognition of public health in a wider context of human ecology means cognizance of the necessity of transforming the human condition; man deals actively not only with the product of his consciousness, culture, but also with the very nature of that consciousness, its epistemology, its subconscious motivations, and its morality.

Values and knowledge form our worldview as individuals and as a society, shaping the way that we process and interpret information and translate it into action (Marten, 2008). Socio-cultural norms and values in fact require fundamental social reorientation, aspiration and engagement. Moreover, the current human impact on nature is driven by institutionalized ideas and values that embody a very familiar ethic, that the consequences of this impact simply do not matter. Thus "the change that is needed involves a 'reawakening of something very old'", or changing to respectful approaches to the environment. Supplanting the place of humans in the world and their ethical systems will in a decade or two be seen as a necessity; in any case, only an awareness of the intimate relatedness and co-dependency of humans with plants, other animals and the places of the Earth will save us from further destruction (Curry, 2011). As Al Gore noted in his seminal work on climate change, equilibrium is the key:

> *"The engines of distraction are gradually destroying the inner ecology of the human experience. Essential to that ecology is the balance between respect for the past and faith in the future, between a belief in the individual and a commitment to the community, between our love for the world and our fear of losing it – the balance, in other words, on which an environmentalism of the spirit depends." (Gore, 1992, p. 242).*

The emerging field of ecohealth for planetary health acknowledges, though, that in contemporary ecological, health and social sciences much remains to be done. There is a great deal still to be learnt from a holistic philosophy, from adopting a whole-of-life view that aligns spiritual, social, and cultural elements in intimate connection with biophysical bases (Kingsley et al., 2013). Most importantly, such changes will not be fast nor easy, as “lifestyle drift” is usually a pervasive phenomenon, and thus any initiatives to move or modify it beyond the existing norms and values possibly requires new thinking to shape, nurture and influence our sustainable choices of living towards the more complex adaptive system, which is definitely necessary to address these unprecedented situations and their associated health burdens. One of the key challenges in managing the arising health effects of global environmental and climate change should be acting in a proactive and practical manner with sustainable ways of living as a culture for health, a form of action in line with the present ecological public health approach to health issues (Li, 2017b).

Evolving consciousness becomes an important component in understanding how people become engaged in purposeful activity to redesign their interrelated systems of living—be they biological, social, psychological, spiritual, or environmental. In this context, this proposed Sapiens approach and its molding of the human spirit for ecological civilizations with concepts in transition is intended to generate new forms of existence of culture and spirituality, functioning as a humanitarian component of the “global spirit”. Alongside with an ecological and determinants approach it will play an integral role in ecological public health education. Both approaches are specifically designed for the empowerment of synergistical intervention under the proposed new waves of public health movements. Consequentially, this combination will also form anew synergistical foundation of public health theory and practice, creating a value-based infrastructural platform from a life-course and legacy perspective, to further validate and advance the importance of sustainable healthcare concepts in parallel with sustainable health developments, and in conjuction with the principal means of universally oriented well-being as part of “an ordered overall movement” towards sustainable ways of living for global interdependence.

The philosophy of history at large, explains the past and predicts the future phenomena of man’s life in the world; pondering how the phenomena of Culture may be classified and arranged, stage by stage, in a probable order of evolution—“To general likeness in human nature on the one hand, and to general likeness in the circumstances of life on the other”; as in the Italian proverb (“*tutto il mondo è paese*”) i.e. “all the world is one country” (Tylor, 1871). In this regard, an worldview of “trans-reality” with scientific understandings is guiding these premises echoed in the aforementioned underlying driving forces of global and ecological determinants of health, to inform and guide interventions that designed to reduce health risk behaviors associated with morbidity and mortality. Subsequently, orientations for lifestyles or behavioural changes need to be cultivated and nurtured by reconceptualizing a need of this "trans-reality" towards sustainable ways of living for our interdependence in this changing globalized society.

> Ecological devaluation and expropriation …
>
> "*The boomerang effect need not manifest itself as a direct threat to life" … "But the effect only exists when it occurs, and when it occurs, it no longer exists, because nothing exists any more."*
>
> Ulrich Beck, 1986 (Featherstone, 1992, p. 38)

h. Lifestyle Medicine for a Sustainable Health Transition

As many causes of global environmental and climate change are anthropogenic in nature, it is often our lifestyles, consumption and choices that pollute and exploit resources in an unsustainable manner (Nichols, Maynard, Goodman and Richardson, 2009). The missing link is perhaps in the journey of searching for a sustainable lifestyle, the affiliations with intellectual capacity to make this journey of humanity must first begin. Managing human impacts on the environment means managing human behavior. This might mean the day to day behavior of an individual, their lifestyle, position within a family, within society, or at work, which include their culture, motivations, past behaviors, habits, social norms, context, or the technology they use, all of which play a role (Meyer and Newman, 2018). Despite there being no commonly agreed upon definition of a sustainable lifestyle, the most widely cited definition is that of the University of Westminster's Centre for Sustainable Development that defines it as patterns of action and consumption used by people to affiliate and differentiate themselves from others, in which patterns must: meet basic needs, provide a better quality of life, minimize the use of natural resources and emissions of waste and pollutants over the life cycle, and refrain from jeopardizing the needs of future generations. Sustainable lifestyles, as in other ways, reflect the specific cultural, natural, economic and social heritage of each society as well (Backhaus et al., 2012).

Nobel Prize winner Eleanor Ostrom began a movement in 1990 which used observed behavior to dispute the validity of the theory of the commons. Ostrom's theory was that the most important factors which lead to cooperative behavior by individuals towards the environment are the trust that the behavior will lead to long-term benefits and the belief that the majority of others are performing the same behavior (Meyer and Newman, 2018). Because ultimately humanity's ability to survive and thrive requires a greatly enhanced capacity for adaptive social learning, in which—groups of people sharing their experiences in action, experimenting with different ways of dealing with common challenges, reflecting together on the meaning of their experiences, and deciding on new forms of co-operative action (McLeod, 2018).

Perhaps, the momentous concern continues to be reliant on social and prescribed expectations and values, which include the conflictual pluralization and multiplicity of definitions of civilization's risks (Featherstone, 1992). Henceforth, a sense of values that the problem matters should be cultivated and nurtured by having the necessary sequence in getting to know our capabilities to deal with the issues of problem. As such the World Economic Forum (2013) has supported the notion that the target of long-term sustainability for health systems should be timely, in order to ensure that short-term priorities do not damage long-term value. Thus, "to achieve a sustainable health system for the future, societies must reshape demand for health services, reducing the disease burden by helping people to stay healthy and empowering them to manage their health". For instance, by encouraging people to develop healthier habits, incentivizing healthier consumption, and developing an environment and an infrastructure that facilitate population health. If humanity can broaden (or evolve) its conception of self-interest to encompass the entire species, and simultaneously preserve sufficient ecosystem services, then the collapse of civilization may be avoided (Butler, 2017).

In view of this context, the means necessary to create such a strategic vision in health system planning must deal with health impacts from human-ecology perspectives. A dynamic ecological public health approach is the ultimate focus required for this transitional need, one essential to make positive movements and mitigations to counter anthropogenic activities through a new perspective of transdisciplinarity in education by reconceptualizing "a Culture for Health" as a "trans-reality" towards sustainable ways of living. It would form the prism for a renewed environmental conceptualization of health with significant implications for the ecological principles which underly the relationship between nature and society (Li, 2017b). Subsequently, different approaches to supporting changes in favor of more sustainable ways of living for better understanding of sustainable lifestyles, as well as more innovation in the design for sustainable solutions in different parts of the world, is crucial for achieving sustainability (Backhaus et al., 2012). Nature has an inherent value for its usefulness to our humanistic needs, and sustainable ways of living are indeed the critical-dialectical choices in helping the attainment of all transitional needs that concerning sustainable health developments in public health practices.

The dramatic expansion of a growing volume of evidence to suggest that the ecological perspective is a useful framework for understanding the range of factors that influence health and wellbeing. Just in considering how the ecological public health framework brings an ecological and determinants approach to relate the interaction of the multiple elements involved, one can see how all the different aspects—including the public health components, the drivers, enablers and quality aspects—influence each other as part of a connected system. A model that can assist in providing a complete perspective of the factors that affect specific health behaviors is a vital part of anew waves of public health movements towards planetary health. Ecological public health education is one of the platforms to connect this important role for public health theory and practice in this new changing global context.

A Conceptual Paradigm in Transition for Ecological Public Health in the Anthropocene

The primary challenge comes from the exceptional capacity of humans to alter their environment profoundly. Human advancement has resulted in us having extended our lifespan, intervened in our reproductive patterns, changed the composition of our diet, and revolutionized the social structure of our societies (Gluckman et al., 2011). In this context, the "environment" includes not only the physical aspects of one's surroundings but also the social environment, with consideration not just of the built environment, but the natural landscape environment too (Anthamatten and Hazen, 2011).

> "S*upported by great technological and medical advancements as well as by access to plentiful natural resources, we have colonized most places on Earth and even set foot on the Moon. The transformations of the last century helped humanity to increase the amount of cropland by a factor of 2, the number of people living on the planet by a factor of 4, water use by a factor of more than 8, energy use by a factor of 16, and industrial output by a factor of more than 40"* (Schellnhuber et al., 2004, p. 5).

It appears, environmental and climate mediated health risks are, in fact, the integrated outcome of those different determinants, and globalization continually makes the world more interconnected and complex. Thus, the ultimate goal of sustainable health developments requires collaborative efforts in a time when we are facing the potential and actual terrible consequences of the Anthropocene.

The linkage of changing synergistic strategies for emerging ecological public health needs require new waves of public health movements and developments that must attend to the health threats arising from major population dynamics in demographic transition, nutritional transition, and the transitional risks from (1) global and ecological determinants of health, and (2) underlying driving forces with consequential causes. The latter are constantly and continually exerting forces in the background and driving the transitional changes from multiple variants with much broader and widened perspectives (Li, 2018a). As this is ever increasing complexity marks the global problematic of this era of Anthropocene, we have to demarcate a clear and holistic set of visions that should be well-aligned with scientific understandings and aware of the significant impacts and consequential effects that put new pressures on expanding our professional roles towards the concerns of sustainable healthcare in all respects.

Therefore, an integrated system-oriented transformative paradigm is utterly essential to act decisively and promote ecological health literacy for supporting the evolving concept of a legacy-value as the fundamental basis proactively towards future sustainable healthcare in the 21st century and the Anthropocene. The need of different ecological thinking and synergistical approaches for supporting sustainable health developments is surely the position for this fundamental basis, which does not deviate from the essentials of Hippocrates' historical paradigm. However, the advanced scientific phenomena characterized in the expanded varieties of health-influencing determinants, together with their impacts of short-term and latent interrelationships arising amongst multi-dimensions of ecological effects on the level of transitional risks, are the significant part of the turning point towards sustainable future in the healthcare functions. Critical values with this evolving concept of "Ecological public health theory and practice in the Anthropocene" are specifically constructed to spark and accelerate this transformative paradigmatic shift, which is meant to reflect the new stage of change and a theoretical basis for professional capacity building towards a sustainable future in healthcare.

In this context, all these exemplify the current proposed paradigm shift from traditional "disease-oriented care" to "sustainable-oriented care" as the added essentials for incorporation into this evolving concept of the paradigm in transition. Specifically, striking a balance among environmental and healthcare goals requires a legitimate, formal, and creative visioning process (Pierce and Jameton, 2004). The underlying premise initiating this newly proposed ecological public health theory and practice will definitely grow with increasing scientific and professional legitimacy. As the piece-meal approach will not serve such system-wide complexities, synergistical interventions remain the utmost effective course of action under this proposed paradigmatic shift towards the changing demands for sustainable healthcare in the Anthropocene. In this connection, such synergistical interventions would embrace all parts of the aforementioned components to form the parts of a whole as a conceptual paradigm in transition for ecological public health as presented below in Figure 6-11.

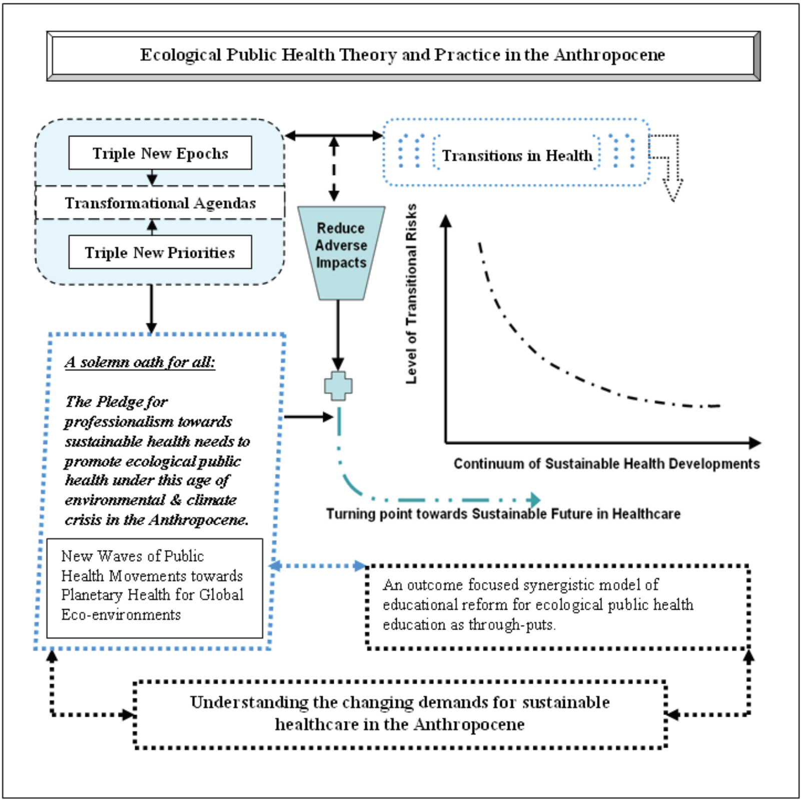

Figure 6-11: A conceptual paradigm in transition for ecological public health theory and practice in the Anthropocene.

As we are already in this age of global environmental and climate crisis in the Anthropocene, it is no longer possible, nor desirable to compartmentalize the essentialities of sustainable health developments and the concerns of sustainable healthcare as an integral part of a legacy-value that goes beyond generations. Now is the time to embrace the mindset of 'the Anthropocene has effects' as a pledge for this emerging conceptual paradigm shift towards the changing demands for sustainable healthcare. Ecological public health education is a powerful tool in responding to this conceptual paradigm in transition. It is high time to have a paradigm shift with this proposed conceptual framework as a reference model to enhance our scientific understandings of the underlying ecological determinants of health and its consequential effects of sustainability and changing needs for all concerns of sustained health. The essence of this shifting broadens our thinking and mindset in order to accommodate the scope of holistic caring for sustainable health developments across generations, as an integral part of new waves of public health movements towards planetary health for global eco-environments.

It involves the required appropriate locus of care with implications for such rapidly changing healthcare boundaries in the Anthropocene as planetary health and the entire eco-environments are now affecting our future sustainable health developments. And therefore, we have to build our heritage as a catalyst for the necessary knowledge infrastructures, including the focus on the concept of holism as a primary means of safeguarding our future sustainable developments in health. This new way of thinking is embedded as an integral part of the sustainable matrix from the "science- value- and legacy-based" multiple perspectives under these unprecedented changing healthcare boundaries in the Anthropocene. Chapter 7 will further discuss the importance of understanding the changing demands in the healthcare environment for sustainable health systems.

All of these synergistically conceptual frameworks interlock with each of the other aspects on multi-parameters in support of our future sustainable developments in health. This conceptual paradigmatic shift simultaneously requires determination and a professional vision to embrace a more all-encompassing mindset with a radical reconceptualization of ecological public health orientations and concepts in transition given their changing professional directions as a result of this fluctuating environment and climate crisis in the Anthropocene.

Conclusion

There is no doubt that the world's global environment and climate is changing and a new paradigmatic shift for public health orientations and concepts in transition is required to address the significant and complex challenges facing us under this new epoch, from evolving concepts of health and ecological perspectives of health, to diseases and their determinants. The proposed new waves of public health movements with ecological public health education are meant, on the one hand, to characterize the many global public health issues that have complex connections between human health and the health of the ecosystems in which people live, and, on the other, to illustrate the possible occurrence of transitional changes and health threats, making vital justifications for sustainable health development through ecological public health education and principles.

It has been realized there is increasing scientific evidence and growing recognition showing the intricate concepts, approaches and definitions that are emerging with important connections to our health. The evidence demonstrates the existence of various transitions: health in transition, demographic transition, nutritional transition, epidemiological transition, together with trends of increasing global burden of disease, and transitional risks with mediating health threats in association with the global environmental and climate crises. Perhaps, the most convincing evidence for embracing the mindset of 'the Anthropocene has effects', which lead us towards facing new stages of public health movements, as well as the proposed paradigm in transition for ecological public health theory and practice in the Anthropocene.

Tarkowski (2009) suggested that public health researchers have a significant responsibility when assisting society to understand and avert the health impacts of global changes. Clues that we must also strengthen our knowledge of a depleted or destroyed natural environment and its implications for population health, as evidence indicates that large proportions of the life-supporting resources of our ecosystems are being degraded and used unsustainably. It is clear that the key aspect of human well-being is our dependence on the intact functioning of Earth's ecological systems. Thus, we should keep in mind healthcare practice must reinforce the restoration and maintenance of global ecosystems (Pierce and Jameton, 2004).

Therefore, the convergence of two suggested approaches paves the way for the proposed new waves of public health movements, which is aimed for having transformative and revolutionary effects towards the changing demands for sustainable healthcare. Clearly, there is an urgent need for a knowledge-to-action response through these two suggested approaches. An ecological and determinants approach for ecological public health education, which can serve as a process of change for instilling ethical and responsible actions, and which is complementarily required for facilitating public health orientations and concepts in transitions through a Sapiens approach. The importance of both is a key means of informing interventional design in the field of public health theory and practice in this new changing global context.

> Confucius (551 BC 479 BC) stated that "不聞不若聞之，聞之不若見之， 見之不若知之，知之不若行之; 學至於行之而止矣", which translates as "I hear and I forget, I see and I remember, I do and I understand".
>
> (Li, 2014a)

This, yet again, implies "understanding" is a practical way to establishing a goal-driven basis for public health theory and practice. A philosophical shift should be recognized as an intrinsic part of evolving sustainable health initiatives and shaping a unitary system of thinking and acting for the purpose of ecological public health. In this respect, concerns raised in support of the changing needs of public health, of ecological public health theory and practice, are absolutely required. A conceptual paradigm in transition as shown in Figure 6-11, which constitutes a shift of different perspectives as critical lenses that initiate a change process to recognize and understand the 'trans-reality' of evolving ecological public health needs as a global trend that anticipates the provision of healthcare for present generations must not undermine the ability of ecosystems and its eco-environments for planetary health to support future generations.

Although public health experts increasingly recognize the significant role the environment plays in public health, setting ecological priorities of environmental concern is inherently ambiguous since the planet is in such a broad environmental and climate mediated risk. Ecological public health movements with a focus on widespread awareness campaigns should be the new priorities of learning the culture of wellness in the evolving concepts of human-ecology. Lifestyle medicines accompanied by a practical change, together with "A Culture for Health" embraced through advancing our understandings in the changing demands of healthcare boundaries as a critical factor—something inextricably interlinked with ecological public health principles—is indeed a significant part of the holistic whole moving us toward the evolution of public health needs under this age of environmental and climate crisis in the Anthropocene.

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CHAPTER 7

UNDERSTANDING THE CHANGING DEMANDS IN THE HEALTHCARE ENVIRONMENT

It is remarkable that public health relevance is in fact increasingly tied to prioritizing the most visible health transition and describing its changes; henceforth, we have to understand the consequential effects of those transitional health risks, as well as the synergistic strategies to counter their actual and potential transitional risks accordingly. As King Lothar I remarked around the year 900 AD, "*Tempora mutantur et nos in illis*" i.e. "The times change, and we change with them". The statement can be applied to how the patterns of epidemiological transition in populations both local and global might appear, as was described by Omran in 1971 (Bygbjerg and Meyrowitsch, 2007), and that helps us to indicate the underlying driving forces behind the consequential determinants that propelled the transitions. There are also hints that the WHO has estimated that at least a quarter of the diseases facing mankind today occur due to prolonged exposure to environmental pollution (Zeneli, Daci, Pacarizi and Daci-Ajvazi, 2011). Thus, only the work of investment in pollution control can break this vicious cycle (Landrigan and Fuller, 2015).

In the same vein of the emerging view, we must transform and respond to the challenges associated with the Anthropocene, an era which has imposed a transition of health and disease from human-environmental interactions with ecological determinants of health that in turn are having greatest and unprecedented effects on unsustainable health developments both directly and indirectly. Sustainable development is indeed a central concern for our age. One starting point is our crowded planet, with over 7.2 billion people competing for resources—roughly 9 times the 800 million people estimated to have lived in 1750, at the start of the Industrial Revolution (Sachs, 2015). The pressue that humanity is putting on Earth's ecosystems, with increased resource use per person—is to gauge the scope of human impact on the environment by referece to the total GWP, which has increased by around 275 times, roughly from $330 billion for the entire world in 1800 to around $91 trillion (Sachs, 2015). This also reflects when combined with the sheer numbers of people that we are "trespassers" on our own planet. As a result, the global burden of diseases caused by pollution impose great economic costs on countries around the world, with direct medical costs and burdens to healthcare systems, plus opportunity costs that reflecting the diminished productivity of populations damaged by pollutions. Given the widespread distribution of pollution degrades the environment, undermines societal development, and condemns future generations to continuing poverty. It is important to point out that endless poor health encourages social unrest, war and migration.

In this scheme of predicaments, a profound awareness must then be formed of the foregoing points to integrate the necessary changes so as to satisfy our vital human health needs that resides in sustainable health developments. Especially in the contemporary era under this new epoch, the importance of ecology has increased because of the overall aggravation of environmental degradation ranging from interconnected environmental, technological and socio-economic demographics (Bhasin and Nag, 2011). The declining condition of the natural environment is beginning to affect the health of populations in many parts of the world, and principles of environmental responsibility and awareness of consequential effects need to be embedded into healthcare education and decisions at every level to further support healthcare professionals in articulating the principles of sustainable health (Jameton and Pierce, 2001).

Using my previously proposed twelve ecological public health principles ("twelve principles") means having a beneficial set of guidelines while its philosophical tenets also applies towards a concept of holism that centers on sustainable health developments. These twelve principles entail the necessity of connectivity with ecological views, and of their interrelatedness to reduce harmful health impacts, both of which are already discussed (see Figure 5-7). These twelve principles would be receptive to the existing global environmental and climate mediated health risks in the Anthropocene, and would act as the basic foundations driven by the increasing evidence that health systems should be proactively responding to the changing needs and challenges of these arising health-related problems. As the WHO (2019) points out, the sustainability of health systems is put at risk if the upstream determinants of disease are not seriously tackled, as about ten percent of global gross domestic product is being spent on healthcare, but very little goes to prevention. For the preservation of the planet to occur, influential people must begin to believe that profoundly detrimental medical situations are linked to our environmental behaviors (Lemery and Auerbach, 2017).

Our planet is an increasingly urbanized landscape, with over half of the human population residing in cities. Urbanization results in dramatic environmental change, including increased temperatures, more impervious surface cover, altered hydrology, and elevated pollution, plus imposed ecological changes to the biotic environment that further affect urban evolution with implications for healthy and sustainable human populations in urban ecosystems (Johnson and Munshi-South, 2017). However, complex challenges often lead to persistent problems in modern health systems, as the increasing demand for long-term care due to the increasing prevalence of NCDs, together with the demographic trends of the growing demand for care plus the changing old-age dependency ratios, all of which dramatically increases the financial burden of healthcare. As a result, many healthcare reforms have focused on cost containment. This again leads us to one of the key concepts in understanding both the persistence of problems and their resolution through a transition from the multi-level perspective (Grin and Broerse, 2017). As Schroeder et al. (2013) indicated, the Earth system is a wonderful yet ultimately vulnerable thing; as its "ecosystems services" include fresh water, clean air, fertile soils, carbon-based and renewable energy sources, as well as a relatively stable climate is vital to all of us. However this planetary system is now under stress due to our human or anthropogenic activity; and those disruptions have various serious consequences for human health, and for healthcare systems, which themselves are already struggling to contain costs.

In this sense, our current healthcare systems are deemed financially unsustainable, and therefore transformative solutions will be needed to enhance the sustainability of health systems in the future (World Economic Forum, 2013). We need a revolution in our health systems with a new synthesis of sustainability and health (Schroeder, et al., 2013). With a growing body of knowledge about the effects of the socio-ecological dynamics of the Anthropocene on human health, including the interacting and cumulative impacts of climate change, demographic shifts, stagnating economic growth, rising socio-political instability, and changing ecological determinants of health, this will undoubtedly require the transformation of existing health systems (Zywert and Quilley, 2020). As part of the efforts underway to advance universal health coverage and other global health agendas, the UN Secretary-General's Independent Accountability Panel (IAP) has sought to examine the evolving nature of developmental challenges and approaches, as reflected in both the SDG agenda and the new Global Strategy (2016-2030). The latter applies to all countries and goes beyond surviving and thriving, to transforming conditions to allow women, children, and adolescents to enjoy sustainable improvements in their health and wellbeing. To achieve this, clear and shared understandings of accountability are needed (Yamin and Mason, 2019).

In 2013, the World Economic Forum made health a global priority, forming an initiative with aims to address two major gaps: access to health and access to care. The initiative related health and its historical context, discussing the achievements and advances in health and healthcare as a major success story of the past two centuries. Though these advancements have been massively significant, such success has come at a cost, with healthcare expenditure having outstripped GDP growth for decades across the Organisation for Economic Co-operation and Development (OECD) countries (World Economic Forum, 2013).

Economic factors, then, often shape the narrative on pressing public health concerns (WHO, 2017). Human capital is a clear determinant of economic growth, and it is only recently that health's role in this process has become a focus of serious academic inquiry; health also serves as a principal determinant of economic growth and this requires not only an investment in healthcare, but in public health policies, sanitation, nutrition, and other sectors that interact with health. A predominant theme in health investment involves devoting funds to a broad range of strategies that aim to improve a population's health, human and social capital, and knowledge of the connections between these strategies will contribute to a deeper understanding of the benefits of investing in health. In turn, good health raises levels of human capital, and its impacts are mid- to long-term in terms of economic growth (López-Casasnovas, Rivera and Currais, 2005). Incorporating into economic theory an understanding of the processes that underlie human capital formation is beneficial, as the effects of human capital variables imply that the investment rate tends to increase as levels of education and health rise. And, the extent of this improvement in human well-being, which leads to faster economical capital accumulation, has been ascertained as an integral part of promoting the primacy of ecological dependency.

Sustainable Demands of Health Needs

Knowledge should be transforming into a form of understanding, with capacities to generate insights for productive interactions, and the understanding then becoming a form of 'knowledge-to-action' in a process that requires health professionals to account for the sustainable demands of our changing health needs. In response to the imbalance of supply and demand, our changing efforts have to be refocused in accordance with the trend of major factors that impact demands on healthcare services as well as the underlying determinants of health that cause such demands. This could imply that epidemiologic changes may occur for reasons other than any particular single factor; in fact, all those previous stages of epidemiologic transition as defined under Omran's classifications, could well happen simultaneously under this new age, as all the transitional risks are interacting dynamically, continuously and accumulatively throughout the world. It then seems reasonable to predict that the catalytic effects might well also be rippling gradually throughout the world. Therefore, we have to reconsider how these issues might be tackled in order to address questions of concern, such as:

- What will be the existing and future trends of major factors impacting demand for healthcare services and the determinants of demand for such healthcare services?
- And what will be the best ways to deal with the existing and future trends of changing demands for the healthcare environment?

With increased emphasis on sustainable health developments and disease prevention, understanding environmental exposures disease-causing is essential for making cost-effective improvements to human health. The recognition and resultant avoidance of bio-assimilated Earth materials potentially injurious to human health is likely to save considerably more money than would be required to treat the adverse public health effects caused by global environmental and climate mediated health risks.

The science of ecology, as we've discussed, sees the world as an integrated web of parts and relationships, within which ecocentrism, or holistic ecology, derives our obligations to nature with the view that the biosphere is an interconnected whole which has moral standing: "As we come to understand (through ecology) our connection to the biotic community, it is natural that our moral sentiments should extend to it" (Pierce and Jameton, 2004). These emphasized viewpoints start with interdependent relationships within the broad-spectrum of processes, engaging in a concept which stands for holistic care within the framework of the currently proposed "Efficacy Model" (which we shall discuss fully later in the chapter). In brief, it is a web of relations interwoven with each other to produce the nature of our health, which represents an integrative system in the previously discussed 'parallel inherence': sustainable healthcare through optimization of sustainable health developments. This proposed efficacy model is concerned with all of the contributing factors and determinants to our health as arising from the total environment, seeking to demonstrate their intertwined flows and the probable consequences they have on each other.

To avoid widespread misunderstanding, it might be useful to add that this articulation could be seen as another dimension of sustainability, as underpinning the idea of stability or balance. Or as an alternative orientation, it might represent two sides of the same coin, on the same foundational principle which serves the purposes of needs and demands. Efficacy requires an openness that is reflected in the fact that holistic systems thinking privileges no single way, but rather assumes the pluralistic and interrelated nature of its objects. This creates an inclusive space for multiple perspectives of knowledge and scientific understanding in considering and conceptualizing these complex holistic frameworks as a systems-based “Sustainable Matrix” in which the frameworks are interconnected with each other. These holistic reflections on health effects are the relevant influential factors that are worth noting for our understanding of the changing demands in the healthcare environment.

A holistic conception of health, one that understands patterns of health and disease in public health, requires comprehension of personal behaviors, biologic traits and specific risks, but also of the characteristics of the social and physical environments that shape human experience, as public health problems are increasingly global and complex. This is especially so with the environmental and social threats arising from global environmental changes, those driven by rapid industrialization, population growth, over-consumption of natural resources and the inappropriate use of technology (Tarkowski, 2009). These arising health threats from global eco-environmental change can be indirect and very often not immediately obvious, and different determinants of health lead to different patterns in the burdens of diseases, as the resultant impacts of urbanization, modernization and globalization on human health and their determinants are all interrelated.

An emerging ecological public health paradigm has been expanding due to exposure to these arising health threats, which, alongside the global burden of disease, is increasing rapidly. These major transitional risks lead to such frightening factors as:

1. unsustainable growth in healthcare expenditures outpacing the growth of the overall economy in many countries;
2. people being deprived of the “the Right to Health”;
3. non-compliance with the SDGs; and

4. transitional and mediating health threats that might lead to unsustainable capitals in all aspects, as presented in my previously proposed ‘Helix of Sustainable Capitals Model’.

The helix of sustainable capitals, interwoven as the “Needs” within the defined “Limits”, suggests potential problems for maintaining good health conditions in the long term. If the earth’s ecosystem is to continue to support human health, each community needs to maintain public health and provide healthcare in ways that will sustain the earth’s ecosystem. Thus, humans have a responsibility toward the natural world for the sake of both nature and ourselves (Jameton and Pierce, 2001). As “Needs” cannot be “Limitless”, a new challenge arises from the perspective of a value-based legacy within the sustainable healthcare system for the welfare of future generations. Therefore a more comprehensive and cohesive conceptual framework and model for gaining insights into the underlying interrelationship of global and ecological determinants of health and diseases is of great significance. These interrelationships, as in the “Helix of Sustainable Capitals”, in fact serve as the basis for demonstrating the interrelated concept of needs as part of the components under the Efficacy Model, together with other conceptual components to form a Sustainable Matrix. From the ecological view of health, the notion of scientific justifications for sustainable health developments serves as the basis. From this basis it expands to declare the holistic demand of a sustainable healthcare environment which is superior than any single aspect of its parts.

The practice of sustainable healthcare in general is governed by the changing demands for sustainable health needs that are linked to the greater sequence of causations. Unsustainable health environments only lead to vicious cycles of “illness” or “sickness”, and the rising healthcare costs which accompany with them continuously indicate the need for a transition towards sustainable healthcare. Yet, the dependence of sustainable public health systems on the eco-environmental integrity under the four bioethics principles of beneficence, non-malfeasance, autonomy and justice are likely to lead to better healthcare for more people in the future. As for population health, its dependence on ecological integrity has been extensively documented (Lautensach, 2015). Ironically, the concept of sustainable development has rarely featured in health system reform, however this concept’s emergence can be traced back to the advent of the “health field” approach that was coined by Lalonde in 1974. Lalonde emphasized people’s responsibility for their own health, the environment’s impact on health, and the importance of healthy communities (Grin and Broerse, 2017).

The WHO (2017) has also recognized that health initiatives depend on well-functioning health systems, and that weak public health infrastructure is often simply bypassed through the construction of parallel systems. The field of public health had much to gain when the narrow biomedical approach to health was extended to include the root causes of ill health and not merely the result of biomedical interventions.

Traditionally, the principles of rule-based health systems are carried out in a complex healthcare environment, which could conflict with the demands of healthcare. Trade-offs are carried out, abiding by allocative efficiency, to make use of healthcare resources for different levels of health demands, in terms of the four levels of care: preventive, promotive, curative and rehabilitative. For healthcare to achieve its goals and to act as an exemplar for others that engage with complex health problems, a prominent notion is that the component of "sustained health" should be added into the existing four levels of care. This proposed level of "sustained health" is not just intended as a value-based legacy of care, but as a representation of "The Right to Health" and looks towards anew possibility of "holistic sustainable healthcare". Though often polarized against a natural scientific view, it would in fact instigate further nurturance of a dualistic view in healthcare, with improving the public's health being its prime initiative. In this sense, the setup of health systems is critical to the idea of allocative efficiency, as through appropriate, responsible and feasible care lies the fulfillment of various fundamental concepts of health, as well as the attainment of the basics of the Right to Health.

There is no easy way to a perfect system, however, any decent system should take into account the determining factors affecting the changing demands of the healthcare environment through a process of pragmatic and scientific considerations. Every principle of sustainable development in health represents the justifiable demands to attain sustainability on the basis of:

(a) a health transition in relation to the influential factors on health risks, especially under this global environmental and climate crisis; and
(b) a positive relationship between the means and the ends, in terms of health inputs and health as outputs (i.e., how well health, being supported for sustainable health development from the start (the input) determines the outcome of full potential health

> developments (the output) that in fact have direct implications for the later demands of healthcare services.

And this sustainable concept is indeed embedded within this Efficacy Model of Healthcare with a set of connected parts that form a complex whole, known as a "Sustainable Matrix", aimed to meet the changing demands in the healthcare environment due to the arising health threats of the Anthropocene. The new revolution is to form the 'trans-reality' of an integrative concepts of "science- value- and legacy-based" model of healthcare, which is the only way for sustainability in our health systems.

> "You never change things by fighting the existing reality. To change something, build a new model that makes the existing model obsolete."
>
> R. Buckminster Fuller (Griffith, 2011)

An Efficacy Model of Healthcare: A Sustainable Matrix

The goal for sustainable global public health care will have to be a frank and open discussion of the issues at hand, as global limits, needs and capacities, rights and duties, and means and ends must be made explicit (Lautensach, 2015). The current proposed Efficacy Model of Healthcare framework offers a means of analyzing and projecting potential benefits by justifying the significance of sustainable health developments as a health-capital-based framework for a long-term value-based legacy which would approach the stability of future sustainable healthcare through strengthening up the interrelationships amongst different levels of capitals that are dynamically interwoven with social, human, economic and natural environments. Bentley (2013) has echoed how to craft an ecological public health for the twenty-first century necessitates re-imagining public health in a way that acknowledges humans as part of their ecosystems. The central proposition of this Efficacy Model is to foster deeper reflection on our worldview with holistic and humanistic preparation for the conditions of applicability that are intended to articulate global interdependencies. Its interrelatedness through the concepts of holism and knowledge with a focus on the dichotomy between the concept of needs, and the concept of limits, is the foundational basis to form the "trans-reality" or "worldview" from a value-based legacy perspective. This further demonstrates the interface of the complexities as a "sustainable matrix" that is encapsulated by its interrelationships in this changing new global context.

The history of public health is not simply the adoption and application of scientific and medical principles by a benevolent government, instead it is more appropriate to see science, technology and medicine as playing a much more transformative role. Renewed interest today could be a result of rising healthcare costs, such as when the "new public health" was recommended in the Lalonde Report in 1974, which focused on calling for improvements in the environment and moderating our lifestyles instead of a reliance on the biomedical model of healthcare (Dew, 2012). Ecological public health principles have shown the complexity and non-linearity of the dynamics under a holistic conceptual framework (as embraced in this Efficacy Model), containing integrative approaches towards attaining an ecological balance, something which is well beyond the traditional confines of the health sector. This spells out an important feature of the understandings required for the changing demands and evolving sustainable health needs in this new era of the Anthropocene.

Sustainable developments in health must deal with the fundamental underlying causes of the determinants of health proactively. In this context, both the views derived from the Lalonde Report and the perspective of ecological public health have their similarities in terms of their focus on widening the responsibilities to address the challenges for the progress of human health and wellbeing. Responses to these concerns have manifested based on the ecological views of health that further affirm our knowledge and scientific evidence on the subject, which so far, has been the most important theoretical and rational basis for ecological public health movements. As Le Treut et al. (2007) stated, the benefits of emerging intellectually to acknowledge science are cumulative and their usefulness is retained. And healthcare professionals strive for an understanding of what is going on in the changing demands of the healthcare environment, and this Efficacy Model intends to systematically reflect a guide to view the "trans-reality" that underpins the sustainability of our health systems.

And in fact, an understanding is already a cognitive success, together with the correct representation of the required changing needs as a set of reflective and relevant facts that add a critical voice to the debate and take us forward an additional step. The value of understanding is a qualified form of realization when we recognize the actual and potential health threats from those illustrated transitional risks emanating from this age of environmental and climate crisis. These problems also account for our value of understanding with professional efforts to support the proposed Efficacy Model, which is a logical and object-directed framework for action, consisting, in our context of value-based legacy principles underpinning the structure of thought and/or formal aspects of the theoretical and practical justifications for building capacities through the renewed or reformed infrastructures for sustainability in health systems. The Twelve Ecological Public Health Principles (as in Figure 5-7) are the notions that further reflect the changing significance of our evolving scientific understanding with regard to the new waves of public health movements seeking planetary health for global environments (see Figure 6-1), which synergistically go with the changing demands of sustainable health needs in the Anthropocene.

A new dynamic definition of public health today simply emphasizes, yet again, that "health is a state of complete physical, mental, social and ecological well-being and not merely the absence of disease – personal health involves planetary health" (Prescott and Logan, 2019). And the "Right to Health" should also be embedded as a full form of care into this caring dimension. That in turn calls for further understanding about the foundational basis of sustainable healthcare needs in the Anthropocene.

Thus the conceptual basis for efficacy takes the most fundamental and critical interrelations regarding health needs from the very basic notion of "wellness" in terms of sustainable health developments. In this regard, to meet the changing demands means maximizing effectiveness to meet the sustainable health needs as the beginning of our health continuum, and as the proposed first level of care for "sustained health". This requires an increasing basic function for achieving sustainable healthcare by framing the relationship between sustainable health developments as the input, and health outcomes as the output. That, in fact, implies a production function of healthcare that justifies the overall relationship between inputs and outputs for health (Folland, Goodman and Stano, 2013).

It is expected that sustainability in health system performance must achieve the best health outcomes possible. However, the inputs of care processes and health outputs are complex, which adds further weight to the need for efficiency and the concept of sustainable healthcare, especially as resources are distributed based on multi-dimensional conditions beyond any single focus. By now we should realize the necessary sequence of thinking for the changing demands in the healthcare environment has to be formed from a perspective of a value-based legacy as that would place a humanistic focus onto caring for people across the wellness to illness continuum under the current formulated concept of holism. This includes:

1. Being aware of the arising health problems from the greatest unprecedented transitional health threats being mediated under the global environmental and climate crises in the Anthropocene;

2. Understanding the underlying causes and determining factors behind such unprecedented transitional risks happening in the process of health transition;
3. Developing the ability or capability to control, reduce or mitigate the underlying causes that directly or indirectly affect the conditions for our sustainable health developments;
4. Justifying and believing that it is important to deal with the arising health threats, together with a will to seek interventional strategies; and
5. Constructing a perspective of a value-based legacy as an integral part of this conceptual framework within a sustainable matrix that represents a deliberate sense of inter-generational moral extension for a humanistic focus onto caring across the wellness to illness continuum, inclusive with the proposed “first level of care for sustained health” through the provisions of sustainable health needs as the public health inputs for a full form of care as a whole.

Henceforth, an insightful understanding of this concept of holism, perhaps should be a justifiable choice in between concepts of ‘needs’ and ‘limits’. This is especially so given the potential future outcomes of these transitional health threats due to the unprecedented health risks of this new epoch. To carry on unchanged would only lead to a vicious cycle of rising demands for healthcare, and would place the healthcare environment under tremendous pressure in every aspect of such a cycle as a result of the ill-health outcomes. Given that one of the major sustainable pathways is strongly linked to ameliorating the predisposition of ill-health imposed by the current global environmental and climate crises. Not surprisingly, this is a determining factor for the responsiveness of health systems in relation to the existing as well as future trends of major influential factors that impact demands for healthcare services, which are continuously causing critical adverse exposures linked to disease outcomes and subsequent rises in the demand for health services and healthcare costs.

A historical view reexamining the key milestones of this epidemiological transition that indicate the transitional health risks—as an integral part of understanding how disease-driven processes accumulate and interact in dynamic ways and from influential determinants—together with contemporary studies indicate that the presence of these transitional health risks and their dynamic trap threaten sustainable health developments with latent and catastrophic effects. In light of this context, it is important to recognize that our health outcomes are in fact the consequence of those cumulative processes that begin even in utero/fetal/conceptive and gestational stages, as by reference to the many studies with significant evidence already outlined in Chapter 3. So the currently presented sustainable matrix in its dynamic, systemic and socio-ecological contexts of social, human and environmental factors, is indeed interlinked with our health closely at a very early stage of our growth.

This conceptual model of efficacy has been created to deal with the growing pressure, signifying the changing demands in the healthcare environment, as to sustain both means and ends for our public health under these unprecedented health threats is indeed urgently needed. Thus, this efficacy model has been formulated for the primary means of safeguarding sustainable health developments from a perspective of a value-based legacy, under the principle that sustainable developments in health will lead to a desirable level of care for sustained health across generations. In this view of the context, understanding the conceptual engagements in terms of the balance of needs and limits in relation to the concept of holism is paramount for visualizing the overall health outcomes as projected through a sustainable matrix under these rapidly changing healthcare boundaries in the Anthropocene.

In this contextual issue, 'health outputs' has to be related to the perception of wellness and illness as that align with the evolving concepts of disease and health, which leads to the actual and potential needs of healthcare demands for supporting sustainable health developments as the fundamental 'health inputs'. Such a relationship is simply based on views concerning knowledge-to-action as closely related to 'transitions in health under the throes of the Anthropocene' as summarized in Figure 5-3 and 'a sustainable health development model' as in Figure 5-2—both of which empower our understanding of the changing demands for the healthcare environment. And this Efficacy model is meant as a reflective frame of reference towards sustainability in health systems for now and future sustainable healthcare through knowledge-to-action as the initiatives for sustainable health developments. Just like the parallel inherence, it is not a linear cause and effect model, but provides indicative criteria that clearly identify the changing demands in accordance with ecological determinants that are affecting human health within a complex system of multiple stressors from the arising and underlying driving forces.

The choice of the "Efficacy Model" as the core value of this conceptual framework, that fits into those dimensions and principles which are in line with the cohesive sustainable elements and components making concerted efforts to define the theoretical basis, is derived from a sustainable matrix under the rapidly changing healthcare boundaries in the Anthropocene, which presents different relational aspects that are in fact comprised of interrelated conceptual ideas. They are formed by balancing a concept of needs with a concept of limits as an integrative sustainable matrix under a concept of holism that extends its dynamical interrelationships amongst:

- the Helix of Sustainable Capitals, as a "concept of needs" nested for sustainable development in health;
- planetary Health for Global Eco-environments, which demonstrates the "concept of limits", as humanity has to be operating safely within the scientifically defined planetary boundaries, which are not limitless; and
- the vision for a "concept of holism", which places humanistic caring as its prime perspective for a value-based legacy to safeguard sustainable developments in health under the rapidly changing healthcare boundaries in the Anthropocene.

Yet again, the scope of this Efficacy Model resonates the interrelatedness of each conceptual component amongst an overall interrelationship that interwoven within this non-linear "Sustainable Matrix" under the rapidly changing healthcare boundaries in the Anthropocene. Given the plethora of dimensions, there is an implicit opportunity to think very broadly about the changing demands in the healthcare environment, the surrounding health developments, and the influential factors that are affecting sustainable developments for health. The interface of the complexities that encapsulate the interrelationships required for achieving sustainable health systems further reinforces the inherent value-based legacy principles of our approach with critical lens for the mission and vision of care extending across generations. Alternatively, we can look beyond the changing demands in the healthcare environment by referencing the linkages running through different components to form a sustainable matrix inextricably interlinked with our health developments.

The ideas of this Efficacy Model depict almost all of the influential factors under the global environmental and climate mediated health risks with their broadest possible context affecting sustainable developments in health, including: (1) downstream factors at the micro-level; (2) midstream factors at the meso-level, and (3) upstream factors at the macro-level. Indeed, they are not separate entities, possibly formed at the cross-level as a web of a sustainable matrix. This web of a sustainable matrix further resonates its preferable or influential ways in transforming creative and equitable balances onto its interwoven interrelationships under this concept—"a helix of sustainable capitals". It is inevitable that we will face challenges along the way, and thus we must be flexible and adaptable; we must reconceptualize the most efficient means of global interdependence for approaching sustainable health developments. Forming coherent value and recognition of the commonality of the components producing health by referencing the core interrelationships as projected in a helix of sustainable capitals as (a) the renewed concept of needs, together with the scientific understanding of the significance of planetary health and its boundaries as (b) the renewed concept of limits, while (c) concept of holism to safeguard sustainable developments in health as part of an integrative and synergistic humanistic caring. The diagrammatic interrelationships of these holistic value-based legacy is indeed formed between this Efficacy Model of Healthcare for changing demands in the healthcare environment alongside a web of Sustainable Matrix under these volatile boundaries in the Anthropocene, which is presented in Figure 7-1.

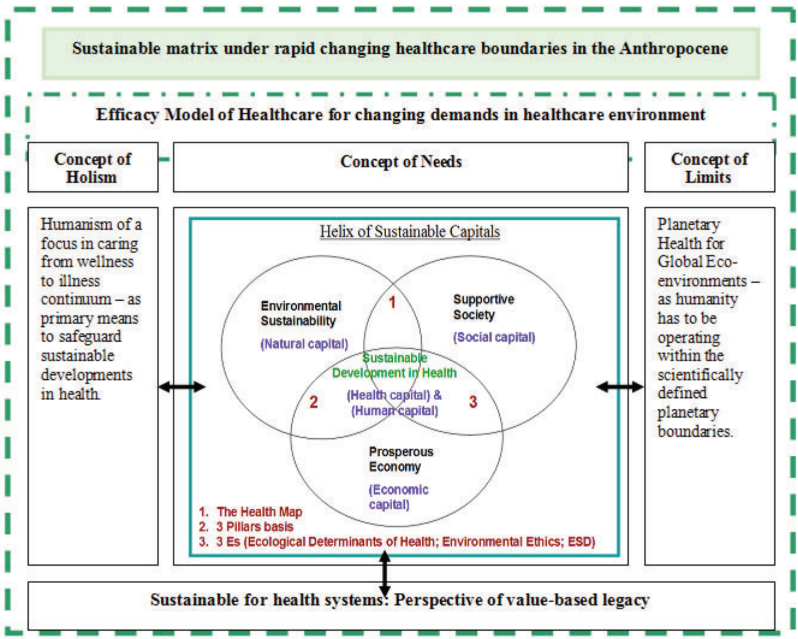

Figure 7-1: An Efficacy Model of Healthcare for the changing demands in the healthcare environment. The outermost green-line represents a web of sustainable matrix under the rapidly changing healthcare boundaries in the Anthropocene.

All of the conceptual components above are meant to be universally valid and to hold good when applied to ecological public health paradigm in our globalized societies of today and of the future. We should further reiterate that "needs" and "limits" have to be balanced for the sake of safeguarding sustainable developments in health from a wide range of perspectives, and in diverse interventional strategies or approaches, based on the ability to produce desirable or intended health outcomes within concept of "holism" *per se*. This further echoes the message given by the World Health Organization in 2014, as it considers health to be the fulfillment of human potential; thus the health of the biosphere and its natural systems must also be allowed to flourish, as only this will allow for the fulfillment of human potential and the realization of "planetary health"—a key part of the frameworks for greater input into our health paradigm (Prescott and Logan, 2018).

As Lautensach (2015) pointed out, the very fundamentals, that is to say the purification of air and water, the provision of foods and shelter, and the processing of wastes, are directly carried out by ecosystems. The sustainable provision of those services depends on the biological integrity of those ecosystems and a healthy planet. To improve public health, systems thinking requires an understanding of societal structures and functions (Zinsstag, et al., 2011). Thus to collate a comprehensive review of the overall relatedness of the many different aspects within systems thinking will require a greater reliance upon a wide range of considerations. This in turn means that professional competencies must be prepared and trained adequately in order to build capacities for sustainable developments as a primary means of safeguarding human health and well-being during this new age.

The complexity and diversity of this Efficacy Model of Healthcare are formed to attain efficacy through a "means justify the ends" approach, which in turn forms the basis of a logical structure for the interrelated sustainable matrix under the rapidly changing healthcare boundaries in the Anthropocene. As Wang (2009) illustrated, the collaborative efforts to improve sustainable development require the collective will to tackle the root causes of the challenges, and to effectuate solutions to these challenges requires humanity to think hard and thoroughly on what we have done wrong and how we are supposed to find a solution. We need, then, to examine our mindset with a new framework. As such, our multidimensional knowledge would benefit from the advantages of this Efficacy Model, which brings a greater depth to the pragmatic outlook and the overall vision for addressing the changing demands in the healthcare environment.

The WHO regards equity as the "principle of being fair to all, with reference to a defined and recognized set of values", and more concretely, equity in health implies that ideally everyone should have a fair opportunity to attain their full health potential and more pragmatically, that no one should be disadvantaged from achieving this potential (Wenzel, undated, p. 4). Henceforth, the focus should be on the ‘first level of care’ dimension, that is, how to achieve “Sustained Health”, added into the other four levels of care, namely: the “promotive”, “preventive”, “curative” and “rehabilitative”. It cannot be overstated how important our understanding of the rapidly changing healthcare boundaries is, as one of the major components for sustainability in our health systems. This is the fundamental reason why the conceptualization does or should not alter the fact that what we need to consider for the sake of enabling the consistent delivery of effective, efficient, and sustainable healthcare is the attainment of efficacy towards this direction. The ultimate end of our theoretical and practical reasoning should be in line with a strategic vision for an ecological public health basis that intends to guide a new period of progress. The conceptual engagements of this “Efficacy Model” are specifically focused on: (1) a concept of holism derived from a balance between a concept of needs and a concept of limits; (2) humanism with a focus on caring across the wellness to illness continuum; and (3) sustainability in health systems from a perspective of a value-based legacy. It aims to aid the paradigmatic shift from a downhill trend affecting the sustainability of health developments, to a path which understands the massive and global underlying forces that influence the changing demands in the healthcare environment under the environmental and climate mediated health risks in the Anthropocene.

Concepts of Sustainable Healthcare Reform: Ecological Dimensions of Our Wellness

Modern medicine began only around 1850. Since then different frameworks have been continuously developed based on relevant evidence-informed concepts and understandings in accordance with scientific justifications. The historical timeline provides evidence of informed actions of transition in health developments throughout different stages of scientific understanding, which is not just a reflection of the relevance in using a particular approach for healthcare, but in fact indicates how the required changing demands were congregated. Figure 7-2 summarizes the timeline of scientific evidence for health developments and changing needs from modern medicine onward into the new epoch of the Anthropocene in the 21st century.

Modern medicine	
1850	"Modern medicine" begins
1854	Cholera outbreak: Jon Snow publishes Broad Street map. Snow demonstrates that cholera bacteria were transmitted in contaminated drinking water.
1855	Rudolf Virchow publishes his now-famous aphorism *omnis cellula e cellula* ("every cell stems from another cell"). He also states that all diseases involve changes in normal cells.
1864	Louis Pasteur: proposition of germ theory; discovery of bacteria
1890	Robert Koch confirms causal link between bacteria and disease.
From germ theory and a pre-antibiotic age to antimicrobial therapy and an antibiotic age	
1928	Alexander Fleming discovers penicillin. It is the start of the antibiotic age.
1932	Gerhard Domagk discovers sulfonamides.
1943	Selman Waksman discovers Streptomycin.
From antimicrobial therapy to antimicrobial resistance	
1948	Penicillin resistance; resistance observed in Staphylococci.
1952	Treatment for plant diseases. Streptomycin is first used in agriculture.
1955	First MDR case. *S. Dysaentriae* outbreak in Japan.
1961	First case of MRSA. Methicillin resistance in *S. aureus*.
1993	The WHO declaration: TB & MDR-TB "global health emergency"
2011	Complete drug resistance. First confirmed case of completely drug-resistant TB in Mumbai. Post-antibiotic age?
Global environmental and climate mediated health risks in the Anthropocene	
1950	The Great Acceleration (we enter into the new epoch of the Anthropocene, taking the Great Acceleration's start point as in 1950).
1972	Frederick Sargent II, MD, the physician and ecologist, advocates for a greater understanding of the interrelations between the "planetary life-support systems" and health. The term planetary health then emerges from the annals of preventive medicine.
1987	The Brundtland Report defines the importance of sustainable development.
1992	Earth summits take place with declarations on the environment and development in Agenda 21.
2005	The Millennium Ecosystems Assessment indicates a major assessment of the human impact on environmental degradation.
2012	The Planet Under Pressure conference, with the attendance of 3,000 leading scientists, releases a State of the Planet declaration.
2012	The World Universities Network for Planetary Health is formed.
2015	Richard Horton and colleagues present report on planetary health in The Lancet Commission.
2015	United Nations 2030 Agenda for Sustainable Development Goals.
2018	The Canmore Declaration: Planetary health principles.

Figure 7-2: Timeline of scientific evidence for health developments and changing needs in the Anthropocene.

We need an understanding of different transitions in health that are driving the historical developments of the complex old and new challenges in the ever-changing public health theory and practice, as well as different approaches and models being used. Historically, the conceptual focuses of transformational frameworks in health systems respond to public health challenges and priorities are to guide large-scale health system reform through different approaches to evidence-based practices and proactive thinking of changing health needs. This is summarized in three stages and described in a report by the World Health Organization (WHO, 2018):

1. The first era from the 1850s to the 1960s. It emphasized a biological focus with the diagnosis and management of acute diseases to improve life expectancy; patients were passive, inexperienced and deferential.
2. The second era from the 1950s to the present day. It has focused more on the reduction of chronic disease, improvements in modifiable behavioral determinants and the integration and coordination of care at the level of the individual. The patient becomes an active partner in care.
3. The third era from 2000 onwards. Overlapping with the previous era, it focuses on creating capacities to achieve goals through the development of community-accountable health development systems at the collective level.

This historical timeline as presented in Figure 7-2 further affirms how views on sustainability for all forms of beings have changed alongside notions of planetary health. This book also illustrates scientific evidence that affirms planetary health as the ultimate determinant of health in the 21st century, together with the proposed transformative frameworks discussed for the changing demands in the healthcare environment, as an integral part of sustainable healthcare reform in support of sustainable health developments for our wellness. It is a matter as illustrated under the helix of sustainable capitals which has now become more urgent because without maintaining the sustainable capitals as a concept of needs, our human or health capitals would be incapable of being maintained. This further reinforces that “needs” and “limits” have to be balanced for the sake of safeguarding sustainable health developments, which are synergistically formed for the changing needs in the Anthropocene.

Yet, based on evidence-informed health in transition as reflected from the epidemiological data on health statistics, in which the underlying determinants are the major driving forces of the consequential effects on health and disease, which comprise part of the reflections from different stages of epidemiological transition. They in turn, lead to the cornerstone for evolving public health needs correspondingly. Sustainable healthcare reform is an urgent need for different reasons and from multiple perspectives of knowledge integration. The perspective should always be supported by the proposed twelve ecological public health principles, together with the interrelationships projected from planetary health for global eco-environments. Given the changing patterns of the global burden of disease, enabling health professionals to acquire an ecological view of health for the various direct and indirect health impacts arising from global environmental and climate change mediated health risks is vital. It is a central tenet for tackling the issues arising in this new epoch contributing to the latest stage of epidemiological transition under these unprecedented predicaments.

The interface of conceptual frameworks relevant to the emerging ecological public health paradigm within public health orientations and concepts in transition should contain sufficient knowledge about the sustainability of human-environment interactions supporting the integration of ecological principles to human health. This entails knowledge of scientific advancements that unfolds the constant changing influential and predisposing factors that lead to the appearance of health-related problems under these unprecedented predicaments.

Correspondingly, our professional roles are vital in the process of this evolution for ecological public health needs. As a response to these essentialities, the relevant justifications must be made based on evolving perspectives, bearing in mind, amongst other aspects, that sustainable health development is the prime focus for supporting the full potential towards sustained health. Thus, concepts of sustainable healthcare reform need to consider the role and scope of health systems as drivers to incorporate the ecological dimensions of our wellness into anew concepts for an integrative ecological public health paradigm.

A vision for sustainable healthcare requires redefining the changing demands in the healthcare environment under this paradigm in transition, in which the entities, concepts and meanings of health and disease have changed, which now characterize this new epidemiological epoch with its unprecedented global environmental and climate mediated health threats. However, in addition to such changes there are also the existential health problems that have accumulated from earlier stages of epidemiological transition, too. Especially achieving sustainable healthcare is a continuous journey on which we must make sure that our actions and decisions include "development that meets the needs of the present without compromising the ability of future generations to meet their own needs", as defined in "Our Common Culture" from the Report of the Brundtland Commission in 1987. Therefore sustainable healthcare is a way of providing care that is "living and working within our means" with regard to natural resources at its core, and one of the major keys is how we maintain health (Schroeder et al., 2013).

Sustainable healthcare reform aims to optimize the structure and incentives in the health systems and to encourage education towards this trend. Yet again, the aforementioned ecological and determinants approach towards ecological public health education, together with a set of previously proposed synergistical strategies aimed to: (a) facilitate public health theory and practice for emerging ecological public health as a paradigm in transition in this new changing global context; (b) understand the changing demands in the healthcare environment; (c) embrace the evolving concepts of health and disease with the proposed twelve ecological public health principles for healthcare professionals; (d) direct a journey of professionalism towards curriculum development through the connectivity of educational platforms; and (e) support the changing needs for preparing, expanding and empowering nursing and health professionals for a sound and well-equipped workforce. In this context, it is utterly essential that nursing and health professionals and health authorities dedicate support to the primacy of ecological public health education, so as to unify the currently proposed and informed process of knowledge-in-action for the well-being of all, as part of a 'practical relevance' concerning sustainable healthcare.

Ecological disasters are already at our doorstep. Because Earth's biological systems are necessary for human well-being, our medical pursuit of health must not diminish the abundance and vitality of the natural world (Jameton and Pierce, 2001). Global ecological risks and the health impacts of social, cultural, and economic activities have resulted in eco-environmental health issues and typically cumulative, long-term, and complex human health effects. Henceforth, sustainability has become a widely used concept as the World Health Organization has pointed out the existing climate change will affect the ability to maintain good health, and healthcare systems should thus take climate change and its implications seriously. This, in turn, has allowed sustainable development to emerge as the accepted basis for integrating environment and health issues, and in Australia, this is often known as ecologically sustainable development (Nicholson and Stephenson, 2004).

It is, therefore, essential to improve risk-based hazard mitigation by bettering our understanding of the effects of natural hazards on public health under existing and future climatic regimes, which represents an important research priority (National Academy of Sciences, 2007). In order to establish policies and practices that create more ecologically sustainable and healthy societies, public health reports at all levels should include indicators of ecological determinants of health in their routine reports, which should also specifically report on a regular basis, reflecting local, regional, provincial, national, indigenous and global contexts (Hancock, Spady and Soskolne, 2015).

> … "[A]s it becomes more widely recognized that natural systems underpin our health, wealth and security, the impetus to protect and restore nature is much more powerful. If successful, we would be the first generation to accomplish such a change in direction."
>
> (WWF, 2018, p. 15)

Most importantly, this proposed approach of understanding ecological public health and applying this understanding through educational interventions to bring about the necessary societal change, will help us not just to understand the ecological determinants of health and diseases, but rather our 'trans-reality' to realize and/or experience of the adverse transitional health threats increasingly arising from those ecological determinants of health. Therefore, we have to develop such understandings in response to human and eco-environments holistically through various key concepts in transition, which can serve as actionable interventions in support of sustainable health developments for all. As a common denominator to initiate the process of change, it is a priority to embrace ecological public health education as academic program. Bentley (2013) states that crafting an ecological public health education is an absolute priority for public health practitioners. In fact, the nursing and medical professions have also emphasized the issue of sustainability and health, and have begun incorporating it into their academic programs (Anåker and Elf, 2014). According to consequentialist ethical theories, the sole justification for an act is the state of affairs it brings about; as a result, consequentialism might appear to be well suited to public health, given that the goal of public health is to enhance the welfare of populations. The attitude also underlies a cost-effectiveness approach to resource allocation that is embraced by many health economists, which seeks to maximize the number of healthy life years in the population as a whole through a distribution of resources that results in the most "quality-adjusted life years" (QALYs) (Siegel and Merritt, 2019).

Times Change and We Change with Them

It is true that "*Tempora mutantur*" ("Times change"), and equally true that "*Tempora mutantur, nos et mutamur in illis*" ("Times change, and we change with them"). We are no longer benefiting from the time of the Quaternary Period in the Holocene Epoch: we are now living in the Anthropocene Epoch and the declining condition of the natural environment is beginning to affect the health of populations in many parts of the world (Jameton and Pierce, 2001). As the World Health Organization pointed out in their health agenda for the 21st century, trends in health across the human life span during the past 50 years have steadily improved. The main issues now are how to sustain those improvements and how to meet the health challenges of the future, while the changing world is experiencing changing patterns of health, including: rapid modernization; an everyday life dependent on technological advances; changing behavior (sedentary living, excessive or ill-balanced diets and smoking); and a deteriorating environment—air pollution, exposure to chemicals, contamination of soil and water, and hazards to food safety (WHO, 1998). Ecological public health education will substantially influence the future direction of the roles of nurses and all other health professionals. The overall educative approach towards this context, for shaping health under the conceptual frameworks e.g.,—as in the "Helix of Sustainable Capitals Model"—will have a powerful interplay with all stakeholders in crafting the central target of "Health capital" through "sustainable development in health" for the good sake of safeguarding our "Human capital" across future generations.

The overall picture can be construed by using different values and their meanings, such as the social, ecological, environmental, cultural, and political conditions; and when changes are emphasized in terms of health issues they are often compartmentalized, and therefore public health efforts are striving to overcome such compartmentalization by reinforcing the idea that health problems are multi-faceted. Efforts to tackle these multi-faceted challenges require the bidirectional effect of the environment on human subjects and, conversely, the human influence on all living systems and their genomes (Prescott et al., 2018).

This "bidirectional effect" appears to be just like "holons". Holons (wholes and parts), exist within what Arthur Koestler first called a holarchy when he coined the terms in his 1967 book *The Ghost in the Machine*. A holon is "a whole that is a part of a larger whole" and a holarchy "the connection between holons" (Höglund, 2016). Perhaps, a deeper meaning and understanding could only be sustained by the human spirit concerning our role and purpose as part of this journey for resolving potential conflicts of values. Indeed, too much of a focus within seems to lead to a certain isolation from the world that deprives us of the spiritual nourishment that can be found in relating to others, and the value of a kind of inner ecology that relies on the same principles of balance and holism that characterize a healthy environment. However there can also be “a separation between facts and values, between the thoughts of a scientist and the moral duties of a human being” (Gore, 1992). Throughout the history of civilization dominant cultures have given rise to a range of quite different cultural arrangements aimed at ensuring the population’s health and prosperity, however “another psychological device for resolving a potential conflict of values is information denial”, which exists as its counterpoint (Boyden, 2004). The threads of global health literacy are significant pathways that may influence the inception of a culture of health. As the Robert Wood Johnson Foundation has pointed out, “the economy [being] less burdened by excessive and unwarranted health care spending” would be one of the principles under the vision for a culture of health (Barton et al., 2018).

> “Without healthy natural systems we need to ask whether future human development is even possible.”
>
> (WWF, 2018, p. 22)

And now, we are the first generation that has a clear picture of the value of nature and the grave situation we are facing. We may also be the last generation that can do something about it, and we all have a role to play in reversing the loss of nature—but time is running out and we will continue to need these natural resources to survive and thrive (WWF, 2018). Our role is ensuring the sort of education and experience which shapes the values and attitudes conducive to the health of civilization (Prescott and Logan, 2018). The benefits of the ‘practical relevance’ for ecological public health are as the hierarchy of the sciences describes, not only in the complexity of the phenomena studied by different sciences, but rather in their stage of intellectual developments. Thus scientific pluralism enables integrative studies and avoids the predominance found in the hierarchy of sciences, which requires an understanding of the epistemology and scientific representations of the disciplines being convened, while sharing theoretical structures and/or paradigms that provide a framework of perceptions on the reality of different fields and the forms of their scientific practices (Morand and Lajaunie, 2017).

In the same vein of this shared thinking, the ‘practical relevance’ is to create a ‘parallel inherence’ for sustainable healthcare through sustainable health developments through the emergence of ecological public health as ‘the means’ to synthesizing the serial synergistic networks of collaborative effort for transforming ecological public health theory and practice for this new changing global context, as integral part of changing demands in the healthcare environment as ‘the ends’. The central theme includes:

1. Educational reform: Knowledge-in-action to facilitate capacity building for the changing demands in the healthcare environment.
2. Universities’ role in curriculum planning and development to facilitate evolving approaches with the proposed twelve ecological public health principles for healthcare professionals.
3. Curriculum development through the educational platform for the necessary connectivity to facilitate knowledge integration under a web of sustainable matrix for the rapidly changing healthcare boundaries.
4. Concepts of sustainable healthcare reform towards ecological dimensions of our wellness through a new principle of relativity in transdisciplinarity (see Figure 6-4).

As in Albert Schweitzer’s concept of Reverence for Life and many indigenous value systems, nature is given its own intrinsic value, and an understanding is fostered that we are part of a living Earth, together with so many other beings, and are not the only species on the planet that matters (Gabrysch, 2018). Therefore, public health should join others in working towards a fundamental shift in the values and social norms of the population in order to create change to address the emerging ecological crisis (Hancock, Spady and Soskolne, 2015). It could take the form of a global campaign for health literacy with sustainable ways of living and a vision for achieving global interdependency for those cogent reasons. Yet, scientific knowledge is inevitably socially mediated, especially for the contextualization of ecological knowledge, which can only be arrived at, described, assessed and applied through human subjectivities, and by implication through social relations (Raffaelli and Frid, 2010). As such, transformative values from legacy-based and multi-perspectives of “Eco-health and Environments” versus “Eco-nomics” to “Climate change” versus “Civilization” are important implications for the development and implementation of strategies for public health hazard-risk information. Therefore, more influential paths to advance and empower planetary health through new waves of public health movements for global eco-environments are absolutely essential, especially as an integral part of evolutions for ecological public health needs in the Anthropocene.

In this context, the "paradigm in transition" discussed in Chapter 5 represents an important and timely shift towards the perspectives from "Knowledge-to-action" to "Knowledge-in-action", while incorporating the requirements and/or principles: (i) an understanding of the changing demands in the healthcare environment under the throes of the Anthropocene and its transitional threats to public health; (ii) evolving sustainable concepts in health developments for nursing and health professionals is absolutely essential; and (iii) directions of professionalization and trends of ecological public health education through educational reform are significant parts of synergistical strategies for capacity building towards sustainable healthcare reform. As time progresses, knowledge transmission, translation, and transformation will begin through the inception of understanding and grow through reconceptualizing and envisioning the changing nature of sustainable health needs in this new era.

Perhaps the timing is right for a call to action to increase nurses' knowledge, attitudes, behaviors, practice resources, and system capabilities to lessen the health literacy-related burden, as nurses are uniquely positioned to create the required cultural change and public health transformation (Loan et al., 2018). The WHO has noted "the growing recognition that health cannot be relegated exclusively to health professionals", and it should be treated as a priority within the global development agenda. To mobilize support, this agenda should include a worldwide campaign for global health literacy. This echoes anew ecological sense of public health is necessary to decipher relationships between environmental issues and human and animal health, which indeed represents the path of articulation to promoting a sustainable future (Li, 2018a). Health literacy is an old concept in nursing and healthcare, but it is also a complex issue (Barton et al., 2018). Together with the proposed conceptual landscape of the new waves of public health movements toward the global health transition that allow us a better understanding of not just the arising health problems, but also the synergistic vision for the strategies required to tackle the driving forces behind the underlying determinants.

Ecological and global determinants of health and diseases approached from different levels with the evolving concepts of diseases that are possibly the most prevalent and undoubtedly one of the most important sets of contextual evidence for the changing demands in the healthcare environment. Historical examples include:

- ☞ different models being used in accordance with different understandings in relation to the concepts of diseases throughout and across different timespans of public health developments;
- ☞ old public health models being used under the time period covering the theory of miasma and later on the theory of germs;
- ☞ biomedical discoveries in the complex interaction between man, an agent and the environment for a new public health model; and
- ☞ an ecological public health model with scientific evidence for the concepts of diseases, from maladjustment of the human organism to the environment, eliciting how changes to the environment have altered disease patterns and human exposure to disease outbreaks.

As Baum (2008) noted, ecological sustainability is at the heart of the aspirations of public health for the twenty-first century (Brown et al., 2013). The importance of considering the determinants of health that have driven the changing demands of public health needs lies in their major effects on health outcomes, especially for those predisposing factors that interact with overall health such as: heredity; environment; lifestyle; socio-economic conditions; health services; health-related systems, etc., which are essential factors influencing better health-related outcomes.

To a certain extent, successfully addressing the determinants of health could lead to healthy developmental progress and a stronger and more sensible position from which to sustain healthcare in a volatile system. Both the upstream and downstream effects of health influence factors guiding the effectiveness and efficiency (e.g., cost) of population-based interventions. For this reason, the know-how of the synergistic strategies with emphases on an ecological approach to disease prevention and sustainable health promotion relating to public health impacts and contemporary transitional health threats under the global environmental and climate crises is the major task or challenge that lies ahead. The challenges of concern, focused on from integrative and transdisciplinary perspectives—thereby converting points of divergence into points of convergence as the ultimate synergistical public health interventions. By so doing, the process of change could be initiatied by creating fertile points interwoven across knowledge and approaches, which in turn allow different domains to be merged into broader scopes and conceptual engagements within this theme of the efficacy model, which will interplay a significant part in the global campaigns for ecological public health literacy, as well as strengthening sustainable health promotion and disease prevention proactively.

Yet again, the proponents of this Efficacy Model are generated and justified through the enormous health needs and ever-growing body of scientific understanding on the rapidly changing healthcare boundaries due to the throes of global environmental and climate mediated health threats. The virtues and justifications for this efficacy model are undoubtedly interlinked closely with the broad range of factors influencing human health at different levels of the health transition, largely due to:

a. exposure to environmental and climate mediated health risks rising rapidly under this new epoch in the Anthropocene;
b. major risks from diet-related, obesity-related and environmental-related diseases leading to: increases in premature death, diminishing quality of life, and increased healthcare costs; and
c. transitional health risks leading to unsustainable factors continuing and worsening under the global environmental and climate crisis.

As Salk and Salk (2018) described, the way through this difficult era is to understand its basis and to focus on new values that will be of the greatest benefit both for humanity and for the planet as a whole. Professor Jonas Salk cites the overarching guideline of "*Tikkun olam*", which is a concept in Judaism literally translating to "repair of the world", as having constructive and beneficial implications for our actions in this regard. Nowadays especially, humanity acquires more than the ongoing productivity of Earth's ecosystems can provide sustainably, and is thus living off the Earth's natural capital. A large fraction of our population of more than seven and a half billion people needs more access to food, water and energy to improve their material standard of living, and the prospect of an additional two billion by 2050 intensifies this need for basic resources, a need that cannot be sustained indefinitely (Steffen et al., 2011).

Yet again, as the Brundtland Report (1987) clearly states, the basic definition of "sustainable development can be defined as development that meets the needs of the present without compromising the ability of future generations to meet their own needs". Thus, collaborative effort and synergistic effects in shaping new insights for a shared vision, as an important part of these puzzles for constructing new waves of public health movements, form essential parts of the journey of evolution for public health needs in this new age. With the inclusion of new waves of public health movements come multifaceted empowerments, adding momentum to the overall beneficial effects of this synergy for sustainable demands of health needs.

As awareness of the factors that contribute to ‘lifescape’ change can help guide the development of strategies to improve the relevance and communication of information outputs (Wakefield-Rann and Fam, 2018). To further elucidate the perspectives that:

1. The Efficacy Model framework for sustainable healthcare development, together with added focus on the previously proposed the twelve ecological public health principles should be adopted.
2. Given the changing needs of ecological public health, the considerable scope for the expansion of capacities for nursing and health professionals through a unified vision for the empowerment of public health systems must be acknowledged.
3. A new revolutionary vision has to be enacted in our healthcare enterprise by encompassing medicine within a much bigger planetary system and putting it in its rightful place, as a new way of ecological and systems thinking for sustainable healthcare.

Times change and we must change with them, understanding the changing demands in the healthcare environment is in fact the guiding principles support the necessary paradigmatic shifts towards sustainable healthcare and developments with “science- value- and legacy-based” platform, so we need to put forward ecological public health as anew orientation for an evolution of public health needs. An evolutionary approach needs to be addressed to improve understanding of human health and disease so as to better support sustainable health developments during this new epoch.

The interconnectedness of human-ecology perspectives can induce a process of paramount importance, particularly with regard to all that is encompassed by “pathocenosis”—its effects and the changes brought about by them—and especially during this age of growing global environmental and climate crises in the 21st century. Human ecology perspectives will broaden public health theory and practice in this new and changing global context, and as McMichael and Beaglehole (2003) postulated “the sustained good health of populations requires enlightened management of our social resources, economic relations, and of the natural world”; they reckoned human population health should be a key criterion of “sustainable development”. The interventional approach of emphasizing a holistic conceptual framework as an innovative model of sustainable care and development for health should be embedded and integrated into the infrastructure of health systems to provide a solid basis upon which to support integrative perspectives for sustainable developments in health:

- ☞ Recognition that the planet is the primary and ultimate ecological and global health determinant of future public health.
- ☞ The need to understand the consequential interrelationships between global environmental and climate change related and mediated health risks.
- ☞ The importance of environmental, social and economic dynamics that can drive the resultant health effects and have subsequent unintended consequences for the healthcare environment.

A vision for an environmentally sustainable health system improves, maintains or restores health and should focus on prioritizing disease prevention, health promotion and public health services by engaging the health workforce as an agent of sustainability (WHO, 2017). The emergent roles of healthcare professionals could then provide incentives for even further change, particularly as we learn more about the determinants of health; and educational development allows us to make competent decisions (Edington and Pitts, 2016). Given the emphasis on the role of professionals in health promotion and health maintenance, professional boundaries have to be expanded through the empowerment of ecological public health education to build workforce capacities as an integral part of the changing demands. Ecological public health education will bring a new dimension and direction towards sustainable healthcare through the empowerment of sustainable health developments.

As the health threats being imposed by the ecological and global health determinants resulting from the interaction of an agent and host in the epidemiological or ecological triad of the disease triangle (with the dilemma drivers of environmental hazards) have to be tackled collaboratively, the ecological paradigm used to do so has to be expansive with regard to the role of public health (Li, 2017a) for all health professionals. Thus, a pledge for professionalism towards sustainable health needs to promote ecological public health under this age of environmental and climate crisis in the Anthropocene should be endorsed as an integral part of our solemn oath (also see Figure 6-11).

As the value-based healthcare concept seems the true health objective, in which value is created from health outcomes relative to the cost of achieving those outcomes (Putera, 2017; Bircher and Hahn, 2017), then to implement value-based healthcare, transformations need to be made (Putera, 2017), and the changes in the healthcare system need to be informed by a comprehensive and actionable definition of health to promote sustained change on a public health scale (Warren, 2017).

Ecological public health responses and initiatives are therefore framed as "the possible" paradigm in order to add momentum towards solutions during the Anthropocene. Figure 7-3 is a summary of a fascinating historical story as an analogy that symbolizes or resembles the message of "the possible"—the current analogy indicates how *Homo sapiens* could also create and have a vision for action to make ecological public health "*the possible*" reality for our sustainable health developments towards the changing demands in the present and future healthcare environment.

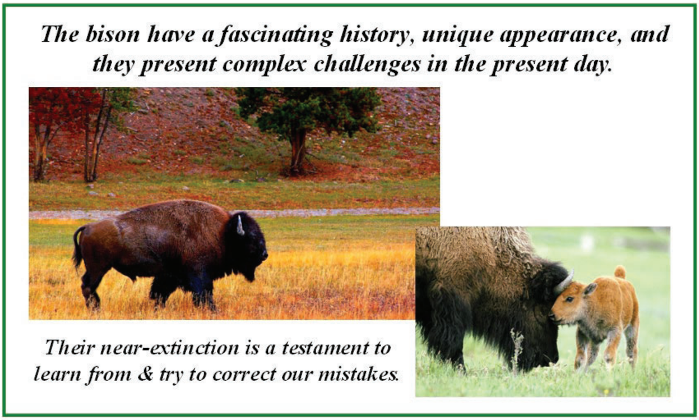

Figure 7-3: Resemblance: "The Possible" (pictures adapted and modified from itl.cat).

Conclusion

The phenomena of crucial events and issues shaping the rapidly changing global environmental and climate crises have led to a growing concern for ecological public health education, which is increasingly one of the focal demands for adapting to this changing healthcare environment, as sustainable health development is the ultimate capacity for ensuring a solid basis upon which to support integrative perspectives for sustainable health more holistically. As Prada, Grimes and Sklokin (2014) recognized, sustainable health and healthcare allow for the appropriate balance between the cultural, social, and economic environments designed to meet the health and healthcare needs of individuals and the population as a whole. In order to address the contexts of sustainable health and healthcare we have to find the appropriate balance of how to meet health and healthcare needs sustainably.

The central tenet of understanding the demand in our changing healthcare environment is that sustainable health developments are an interrelated part of our co-existence with “others”—with other humans, animals, plants, ecosystems, etc.—within the eco-environments of our planet and not separate from it. Therefore, the theme of the efforts in an attempt to deal with the existing and future trends of demands in the healthcare environment is synthesized as an integrative sustainable matrix embraced within this proposed Efficacy Model of Healthcare in order to form the credibility to verify that particular interrelatedness. This interrelatedness is aimed at reconciling objectivity and impartiality with considerable measures and extended dimensions of connectivity as the feasible way towards sustainability in health systems. Therefore, the derived concept of holism is formed by or consists of the choice between two components: a concept of needs versus a concept of limits.

It is simply because every evolutionary concept, in understanding the changing demands in the healthcare environment, is or should be typified by an integrity of virtues, in the sense that it unfolds the magnitudes of understanding through both its means and ends. Ecological public health education makes it possible to recognize that these caveats are part of a pathway towards sustainable health developments, as planetary health is one of the ultimate ecological determinants of public health. As far as the overall health in transitions *per se* under this age of environmental and climate mediated health risks in the Anthropocene, this Efficacy Model is meant to foster an understanding of that particular interrelatedness as derived from the web of a sustainable matrix. Consequentially, health and health systems require a changing profile and complex solutions to those cascading mediated and transitional health risks. Efforts towards the ultimate goals of ecological public health, then, should be in focus with an understanding of the social and economic effects acting as a guiding vision towards all the demands of the changing healthcare boundaries.

To that end, the efficacy framework is interwoven with interrelated outcomes of health stewardship for assessing its effectiveness and efficiency, which can positively affect healthcare needs, as our health status has direct indications for the varying needs that in turn, affect the effectiveness and efficiency of healthcare environment at large. This is especially so, as dealing with power relations in the realization of the needs of sustainable healthcare transition requires a very broad scope of involvement, of empowerment, in addition to the creation of a professional role in promoting the required knowledge for sustaining the necessary health transition intellectually, intelligently, efficaciously and effectively. The purpose of the sustainable healthcare movement is to better acknowledge the totality of relations that exist amongst people and their environments, and to better respond to sustaining our health systems humanistically and holistically as a whole.

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CHAPTER 8

ECOLOGICAL PUBLIC HEALTH EDUCATION FOR NURSING AND HEALTH PROFESSIONALS

Public health is an important moral force, and as such plays a significant role in shaping society and humanity at particular historical moments in its many forms of caring. It is the unprecedented greatest challenge of our time in this new era of the Anthropocene, especially with understanding of its praxis as the intended values of theoretical knowledge utilizations which goes beyond structures within any single health profession. In particular medical and health sciences practice has evolved over the century, thus this serves as driving forces that will be continuously shaping professional developments within nursing, medical and all health fields. It has an increasingly pervasive influence on advocates and academics, and also tends to be integrated into their own roles in relation to the politics and science of population health (Dew, 2012). Often facing difficult decisions due to without adequate training and preparation, which apparently is a feature of the public health context, and therefore that motivates us to think carefully about approaching and dealing with the arising health problems, and how we articulate and address their resultant challenges (Siegel and Merritt, 2019).

This book has proposed various conceptual engagements conforming to the current global environmental and climate mediated health risks arising in this new epoch, many of which oblige us to face challenges in a manner that is continuously refining, expanding, and advancing our professional competencies through education and curriculum reform for the fulfillment of evolving ecological public health needs. It is worth noting that the impetus for ecological public health education is meant to strengthen existing and new ecological views in support of sustainable developments in health, which in turn serves as an integral part of advancing competencies for nursing and health professionals, as well as to expand the scope of ecological public health from theory into practice for this new changing global context in the Anthropocene.

Blending Health Needs for Ecological Public Health Education

Historically, public health education as a formal academic activity in the United States dates back approximately 100 years to the 1915 Welch-Rose Report funded by the Rockefeller Foundation, which focused on graduate education designed for those with previous professional education, particularly as physicians, nurses, and engineers at schools of public health (Riegelman and Kirkwood, 2015). The professionalization of public health nursing had begun in England in the second half of the 19th century, whereas in Europe it dates back to the last third of the 19th century and the first decades of the 20th century, as Europe witnessed the formation of what has been called the "international health movement" for attaining higher levels of health and well-being. Public health nurses slotted perfectly into the new healthcare model developed in the fields of hygiene and social medicine at that time (Galiana-Sánchez, 2019).

Public health nursing involves working on primary prevention and health promotion for the wider population, both of which evolved in the context of historical and philosophical perspectives on health, preventive healthcare, and the professionalization of nursing in diverse settings. By the early 1900s, the roles of public health nursing had already extended beyond the care of the sick, but also to encompass advocacy, community organizing, health education, and political reform as well (Kulbok, Thatcher, Park & Meszaros, 2012). Education of public health nurses continued as a major concern in the mid-twentieth century in the US, and nowadays there is growing public recognition and interest in enhancing overall health and well-being, rather than waiting to cure illness. An overview of historical developments and their impact on nursing reveals the rise of our professional identity, which also gives an insight into the efforts and devotions needed to further pursue professionalism in the face of the challenges of 21st century healthcare.

However, the impact of the human footprint on the ecology of our planet is a primary determinant of human health has been neglected; despite since 1986 the International Council of Nursing (ICN) has already recognized that:

> *"The preservation and improvement of the human environment has become increasingly important for man's survival and well-being. The vastness and urgency of the task place on every individual and every professional group the responsibility to participate in the efforts to safeguard man's environment, to conserve the world's resources, to study how their use affects man, and how adverse effects can be avoided" (ANA, 2007).*

Thus, recognition of the failure of our current models of health development is crucial, and subsequently that constitutes a call for each of us to profoundly revise our frameworks for action (Brousselle and Butzbach, 2018). However, until now in the 21st century, this directive educational reform and change-making has underperformed in terms of forming such necessary visions for action. In this respect, blending the health needs for ecological public health education is ultimately preventing further destructive maladjustments to our biophysical and man-made environments all over the planet. The WHO (2018) has supported that ecological public health must now be developed further as the concept of planetary health that focuses on the requisites for planetary sustainability, which is needed to deal with some of today's major public health issues, such as climate change, air pollution and their social and economic impacts.

Sustainable development also depends on the mutualism of health and well-being of humans, animals and the ecosystems, as only in which they can co-exist (Zinsstag, Schelling, Waltner-Toews and Tanner, 2011). Just as Rosa and Upvall (2019) reaffirmed, knowledge regarding the planet's systems, species, ecosystems, and myriad environmental dimensions must be integrated throughout nursing education. Planetary health encompasses broad aspects of the accelerating pressure on the global environment, and nurses have an obligation to prepare for climate change and other impacts of ecosystem strain on human health (Kurth, 2017). If nurses are to understand their roles in the healthcare system and have their professional attainments work effectively then they must be taught the scope of their practice including their roles and responsibilities for the public's health (Aarts et al., 2010). As the WHO (2011) indicated, existing climate change will affect our ability to maintain good health; hence healthcare professionals should equip themselves with understandings of the ecological factors that influence the public's health on a global scale.

In this connection, the field of planetary health has emerged as a way to prevent further destabilization of the Earth systems and to avoid actions that would herald large-scale morbidity and mortality. Therefore, the educational directives that dictate the training of health professionals should be forming a dedicated effort to advocate for health, communicate risks, and manage complex systems in order to raise awareness of and educate about such significance of planetary health for sustainable health developments towards 'The age of sustained health' (also see Figure 6-1). Health professionals are uniquely placed in their position in society given their ability to understand and represent science-based issues in the context of environmental and climate impacts on human health, making them well-placed to support the required efforts to address and communicate to others about these health impacts of climate change that are manifesting across the world (Luber and Lemery, 2015).

Complementarily, this vision also reflects from one of the paradigm shifts which has been proposed is from “global public health nursing” towards “planetary nursing” in order to more effectively engage worldwide health initiatives, such as the United Nations 2030 Agenda for Sustainable Development, by expanding the understanding of “health” from a phenomenon focused on humanity and its significance of interdependent animal, environment, and overall planetary well-being. Such a shift requires recalibrating the future roles and responsibilities of nursing accordingly (Rosa and Upvall, 2019). Health professionals can have an influential role in promoting planetary health as an opportunity for action (Whitmee et al., 2015). In particular, public health nurses have now a renewed opportunity to act upon the lessons of the past to form anew future for sustainable health. In this regard, the quality references of criteria come from the premises of its essential nature, from the historical and current widespread recognition of its genuine value in providing care for sustaining our health, together with theories and philosophies that form the basis of contextual structures with a renewed conceptualization for the thoughts and actions in practicing the healthcare professions.

This inevitably raises questions about the adequate preparation of nurses for today’s public health challenges, as today we once again need extraordinary leadership to provide vision, to improve population health, and to shape a sustainable future for the specialty of public health nursing (Kub, Kulbok and Glick, 2015). Ecological public health education is targeted at accommodating all health professionals, especially those specialized in the public health domain, be they nursing, medical or public health practitioners.

Understanding and responding to the degradation of the living systems on which all life depends, including the well-being of humans, is especially important for nowadays public health education, and the pragmatic perspective on motivating reasoning towards this significant challenge will depend on a synergistic view embedded with ecological dimensions in the evolving concepts of health and disease. It is also due to its interrelatedness that it has become a significant part of the overall impetus for affecting our sustainable developments in health. As Patz (2016) postulates, today’s substantial global public health demands are being undermined by the threats of climate change, in which a wealth of evidence shows that global public health and global climate and ecological conditions are inseparable. Therefore, all health professionals should raise awareness of such arising health implications, and should therefore assess and address the subsequent health risks accordingly. In this contextual concern, expanding the professionalism of its functional roles with the dimensions of ecological public health under such significant evolving factors of environmental and climate change, as well as its health impacts globally is of the utmost essentiality and professionally obligatory.

While taking this global view, ecological public health education allows all health professionals to take a further proactive step towards the necessary refining concept of human caring, with its embracement aligning planetary health under the “One Health” vision and “One World” concept. This initiative would take account of curriculum planning and educational development, as blending such health needs for the changing demands in healthcare environments. Simply, the adverse health effects from climate change demand action from all health professions. And therefore, the integration of climate change into nursing [and all health] education is essential so that the knowledge, skills, and insights critical for clinical practice in our climate-changing world are incorporated in curricula, practice, research, and policy (Leffers, Levy, Nicholas and Sweeney, 2017).

Thus, to address the educational needs as collective organized calls for public health engagement through educational based on ecological determinants of health should be viewed as an important lever of systems change and a key driver of future practice, policy, and research (Parkes et al., 2019). A statement of recognition should therefore translate into practical action, as only such action will advance and empower nursing and health professionals through educational reform. That in turn, acts as a fundamental basis for human caring through balancing various evolving health needs within ecological public health education *per se*, making it part of a global direction and international call for action. In view of this scientific understanding, the growth of nursing and health sciences for a meaningful human caring discipline requires developing its theory from different competing modes of scientific activity, including medicine, social and physical science, as well as pedagogy ensuring that nursing and all other health curricula keeps up with contemporary research, knowledge, understandings for the changing nature of the demands of the healthcare environment in the Anthropocene.

Nursing academics must play a role in the advocacy of nurses, who must be prepared to meet this challenge, as climate change is already and will become an increasing major health issue that nurses need to consider. They must bring focus onto this aspect of human caring in terms of its transitional public health impacts in relation to sustainable health developments. Hence, the necessity to train nursing and health professionals with ecological public health education, as an integral part of human caring towards sustainable healthcare principles, represents blending the changing health needs in the Anthropocene.

Human Caring for the Necessity of Changing Health Needs in the Anthropocene

The tides of changes have arrived, and it has become necessary to revisit the ideas of holistic nursing and caring science in order to determine a bearing of significance for the twenty-first century (Dahlberg, Ranheim and Dahlberg, 2016). Professionally, nursing is no more or no less than the professionalization of the human capacity to care through the acquisition and application of the knowledge, attitudes, and skills appropriate to nursing's prescribed roles. Jarrin (2007) describes how Fawcett's meta-paradigm concepts (nursing, human being, health and environment) are a powerful unifying core for the profession, in which we know and come to know as nurses. Nursing uniquely focuses on caring as its central value, its primary interest, and the direct intention of its practice, which is firmly recognized as living in caring and growing in caring (Masters, 2015). As described in Fry's (1993) statement concerning human caring, which "is a moral concept when caring is directed toward human needs and is perceived as a duty to respond to need" (Hitchcock, Schubert and Thomas, 2003).

The progress of a discipline and profession in accordance with changing health needs is our commitment to the caring praxis, and we are now facing unprecedented challenges for sustainable health developments under the adverse impacts of the global environmental and climate crisis in this new epoch of the Anthropocene. And the subsequent impacts of ecological crisis together with the arising and mediated transitional health risks could harm catastrophically all forms of life and their well-being. This is a significant concern and crucial dimension to the current caring praxis, and it is indeed a challenge as "time paradoxes" emerge from the new perspective of evolving concepts of health and disease. The caring science paradigm has to be expanding across this timespan, across place, culture, population, societal trends and worldview towards another level of renewed conceptualizations through the process of 'trans-reality'. All in all, it is clear that human caring has to be expanding accordingly for the necessity of changing health needs in the Anthropocene.

In particular, the dominance of ecological determinants of health is making imperative underlying forces through an integrative process of domino effects on sustainable health developments under this age of global environmental and climate crisis that adversely propels our health in transition. In this connection, the vision of "trans-reality" is indeed part of the professional socialization in support of human caring with the necessity of the practicalities, theories and philosophies, which form the basis of contextual structures with renewed conceptualization for the thoughts and actions in advancing this 'caring' profession. This basis directed our practicing arena in relation to the patterns of recognized understandings of changing health needs, and knowing as an integral part of the caring praxis *per se*. The transformative agenda requires action to accommodate the changing health needs of caring towards sustainable developments in health and the obligatory expansion of professionalism for blending such needs of ecological public health education. As a result, the nursing education reform with connection under the current situational transitions in this new epoch of the Anthropocene is the mentioned "trans-reality".

Simultaneously, a paradigmatic shift into collaborative paradigms rather than only one paradigm prevailing means sharing a new form of sustained care by widening the health systems through preventing adverse effects induced in the Anthropocene. As a result, the sheer range and diversity of models, theories, and frameworks as proposed throughout this book are the master keys for understanding the importance of knowledge mobilization in healthcare, and this also presents significant challenges in terms of how we evolve our thinking to notice the connections between them. If the health systems are no longer capable of providing this caring praxis for sustainable health developments under such ecological crises in the Anthropocene, it will only further aggravate the future healthcare and its systems. Therefore, sustainable healthcare requires developing and sharing new forms of sustained care without losing sight of the larger new global context as a lever for reification in the process of blending such changing health needs as an integral part of caring.

The theory of nursing as a caring profession was actually developed through the embracement of curriculum development, with the ideas being formed into a comprehensive caring conceptual framework that expressed the meaning and purpose of nursing as a discipline and as a profession. As it related to caring and was the expression of caring as the ends – rather than the means – of nursing, the definition of caring was the intension of nursing, rather than merely an instrument of nursing (Masters, 2015). Most importantly, the growth of curriculum development will be no exception, and indeed the components of a more holistic caring growth for nursing and health professionals is necessary under this age of environmental and climate mediated health risks in the Anthropocene. These are intriguing critical challenge that requires supportive interventional strategies for solutions towards sustainable healthcare, especially under such scientific progress of epistemic diversity, and therefore principally the philosophical and practical values to advance the caring praxis are utterly essential. As they are co-existing in connection with the emergence of a set of complex and interconnected challenges, as part of the creation of human caring and promoting the health needs toward sustainable health developments.

Nursing Theories Entail the Growth of Curriculum Development

The central focus of the profession of nursing is using the art and science of caring to improve the health of human beings within their environments, and as we move forward it is important to look to the past and to the future when we discuss how knowledge should be acquired. It ought to signify and optimize the usage of scientific understandings with epistemological diversities for the application of quality and holistic care through proper use of health literacy, as knowledge is the vital power to practice and advance the profession of nursing. It would therefore seem the pertinent question is "how could members of a discipline engage in cumulative knowledge development without giving attention to the focus and nature of inquiry in the discipline or to the primary mission of that discipline?" (Meleis, 2012).

Nursing theories and knowledge in fact have become legitimate for our heritage evolved with increasing epistemic diversity and integrative processes in empowering our abilities and capacities to advance scientific knowledge. The field has provided contributions to optimize health and well-being developments as an integral part of quality and humanistic care. In that understanding, theoretical development and progress is particularly important, as it offers the intended purposeful knowledge to enrich the expansion of different aspects of our professional domains forward through the scientific praxis. It is worth understanding that the driving force in its heritage evolved with deliberate articulations from different aspects of theoretical nursing development that enhanced ultimate expansions in different domains towards care through constant professional developments in shaping and reshaping nursing knowledge.

According to Alligood (2014), evidence indicates that this is the "theory utilization era" of nursing history and that applications of conceptual models of nursing and nursing theories produce evidence of "normal science" for the thought and action (i.e., praxis) of professional nursing practice, and in fact the progression of nursing towards theory utilization and theory-based practice is best explained by nursing history. For instance, we can refer back historically to the propositions of Florence Nightingale, who was a holistic advocate for health and wellbeing, and opined that "*When we obey all [of nature's] laws as to cleanliness, fresh air, pure water, good habits, good dwellings, good drains, food and drink, work and exercise, health is the result: when we disobey, sickness"* (in Rosa, Upvall, Beck and Dossey, 2019).

> In 1860, Florence Nightingale provided the foundation for nursing attention to environmental exposures and health effects when she wrote about the need for fresh air and clean water in *Notes on Nursing* (Nightingale, 1860).
>
> (ANA, 2007)

"As Nightingale stated: 'The health of the unity is the health of community. Unless you have the health of the unity there is no community health.' A healthy society, Nightingale reflected, relied on a unified nursing presence to ensure the public's health" (Lewenson, 2017).

Back in the late 1870s, Lillian Wald emerged as the leader in the field of public health nursing in the United States, and the history of public health nursing is rich with her contributions. As Wald stated: "Our basic idea was that the nurse's peculiar introduction to the patient and her organic relationship with a neighborhood should constitute the starting point for a universal service to the region"; and this is indeed the essence of public health nursing (Morrissey, 2012). Wald believed that public health nurses must treat social and economic problems, not simply take care of sick people (Fee and Bu, 2010). Wald's vision resulted in nursing practices that went beyond caring for families during illness to encompass an agenda of reform in health, industry, education, recreation, and housing. She conceptualized a new paradigm for nursing practice and called "our enterprise of public health nursing" the changing emphasis of the "public health campaign", simultaneously creating yet another aspect of the bond between nursing and public health (Buhler-Wilkerson, 1993).

In that understanding, nurses are also responsible for engaging public health issues globally, with the need to perform their work in such a way that the environment will be protected and preserved (Anaker and Elf, 2014). In this connection, nurses play an important role in promoting public health, as the traditional focus of health promotion by nurses has always been on disease prevention (Kemippainen, Tossavainen and Turunen, 2012). Accepting these caveats, the conceptual focus signifies the importance of environmental reform for illness prevention and health restoration. In a similar vein, another paradigm shift in nursing began when “Martha Rogers (1970) asked what [was at] the center of nursing’s purpose and began to describe the living system differently than it had been described before”: she described the human being as a unitary system that is open and in interaction with the environment—with no real boundaries (Parker, 1990). As convincing evidence shows the significance of this undeniable fact was to broaden ecologically-informed perspectives on health, as the health of each of us is intricately and inextricably connected to the health of our planet (Prescott and Logan, 2019).

The eventual legitimacy is precisely this affinity that in fact represents an effective and precise intervention as a “trans-reality”. In this sense, the context increasingly indicates the need to shape health through the use of ecological and sustainable nursing theory by using a structured framework that defines the evolutionary needs by showing the critical situation and interrelationships amongst the value of theoretical knowledge, nursing theories, and nursing practice. Meleis (2012) supported that nursing theories reflect some realities of nursing at the time of development, and they help to shape the realities of nursing care over time, which are an integral part of our history.

Change comes slowly and is influenced by eras of development, but it does come. Statistical and scientific understandings lead to the outcome of complex pathways in the rise of ecological determinants of health that translate to effectively evidential informative and particular reflections on ways to widespread awareness. There are challenges for this translation to health literacy discourse on the basis of underlying determinants and their complex pathways into explanations for evolving concepts of health, and the subsequent importance of sustainable health developments *per se*.

In sum, this is a crucial professional position for nursing theories and their growth. Nursing theories embrace values and ways of thinking that guide and improve nursing practice and, therefore, theories are mental patterns or frameworks created to help understand and create meaning from our experience, to organize and articulate our knowing, and to ask questions leading to new insights (Smith and Gullett, 2020). As such, nursing theory expresses the values and beliefs of the discipline, creating a structure to organize knowledge and illuminate nursing practice, which should provide the basis for nursing education and the framework for organizing nursing curricula (Smith and Gullett, 2020). Naturally it entails the growth of curriculum development, and as with any discipline is dependent upon theories to justify frameworks and to support the changing needs of curriculum development, in order to constantly advance the body of knowledge and form an integral part of professional practice. As Abdellah and Levine pointed out:

> *"In nursing, a conceptual framework is a theoretical approach to the study of problems that are scientifically based that emphasizes the selection, arrangement, and clarification of its concepts" (Bevis, 1989).*

The point of this is the trends of curriculum serve as the directional indicators for the desirable change in curricula in attempts to accommodate, constructively, proactively, effectively and professionally, the multiplicity of variables that affect our health at different periods of health transitions. For instance, a number of concepts were identified by interaction theorists as central to nursing or as significant components of the discipline during the time period before the 1970s. These concepts were championed by such nursing theorists as King, Orlando, Paterson and Zderad, Peplau, Travelbee, and Wiedenbach; and this continued with the next era of nursing theorists, with Johnson, Rogers, Levine, and Roy, who conceptualized the goal of nursing care as bringing back some balance, stability, and preservation of energy, or enhancing harmony between the individual and the environment. Parse's theory of "human becoming" is also in the same vein and emphasizes the ongoing and changing nature of the process of the human being's living health, with four essential ideas that are reflected in its concepts, assumptions, and propositions (Masters, 2015):

1. The human-universe mutual process.
2. The co-constitution of health.
3. The multi-dimensional meanings the indivisible human gives to being and becoming.
4. The human's freedom in each situation to choose alternative ways of becoming.

Their conceptualizations were based on systems, adaptation, and developmental theories, with which had a focus on the outcome of care (Meleis, 2012). Whereas the idea as reflected in Roy's theory is that "Human meaning is rooted in an omega point convergence of the universe", and "persons are accountable for entering the process of deriving, sustaining and transforming the universe". It is equally important that the discipline is able to meet its obligations to society and, therefore, the philosophical and conceptual or theoretical dimensions are of significance to guide core disciplinary knowledge in its development (Grace, Willis, Roy and Jones, 2016). Thus, nursing theory should also be incorporated with the advancement of up-to-date knowledge and should broaden its scope, conceptually and realistically speaking. In this way, theory is viewed as a product that proposes and shares possible explanations or solutions with insights and interpretations to inform us about a *pattern* (not just a *part*) of human health (Reed and Crawford Shearer, 2018).

As we've discussed, in Nightingale's early conceptualizations were the seeds for the theoretical development of nursing as a professional discipline, seeds that would articulate its distinctive focus. She believed that creating an environment that provided the conditions for natural healing to occur was the focus of nursing (Smith and Gullett, 2020). Thus, inquiry into the current widespread consequences of our individual and collective choices on the planet, we are beginning to see how the foundational premise of nursing—to preserve and protect human dignity through the promotion of good health and wellbeing—must now be expanded in order to create and sustain a more equitable and inclusive world with more universal considerations in the fields of global public health and global nursing for the future of planetary wellbeing. Laustsen (2006) agreed that elucidating a nursing ecological theory may guide our profession toward new directions in holistic care, as nurses face a challenge to translate global environment concern and ecological beliefs into professional activities. For instance, Watson's theory is proposed as a nursing framework that is philosophically congruent with contemporary global approaches, and identifies the centrality of caring, holism, and ecology for a population-focused health promotion approach as it has evolved over the past two decades (Adeline, 2000).

> Watson's model "does not consider caring as a soft nice thing for nurses to do, or a nice way to be, in some romantic pre-modern sense," but rather "it posits caring knowledge and actions as a serious ontological, ethical, and pragmatic concern for the discipline."
>
> Jean Watson (in Masters, 2015)

As Florence Nightingale also wrote, "*Health is not only to be well, but to be able to use well every power we have*" (as quoted in Alligood, 2014, p. 85). The paradigm shifts in the roles of nursing are constantly and continuously expanding in accordance with the advancements of scientific understandings in relation to the changing health needs. Jarrin (2007) points out that the contemporary philosophical and epistemological grounding of nursing in systems theory has been challenged, but not rejected, as it provides a succinct way to connect our profession with others and create the future we desire (whatever that may be), which serves as an effective template in this new vision for the unification and growth of nursing as a discipline and a profession.

As we can see from the many remarkable examples of nursing frameworks as derived from different nursing theories and theorists, which have their specificity of application in emphasizing the components of their related conceptual frameworks, they may potentially be used to operationalize their representations in the process of curriculum innovation through the praxis of restructuring the needed interpretations. And now, nurses face a challenge to translate global environment concern and ecological beliefs into professional activities, to form a nursing ecological theory with the goal of broadening nursing perspectives by incorporating expanded scientific concepts of global ecosystems, communities and interrelationships derived from ecological sciences (Lausten, 2006; Dahlberg, Ranheim and Dahlberg, 2016).

With professionally-driven goals being the mission of the roles and functions in nursing under the global context, we need to apply those concerns to the nursing theories which emanate from paradigms that are extrapolated and congruent with a nursing philosophy and which would contribute to the reference-criterion towards meeting present and future eco-environmental demands of human needs in support of sustainable health developments. This is something which is especially needed for a new generation of health professionals, who must be adept at thinking and responding systemically to affect meaningful and long-term improvements in health development, in a way that validates the underlying premise, yet acts as a focal point for continuing resonance in sustaining our health. As Rosa (2019) states:

> *"The SDGs are based on five major themes considered essential for long-term human well-being and survival: People, Planet, Peace, Prosperity, and Partnership. Health is a common thread weaved throughout the agenda and that means nursing is poised to be a leader in creating 'the world we want' through SDG attainment."*

The altruistic value central to nursing is to remember humanity (Rosa, 2017). And blending health and caring needs for sustainable health developments are indeed the fundamental basis of humanity. From empirical exploration, a notion of ecological care is indeed a way revisit the original ideas of caring science that leads one to once again find one's place in a world that is characterized by interconnectedness. As life processes and the development of ecological systems are understood starting from the interdependent relationships between humans and different organisms and their environment, in sum: *"Ecological care is not only about fighting an illness, but also recognizes a patient from inside a world that s/he is affected by and affects, that s/he is understood and understands from"* (Dahlberg, Ranheim and Dahlberg, 2016).

The philosophical values, theoretical scope and theoretical orientations we are discussing will, when put into practice, be able to approach human needs in such a way that our organization and understanding of human phenomena is amplified (Kim and Kollak, 2006). One element of our focus is on cultural and lifestyle issues where key changes must occur in order to address the serious daily threats to the biosphere through our production and consumption systems, which are having a growing impact on the environment, through pollution, by displacing and eradicating countless species and ecosystems, and by disrupting the climate balance, all of which endanger the very basis of humanity's future development, prosperity and sustainability (Wijkman and Rockström, 2012).

The consequences of sustainability developments are incorporated into the evolving concepts of health and their subsequential effects, which are interlinked as power dynamics encompassing the necessity basis of changing health needs. As Pratchett (2010) suggested, sustaining the Earth's resources and environments with value frameworks and emotional relationships with the planet will motivate our concern for and participation in addressing these challenges. We must promote widespread understanding and an adequate response to the need for emission abatement and preparation of health services to which health systems could successfully adapt (Adlong and Dietsch, 2015).

In view of this context, academic entities which need to engage with curriculum development are well justified in seeking to ensure the broader global framework is weaved into all aspects of the educational pathway, rather than appended to the existing curriculum (Gimbel, Kohler, Mitchell and Emami, 2017). Our great compassion to progress human caring through the empowerments for knowledge-in-action under the caring praxis towards sustainable health developments has indeed gained a new sense of urgency. It is essential for nurses to promote a sustainable future with knowledge-to-action, and to acknowledge the need for integration of this particular ecological health literacy knowledge into nursing and healthcare education curricula.

The initiative to adapt nursing to ecological necessity should therefore be focused on collaboration between education and curricula reform to establish sustainable capacities based on the trends of health needs and the global direction of professionalization in building a workforce that acts towards sustainability in the long term. In this context, the journey which focuses on an analysis of nursing as a discipline and acting as a connecting bridge for the meaning and structure of our evolving discipline, with the components that make it a coherent body of knowledge is a significant step for the evolving epistemic diversity of the discipline (Meleis, 2012). And this resultant expectation is in line with a systems thinking approach, and the interrelationships under the caring praxis by progressing professional domains towards sustainable capacity building through the growth of curriculum development.

In this context, nursing theory is used to structure the ideas of ‘parallel inherence and practical relevance’ from a perspective of knowledge-to-action, and so to create a supportive framework for the intended purposes of evolution through transdisciplinary learning, which will make possible the necessary growth in the processes of interactive, integrative and transformative paradigms. Additionally, the contention of transdisciplinarity has the ability to transform mentalities by the enrichment of the curriculum in environmental and climate concerns for sustainable development in health, which represents the integrative way to foster holistic learning and reconceptualization towards the necessity for blending the changing health needs. In fact, every renewed conceptualization signifies simply the unit of determinations that belongs to the parts of the whole, which shapes a wide variety of factors and mechanisms as there are serious health impacts under this new epoch in the Anthropocene. It appears, like the “holographic paradigm”, as a way of understanding that “the whole is in the parts”, which is indeed the necessary conceptualization in designing nursing and healthcare curricula for the changing needs of 21st century nursing and healthcare education. Simply, and to summarize slightly, the nursing curricula should accommodate and align with the following:

1. Reconceptualizing the curriculum for desired goals. It should (Li, 2016):
   a. Be evidence-informed
   b. Be context-relevant
   c. Be unified
   d. Accommodate the changing needs
   e. Foster the professional abilities required in the expanding roles within the discipline
   f. Encourage the discipline to engage in cumulative knowledge development for advancing its professionalism

g. Evolve epistemic diversity by reconceptualizing the need of curriculum development to reflect its continuous growth.

2. The necessity of blending the changing health needs through prioritization and development of educational opportunities.
3. Universities being the educational platforms for defining academic structure through curriculum development.
4. Expanding the scope of roles for nursing and health professionals.
5. Professional training as a required involvement with the nursing entities critical for professionalization.
6. The supportive role of medical and nursing councils as being crucial.

> "Disciplines should be dynamic to respond to emerging and changing needs of societies and to new demands imposed by population movements, health care reforms, and transformation of global order."
>
> (Meleis, 2012, p. 2)

An Outcome-focused Synergistic Model for Ecological Public Health Education

Human activity is rapidly transforming most of Earth's natural systems, and the magnitude of the associated disease burdens are relatively new subjects within the field of eco-environmental health. These accelerating environmental changes are affecting human health in a variety of important ways (Myers et al., 2013). Especially with the planet's widespread industrial development and the rapid growth of population, ecosystems are in urgent need of ethical consideration (Li, 2003). It is, therefore, important to understand ecological factors such as the effects of ecosystem services, environmental hazards and their related impacts on eco-environments, and the issues surrounding global environmental hazards to human health such as climate change; stratospheric ozone depletion; loss of biodiversity; changes in hydrological systems and supplies of freshwater; and land degradation and stresses on food-producing systems; together with other ecological determinants such as health threats from the human animal-ecosystems interface (HAEI) and zoonotic diseases (zoonoses) (Li, 2017a).

It has been argued that human power over nature has altered and weakened in dominance, markedly since the emergence of Rachel Carson's book *Silent Spring* in 1962, and later concepts of Gaia, Deep Ecology, and Sustainable Development. Moreover, humanity's power toward nature has become one of a moral sense of protectionism or the safeguarding of the environment, including those metaphorically outlined in “The Tragedy of the Commons”, which argues that the four laws of ecology are counter intuitive with the four laws of capitalism (Seymour, 2016).

In this sense, moral and ethical education for changing people’s attitudes requires a conceptual change, otherwise the likely consequences are that we will fail to alert the public of the need to achieve global sustainable development. An ecological public health approach for global climate change is of significance to the ways of learning towards sustainable living for global interdependence, which can be viewed as a new kind of humanism; and that is utterly essential under the existing environmental crises (Li, 2018b). And therefore “a Sapiens approach” has been proposed and discussed in Chapter 6, together with a set of concepts in transition that caters to the evolving public health needs for empowering our human spirit towards ecological civilizations.

In fact, this is a significant part of outcome focused synergies. In particular, the moral imperative is to be largely achieved through our conceptual change, that acts as an integral part of the power of society and culture, allowing us to then recognize the nature of many health threats arising directly and indirectly from environmental and climate mediated health risks. And the power of societies and cultures lies in their contributions to beliefs and meanings at large. Thus, the purpose of ‘knowledge-to-action’ is to contribute to our scientific understanding about the effects of climate change and its meanings behind the biggest global public health threats. Only through providing more cogent reasons, with which come more effective means, does the hope to achieve what needs to be done through ecological public health education flourish.

All forms of organized intervention in relation to the developmental history of public health remain a major reference point for a health-enhancing way of life to all concerned parties, while we all face complex, multifaceted challenges to such massive transitional changes that could shape our health conditions ‘unsustainably’ and ‘catastrophically’. Henceforth, to broaden the view on global and ecological determinants of health in transition requires input-based needs and actions as synergistical strategies for strengthening this currently proposed outcome-focused ecological public health education. In order to blend such health needs, we need to have strategies for empowering their themes, and to explore the opportunities for building professional capacity. As the proverb says: “Strategic planning is worthless – unless there is first a strategic vision” (Naisbitt, in Crosby, DiClemente and Salazar, 2013).

In respect to the scientific advancements that unfold our professional knowledge in addressing today's contemporary ecological view of health for sustainable developments in public health, it is crucial to build global coalitions for advocacy and action concerning the persistent needs for a sustainable and habitable Earth. This action should take the form of transdisciplinary support of planetary health and eco-environments as a critical health issue for humankind. Therefore, a new advocacy of the ecological public health movement is urgently needed with evolving approaches containing ecological public health education for all healthcare professionals under such serious global environmental and climate mediated health threats in this era of the Anthropocene. As Polivka, Chaudry and Crawford (2012) indicated, the significance of the linkage between climate change and its harmful effects for both human health and the environment necessitates responsive action by public health professionals, with effective human interventions needed to arrest and prevent continued climate change.

In fact, addressing these issues presents a considerable challenge for nursing professionals at all levels, which is to advance this concept through education—that is, to raise awareness of the relevance and importance of the global environment to health, and to empower nurses with sufficient understanding of the issues to respond adequately to the challenges (Kirk, 2002). Nursing educators must also commit to this as part of the mission in seeking a high quality of education that represents the changing demands of health needs under these global trends of education for sustainable development (ESD) in the health sector. And the important aspects of ecological public health education are to develop understandings with knowledge, skills and attitudes that nursing and medical health professionals and practitioners will need to address the challenges of caring towards the ultimate goal in support of sustainable health developments.

The overall focus for ecological public health education is to facilitate the achievement of sustainable health developments, as part of synergistical strategies for future sustainable healthcare *per se*. This newly proposed "Outcome-focused Synergistic Model for Ecological Public Health Education" is also meant to be geared towards consolidating a collaborative basis or foundation to facilitate this direction of health needs; and to foster opportunities for professional capacity building under the rapidly changing healthcare boundaries in the Anthropocene. This proposed model of education reform for ecological public health education is formulated with a strategic vision, as shown in Figure 8-1, which comprises:

1. *Inputs*:
   a. Roles of different stakeholders, such as the role of universities in curriculum planning and development
   b. An educational platform for necessary connectivity
2. *Throughputs*:
   a. The roles of medical, nursing and health authorities
   b. Transitional needs in health systems
   c. An academic infrastructure in place for ecological public health education, including curricula reform
3. *Outputs*:
   The pathways of understanding sustainable health developments, with knowledge on:
   a. the importance of planetary health and EcoHealth for human health
   b. the impacts of ecological and global determinants of health in transition
   c. the transitional risks imposed by this unprecedented global environmental and climate mediated health threats in the Anthropocene
   d. evolving concepts of health in transition during this current stage of epidemiological transition

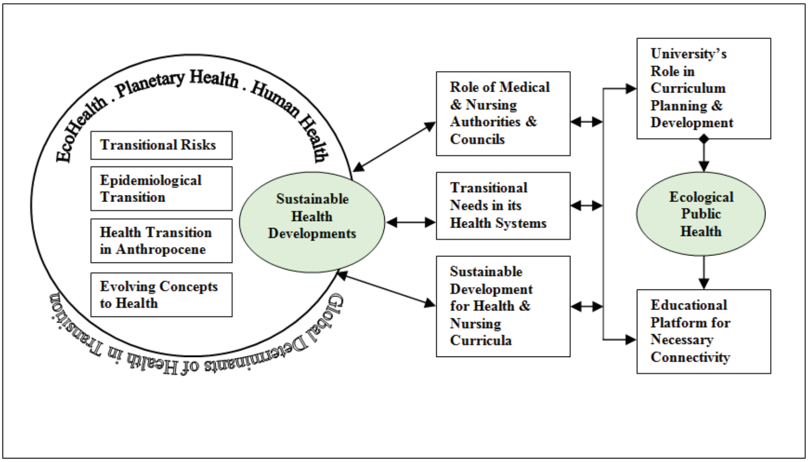

Figure 8-1: Outcome-focused Synergistic Model for Ecological Public Health Education.

This Outcome-focused Synergistic Model is created for the evolving public health needs through integrative learning strategies in support of blending ecological health needs for future roles in nursing and health professionals. The fundamental basis of this model is meant to spark better accountability with broader systems thinking by providing a starting point for translating strategic competencies to advance the required educational reform in relation to ecological public health needs. This expansion is pivotal for assuring professional competencies regarding ecological public health principles, and will act as a process of change through curriculum reform for this new epoch practically, humanistically and holistically. Such new constructs need to be validated as the necessary professional competencies and entered into academic structures as part of educational reform. In particular, this operates under the parameters of academic structures as the supportive pipelines to then lead towards the intended target for empowering our professional competencies for the present and future transitional health needs in action. To do so, universities are required to initiate the imperatives of ecological public health education as the required professional competencies for the unity of knowledge. This process of implementation requires multi-dimensional support from various stakeholders and contributors through recognizing the needs of the change, as well as influencing and endorsing it as the basis of advancing the professional unity.

In fact, all changes is bound with the advancement of knowledge and scientific understanding. Any of such changes in professional development is an important cognitive process that pertains to advance knowledge-to-action competencies. It is indeed about complexity, emergence and the intellectual fusion of disparate worldviews into new integral knowledge which then connects and creates transdisciplinary knowledge (McGregor, 2015), just as Li (2017b) indicated that transdisciplinarity is a new form of learning that further reflects the significance of human empowerment and potential through education on the concepts of sustainable development from the impacts of anthropocentric worldviews. Thus, the need is essential for a transdisciplinary focus with holistic approach across such diverse areas of knowledge, rather than isolated disciplines; pramagically it is critical for these unprecedented and complex problems in this new era. The transdisciplinary approach should also engage with all academic and other health-related disciplines, bringing collaborative support together from governments, international agencies, NGOs, communities, and medical, health and nursing authorities and councils.

Curriculum trends and designs for health education and training are indeed representing a significant part of workforce development in the healthcare system. Education and training are central to the development of most health professions, and in fact, defining and enforcing educational requirements are also pivotal in creating and maintaining a profession (Riegelman and Kirkwood, 2015). In this regard, the continuum of education for ecological public health workforce development indeed supports the changing health needs and demands of the future healthcare environment, which is a crucial cornerstone for a comprehensive array of health services. For this continuum to remain effective, broad shifts in thought and action are required in order to attain the paradigm shift needed for the new and changing global context in the Anthropocene. This is especially so as global environmental and climate change is a grave threat to human health this century and has been recognized evidentially by many studies, reviews and reports. Therefore, the ultimate concern for beneficial sustainability development regarding the rising environmental and climate crisis ubiquitously across the world and future generations with actual and potential transitional risks and mediated health threats are being discussed and illustrated throughout this book.

And it is the time for all health professionals and experts across their respective fields to work together in the increasingly complex and interconnected world of the 21st century, to explore how eco-environmental health has direct and indirect impacts on planetary health itself, including human, plants and animal health. Perhaps we may also see how this planetary approach opens up new possibilities as we move into a culture of One Health, with a planetary vision of the One World concept. This strives to ensure the health of humans and animals and the environments on which all life is dependent (Deem, Lane-deGraaf and Rayhel, 2019).

Yet again, the need for ecological public health education aims to advance knowledge to counter ecological public health concerns and implement the most effective means of interventional strategies for disease prevention and health promotion. In view of this context, we have to understand the changing concepts of diseases and health, as well as the adverse impacts arising from different ecological determinants of health (directly and indirectly) that have various diverse implications for the global burden of diseases. Understanding the changing demands of the healthcare environment from multiple perspectives, including new waves of public health movements with synergistical strategies and interventional design for “A Culture for Health”, and “Transdisciplinarity in Education for Sustainability Development” as discussed in earlier chapters, is a significant part of society’s role in sustaining the environment. Behbod et al. (2016) also supported behavioral lifestyle choices that promote health and reduce environmental impact. The emphasis here is on an inclusive and humane approach that highlights the importance of mutual existence in nature, in contrast to the restrictive or anthropocentric attitude (Patwardhan, Mutalik and Tillu, 2015).

As Nicolescu (1997) has recognized, to make mentalities evolve, education must introduce courses at all levels in order to sensitize students and awaken them to the harmony between beings and things as a significant part of knowing or acting to reconcile. The most important factor in bringing this as cognitive management is the transformation of information into knowledge, particularly when it solves the task of forming social capital and increasing the student's cognitive competence (Smokotin, Petrova and Gural, 2014). The knowledge gained can then be translated into practical strategies that people can adopt in their social contexts. The aim is to put everything in place so that the seed of complex thought and transdisciplinarity can penetrate the structures and programs of the university of tomorrow, ensuring such an operation is *bona fide*, and that its place is not threatened by the absence of meaning or by the refusal to share this knowledge.

There are two major public health education challenges: (1) preparing the health professionals workforce by training it with ecological public health principles applied to both human health and planetary health for global eco-environments; and (2) providing appropriate education of ecological health literacy to the public. In fact, various international nursing organizations have argued that nurses should be actively engaged in education concerning sustainability initiatives and should share resources for curriculum development in nursing. In collaboration with today's nursing educators they can help preparation for this role (Barna, Goodman and Mortimer, 2012). There are many international medical and nursing authorities, councils, and associations that have already taken professional responsibilities in this direction; for instance, the AACN (2011) provides recommendations and various means of support for baccalaureate and graduate students, including promoting environmentally sustainable practices throughout its 669 member schools of nursing, and advancing the capacity of educators to incorporate relevant content and competencies into the curricula. In the UK, Goodman (2011) supported the imperative to address sustainability and climate change in nursing education, with the need for (1) a "sustainability curriculum"; (2) the transmission of skills; and (3) knowledge of the "triad" of "sustainability-climate change-health", in order to prepare graduate nurses for a role in the National Health Service.

The CDC's policy on climate change and public health has also identified health workforce development as a priority area involving a specific kind of "eco-health literacy" and looks at how medical and public health systems may need to be modified to address the changing environmental conditions (Hellerstedt et al., 2017). In this connection, evolving needs within ecological public health education can now be further illustrated proactively, given on the one hand how its past has shaped its present, and on the other hand how the influencing factors that should drive this trend of ESD are embedded in nursing curricula. And they have also been identified and recognized by various international agencies, such as the International Council of Nurses (ICN), UNESCO, and various international universities. It is of significance to reflect such reinforcements seek to foster a holistic learning framework to support environmental-sustainability concepts for the linkage of health and environment as part of the evolution in the professionalism of nursing and health professionals (Li, 2016).

Evolving Needs for Healthcare Professionals

As nursing's fundamental responsibilities are to promote health, prevent disease, and alleviate suffering, such duties call for the expression of caring for humanity and environment within a nursing praxis in the global community (Falk-Rafael, 2006). The sustainability of planetary health requires a shift to address the needs of humanity and to positively sway the tide of its future. As William Rosa suggested (in Kreitzer and Koithan, 2019), planetary health moves us from the idea of one man, one woman, one child, one country, or one continent toward the experiential wisdom of One Mind – One Health – One Planet as the affirmation of becoming a planetary citizen who incorporates all ways of knowing as ethically rooted action with measurable outcomes. And, as under Rosa's concept, planetary citizenship inspires a holistic lens that promotes our interconnected and interdependent well-being, which moves beyond man-made borders and limitations to the universal principles of a shared and reciprocal humanity and an all-life relationship within the theory of integral nursing looking toward the 22nd century (Smith and Gullett, 2020).

Nursing is a professional discipline focused on the study of the wholeness of human-environment health and healing through caring; Florence Nightingale defined nursing as putting the person in the best condition for nature to act, insisting that the focus of nursing was on health and the natural healing process (Smith and Gullett, 2020). It is the nurse's role to promote adaptation in situations of health and illness and to enhance the interaction of human systems with the environment (Masters, 2015). In this connection, the pivotal role of nurses in the healthcare arena, be it local or global, should and hopefully will be growing towards encompassing everything from personal to planetary health, as well as the Agenda for Sustainable Development. This again harks back to the environmental theory developed by Florence Nightingale in the second half of the nineteenth century in England, which focused primarily on the environment, interpreting it as all external conditions and influences that affect the life and development of an organism, that are able to prevent, suppress or contribute to disease and death. In other words, the nurse's function is to balance the environment, in order to save the patient's life energy to recover from the disease (de Almeida Medeiros, Enders and De Carvalho Lira, 2015).

Despite Nightingale's environmental model emphasizing relationships that are not regarded as either revolutionary or complex by current standards, the propositions of this theory pointed out the fundamental relationships within nursing are desirous of health, so that the nurse, nature, and the person cooperate for all reparative processes occur (Masters, 2015). However, Nightingale sparked a revolution in the concept of health going beyond the absence of disease, in which the goal is to be well and ultimately "to put the patient in the best condition for nature to act upon him" (de Almeida Medeiros et al., 2015).

On that broader canvas, the modest aims of evolving needs are to expand the emphases on the direct and indirect public health impacts imposed by global environmental and climate mediated risks in this era of the Anthropocene. As we've discussed, the ultimate goal of sustainability in nursing is to maintain an environment that does not harm current and future generations' opportunities for good health. This indeed echoes Thomas Berry's (1992) belief in planetary health as essential for the well-being of every living creature, and future healthcare professionals must envisage their role within this larger context (Prescott, Wegienka, Logan and Katz, 2018). Planetary health is at the core of an integrative way of life and living, for, in the end, the planet—its life forms, oceans, and lands, and the caring-healing heart of humanity itself—is all that will sustain us. Hence, planetary health is the next era of integrative nursing scholarship that requires our immediate and wholehearted commitment—a commitment to oneness and the universal wellbeing of all forms of life across the spectrum of existence (Kreitzer and Koithan, 2019).

Nurses play essential roles in public health, clinical care, emergency services, research, and advocacy through their work to reduce and respond to the health consequences of climate change (Leffers and Butterfield, 2018). Especially under this unprecedented time of local and global environmental concerns, people, as individuals and communities, should look increasingly to the healthcare system for information and advice on identifying and reducing the health risks associated with environmental exposure to actual and potential hazards.

History matters to nursing especially, as in its rich and complex nature are the broad range of concepts and events which, over time, have become an integral part of professional practice in public health nursing. The work of Lillian Wald, who was the founder of public health nursing, is a prime example (Patricia, 2010), and nurses are in a position to provide considerable support in response to the growing awareness of the need to enhance environmental health content in the practice of nursing (Pope, Snyder and Mood, 1995). In fact, people who work as professionals in public health have received education and training in a wide range of disciplines—including medicine, nursing, dentistry, social work, environmental sciences, veterinary medicine and allied health professions—and they all contribute to improving the public's health in numerous ways by addressing a wide range of public health problems (Gebbie, Rosenstock and Hernandez, 2003). For instance, efforts are needed to place human health at the core of urban sustainability (Schneider et al., 2009).

As the ICN stated, "the concern of nurses is for people's health—its promotion, its maintenance, its restoration. The healthy lives of people depend ultimately on the health of Planet Earth—its soil, its water, its oceans, its atmosphere, its biological diversity—all of the elements which constitute people's natural environment" (ANA, 2007). Understanding problems of this nature requires conceptual engagement with all of the important insights arising from the inextricable links and interconnections of our environments. The ultimate goal of promoting global public health and applying ecological public health principles in this manner is to foster a holistic learning framework to support environmental-sustainability concepts for the linkages of health and environment. These linkages signify the trend of demands in the ever-changing roles and professional practices of the public health domain, and such linkages must be incorporated into professional practice and nursing curricula.

> "The result of theory being unable to keep pace with knowledge development is stagnation of the discipline".
>
> Lorraine Walker, 1971 (in McKenna, 1997)

Perhaps, the resolution of this schism, along with many other dualities and paradoxes in the workings of nature and the universe, have been and continue to be the provocative "quantum questions" of investigation for holistically-minded scientists, with their theoretical, contextual, and relativistic thought articulating new intellectual maps (Dabrowski, 1995). These are the ideas behind ecological public health education as they are generated based on the scientific findings of collective studies, on evidence, and on the inferences concerning the actual and potential chain effects and impacts, including how health may be shaped by the Earth systems, and how medical and public health systems may need to be modified in order to address the arising health-related problems. In fact, they also signify the scope of the professional role expansion required for this new age of global environmental and climate crises in the Anthropocene.

Henceforth, evolving needs with trends of ecological public health principles should enter into curriculum structures as part of educational reform for the role expansion of professional competencies towards such changing demands in the healthcare environment in the 21st century. Such reform is inevitable and an obligatory duty in the journey of nursing and other health professional disciplines. The healthcare environment is a setting where understanding the changing demands of such evolving health needs and enacting professionalization amongst their interrelationships for knowledge-to-action are absolutely essential and critical for managing the ongoing global environmental and climate mediated health crisis in this new era of the Anthropocene. The history of nursing is indeed intertwined with historical developments in nursing education, both of which critically reflect on and assist in defining our professional identity.

The Trend of Demands in Ever-changing Roles: Implications for Educational Reform

With significant historical influences, meeting the trends of demands is of significance to the journey of transforming, developing and evolving the profession of nursing over different periods in need. The role of nursing today is rapidly and drastically evolving, particularly with regard to demands in the standard of higher education requirements in order to advance its professionalism. One of the essential and more poignant roles of nursing is the incredible strength and diversity of the profession to serve as an agent of change for individual, population, global, and perhaps now planetary health. Nursing can in profound ways influence every aspect of our health, well-being, and wholeness (Rosa, 2017). Ecological health models highlight the importance of the health of interrelationships between human beings and the broader environment in which they exist, including the "elements" influencing (or potentially influencing) their health (Townsend and Mahoney, 2004). And ecological public health is complementary in support of such international and global changes, as well as challenges. Such evolution in health professionalism is also an integral part of the challenges we are now facing under these unprecedented global environmental and climate mediated health risks in this age of the Anthropocene.

In order to anticipate a sustainable health transition through an ecological view of health, these perspectives should be integrated, as their functions are interrelated. The acquirement of the educational content demanded for the fulfillment of such a function rests upon nurses themselves understanding nursing's part to play in social reconstruction; thus they cannot plead ignorance. For health professionals, it should be seen as an inalienable right to demand the educational content through which their most effective service may be rendered; and the means through which such services are rendered should be made universally available (Goodrich, 1936). And now we are in this age of the Anthropocene, the evolution of educational priorities in line with professional enrichment means fostering all these critical links, together with the necessary changing health needs to serve and guide professionalism forwards to the required level, as well as to bridge the gap towards meeting this trend of demands in our ever-changing roles.

Thus, expanding professional practice involves interpreting the necessary professional competencies through this proactive lens with extra curricula designed to complementarily respond to this necessity is the critical links. Recognizing the importance of planetary health and the related concept of ecological public health may be the ultimate issue of our time, as outlined by The Rockefeller Foundation-Lancet Commission on Planetary Health. And professionalized practice is definitely required to keep pace with this renewed concept of knowledge development for all the health disciplines. Knowledge is thus needed to support this renewed nature of healthcare demands and recognize that public health has evolved ecologically. So our responsibility must go towards the core of future sustainable healthcare, ecological public health professionals competencies and capacities for our workforce development.

Especially nowadays in this new epoch of the Anthropocene, the gradual shift in characteristics of disease patterns in health transition, as referred to at different stages of epidemiological transition, are by no means simple. The ever-changing role for healthcare professionals is to integrate ecological public health education as a holistic vision and action agenda in support of sustainable health development (Li, 2018b). The time has come to more deliberately address the matters of human development and well-being that occur at the intersection of the ecological and health sciences; addressing them in academia as a basis for designing effective intervention and prevention is indeed the inevitable practical way to do so (Aguirre, Ostfeld and Daszak, 2012). This further reinforces all healthcare professionals should be well aware of and equip themselves with the changes in concepts of disease and health, which are putting burdens not just on the quality of life of the public, but on healthcare costs acting as barriers toward sustainable health developments. In this way, our scientific journey plays a crucial role, providing new insights for our intensive needs in all dimensions, and signaling how humanity must catch up to the actual and potential impacts of these unprecedented health threats.

Historically speaking, in the nursing discipline, there is a process of advancing contemporary views through utilizing the history of science, in which different themes of emphasis aid nursing's theoretical base and epistemology in the process of their role expansion. A course of action can then stem from the nursing curriculum, reflecting an integral development. This is why promoting and enhancing educational programs that can provide an extensive synopsis of the significant issues and challenges associated with the contemporary trends of international standards for professional nurses are important. In addition, concepts and theories with broader epistemic origins can further reflect nursing's intellectual heritage, its different perspectives and themes of context, all of which can act as the mirrors of concern for the paradigmatic phenomena throughout different periods of time in the continuum of development in nursing education.

Public health for the 21st century has been changed in its scope, especially since we are facing massive health threats imposed by environmental and climate change in this era of the Anthropocene. This shift in focus may also call for an attunement of the integrative nursing principles to better serve as guideposts for this emerging role. As the planet is a whole system in which humanity, animal life, ecosystems, the environment and its natural resources that are the innate capacity for all forms of life, wellbeing, and sustainability, which are inseparable (Kreitzer and Koithan, 2019).

This will be a learning journey along a path that we must invent as we go; it is not a singular event but an ongoing universal process within which each one of us has a part to play (McLeod, 2018). The nursing education system exerts a certain bearing on society's needs in terms of healthcare demands and the means of preparing a workforce to meet such demands. Thus all nursing and health professionals' roles are required to keep abreast of such changing demands is emerging. As witnessed through the historical development of nursing, the discipline is constantly evolving in accordance with ongoing expansions in healthcare development that reiterated evidentially such as: educational demands, accommodating scientific advancements, and societal changes. In fact, the ever changing roles and functions in nursing have helped to form a legitimate, scholarly and evidence-based profession, and therefore nurse educators are obliged to develop curricula responsive to the continual developments for nursing education.

Constantly examining healthcare needs means having the capacity for the reorientation of the nursing curriculum, allowing it to accommodate the emerging health needs through expanding educational capacities and fostering professional competencies simultaneously. Nurses should achieve higher levels of education and training through an improved education system that promotes seamless academic progression, as nursing education should serve as a platform for continued lifelong learning (IOM, 2011). Henceforth, one of the ultimate goals is ensuring that education makes a difference through a process in which new and emerging scientific concepts are incorporated into curricula transformation to cater the growing complexity of evolving public health needs. It also entails developing human understanding, building alliances and communicating ideas and best practices through advocacy, which nurses must engage in with an expanding role (Sherwood, 2007). And therefore, we must facilitate these intended purposes and curricula transformations, modifications, changes, and innovations to accommodate the growing complexity of ecological public health needs while advancing our professional developments as this growing complexity emerged.

In actual point of this progression, since the emergence of nursing education from the time of the first Nightingale schools of nursing and from apprentice-type schools to the majority of the educational programs, and now in institutions of higher education. All the changes in the healthcare system and healthcare needs of the population have apparently run in parallel with the development of nursing curricula, which have constantly and continually been created, revised, and geared towards the expanding scope of professional roles. Curriculum change can help further signify the trend of demands in nursing's ever-changing roles and the inevitable required expansion of its professional practice towards the 22nd century. In this connection, global ecological public health education reflects an important evolution in both thinking and collective action and it is high time to realign our concept of health in the Anthropocene as in relation to the commonality of transitional health issues *per se*. There have been calls for years to reconceptualize the evolving concept of health with the changing demands towards future sustainable healthcare through the embracment of increasingly relevant ecological public health principles as proposed in Figure 5-7. For this to be successful we must:

1. advance knowledge and skills with ecological thinking to shape this reality, as well as the processes of change through a 'trans-reality';
2. comply with global trends, changes and demands for sustainable health developments; and
3. engage with and further anticipate ESD and the value-based legacy of ecological health associated with sustainable health developments, and future sustainable healthcare.

Knowledge-in-action should be used as the synergistical strategies for strengthening ecological public health needs and practices for the rapidly changing healthcare boundaries as discussed in earlier chapters, and therefore initiating a value-based legacy of sustainable healthcare; a "silo" approach to healthcare simply cannot continue. The renewed concept must emphasize on: (i) the legacy-based value as evidence-based practice; (ii) outcome-focused wellness through sustainable health developments; (iii) adding the "fifth dimension" of a "sustained health" as a required level of care into the existing four dimensions (promotive, preventive, curative and rehabilitative); and (iv) the use of curriculum reform as a foundational platform for professionalism.

It is therefore essential for us to have comprehensive views on the changes and developments in such evolving concepts of diseases and health for the benefits of a better quality of healthcare through up-to-date educational attainment, which is an integral part of health curriculum reform. Clues that understanding and addressing the concerns of these issues for sustainable health development are both vital for nursing professions and health systems. As nurses are the backbone of our health systems, education and professional training must match these concerns and contextual characteristics for the changing demands and evolving needs of health systems towards the global directions and evolutions of ecological public health in need. Ecological public health education will be an extremely valuable resource for informing and empowering nursing and all health professionals toward the sustainable healthcare requirements forming the basis to support sustainable health developments in this age of environmental and climate crisis in the Anthropocene.

The WHO (2016) has published *Nurse Educator Core Competencies*, in which acknowledging that nursing education and practice are changing. This confirms that the nursing profession must practice, lead, and adapt to new evidence, to increasingly diverse populations and to changing needs.

It also reaffirms education is an important starting point for change (Dyson and McAllister, 2020). And, as noted in the IOM report, the best place to initiate such transformations in healthcare is in the education of our students (Allen, Penn and Nora, 2006). A major change for the continuum of public health education has been established as a goal that “all undergraduates should have access to education in public health” as recommended by the Institute of Medicine since 2003, and in fact this statement referred to all health professionals (Riegelman and Kirkwood, 2015). In this view, understanding the continuum of development in nursing and public health education as well as its essence of demands, means being able to promote and enhance educational programs that can provide an extensive synopsis of the significant issues and challenges associated with the contemporary requirements of professional nurses and public health practitioners (Li, 2016).

In point of fact, public health work is regarded as a health co-benefit of climate change mitigation and is an important role for all nursing professionals (Nicholas and Breakey, 2017). Global climate change is expected to have further broad health impacts (Patz and Khaliq, 2002), and global warming in particular has emerged as a public health challenge requiring serious and concerted action (Staropoli, 2002). Climate change is an emerging challenge linked to negative outcomes for the environment and human health. Our awareness of the importance of climate change to public health has also been growing, which calls for health professionals, including nurses, not just to recognize but to generate and disseminate knowledge about these health consequences as part of their professional duties.

In this regard, Nicholas and Breakey (2017) also urged the nursing profession to address not only the health issues that are increasingly prevalent related to heat-related illnesses, respiratory and cardiovascular problems, malnutrition due to lack of available food, air pollution, and lack of water, but also assume a leading advocacy role regarding this urgent global public health issue. And the challenge for nurses in the 21st century is to bring to fruition their professional doctrine of holism in providing continual improvement to the lives of others, making them and their communities better and healthier. For that reason, nurses have the potential to contribute to the furtherance of many dimensions in sustainable health development, and indeed to its ultimate purposes in terms of the ideals and values of sustainability. In this vein, the Australian Nursing Federation has increasingly called for nurses to engage in strategies to reduce the impact of climate change, and this momentum is growing globally for nursing involvement (Adlong and Dietsch, 2013).

And also for this reason, nurses, and hence nurse academics engaged in curriculum design and education, have an important role in anticipating and responding to the direct and indirect health effects of climate change (Adlong and Dietsch, 2013). Because only with this understanding can we then adapt to the trend of demands in ever-changing role for advancing professionalism and curricular reform for nursing education. In this context, a conceptual analysis of the justifications for subsequent changes and modifications of nursing curricula as required for the twenty-first century nursing education will be as the way forward (Li, 2016).

As Blewitt and Cullingford (2004) stated at the Earth Summit in Rio in 1992, education was identified as one of the key forces central to the processes of sustainable development during the 21st century, and since then the goal of sustainability has related strongly to the need for education in all of its forms to be seriously engaged with, something which has remained an imperative and as significant as ever. This impetus was further strengthened by the Bonn Declaration, which emerged from the UNESCO World Conference on ESD, held in Bonn, Germany in March 2009 (Jones, Selby and Sterling, 2010).

At the event, UNESCO demonstrated their commitment to ESD and urged through the Declaration that stakeholders "mobilise the core functions of universities: teaching, research and community engagement to strengthen global and local knowledge of ESD" (UNESCO, 2009). The Delors Report also supported movement in this direction, advocating the provision of an outcome-based framework for use in the nursing curriculum to foster a holistic learning framework milieu to support environmental-sustainability concepts as part of a wider evidence-based educational resource for sustainable practice in managing the linkages of health and environment. And in the deliberations surrounding this international trend of movements in ESD, in particular the response to the calls for integrating ESD into the curricula for nursing education, opportunities have been found implying and projecting the expansion of historical eras of nursing's search for specialized knowledge under this ecological era in the 21st century of healthcare demands and international trends in global public health.

These are fragile and uncertain times for the health and survival of both humanity and the planet-at-large, which reflects why the rapidly evolving field of global health calls for wisdom and advocacy firmly rooted in a nursing perspective and an integrative lens (Rosa, Upvall, Beck and Dossey, 2019). As we are beginning to understand that our health and even survival of all life on the planet is deeply connected to cross-border issues such as population, water and land use, and social system stability, thus from the global perspectives and intercultural competencies are required for all levels of nursing education (Dyson and McAllister, 2020). As Jones, Selby and Sterling (2010) supported, "sustainability concepts and ideas hold a great deal of potential that has yet to be realized in nursing", and nursing education could embed the idea of "ecological literacy" into curricula and pedagogical strategies. The research from the WHO is also dedicated to the realization of ecological public health principles for nursing and healthcare professionals through educational reform.

Professionals have to recognize the influences of climate change on health and its subsequent health risks; knowledge of these health needs is absolutely essential for curriculum to achieve concepts of sustainable health developments, and the importance of ESD (or, interchangeably, Ecological Sustainability Development). The power of these frameworks has already gained international momentum in conjunction with the global trend of keeping pace with knowledge development. As Keating (2015) illustrated, the extent of revision or development needed to produce an up-to-date and vibrant curriculum with these essential components of the curriculum for the various levels of nursing education is essential.

Curriculum as the Functional Platform for Educational Reform

It is certainly important to equip nurses with the knowledge and attitudes to address the emerging public health concept of planetary health, as climate change and threats to ecosystems are very real health concerns. Ecology and sustainability in nursing sciences are discussed by Anåker and Elf (2014) and Kangasniemi, Kallio, and Pietilä (2014) as being a present-day issue in healthcare. They are also mentioned by Dahlberg and colleagues, with the goal of maintaining an environment that does not harm current and future generations' opportunities for optimal health (Dahlberg, Ranheim and Dahlberg, 2016). Lang and Rayner (2012) have also argued that public health must not be scared to address complexity nor dare to confront power. Others have since reinforced this understanding, which ought then to be part of the conceptual language of health promotion used by nurses (Goodman, 2014).

As the ICN states that nurses need to be concerned with the promotion, maintenance and restoration of the health of the natural environment, particularly with the pollution, degradation and destruction of that environment being caused by human activities. In this regard, the ANA (2007) has provided a set of foundational principles for nursing practice:

- ☞ Human health is linked to the quality of the environment.
- ☞ Air, water, soil, food, and products should be free of potentially harmful chemicals.
- ☞ A healthy environment is a universal need and fundamental human right.
- ☞ Environmental and social justice is a right of all populations and assumes that disparities in health are not acceptable.
- ☞ Current generations should meet their needs without compromising the ability of future generations to meet their own needs as stated in the 1987 Brundtland report.
- ☞ Pollution prevention should occur at its source.
- ☞ The concern of nurses is the promotion, maintenance, and restoration of people's health.
- ☞ Nurses have an obligation to address health disparities and environmental injustice.
- ☞ The nurse should collaborate with other professionals, policy makers, advocacy groups, and the public in promoting local, state, national, and international efforts to meet health needs.

National nursing organizations have already addressed the importance of education and advocated the clinical relevance of current and future nurses being able to provide care within a climate-changing environment, thus nursing education should have a mandate to integrate knowledge about climate change issues across all its levels. In this context, the Task Force on Environmental Sustainability of the American Association of Colleges of Nursing (AACN) has also provided recommendations back in 2011, with various means of support, for incorporating content on environmental sustainability into the nursing curricula, seeking to improve the educational competencies related to environmental sustainability for baccalaureate and graduate students (AACN, 2011).

Despite this recognition, many nursing students are not adequately prepared regarding the health impacts of climate change and the nursing profession's response (Leffers, Levy, Nicholas and Sweeney, 2017). Indeed, Bevis (1989) reinforced that nursing care demands are exploding in kind, quality, and quantity under healthcare delivery systems, and that all health professionals' jobs, requirements, and educational systems are grossly obsolete and inadequate. This fact has resulted in what Toffler has named "future shock", given the rapidity of change in nursing. A paradigm shift with a focus on significant directive progress upon the justifiable course of actions in response to the required conditions and situations is therefore, a necessity. It is likely, though, that any approach to knowledge development involves a dynamic network or web of components that includes the philosophical, empirical, and theoretical dimensions of the discipline, which should be a process paralleling the wider processes of change (Reed and Crawford Shearer, 2018).

Nursing is a professional, legitimate, scholarly and knowledgeable discipline, with changing professional obligatory duties in response to changing health needs, and therefore trends of nursing curricula should embrace those legitimate characteristics that are congruent with the professionally competent and educated mind for our discipline to develop its desired characteristics and meet its multifarious demands. The domain of public health was one of the essential areas incorporated into this profession long ago as a part of many international university curricula globally, reflecting the growth of professionalism in this arena. However the focus on ecological public health is apparently being neglected, despite scientific advancements constantly expanding this area of concern. It is therefore, recognized that curriculum development in nursing education is utterly indispensable, as this is a scholarly and creative process intended to produce an evidence-informed, context-relevant, unified curriculum for an ongoing activity whose extent of development ranges from regular refinement to reconceptualizing the curriculum for a desired goal, set of values, or changing needs of a society (Iwasiw and Goldenberg, 2015). Henceforth, it is a critical time for curriculum reform towards creating a functional platform for the educational connectivity needed to keep abreast of such significant changing health needs in a proactive manner.

Breakey et al. (2015) have pointed out the characteristics of three generations of educational reforms: the first generation focuses on a science-based curriculum; the second generation introduces problem-based instructional innovations; while the third generation proposes a systems-based approach to improve the performance of health systems by adapting core professional competencies to specific contexts. In this same vein of concern, the fourth generation is therefore proposed herewith as a sustainable-based ecological public health approach, which is required for competency-based professionals to function effectively and to act as agents of change in the health system. As for this intended purpose, a newly proposed "fourth generation of educational reform" should therefore be characterized by a specific focus on an "ecological and sustainable-based" approach towards this century and beyond.

Curriculum reform can serve as a signpost to guide ecological public health education and lead professional training back to the application of anew knowledge and skills, embodied in principles of quality value-based legacy for sustainable development. Securing such reform is a pivotal requirement in meeting the healthcare demands and responding to the changing health needs in the Anthropocene. In fact, it is an important factor and bears further consideration in recognizing not just the changing ecological and global determinants of health *per se*, but more importantly their profound impacts, catastrophic effects and transitional risks onto our health both now and in the future. Yet, it is necessary to ensuring our sustainable survival across generations. Complementarily my proposed the twelve ecological public health principles (as in Figure 5-7) serve as an indicative vision for this integral part of professional capacity building towards future sustainable healthcare.

The conceptual developments and dimensions of nursing education reflect the characteristics of our profession, and the ever-advancing scientific and societal changing needs that have deeply influenced and dictated the trends of nursing curricula. They represent vital roles in their work for knowledge advocacy, as well as an intrinsic part of the wider global campaigns for ecological health literacy. Bevis (1989) indicated that a theory of nursing should provide a checklist, guide, or device for seeing nursing holistically and dynamically, in terms of providing definitive content-organizing strategies for the curriculum. Further analysis of and re-defining of educational philosophies, learning theories, and educational frameworks and pedagogies for formulating goals and outcomes should also be clarified before being undertaken, so as to keep up with nurses' expanding professional roles.

The importance of curriculum reform in nursing education is to apply new knowledge swiftly and in practice with contextualized learning skills. For the benefits of changing health needs, this should be one of the recommended primary strategies to align education with professional training in order to achieve an effective health system. It would help result in the creation of a truly sustainable nursing workforce. In particular, estimating the future influence of global environmental and climate change on health and addressing the scarcity of skilled nurses within the current healthcare environment. The concepts on the curriculum should be focused on the trends arising from the changing healthcare needs and the required professional abilities to fulfill nurses' expanding roles. Thus, the conceptual theories of the educational framework should be enabled to ensure continuous growth towards professional advancement for proactively tackling the transitional health risks.

As Iwasiw and Goldenberg (2015) postulated, the creation of an evidence-informed curriculum begins with relevant definitions of that curriculum that are responsive to the current and projected context. Having a relevant and unified curriculum is the core focus of the requirements for the body of nursing knowledge, as this promotes the inherent need for the ongoing growth and expansion of nursing curricula with context-relevant and evidence-informed resources in support of this call for action. Hence, curriculum planning and development is a vital path to guide professionals through this process of change and can function as the platform for this learning connectivity. Breakey et al. (2015) agreed that we do need good informative learning, because we want people to be experts in their respective professions, and therefore it is significant to build on the basis for expertise with the shared views moving on from informative to formative, and to transformative learning.

Subsequently, any development for a curriculum or its subsequent modification and change has to be explained in terms of its purpose, meaning, necessary conditions, and relationship to existing or projected theoretical perspectives. This is also an integral part of quality assurance as based on the historical developments within curriculum theory as reflecting different changes in the purposes, principles and content of curricula. For these reasons, curriculum planning and development have to be based on the justifications on the changing health needs *per se*. And this is a critical step for the development of understanding and to improve the capacity of transformative learning for the evolving health needs in the Anthropocene.

> "Education is a progressive discovery of our own ignorance."
>
> (William James Durant)

Jones, Selby and Sterling (2010) commented on the necessary relationship between sustainability and interdisciplinarity and how this should be reflected in discipline-based structures for higher education: *"The World is a complex, interconnected, finite, ecological-social-psychological-economic system. We treat it as if it were not, as if it were divisible, separable, simple, and infinite. Our persistent, intractable, global problems arise directly from this mismatch (Meadows 1982, p. 101)"*. Therefore, to establish philosophical and educational approaches for a unified curriculum on an interdisciplinarity basis there should be more extensive strategies for designing evidence-informed and context-relevant frameworks for concept-based inter-professional education to be transformed into a journey of new principles in transdisciplinarity, as discussed earlier in Chapter 6.

Compartmentalized and partial understandings of ecological phenomena are being produced when multifaceted and contextualized scientific views and knowledge are needed. Our goal is to achieve curriculum reform by reinforcing transdisciplinarity and integrative understandings with effective and efficacious conceptual engagements aimed at advancing our professional and intellectual frontiers towards sustainable concepts in health development. Ecological public health education is therefore recommended.

Universities' Role in Curriculum and Educational Developments

Universities are meant to be established on the basis of advancing knowledge; thus, the advancement of human knowledge and understandings through learning and research has become their mission. Their engagement is thus one of the essential and significant steps towards creating an educational platform which will move nursing and health professions forward by fostering connectivity with an emphasis on strengthening the necessary professional competencies required for the evolving and transitional public health needs in this new epoch of the Anthropocene. The necessity for ecological public health education is an integral part of our professional obligations in response to the existing transitional health threats in the Anthropocene.

University-level collaborative networks foster broader connections, and healthcare professionals must be well aware of climate and environmental issues at the global level and the adverse public health impacts directly and indirectly imposed by those health threats. We must also see that environmental devastation will not be stopped in conference rooms and treaty negotiations: only mass action can make a difference (Angus, 2016). An understanding of human ecology is therefore needed, so that humans may become a positive force in their relationship with ecological systems, with a focus on the importance of sustainable health developments. Life must be lived forwards so the transitions in health locally and globally should also reflect the needs of public health movements in terms of ecological views of health. These priorities in sustainable and equitable solutions are required; thus, to address the interconnected challenges of protecting the health of the natural environment and protecting the health of human populations with approaches in united human-environment systems is of significant concern (Galvani et al., 2016).

A valid educational platform to address existing and future ecological public health challenges is absolutely necessary, something increasingly so as the health of human populations is ever-further influenced by large-scale environmental changes with increasing degradation and pollution of natural resources from the underlying drivers of human-induced changes in climate, habitat, and the use of terrestrial and marine ecosystems (Aguirre, Ostfeld and Daszak, 2012). Henceforth, universities need to be proactive in support of the emergence of ecological public health education into academic structures, perhaps as a requisite for nursing and all healthcare education.

The importance must be stressed of creating the necessary connectivity for a shared value-based legacy to ensure long-term results of sustainable health developments as evolving parts of future sustainable healthcare approach. Hence, universities are of significance in promoting the concept of sustainability literacy and thus expanding the evolving interrelationships between concepts of health and healthcare. In fact, this is a proactive and holistic way of thinking which is coincidentally in line with the vision of “sustainable healthcare”. The vision should draw upon cross-disciplinary perspectives, and promote them as a globalized trend with international relevance, as the more synergistic understanding of the environmental, social, cultural and economic factors that lie behind our prime concerns, which will be fundamentally motivate sustainable ecological considerations towards planetary health for the better eco-environments.

As MacPherson (2011) states, ecological values require interdisciplinary inquiry, and there is a need to enhance ecological awareness and values across the curriculum and at different levels. This sense of participation and responsibility generates the motivation to be more proactive in protecting these ecosystems. In this respect, the ends of sustainability and ecology education must be socially and culturally framed, not just presented as mere information. Within this purview, public health is seen as a system of principles for action, and a guide to planned activity that seeks to negate those factors of disease. In that understanding, we can bring about the necessity for action as a consequence of ecological consciousness (Kartman, 1967). And this way of thinking requires taking historical revelations that lead to inhibit the intelligent, conscious, and purposeful struggle of greater humanity.

Curriculum development should then be used as the defining basis for the connectivity of this new kind of humanism, a humanism that symbolizes the corresponding values, significance and meaning sought through the health education agenda. In this regard, the value-based legacy for sustainable healthcare as a framework to demonstrate its importance of numerous relational dimensions, including the widening understanding of trends for sustainable health developments. It represents a form of working together to reach this vital landmark. It should act as the educational building blocks and as a model for future action, with its parameters set through the university (Li, 2018b).

Universities will be in a position to offer the possibility of bringing ecological public health education to healthcare professionals around the world, and indeed their role in curriculum planning and development as the educational platform for the necessary connectivity is utterly essential. For it to be a success, universities' role in curriculum and educational development is to enforce the incorporation of ecological public health education into their academic structures, and then ensure that advancement meets real-world health concerns both theoretically and practically. In this vein, academic structures need to be strengthened as an effective pipeline to bring in new structures, specifically when engaging with health challenges and with regard to meeting the 2030 SDGs (Gimbel, Kohler, Mitchell and Emami, 2017). Efforts to build strategic and collaborative partnerships with effective promotion of this professional recognition are entirely critical, as only through structures and processes can we drive outcomes towards the betterment of holistic and humanistic caring under this age of global environmental and climate crisis in the Anthropocene. As University is regarded as one of the principle agents of change in the process of educational reform, and thus is in line with our action-oriented perspective for professional capacity building.

Roles of Medical, Nursing and Healthcare Authorities, Organizations and Councils

Ecological public health for nursing and health professionals means implementing a knowledge-to-action approach, which can help combat the transitional risks imposed by environmental and climate mediated health threats in the Anthropocene, and therefore should be in line with the advancements of public health developments with regard to the contemporary needs for ecological public health education. The global trends of changes in nursing education, practice, and policy development are constantly influencing nurses' roles for the 21st century, and today some general principles about global public health and their impact on nursing are introducing new challenges and opportunities for nurses (Sherwood, 2007). The drivers of planetary health in particular are all intimately related to health, and the role of nursing has evolved and expanded over time, meaning its current priority is achieving sustainable development goals by making health systems more resilient in an era of increasing stresses (Kurth, 2017). Ecological public health education is an empowering process in shaping and envisioning the changing health needs that in fact drive the ultimate goal of understanding the value of theoretical knowledge from different epistemological perspectives. Propositions of health determinants are thus essential for improving the outcomes of quality healthcare towards sustainable development. Hence, the roles of medical, nursing and healthcare authorities and councils should respond and support this trend of changing demands.

In particular, public health draws on a vast array of disciplines and its focus has changed over the modern period. Within public health today we can see a number of different orientations towards its objectives as well as different values underpinning the discipline (Dew, 2012). Back in 2013, public health nursing was defined by the American Public Health Association as the practice of promoting and protecting the health of populations using knowledge from nursing, social, and public health sciences (Lewenson, 2017). At the core of the concept of public health is the human right to health, and the responsibility of governance for establishing the equitable promotion of health and well-being requires the functioning capacities in both public health and its health system. Despite the differences in the history of how public health nursing and its equivalent services began and evolved, countries around the world began copying each other in respect to the development of public health and public health nursing (Edgecombe, 2001).

The goals of public health practice will thus continue to be the planning and organization of innovation and improvement strategies in this regard, including the nurturing of a learning system towards common health-optimizing goals (WHO, 2018). The advancement of public health theory and practice is closely associated with the changing demands in the healthcare environment and the new changing global context in the Anthropocene. As a result, promoting the advancement of professional competencies and the role of ecological public health education deserves prioritizing for the totality of scientific and sustainable healthcare systems.

Contributing to the transition to a sustainable, just, and healthy future has become an integral part of the health sector’s role and responsibility, thus recognizing the need for a concerted response to meet the education, training, and professional development of current and future health needs for professionals to more fulsomely address these emerging challenges is essential (Parkes et al., 2019). For this reason, there is a pressing need for increased recognition of the importance of the environment and its ecosystems for health, and the reconceptualization of the concept that a healthy environment is a fundamental determinant of health, for both current and future generations. Indeed the lack of an ecological understanding of the dynamic relationship between humans and the rest of the natural world, or the life-support role played by those natural systems, would result in an overly intensive and disruptive human interaction with the natural world (Tait, McMichael and Hanna, 2014).

The value of theoretical knowledge lies in the widespread recognition for professional nursing practice and the utilization of nursing philosophies, models, and theories to guide and apply for nursing developments in this direction. The application of organized knowledge is the wisdom of “heart and soul” combined for guiding the thought and action of nursing practice in terms of progressive disciplinary professionalism through advancing curriculum development in nursing education. This initiative is a dynamic process of changes, and therefore, all medical, nursing and health authorities and councils should have responsibility and a role in supporting this significant initiative.

As Keating (2015) stated that there are several major changes that will influence nursing curricula in these early decades of the 21st century, including the most influential recommendations of the Institute of Medicine (IOM) for the need of higher education for nurses to meet healthcare demands, and the recommendation of the AACN. The Council for the Advancement of Nursing Science also aims to facilitate and recognize life-long nursing science career development as an important part of its mission, and offers a renewed vision towards pathways of excellence for preparation of the next generation of nursing scientists (Henly et al., 2015), which should also be part of these broader forces. Especially, nurses play an important role in promoting public health with their traditional focus on disease prevention. This journey of knowledge advocacy from aspiration to achievement is not only achieved through the enhancement of scientific understandings, but also requires support of the authorities. Drilling down to such a process of changes requires broad action globally from medical, nursing and healthcare providers, organizations and authorities. From this perspective, the history of professional authorities, including medical, nursing and public health organizations, has a pivotal role in advocating and ensuring ecological public health education for the advancement of professionalism in the domains of medical, public health and nursing sciences, and which will definitely generate a positive effect on the transition towards the future sustainable healthcare.

Conclusion

Since the early years of the profession, nursing leaders such as Florence Nightingale and Lillian Wald have recognized the role of nurses in controlling the influence of environmental factors on health (air and water quality, food, sanitation, cleanliness, chemicals, pesticides, waste products). This knowledge underpins nursing practice as expressed by Florence Nightingale in her First Rule of Nursing: “Keep the air within as pure as the air without” (Nightingale, 1859; ANA, 2007). The environment is an established domain of nursing knowledge, as human activities are bringing about global changes through their impact on biogeochemical cycles; land use and mobility of organisms; altering biodiversity and climate; and ultimately compromising the ecosystem services that sustain our planet. It must, however, be recognized that one of the key principles of evolutionary medicine is that selection acts on fitness, not health or longevity; our evolutionary history does not cause disease, but rather influences our susceptibility to increased disease risk in particular environments, because the individual has been exposed to an environment that is beyond their evolved capacity (Gluckman et al., 2011).

As we face complex patterns of global change, the inextricable interconnection of humans, domestic animals, livestock and wildlife, as well as their social and ecological environment is indeed evident, and requires integrated approaches to human, plant and animal health. This includes the respective social and environmental contexts that go beyond just humans and animals, but are rather based on complex ecological approaches with linkages between ecosystems and health (Zinsstag, Schelling, Waltner-Toews and Tanner, 2011). Global drivers and different underlying ecological determinants of health are potentially catastrophic and have highly complex dynamics leading to direct and indirect effects on widely diverse health impacts; thus the establishment of ecological public health is crucial to modern public health (Li, 2018b). In particular, the current healthcare systems are struggling substantially to keep up with the changing patterns of various diseases that result both from a rapidly changing and degraded Earth and from the way people live. It is clear, therefore, that activity based on holistic views is needed because we must understand that the impacts of global environmental and climate crises have been identified as rising health threats (Li, 2018b).

Knowledge gained should be in parallel with the application of evidence-based practice, which then becomes in the progress of professions a coherent vision in all scientific endeavors and to all health professional undertakings. Healthcare starts with caring and grows with caring, and the concept of supporting sustainable developments in health is growing one step further for the necessity of caring praxis in this new epoch of the Anthropocene. Therefore, expanding our professional competencies towards this trend of directions is a critical step of quality assurance for sustainable healthcare now and in the future. As healthcare professionals in nursing and public health, we have an obligation to take the lead in terms of protecting the integrity of nature and the natural environment for the sake of our health. Nurses have long appreciated that a healthy environment impacts the health of individuals, families, communities, and populations. As the WHO affirms, eco-environments and their beneficial impact on our health are indispensable. Therefore, the essential competencies discussed in this context allowing nursing and health professionals to take a pioneering and leadership role to promote such significant notions of global public health literacy in relation to ecological public health action. As they are unprecedented in terms of their need of connotations that embark on the preservation of sustainable health developments as the focuses of parallel relevance towards different facets of the changing demands of health needs. Yet, perhaps this is one of the important moral forces embedded within ecological public health, shaping society and humanity at this particular historical moment in its many forms of caring praxis.

Achieving our goals requires transformative action towards evolving approaches within ecological public health education *per se*, to deepen our understanding of both the significance of sustainable concepts in health developments and the required professional obligations to see them enacted. This is especially so, given the massive transitional risks with mediated health threats that we are facing during this current health in transition. To sustain health developments in all of the areas under our concern, ecological public health presents the essential course of action in our professional journey of humanity and caring praxis. Henceforth, the essentialities of educational and curriculum reform for blending such necessity of changing health needs, and as a part of professional guidance and recognition are indeed the critical inputs and through-puts in a process of change that advances the healthcare profession efficaciously and effectively under this new epoch of the Anthropocene in the 21st century.

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