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PLANETARY HEALTH: AN INTERDISCIPLINARY PERSPECTIVE

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Abstract

This paper addresses the issue of planetary health under a multidisciplinary profile. It starts with defining the scope of planetary health, retracing its most salient historical points. It then reflects on the socio-political changes needed to achieve transformational change in society. The concepts of health literacy and environmental health literacy are explored as a useful means of disseminating and raising awareness about planetary health. Finally, a case study related to heart disease is explored to demonstrate why this approach is more necessary today than ever.

Key words: climate change, climate justice, environmental medicine, planetary health

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1. An introduction to planetary health

Planetary health is a rapidly emerging field that provides a unifying framework for many of the most urgent challenges of the coming decades. It focuses on understanding and quantifying the human health impacts of global environmental disruptions, including climate change, food-systems collapse, rapid biodiversity loss, and widespread pollution, among other urgent threats to human lives and livelihoods (Myers, 2017; Whitmee et al., 2015). Planetary health also advances the development of solutions that will allow humanity and nature to thrive into the future (PHA Website, 2022). The planetary health framework is foundational for a new, broad-based societal awareness that the wellbeing of humanity is deeply connected to the state the biosphere and bold solutions are urgently needed to safeguard human health and well-being, and the rest of life on Earth, now and into the future (Haines and Frumkin, 2021; Myers, 2017; Myers and Frumkin, 2020; Myers et al., 2021; Wabnitz et al., 2020; Whitmee et al., 2015; WHO, 2021). Driven by rapid population growth, even steeper growth in per capita consumption, and industries with large environmental impacts, the scale of the human enterprise now surpasses the planet's capacity to absorb wastes or to sustainably provide the resources used across all sectors of society. Human activities are driving changes to earth systems and the living world at rates that are much steeper than have existed in the history of our species (Myers and Frumkin, 2020; Steffen et al., 2015).

These unprecedented changes include: 1) anthropogenic climate change; 2) widespread pollution of air, water, and soil; 3) rapid biodiversity loss; 4) reconfiguration of biogeochemical cycles for carbon, nitrogen, and phosphorus; 5) pervasive changes in land use and land cover, and 6) depletion of fresh water and arable land (Haines and Frumkin, 2021; Myers and Frumkin, 2020; Steffen et al., 2015; Whitmee et al., 2015). Each of these alterations interacts with the others in ways that undermine the foundational conditions needed for human health, including air and water quality, and the production of food.

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These global scale environmental changes also influence the emergence and spread of infectious diseases, the increase and severity of extreme weather events, and the habitability of many parts of the world. These transformations impact every dimension of our health and wellbeing (Haines and Frumkin, 2021; Myers and Frumkin, 2020; Whitmee et al., 2015).

The harms associated with global environmental change do not fall upon all people equally. They exploit the fissures in human societies that social and racial inequities create and, at the same time, global environmental changes also create conditions that favor more inequity and injustice. Activities that degrade Earth's natural systems tend to benefit the privileged, while the world's poorest people, indigenous communities, people of color, and future generations disproportionately bear the associated health burdens. As such, equity and justice concerns form the basis for understanding and addressing global environmental change and health (Haines and Frumkin, 2021; Myers and Frumkin, 2020; Myers et al., 2021; Redvers et al., 2022; Whitmee et al., 2015; WHO, 2021).

To provide for a healthy, just, and sustainable world, there needs to be an awareness and understanding of the human health impacts of global environmental changes and to use this knowledge to develop solutions that will allow humanity and the natural systems our society depends on to thrive. The Great Transition (Raskin, 2016; Spratt et al., 2010) is a term used to describe the societal transformation to a world that optimizes the health and well-being of all people and the planet. To safeguard the future of humanity and all life on Earth, there needs to be rapid and deep structural changes across all dimensions of society (Myers et al., 2021; Whitmee et al., 2015). It will require a transition to a new set of values that incorporate diversity, equity, and inclusion of all people as well as respect and recognition that the health of people are dependent on and interconnected with Nature (Haines and Frumkin, 2021; PHA Website, 2022).

A cornerstone of planetary health is that it is a community forged in urgency, hope, and action. Two examples of actions include a planetary health pledge for health professionals (PHA Website, 2022; Wabnitz et al., 2020) and the São Paulo Declaration on Planetary Health (Myers et al., 2021). The proposed planetary health pledge is based on the Declaration of Geneva for the medical profession and is a way to bring planetary health principles and values into the culture, education, and practice of health professionals. The authors also urge other professions to adapt the pledge to their occupations to stimulate the transformative changes needed to achieve planetary health (Wabnitz et al., 2020). The São Paulo Declaration on Planetary Health was launched in 2021 and is the first document of its kind from the global planetary health community outlining what actions are necessary to achieve the Great Transition. It was produced by the planetary health community at the 2021 Planetary Health Annual Meeting and Festival in São Paulo, Brazil (PHA Website, 2021), concluding with a global consultation of nearly 350 participants from 70+ countries. It outlines recommendations for planetary health action across 19 sectors, including governments, private sector, civil society, and the general public (Myers et al., 2021).

The strength of the planetary health framework is that it focuses the many individual conversations and activities about climate, biodiversity, oceans, global food systems and pollution into a single discussion about the survival of humanity and all life on Earth, with an emphasis on social justice. It addresses the scale and urgency of both the current societal challenges and the solutions needed to achieve the Great Transition. The evidence base that comes from the planetary health field can be used to develop and inform the growing social movement calling for action to equitably harmonize human development gains while protecting the planet's natural systems and all life on Earth.

2. Socio-political changes needed for planetary health – a reflection

The planetary limit approach, first established in 2009 (Planetary health alliance website), has captured the imagination of scientists and politicians. But a technical approach to planetary threats has limitations. A neglected area is the quality of socio-political and economic institutions that provide answers to the dangers identified by Rockström and others (Myers, 2017). How we organize the actions of society in the face of threats is more important than the threats themselves. Science is an example. Science has made enormous contributions to understanding planetary threats. But a new planetary perspective for our difficult situations invites us to rethink the way knowledge is produced and used by society.

Currently, knowledge exists mainly within closed systems. It was generated within the institutions we call universities. Universities are organized into narrow academic disciplines that work with short-term funding and are focused on publishing research articles in largely inaccessible journals. Scientists set their own research agendas, keeping their knowledge system closed. Planetary health requires more open knowledge systems where grounded knowledge comes from many societal sources, where universities are organized according to the problems facing society, where investments are long-term and the products of research are at available to all in the forms that meet the needs of the various public communities. What is needed today is an investigation into the threats to human civilizations and our survival from perturbations of planetary systems. We need to go beyond the global health manifesto and instead adopt a planetary view of human health. As Jared Diamond wrote in his 2005 book, Collapse, "For the first time in history, we face the risk of global decline. But we are also the first to enjoy the opportunity to learn quickly from developments in societies anywhere in the world today“. The global health task is not finished. But now it needs to be integrated with a new perspective on our future-health of the planet” (Diamond, 2005).

In this vision, the goal of protecting and promoting health and well-being, to prevent disease and disability, to eliminate conditions that damage health and well-being and to promote resilience and adaptation, become one with the sustainability concept. In achieving these goals, our actions must respond to the fragility of our planet and our obligation to safeguard the physical and human environments within which we exist. A strong reaffirmation of primary prevention, indeed a true historical nemesis in the proper sense of the term that recalls in Greek and Latin mythology an act of compensatory or restorative justice for what, exceeding the right measure, disturbs the order of the universe.

With the current pandemic, we are also facing infectious zoonotic disease increasing, and we see mental health effects associated with eco grief, and other disruptions. With all of this change we see civil strife and trauma, forced displacement and migration, all of this which impacts human well-being and the ability for us to live with a wellness into the future. So, in other words we've mortgaged the health of our future generations to realize economic and development gains in the present. This statement comes from the 2015 Rockefeller Lancet Commission’s Report on planetary health (Myers, 2017), which called for action to address these urgent issues. It called for creating a transdisciplinary field focused on the evidence base connecting human health and environmental disruption, and it called for creating an entity to galvanize the community of planetary health practitioners.

Already in 2013, Richard Horton, a member of the aforementioned Commission, reflecting on "global health" wondered if this new and powerful discipline, born in the last decade mainly from the Millennium Development Goals, was able - with its definition and its purposes - to answer the questions our societies currently pose. Global health has included in the concept of health that of equity among peoples, social justice and solidarity, indicating the path of transnationality and interdisciplinarity but has not kept - according to Horton - the substratum in which we live, the planet itself.

Our planet is under pressure, and not only for the additional 2 billion people who will inhabit it between now and 2050. The post-2015 era will be characterized by "sustainability", the idea that not only human and natural systems are interdependent, but also that nonlinear transformations in such systems could be catastrophic for our future. The planet's potential to support our species is slowly declining. The most important post-2015 idea is that global sustainability is the prerequisite for human health, survival and prosperity. Horton also introduces the concept of planetary boundaries, the idea that our species must live within an operational space of security, and citing Johan Rockström specifies that this space is much more than climate change, it includes dangers such as ocean acidification, depletion of the ozone layer, disruption of nitrogen and phosphorus cycles, depletion of freshwater resources, land system change, biodiversity loss, atmospheric aerosol load and chemical pollution. If these limits are transgressed, the survival of our species will be compromised and this represents the ultimate threat to global health.

3. Towards a new approach: health literacy and environmental health literacy

Climate and health education should play an important role in health promotion. Planetary health goes far beyond the concept of climate change and, therefore, requires a communicative approach to illustrate adequately the connection between our health and that of the planet. The field of climate change communication can inform such an approach given the large body of environmental communication research. One of the most prominent climate change communication approaches is the use of a series of “frames”, or interpretative narratives that help specific populations understand why information is relevant in specific contexts (Nisbet, 2009). The health frame (a subset of the social progress frame) is functional and effective for communicating climate change information because it addresses the primary difficulty of climate change communication, namely the fact that climate change is perceived as something distant in space and time (Nisbet 2009). Health is instead something close and personal, and we have direct and immediate negative consequences if we do not safeguard it (Maibach et al., 2010; Myers et al., 2012).

3.1. Health literacy (HL)

In the last twenty years, the meaning and dimensions of health literacy (HL) have grown progressively to include the ability to access, understand, and use health information from numerous and different sources. HL as a key element of health promotion and public health was defined by the WHO in 1998 to encompass those cognitive and social skills that determine people's motivation and ability to access information, understand it, and use it to promote and maintain good health (WHO, 1998). This definition encompasses three domains of health literacy: functional health literacy, interactive health literacy, and critical health literacy.

Functional health literacy refers to the basic skills of reading, writing, basic numeracy, and general literacy that allow people to understand communications concerning health and the use of services in healthcare contexts. Examples include the ability to adhere to medical therapy (correct timing, dosage, and administration method) and schedule appropriate medical examinations and visits. Interactive health literacy is the set of communication and social skills that enables someone to extrapolate and understand meanings from different forms of communication and to apply new knowledge to changing circumstances. Examples include communicating with a doctor about care pathways and exchanging health knowledge and information with contact networks via verbal interactions or online discussions. This form of literacy promotes the development of personal skills in a supportive environment. Finally, critical health literacy is a higher level of cognitive and social critical analysis that enables greater control over life events and situations. Critical health literacy is necessary for empowering effective individual and collective action to address the social, economic, and environmental determinants of health.

People with adequate HL are empowered to understand their rights, to act as informed consumers, and to promote individual and collective action for health improvement through active participation in society (Kanj and Wayne, 2009). Such empowerment is encapsulated in the right to vote, the right to participate in social movements, and the right to demand environmental protections collectively through social organizations like neighborhood committees.

This concept of a community health appears within the definition of another type of health literacy, that of public health literacy, the set of skills necessary to understand that choices have an impact not only on the health of the individual, but also on that of the entire community (Gazmararian 2003; Freedman 2009). Following an extensive review of the literature, the European Health Literacy Consortium developed an integrated definition of health literacy that summarizes its evidence-based dimensions and acknowledged the awareness and skills necessary for making informed decisions and judgments about disease prevention and health promotion to maintain or improve quality of life. (Sørensen et al., 2012). Knowledge, skills, and motivation constitute the heart of this HL definition, distinguishing it from notional knowledge acquisition or skills achieved through training. This definition envisions health literacy as the ability to access, understand, evaluate, and act on health information throughout the course of life. These abilities are associated with three domains, namely care, prevention, and health promotion, and they represent a progression from the individual to the collective perspective, encompassing both a clinical and a public health perspective. According to this integrated definition, numerous antecedent factors influence individual- and population-level HL, including age, gender, level of education, general literacy, previous illness experiences, socioeconomic level, employment, language proficiency, cultural background, the presence of physical disabilities or cognitive impairment, and impaired vision or hearing, in addition to family, social, and environmental determinants. Just as these factors influence HL, HL influences health behaviors and the use of health services, and consequences are measured in terms of health outcomes and costs for the individual and the community. This perspective identifies health literacy as a determinant of health that impacts the equity and sustainability of health systems as well as opportunities for improving the quality of life of individuals and populations.

HL, therefore, is a set of cognitive and social skills that may in part be developed through health education and information acquisition. However, developing these skills also requires exposure to different forms of communication and effective messaging, rather than relying solely on individual cognitive abilities (Nutbeam, 2009). If health messages and the communication modality are not aligned with a recipient's needs, the information will not be easily accessible or comprehensible, and those with low HL levels may experience health inequalities.

3.2. Environmental health literacy

Environmental health literacy (EHL) is a new HL subset born from the fusion of the principles of HL, risk communication, environmental sciences, communication research, and safety culture. EHL is the comprehension of connections between environmental exposures and health with a focus on actions that exert positive impacts on individuals, communities, and the environment. EHL may be understood as "the wide range of skills and competencies that people need in order to seek out, comprehend, evaluate, and use environmental health information to make informed choices, reduce health risks, improve quality of life and protect the environment" (Society for Public Health Education 2008, as cited in Finn, 2017).

EHL is comprised of the same three domains as HL but with an environmental focus (Gray, 2018). The first domain concerns how the socio-cultural dynamics and the environments to which we are exposed affect our health, whether in the context of the relationship between environment and health or a specific environmental pressure. The second domain is derived from social cognitive theory and focuses on decision-making, competence, and self-efficacy with respect to influencing one's own health and that of one's community. The third domain involves individuals or groups applying their knowledge and agency to protect collective health. In this case, both individuals and groups use self-efficacy to implement behavioral change to reduce harmful environmental exposures and improve collective health.

As with HL, communication is important for EHL. For example, social media may play a role in disseminating information about environmental risks. Individual- and population-level EHL has numerous determinants, including objective factors like literacy, the ability to understand health-related numbers (functional HL), and access to "quality" information sources, and subjective factors like emotions and individual motivations that can affect environmental exposure risk perception of things like the imminent construction of an incinerator in an area close to one's home or news regarding the spillage of harmful wastewater near places secularly considered "sacred", such as schools and kindergartens.

The complexity of information about the relationship between health and environment made available to the public continues to grow. While information sources have become easier to access, they often report conflicting information and increase perceived uncertainty around the results of scientific studies (Fischhoff and Davies, 2014). Non-experts (i.e. the general population) tend to be less familiar with the concept of uncertainty and probability and usually think of things in absolute terms (e.g. good/bad), which produces distortion in the perception of health risks (Politi et al, 2007). Numeracy is particularly important for understanding uncertainty. But understanding uncertainty also requires knowledge gained from previous life experiences, emotional involvement, and the ability to accurately assess risk-benefit ratios in the short, medium, and long term (NASEM, 2017). HL and EHL can play important roles in understanding risk and uncertainty related to health problems.

Following are three examples of the intersection of HL and uncertainty. The emergency nature of a pandemic is necessarily uncertain because the nature and severity of the illness is unknown, as are the probability with which adverse outcomes occur and the effectiveness of preventive actions. Communicating this uncertainty is essential for maximizing the confidence and empowerment of the population to accept those interventions that experts indicate to be most effective (NASEM, 2017). Communicating the uncertainty of science during public health crises is complex and if it is not well managed, the resulting ambiguities can damage public trust in the reliability, credibility, and adequacy of the information the public encounters, while confusion, disorientation, and vulnerability increase. These problems exploded during the Covid-19 pandemic when communication chaos imperiled prevention measures and medical treatment, illustrating that “a pandemic is a communication emergency as much as a medical crisis" (Duhigg, 2020). Thus, HL – even in the specific forms of digital HL and media literacy – can help people access and navigate reputable information. Interventions that increase HL, digital HL, and basic literacy can help users distinguish accurate content from inaccurate content and limit exposure to inaccurate messaging (Rapp and Salovich, 2018). Investigations into the role of HL in understanding uncertainty in a pandemic are still very scarce, but a 2018 study of 2700 subjects to whom a hypothetical pandemic scenario was described found that the individuals with low HL were less able to process uncertainty in health messages (Han 2018).

A second example testifies to the association between health literacy and uncertainty in the case of genetic predisposition. The evolution of diagnostic techniques has made possible the identification of genetic predispositions or susceptibilities to certain pathologies. Understanding the implications of the results of these tests is difficult for laypeople because the tests are complex and because the results a person receives can impact their emotions and their individual risk perception (Kaphingst et al., 2018). An individual’s level of health literacy can affect how they process genetic test results, and patients with low HL may require support to understand these results (Mason et al. 2017). Healthcare professionals who communicate information like this should be trained how to deliver it to subjects with low HL (Rowlands and Nutbeam, 2013).

Finally, uncertainty also plays a fundamental role in EHL and how environmental risks are perceived. Risk maps are a widely used tool for communicating environmental exposure and health risk. While studies of the role of HL and EHL in understanding environmental risk maps are rare, such studies indicate that individual HL and EHL levels are associated with the ability to understand risk maps and uncertainty associated with potential health impacts (Stieb et al., 2019). Risk maps, therefore, may provide a potential element for increasing individual and community EHL across all three EHL domains, including the relationship between environment and health, the decision-making competence to condition individual and community health, and the application of health protection knowledge to improve collective health (Gray, 2018).

4. An example of impact: cardiovascular disease

Cardiovascular disease is the leading cause of worldwide morbidity, more than cancer. However, recent analyses showed that cardiovascular disease is the leading cause of death in middle- and low-income countries, yet in high-income countries cancer causes twice as many deaths as cardiovascular disease (Dagenais et al., 2020). This proportion related to income is maintained except during the current pandemic era where Covid-19 is the main cause of death in the presence of a significant and abrupt reduction in cardiovascular diagnostic testing across the globe (Einstein et al., 2015).

Cardiovascular disease is one of the main comorbidities in anesthesia and intensive care. Of note, several days after major surgery myocardial infarction occurs in surgical patients without any kind of cardiac injury as well as in people at high risk of morbidity due to coronary artery disease. It is known that the onset of perioperative myocardial infarction may be related to several conventional risk factors (i.e., cigarette smoking, diabetes, hyperlipidemia, and hypertension) as well as perioperative withdrawal of cardiovascular pharmacotherapy (Lionetti et al., 2020). Recently, the exposure to climatic and environmental factors is emerging as new perioperative risk factor (Sarkar et al., 2020). This is a relevant original issue since heart diseases have implication for the more than 300 million people undergoing non-cardiac surgery worldwide every year. What climatic and environmental factors have the greatest impact on the perioperative period? New further investigations are needed, although the pathophysiology of perioperative myocardial infarction remains unclear despite the last 20 to 30 years of studies. To date, we know that a small proportion of nonmodifiable risk factors are due to aging and genetic alterations, but more than 70% of cardiovascular disease worldwide is caused by modifiable risk factors. Among the latter, the main ones are metabolic risk factors (i.e., a large waistline, a high triglyceride level, high fasting blood glucose), the second ones are other factors related to our lifestyle, such as tobacco use, hypertension, physical activity, social relationship, cognitive activities or psychosocial stress (Yusuf et al., 2020). The climatic and environmental factors are emerging as the third modifiable risk factors leading cardiovascular disease in the worldwide population, such as the global warming, heat events and air pollution (Nature Reviews Cardiology, 2021).

A recent study conducted among Chinese adults demonstrated that the long-term exposure to temperature variability from plus 5 to plus 15 degree Celsius increased the estimation of the risk of cardiovascular disease (Kang et al., 2021). Moreover, people less tolerant to this climate-disease relationship are older people (Giang et al., 2014). For cardiovascular disease, stroke and coronary artery disease, the percentage of lost disease-free years are progressively reducing below 16 years old. Although it is possible to identify a population that is much more at risk of cardiovascular diseases, the leading causes are not the same around the world (Yusuf et al., 2020). Recently, The Lancet published a study - the PURE study (Dehghan et al, 2017) - that showed as the proportion of cardiovascular disease cases and the cardiovascular mortality change in different countries like low-income, middle-income and high-income countries (Yusuf et al., 2020). Indeed, we cannot ignore that exposure to household air pollution is much more related to cardiovascular disease morbidity in a low-income rather than in high-income country: that's why we need global strategies to take a local and a tailored approach in each country. We should be much more focused on tailored regulation of primordial prevention in each country.

Air pollution means long-term exposure to particulate matter that have different dimension: 1) less than 0.1 micron, 2) equal or less than 2.5 micron and 3) equal or less to 10 micron. It is well known that the particular matter with the size less than or equal to 2.5 micron is the killer of our cardiovascular cells and the magnitude of injury is related to their concentration and exposure time (Liang et al., 2017). Interestingly, the low-income countries have a higher concentration as microgram per cubic meter (i.e. North Africa, Bangladesh, India, Pakistan, some area of China). This finding depends on the regulatory policy setting limits on certain air pollutants in each country. If you consider the threshold of the WHO targeting Particulate Matter (PM) 2.5, the limits are smaller in the US compared to the EU or India. Since the exposure to air pollutants over the threshold leads to higher risk of cardiovascular disease, the primordial prevention will require strict setting of threshold for PM 2.5 to prevent no communicable diseases (Peters and Schneider, 2021). Another evidence supporting environment/health relationship for the onset of cardiovascular diseases has been observed in China. As showed in a recent map of China, the brown and darker area means that population is exposed to higher concentration of PM 2.5, higher concentration of air pollutants, which corresponds to higher cardiovascular disease incidence and death (Liang et al., 2017). This original relationship further supports the occurrence of higher incidence of cardiovascular major events during the perioperative time in countries experienced worst air pollution. To date, we cannot ignore that air pollution may induce an effect - a dramatic effect - on perioperative care. Moreover, climate change is another relevant emerging risk factor of perioperative myocardial infarction and should be considered by anesthesiologists (Roa et al., 2020).

We know that the long-term exposure to different air pollutants induces an inflammatory response and oxidative burst affecting the heart as well as the brain through the immune-mediated dysfunction of the autonomic system and the release of mediators leading to inflammation, cell death or hypercoagulable state. In fact, the activation of coagulation factors trigger clots formation into the coronary microcirculation leading to myocardial ischemia (Rajagopalan et al., 2018).

Yet, what are the underlying mechanisms induced by particulate matters? Till now, scientists were focused on progressive oxidative-based cell injury leading to mitochondrial dysfunction and endothelial injury, which impair the myocardial perfusion up to the onset of diastolic and systolic dysfunction. In the last years, the better understanding of epigenetic mechanisms, which regulate gene expression without altering DNA sequence, suggested the hypothesis that chronic exposure to higher concentration of air pollutants may interfere with the epigenetic life of each of us even before our birth (Micheu et al., 2020). It is conceivable that exposure to high concentration of PM 2.5 during early embryonic and fetal development, and lactation, may induce the expression of genes associated with adult-onset heart disease susceptibility. Cardiovascular disease susceptibility may depend on the maternally provided environment (i.e. living and working place) and it can be transmitted up to the third generation. Therefore, we can assume that environmental health conditions human health, such as the healthiness of the place where you stay much more time during the day, similarly to intake of medications, drugs, junk food or alcohol, or the exposure to tobacco or asbestos.

Of course, it is a suggestive new medical hypothesis supported by growing scientific evidences. It is more than plausible that the exposure to a safe or unsafe environment can affect your health status and well-being. If you are exposed to safe environment you have much more opportunity to have a normal development during your pre-birth life, or you can have a healthy aging during your adult life by avoiding the susceptibility to metabolic diseases (i.e.: diabetes mellitus, obesity) or mental illness. Although the exposure to harmful environment can induce cardiovascular disease during your adult life, it is much more important the exposure time during your life in order to understand the pathophysiological impact of epigenetic modifications, which will be stably transmitted to subsequent generation when affect germinal cells or embryo (Aguilera et al., 2010).

Epigenetic mechanisms affect gene expression at transcriptional, post-transcriptional and post-translational level through chemical modifications (i.e.: de-/methylation, de-/acetylation, ubiquitylation, de-phopshorylation) or the expression of microRNAs, which are small single-stranded non-coding RNA molecules (containing about 22 nucleotides), acting on different area of the chromatin or in the cytosol to modulate mRNA expression and protein degradation (i.e., sumoylation, ubiquitylation, glycosylation) or activation (i.e., phosphorylation, acetylation). It is established that epigenetic signatures related to air pollution involve process of DNA methylation of some area of chromatin. Indeed, DNA methylation at levels of specific promoter may alter the expression of pro- or anti-inflammatory genes rather than pro- or anti-oxidant ones leading to subclinical vascular injury, such as atherosclerotic plaque, or cardiomyocyte apoptosis without evidence of symptoms up to the onset of myocardial infarction and severe heart failure (Suades et al., 2019).

An interesting experiment demonstrated that the exposure of endothelial cells to PM 2.5 at increasing concentrations progressively reduces their viability. It results like a bombing effect on the endothelium by particulate matters leading to myocardial infarction (Zou et al., 2021). Other study has also demonstrated a gene-mediated effect. In particular, the nuclear levels of specific transcriptional factors are increased following the exposure to PM 2.5 and it means that are activated. Interestingly, the activator signal is the interleukin-6 (Dai et al., 2016), the same pro-inflammatory cytokine rising in Covid-19 patients.

We can conclude that the cardiovascular tissue is altered following inhalation of particular matters in a time and dose dependent manner, as demonstrated in human beings and animal models (Kunovac et al., 2021). It is established that the long-term exposure to air pollutants may induces the death of cardiomyocytes (Yang et al., 2019). The loss of cardiomyocytes progressively decreases the cardiac contractility as you have less contractile cells and larger deposits of collagen until the onset cardiac remodeling and heart failure (Lionetti et al., 2014). The heart enlarges and develops thin walls that are not able to contract and relax properly and defects of myocardial repolarization even occur (Wold et al., 2012). The risk of lethal arrhythmias increases in population exposed to higher concentration of PM 2.5/PM 10, like atrial fibrillation and other disorders of myocardial repolarization (Zhang et al., 2021). Moreover, peripheral organs (i.e. brain, kidneys) are also affected by less blood perfusion due to decay of cardiac function. In order to define mechanisms, previous study already mapped genes up- or down-regulated by the exposure to air pollutants compared to people not exposed to same environment (Kunovac et al., 2021). For example, NFkB, an established transcriptional factor leading to the expression of interleukin 1b, interleukin 6, TNF- alpha, regulates the inflammatory response that extent increases during septic shock. Levels of angiotensin II increased as well as during a systemic inflammation, infection and during arterial hypertension. Conversely, other cardioprotective genes, such as antioxidant proteins, superoxide dismutase type one or VEGF type a, are significantly downregulated (Kunovac et al., 2021).

In order to understand underlying epigenetic mechanisms, a recent study has demonstrated that exposure of pregnant to high concentration of pollutants increased levels of DNA methylation in specific area of chromatin silencing some microRNAs involved in the angiogenic response and pro-survival pathways (Tsamou et al., 2018; Ferrari et al., 2019). Other epigenetic modifications are involved. For example, the acetylation of lysine 9 of histone H3 induced the expression of two relevant gene related to progenitor cells activity; while, the methylation of lysine 4 of histone H3 increased expression of STAT3, a pro-inflammatory transcriptional factor, and HIF1alpha, a transcriptional factor modulating the response to hypoxia. Therefore, we can assume that during our epigenetic life, when we are still in uterus, and our mom is exposed to air pollutants that enrich the air (i.e. particulate matter, nitric oxide donors or metals or CO_2) the expression of our genes is modified without changing DNA sequence (Breton et al., 2019). Air pollutants interfere with activity of different enzymes leading to several patterns of chromatin remodeling that induce the expression of “bad” genes or down regulate the expression of “good” genes. These modifications may underlie higher or lower susceptibility to different disorders like cardiovascular diseases.

We refer to transgenerational inheritance, where epigenetic modifications cause transgeneration inheritance of resistance or susceptibility to disease. For instance, someone inherits a predisposition to diseases that do not belong to the family following the chronic exposure to environmental pollutants. What are the perspectives? Recently, *Circulation,* one of the main lead journal of cardiovascular science, the official journal of the American Heart Association, published an interesting perspective article suggesting the need to expand the framework of environmental determinants of cardiovascular health from climate change to planetary health (Chang et al., 2021). It means much more regulatory policy and studies focused on impact of environmental risk factor and climate change on human health. Indeed, climate change cause different type of disasters, including global warming and heat waves, may increase risk of heart diseases in the presence of air pollution. Of note, older and fragil people are more vulnerable to this type of synergy exposure. Age is a critical determinant of the socio-economic status of population. However, healthy aging in a contaminated place may be unrelated to the salary, intake of good food, co-medications or quality of healthcare system, which might be not enough to defend frail population from climate and environmental changes. Indeed, elderly people with comorbidities are less tolerant to risk factors of cardiovascular diseases compared to others.

Everyone are exposed everywhere to climate and environmental synergy. Of course, people living in poverty, women and children and elderly, outdoor workers, patients with chronic diseases are the most vulnerable to effects of long exposure to climate and environmental factors. In order to counteract the climate change and air pollution synergy, we should promote program of translational multidisciplinary research and education in faculty of medicine, and new regulatory policy in order to design more effective primordial and primary prevention.

5. Conclusions

Planetary health is an increasingly vast field of study, which attracts increasingly varied and complex contributions. This complexity has been illustrated in the paper in question, which does not pretend to be exhaustive, but which aims to provide some keys to understanding the new concept of planetary health.

In the future, it will be increasingly important to understand how environmental sciences, medical sciences, social sciences and other fields of knowledge must work together to solve the challenges we now, as mankind, are called to face. This is because ecological challenges and climate change pose multidimensional questions, both in space and in time, which risk condemning generations that have not been the cause of the problems present today. Interdisciplinarity will be a key point to complete this path, as academics and as human beings.

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