FOREWORD

Philippe Kourilsky
Professor Emeritus at the Collège de France, Honorary Director General of the Pasteur Institute,
Member of the Veolia Institute Foresight Committee

Health and the environment: what has changed in twenty years?

It has now been 20 years since the Veolia Institute and Pasteur Institute first co-organized an international conference on Education, Environment and Health. At the time I felt that the extremely broad theme was hard to delineate and complicated to conceptualize. The molecular biologist I was then struggled to link it to scientifically defined content. A strong emphasis was put on education. The meeting's conclusions remain of great interest and I would encourage everyone to read them.[1] The wide-ranging contents presented in this issue of FACTS illustrate the considerable progress achieved over the past two decades. How can this progress best be described? Where can we imagine it will lead us? Although they necessarily only offer some pieces of the puzzle and are fairly personal, the observations that follow may assist readers in forming their own opinions.

> *"The environment is as much physical as biological, yet the two are inextricably intertwined in the soil, the oceans, and the atmosphere."*

Both terms of the equation – environment and health – have evolved, with a partly common background. The enormous growth in life sciences, characterized by the massive acquisition of relevant data.

Super-fast genome sequencing[2] has changed molecular genetics, a discipline born in the 1980s, out of all proportion. Scientific viewpoints have shifted as a consequence, from the reductionist approaches of molecular biology's early days to an approach that is far more systemic. Other technologies, such as imaging, have also contributed to revolutionizing biology, a science now characterized by its increasing mastery of complexity.[3] Considerable progress has been achieved in our understanding of all the biological systems that make up human beings: the nervous system, immune system, endocrinal system, and so on. The same applies to studies of human pathologies. Simply put, medicine has become more scientific and, as a result, more personalized too. With artificial intelligence used to help analyze, model and exploit this ever-growing mass of data, medicine will undergo further profound changes that we are only just starting to glimpse.

It is not only humankind that has been impacted by this whirlwind of new knowledge. In the 20th century, our knowledge of the environment was constructed on the basis of a handful of model organisms such as beer yeasts, the *E. Coli* bacteria, *C. elegans* worm, *Drosophila* fly, *Arabidopsis* herbaceous plant, and the mouse. Today, our knowledge has expanded to include a wide range of organisms, particularly from the plant world. Not to mention research on fossils and the insights it offers into how species have evolved. Lastly, we are also now delving far deeper into the study of ecosystems that are composed of a great many different organisms.

The environment is as much physical as biological, yet the two are inextricably intertwined in the soil, the oceans, and the atmosphere. A single gram of soil contains close to one billion bacteria, and a milliliter of seawater contains ten million viruses.[4] As for the atmosphere, depending on the location and human activity, it contains thousands or millions of particles that we breathe in and that can carry microorganisms. And let us not forget the now infamous CO_2, produced and absorbed by living organisms as well as being generated by human pollution.

1 The conference program and summary are available here: https://www.institut.veolia.org/en/our-events/international-conferences/education-environment-and-health.

2 The genomes of several tens of millions of people and over 5,000 different species have been fully sequenced, and many more have been partially sequenced. DNA data extracted from fossils, although only partial, is essential to analyzing how species have evolved.

3 Kourilsky, P. (2023). *Mes années Pasteur* [*My Pasteur Years*], Odile Jacob.

4 These viruses essentially regulate plankton growth and are harmless to humans.

As a result, the impact on health of air, water and soil quality is increasingly understood. This deeper understanding of the environment opens the door to innovative new areas for research, such as how to anticipate the emergence of harmful infectious agents using *in silico*[5] models combined with studies of the cascade of characteristics at the origin of potential epidemics.

Human beings are closely linked to the environment through their metabolism. A human's intestinal microbiota contains 50,000 billion bacteria divided into several thousand separate species. Although sometimes the subject of excessive media attention, this should in no way mask its importance: the intestinal microbiota is a major metabolic "organ" that mediates between humans and their environment. The other microbiomes (lungs, skin, and mucous membranes) are also invaluable mediators whose roles we are beginning to appreciate. They all play their part in a range of different pathologies.

"I am convinced that the most serious consequences of the current environmental crisis, particularly those resulting from climate warming, will be social. There will be colossal direct and indirect repercussions on human health."

Humans are doubly social beings. On the one hand, we do of course live in societies. And on the other hand, the development of the brain, particularly in childhood, depends on what we perceive and receive from our environment. Certain human characteristics are innate, such as the ability of newborns to count to two or three. Many others, however, are acquired. The ways in which this remarkable organ is formed are as complex as they are multiple. The immediate social environment, as provided by family and educators, is critically important. We can, however, legitimately question the impact of more global environmental changes, whether social or even climate-related.

One example would be the impacts on mental health of wars in Vietnam, Korea, Iraq, Algeria, and, today, Russia's invasion of Ukraine: assessments of their severity are continuously being revised upward. This is all the more important since certain behavioral traits can be transmitted across one or two generations via mechanisms, sometimes called epigenetic,[6] that are still not well understood. From this perspective, the Covid-19 pandemic and the various lockdowns imposed as a result offer an interesting area for study. And how will climate refugees be affected?

It may be argued that the social environment I refer to has little in common with the "real" environment which is rightly the object of such concern to ecologists of all persuasions. But are we really so sure? Stress in all its forms is potentially harmful to human health, as many studies of cancers have shown. It is important to understand how it becomes "imprinted" on the organism via the brain or the microbiome, both of which are connected to the immune system and the other systems that organisms use for regulation and defense. Similarly, the environmental stresses impacting ecosystems point to problems of robustness and resilience that are conceptually relatively similar to those that can affect humans.

Returning to a more conventional ecological vision of the environment, we have undoubtedly witnessed a major change over the past two decades with the worsening of the environmental crisis we now face.

This manifests in four interconnected ways: climate warming, exhaustion of vital natural resources, pollution of every type, and a reduction in biological diversity. All of these can (and will) impact human health as well as that of other physical-biological and social ecosystems. Faced with these challenges, the problems to address will not be simply scientific and technical, they will be ethical too. The environmental crisis is already exacerbating inequalities we have spent decades trying to reduce. Poverty was falling but is now on the rise again.

I am convinced that the most serious consequences of the current environmental crisis, particularly those resulting from climate warming, will be social. There will be colossal direct and indirect repercussions on human health. This is why I argue strenuously for a broader vision of the links between environment and health.

I believe, now more than ever, that ecology must be a moral science.[7]

5 Theoretical research methods, particularly involving computer models, used to predict the likely toxicological, or other, effects of substances (European Food Safety Authority).

6 The study of heritable changes in gene function that do not involve changes in DNA sequence (Merriam-Webster).

7 Kourilsky, P. (2023). *Innovation for Ecological Transformation.* Veolia Institute. https://www.institut.veolia.org/sites/g/files/dvc2551/files/document/2023/11/Veolia_FACTS_25_2023_GB_Web_Interactif_V3%20%281%29.pdf.