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ORIGINAL

Biogeomedicine: The earth as the new patient for biomedical sciences under the "one health" concept facing climate change

Biogeomedicina: La tierra como el nuevo paciente para las ciencias biomédicas bajo el concepto "una salud" ante el cambio climático

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Abstract

Introduction: Climate change (CC) is an underrated issue for health sciences. But, CC -the worst current ecotoxicological phenomenon- is the main threat to Public Health and the majority of living populations taking into account similar earlier events in Earth's history. So far the leadership for controlling CC has been primarily focused on politics (geopolitical agreements) and Geoengineering. However, this complex problem calls for deeper analysis of *health and life sciences*.
Objectives and methods: The involvement and action of the foregoing sciences mediated by transdisciplinary integration is a deontological duty. Moreover, attention is needed when observing the present refractory amplification of CC. Thus, Documentary Systemic Review combined with *Cross-cutting transdisciplinary* interpretation is the chosen methodology. Identification of integrative triad models for epistemological explanation and exemplification is also used.
Results: Faced with the present disassembled state of disciplines in CC that are trying to regroup facing new complex studies, a new paradigm between life and health sciences is proposed. Based on ecotoxicology and epidemiology's triads and other recent combined fields in *life, health and Earth's sciences*, Biogeomedicine results as such a transdisciplinary perspective.
Conclusions: Transdisciplinary and qualitative investigation on the subject bring back the very essence of the *Ars medica*. Widening the approach to the problem leads to the identification of a missing field for studying CC's therapeutic neutralization. Biogeomedicine can be built relying on the *"One Health"* concept from mixed biomedical perspectives, basic and applied sciences and geosciences. Inferring qualitative approach strategies, either from medical humanities (micro and macrocosms analogies) or Von Bertalanffy's theoretical biology would lead to a better, more complete understanding of the problem and how to control it.

Keywords: Climate Change, Ecotoxicology, Biogeomedicine, Medical Geology, Transdisciplinary research

Resumen

Introducción: El Cambio Climático (CC) ha sido un problema infravalorado para las ciencias de la salud. Pese a ello, el CC -también el peor de los problemas ecotoxicológicos actuales- es la mayor amenaza para la Salud Pública y la mayoría de las poblaciones vivas teniendo en cuenta antecedentes similares en la historia terrestre. Hasta ahora el liderazgo para tratar el CC ha recaído en los campos de la política (a través de firma de acuerdos geopolíticos) y la Geoingeniería. Sin embargo, este complejo problema clama por mayor análisis desde las ciencias de la salud y la vida.
Objetivos y métodos: El involucramiento y acción de estas ciencias, mediadas bajo integración transdisciplinaria, es una obligación al observar la refractaria amplificación que se ha notado recientemente del fenómeno. Revisión documental sistémica combinada con *interpretación transversal transdisciplinar* es el método seleccionado. Identificación de *triadas modelares* es utilizada para ejemplificar y explicar el análisis epistemológico.
Resultados: Se observa que en las últimas décadas varios campos científicos se están reagrupando otra vez de cara a estudios complejos. Basados en el ejemplo integrativo de las triadas de la epidemiología y la ecotoxicología en la lectura de la realidad, aparece la Biogeomedicina como la perspectiva transdisciplinar buscada.
Conclusiones: La investigación transdisciplinaria y cualitativa regresa la esencia del *Ars medica*. Ampliar la aproximación disciplinaria del problema lleva a descubrir el campo faltante para estudiar la neutralización del CC desde una óptica terapéutica. La Biogeomedicina puede construirse al fundamentarse en el concepto *"Una Salud"* desde perspectivas biomédicas, ciencias básicas y aplicadas, y geociencias. Inferir estrategias cualitativas de aproximación bien desde las humanidades médicas (Micro y macrocosmos análogos) o de la biología teórica de Von Bertalanffy, basada en la integración de sistemas, puede arrojar un mejor y más completo entendimiento del problema y su control.

Palabras clave: Cambio climático, Biogeomedicina, Ecotoxicología, Medical geology, Investigación Transdisciplinaria

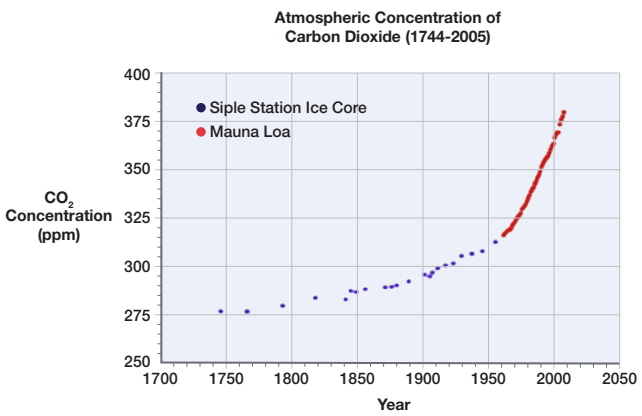
Introduction

On one hand, Climate Change (CC) means not only *the biggest threat for Public Health in the XXI century*[1], but also the main risk of foreseeable mass extinction. Many biological populations, including different taxonomic kingdoms, species and systemic habitats (*i.e.* terrestrial and marine ecosystems; rural, wild and urban habitats) are vulnerable to drastic changes in weather[2, 3, 4].

At the same time, it is evident that the globalized society has relied, since 1992, on ***Geopolitical agreements and Geoengineering*** to face refractory CC[5]. Meteorological tendencies, however, continue to worsen. Notwithstanding, the great damage as well as the particular mechanisms and impacts of this complex problem belongs to the realms of ***Earth, life and health sciences***. For instance, if global warming exceeds 3°Celsius (C) over the 21st century, it could eliminate many species on the planet (approximately 60%) due to physical-chemical effects of unbalanced gas dynamics in the atmosphere[6]: That would mean the loss of planetary homeostasis and diverse populations.

When establishing Paleo-bioclimatology comparisons for equivalent past imbalances, the *"Big five"* Earth's mass extinctions (involving the loss of 50-90% of species each time) were accompanied by global temperature changes of at least 5°C[7]. Likewise, those depletions in living populations were preceded by a set of changes to environmental conditions, which resembles today's current tendencies[8]: *multiple-simultaneous disintegrative events, atypicalhigh-intensity milieu stressors, unusual climate change and highly elevated atmospheric* CO_2 (**Figure 1**). From a transdisciplinary viewpoint it means an increasing event of *entropyat* the Physical chemistry level, which is produced within the troposphere's Geochemistry byadding complex *positive feed-back* mechanisms inside the biogeochemical cycles, and therefore, the Earth's macro-system.

Figure 1: CO_2 Global Atmospheric Concentration according to Mauna Loa and Siple Station Ice Core Data. Source: National Oceanic and Atmospheric Administration.



On the other hand, *transdisciplinary research* (TR) combines information from different fields, aimed at finding solutions for complex *life-world* problems, including scientific perception, objective and subjective data and theoretical analysis. This process of narrowing down key-components and widening epistemological perspectives for problems, contrasting scientific information helps us to readjust previous interpretations. In addition, it reframes knowledge theory and results in integrative solutions because it allows the combined use of experimental and social science[9, 10].

Consequently, Health law and TR are natural allies considering their methodologies. Moreover, the latter develops descriptive, normative and practice-oriented knowledge in order to help solve, mitigate or prevent life-world problems identifying complex structures[10].

Applying transdisciplinary analogies may match previously unnoticed relationships and compatible categories between different epistemological fields. For example, under the so-called phenomenon of *"extinction"* –in biological and geological terminology–, devastating episodes of *morbidity and mortality rates* can be seen from a Public Health perspective. The foregoing reveals CCs importance for contemporary health impact studies focused on the analytical category known as *"populations"*. The need for these types of connections and systemic analogies for developing a complex *health-system of thought* towards CC, is urgent to dismantle mechanisms that have worsened lately. Medical deontology, trained professional thought and therapeutic knowledge should be integrated and aimed to stabilize unbalanced organic systems to benefit its different-level components (*cells repertoires, tissues, organs, apparatus, individuals, symbiotic groups, ecosystems, etc.*). That is compatible especially with the deontological responsibility, learned rational reasoning and inherent skills of health workers.

Material and methods

This work was carried out from exhaustive comparative *Documentary Review* material. Methodologies of *Qualitative-Transdisciplinary Research*[9] were applied in order to extend and deepen knowledge on Climate Change (CC) for biomedical understanding. To contrast current approaches to and perceptions of CC, relevant *background* and *state of the art* from different disciplines were observed from multidisciplinary academic literature. Following the standards of the *Handbook of Transdisciplinary Research* byusing *Cross-cutting interpretation*[9, 10] was the methodological approach developed to detect the similarities between epistemological, cultural, terrestrial and organic systems. The analysis was oriented to signal *milestone articulating elements* for the different fields through theoretical triad composition. Policy-relevant suggestions to identify common normative critical

points for health, life and Earth sciences' professional intervention were highlighted.

Results

First triad: the shared fundamentals for medicine, geology and ecology

Remarkably, Hippocrates is strongly clear when initiating the treatise *"On air, waters and places"* in his *Corpus Hippocraticum*. There,he develops his *Ars medica* with a surprisingly detailed deontological instruction based onunderstanding of nature, especially valuable at present when dealing with Climate Change:

"Whoever wishes to investigate medicine properly, should proceed thus: in the first place to consider the ***seasons of the year****, and what effects each of them produces (for they are not at all alike, but differ much from themselves in regard to their changes). Then the* ***winds****, the* ***hot and the cold****, especially* ***such as are common to all countries****, and then such as are* ***peculiar to each locality*** *(…) From these things he must proceed to investigate everything else"*

Hippocrates, accordingly, conceived hygiene as an amplified concept: *"an influence of atmosphere, soil, and water on human health"*, commenting that *"every disease has its own nature and arises from external causes"*. The principle upon which the deontological labor of medicine relies is a natural triad (understood conforming to the Merriam-Webster dictionary as *"a group of three closely related compounds or elements"*). In this case: *Air, water and soil* (**Figure 2**).

By widening the comprehension of health problems, Hippocrates gave more importance to the expected outcome (*prognosis*) of the organic disequilibrium rather than its identification (*diagnosis*)[11]. However, in this translation from the planetary *Phýsis system* to the so-called organic *MikroPhýsis* of the human body's system[12], it is possible to identify the first triad template for *Biogeomedical* considerations.

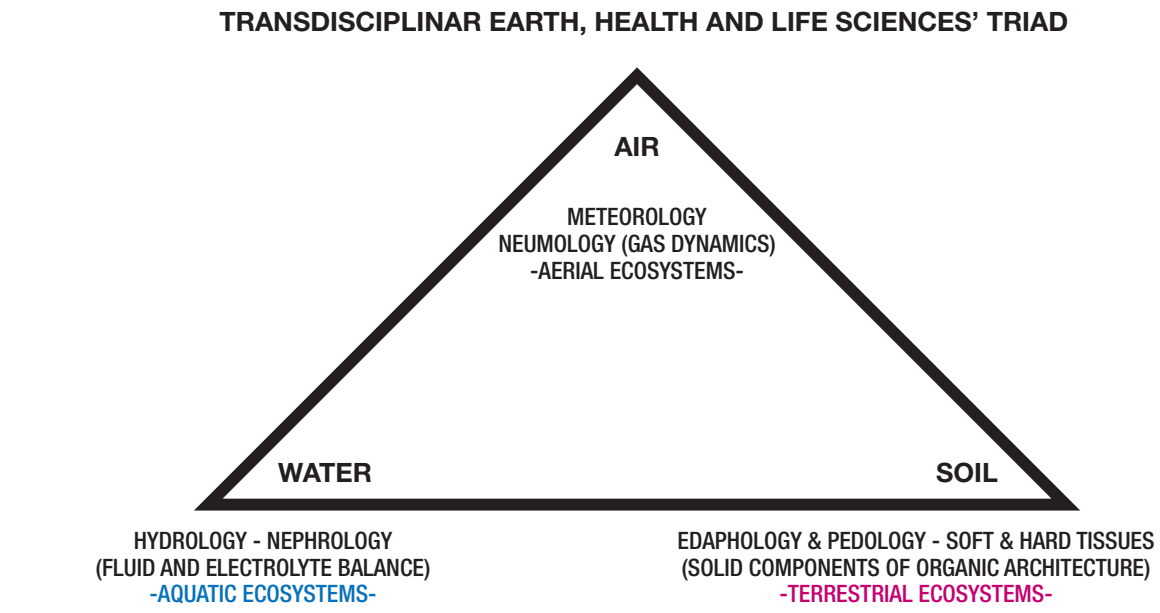
For each of the 3 elementsconsidered since Hippocratic medicine started, there is an equivalent system, which interact on an *individual*, *ecological and planetary level* with each other. The bottom line of this synthetic idea for medicine was: *systemic equilibrium preserves health*[13]. Meanwhile, systemic imbalance,either by excess or deficiency, can lead to illness and death. CC shows, for instance, that a gas imbalance produces land and aquatic impact[1, 25].

Second triad: population becomes *a new patient* for medicine

In Health sciences a second transdisciplinary precedent was Public Health itself.This new paradigm was a mixture of sciences, skills and convictions that were focused on the preservation and improvement of the health of populations through preventive (rather than curative) measures[14].

Public Health was one of the first examples of modern interacting disciplines based on transdisciplinary approaches: *social and political sciences went into dialogue with medicine.The reason?* Back then, there was another body that was demanding health care in times of multiple epidemicsin human and animal medicine: *the social body*. This concept included *population* for *Health analyses*. The word epidemiology comes from the Greek words *epi-*, meaning *"on or upon"*, *demos*, meaning *"people"*, and logos, meaning *"the study of"*[demi]. Population -as intellectual concern- was the center not only of *Public Health*, but also is the core forcurrent complex knowledge fields such as *Political Economy* and *Biopolitics*[15].

Figure 2: Elementary common system triad of elements for *Earth, health and life sciences*



Respectively, epidemiology is considered a basic science of Public Health[16]. Epidemiology, being the study of the distribution and determinants of health-related states in populations, and the application of this study to the control of health problems, identified another triad: *The epidemiological triad* observed mutual action-reactions, constant co-factors for illnesses, and cause-effect mechanisms through *three main interacting disease elements* and often, a vehicle of infection (vector) that is commonly a biological population as well (**Figure 3**).

It is noteworthy that the modulatory element for the interconnecting triad –that is also the key element for *Climate change*–, is the *environment*. This goes in agreement with the U.S' *Centers for Disease Control and Prevention* (CDC), so Hippocratic observations were proved correct.

Third triad: environment as subject of biomedical intervention

CC is a relatively recent problem. Scientific consensus estimates CC started around the middle of the XVIII century. Less than 250 years determine the period of atmospheric disturbance as stated in different fields of science that has caused ecosystem, atmospheric and thus climatic imbalance threatening Health.Among gases, *gas pollutants became* a menace. Environmental toxicology had changed to Ecotoxicology under the pressure of solving major related problems (Chernobyl, Agro-chemicals as endocrine disruptors, Fukushima, lixiviates contamination, Climate change, etc.)[17].

Discussion

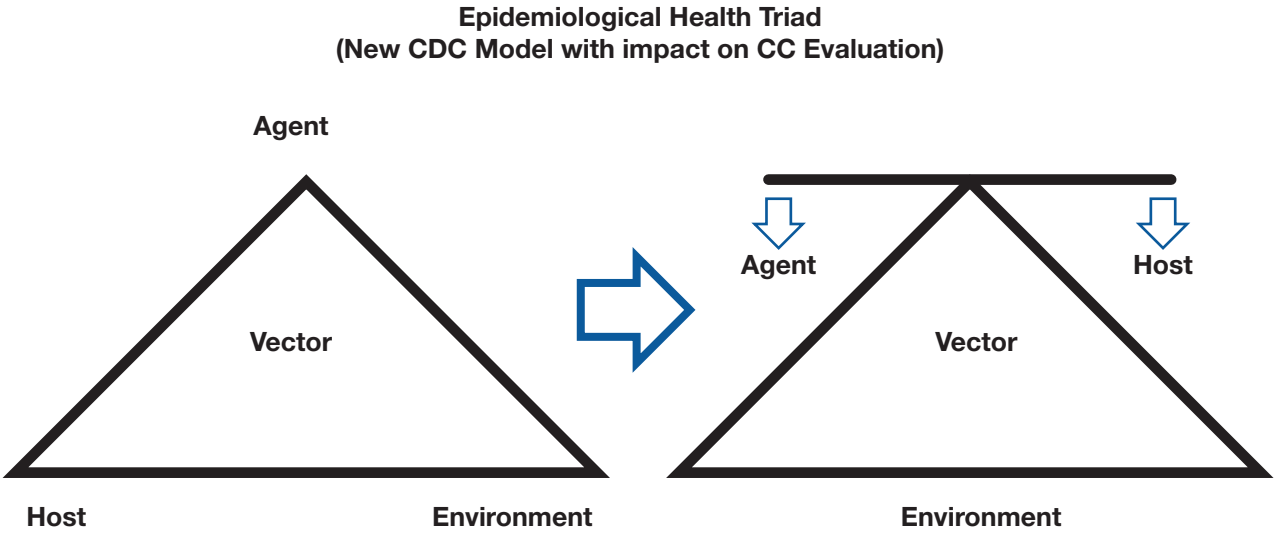
Causes for CC initiation were the following civilization changes that are culturallystill occurring: 1) the *Industrial Revolution*, 2) *Urbanization (hardening)* of natural lands, recruitingat the same time the main part of the human populations in cities, from where nature (another species analogue tocell repertoires) is expelled inducing *Biotic homogenization*, 3) Abandonment of previous *(Naturalistic-Classical) ethics* which arereplaced by a utilitarian/hedonistic/materialistic system of customs, then globalized [17, 18, 19, 20, 22, 24].

Ecosystem Imbalance means Health Impact

If there is an Eco-ethics sense,ithas gradually been lost since most of theurbanizedhuman populationhas ceasedreal contact with nature. Moving to cities with specialized knowledge, having limited perceptions andartificial habitats hascreated virtual-delusional environments. In contrast, the real (objective) *Life-world* in transdisciplinary studies[9, 18] continues to depend on the same *materialistic* mechanisms of its necessary physical-biological functioning.

When articulating different fields' readings it is possible to comprehend that the denominated *climate change* for Earth sciences terminology, is the sameair *pollution* phenomena in medical terms. Its health impact, therefore, could have been underrated so far, and is only understandable by means of the *"One Health"* concept. According to this approach, human, animal, plant, and environmental health work as one integrated larger system. As a case in point, *pollution hasat least two subtle mechanisms of affecting systemic health* following recent French studies: 1) the *Direct health impact* is severe in line with sanitary authorities. For instance, *Air pollution* kills 48,000 people a year in France and 34,000 of these deaths are avoidable. Pollution caused by human activity such as transport, industry, heating and agriculture, causes nine (9%) percent of the French annual death toll[19]. 2) *Also the Indirect mechanisms* are notorious and can be exemplified with *the health related costs* of air

Figure 3: Epidemiological Health Triad from its Conventional to its New CDC model.
Source: Based on *CDC's Principles of Epidemiology in Public Health Practice*, An Introduction to Applied Epidemiology and Biostatistics, Third Edition



pollution (medical treatments, premature death, absenteeism, etc.). Itsannual cost, for 2015, ranged *"between 68€ and 96€ billion"*. It means less budget for basic health funding, access to therapy and medication, financial support for health research, etc. Moreover, for increasing catastrophic phenomenon such as CC, the risk of institutional collapse and social conflicts (hunger, water scarcity, displacements, conflictsand wars) raise in parallel up to become a governmental problem with these types of *system crises*. Simultaneous ecosystem affectation, evident through the *non-health related costs* (decline in agricultural yield [and ecosystem services], degradation of buildings, preventative expenditure, national productivity, etc.) was calculated around 4.3€ billion/year just for France. Taking into account the magnitude of the CC pollution case related to health problems in France: the transport sector aloneproduces 59% of the country's *nitrogen oxide* (this means just 1 out of the 6 main greenhouse gases for CC) and up to 19% of its *fine particle emissions*[20].

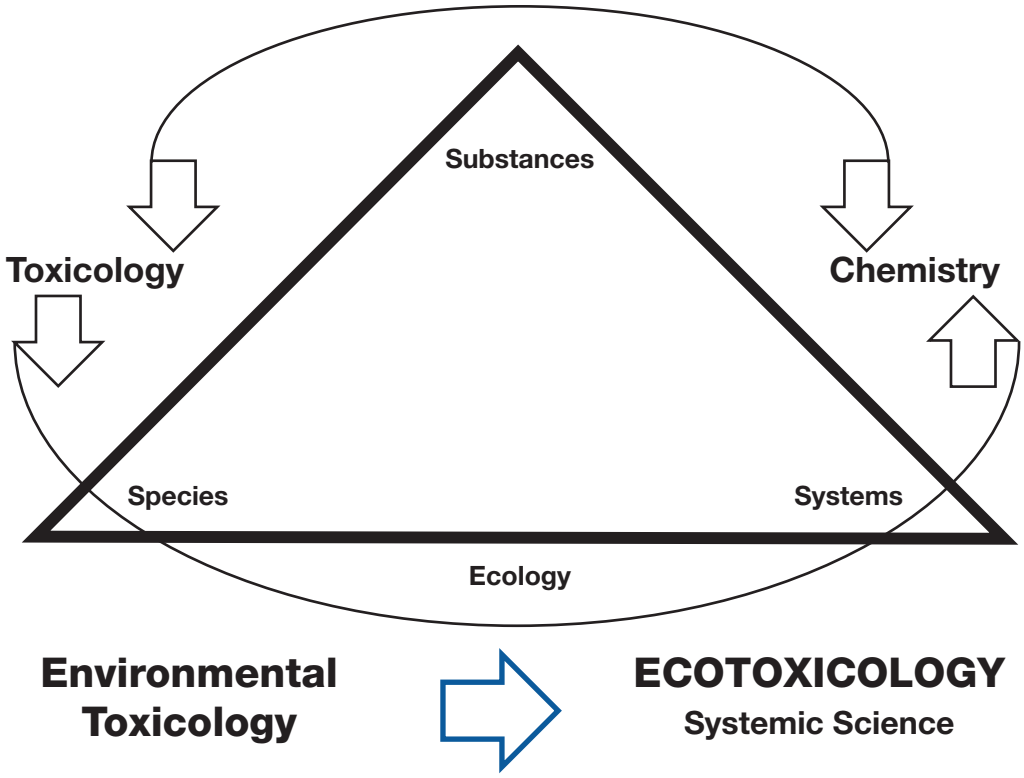
Previously mentioned cultural customs, however, keep changing the ecosystems worldwide. Because of the efficiently built machinery, the surface of the Earth's macro-system has been transformed very rapidly. The mass deaths of other species-populations imply induced deterioration in the functioning of their local ecosystems (*e.g.* mass release of methane and CO_2). Forests have been cut down. Pollutantsincreasingly deteriorate-normal gas proportions and their dynamics in the atmosphere. Smoke from productive labour, transportation, and industrial processes keep accumulating and have not efficiently been buffered. Residues and industrial by-products of new livelihoods and food-types have created continuous sources for diseases, etc[19, 20, 21, 22].

From a macro-systemic view, multi-functional injuries in organic systems are exceeding the harmful/indifferentactivities of the potential healing repertories: human populations. An ecoethical change is still pending and has to be oriented by biological –not ideological– rules.

Curiously, since the second half of the XXth century humanity has witnessed how several fields and disciplines have started to *re-join* to answer phenomena of a destabilized world. Most of the developments in that sense, such as *Ecotoxicology* –for which the newreceptor of diagnostic efforts is the altered environment–, have happened symptomatically in the most recent decades.

Ecotoxicology breaks down strict disciplinary boundaries since the 70's[23] (**Figure 4**).

Figure 4: Construction of Ecotoxicology as paradigmatic example of transdisciplinary fields associated with co-relative compound disciplines (Graphic made by authors)



Biogeomedicine: The earth as the newpatient for biomedical sciences

Amongst the cascade of these lately developed fields, it is possible to recognize the composing units for a transdisciplinary task, hereby we propose: *Biogeomedicine* (**Table I**), which seems tobe the integrative novel field for biomedical interpretation that may confer systemic understanding and applications for the *"One Health"* concept. Reinterpretation notesbiological populations are similar to cell repertoires, thus, they are able to procure recovery of the system they belong to.

The compatible framework *"One health - One medicine"* was officially started by the President of The *American Veterinary Association (AVMA)* Roger Mahr DVM and epidemiologist Laura Kahn MD, together with the president of the *American Medical Association (AMA)* Ronald M. Davis. In 2007, the transdisciplinary AVMA and AMA Resolution 530 (A07) was also signed by the American College of Preventive Medicine, the American College of Occupational and Environmental Health, the American Association of Public Health Physicians and the Academy of Pharmaceutical Physicians and Investigators. In doing so they collaborated to improve *the health of all species*. This institutional objective is much more practical when understanding the interaction of different species and contributing habitats as *related-integrating-subsets of the functional planetary macro-system*.

The articulation of AMA-AVMA reached the international institutions. In 2010 the *World Health Organization (WHO)*, *World Organization for Animal Health* –former Organization International des Epizooties *(OIE)*– and the *World Bankjoined* efforts; which has resulted in multidisciplinary (still not intentionally transdisciplinary) contribution all around the world for the sake of health[19].

Conclusion

This open-minded structural change has derived, as other paradigmatic changes, from a self-critique of *deontological practical reason for health sciences*. It has happened just in time to, holistically, face the turmoil of Climate Change described as *"The biggest global-health threat of the 21st century"* as reported by *The UCL-Lancet Commission*[1, 25]. If *"One Health"* means the adequatenew framework to approachcomplex health problems such as CCunder transdisciplinary methodologies, *Biogeomedicine* would fulfil its development and contents.

Table I: Transdisciplinary fields and some fields' initiators for biogeomedicine building

1. Medicine (Hippocrates, 460-370)
2. Philosophy (Socrates, 470-399 BC)
3. Political science & Epistemology (Plato, 427-347 BC)
4. Logic, Meteorology & Veterinary Medicine (Aristotle, 384-322 BC)
5. Botany (Theophrastus, 371-287 BC)
6. Toxicology (Orfila i Rotger, 1813)
7. Geochemistry (Schönbein, 1838)
8. Environmental and Health Law (1858-1956)
9. Soil science-Plant physiology-Phytopathology (Strasburger, 1894)
10. Land Ethics (Leopold, 1948) / Neuroethics (Pontious, 1973)
11. Paleo-bioclimatology (Zagwijn, 1957)
12. Bioethics (Jahr, 1927; Potter & Hellegers, 1970)
13. Medical Humanities (Laín Entralgo, 1973)
14. Medical Geology (Bunnell, 2004; Selinus, 2005)
15. Ecoethics (Sosa, 1996; García Gómez-Heras, 1997; Capó, 2007)
16. Geomedicine (Steines, 2009)
17. Veterinary Geology (Myburgh & Gupta, 2012)
18. Astro-physics& Physical Chemistry
19. Bio-chemistry& Bio-Physics
20. Geo-botany & Phyto-geography
21. Public Health / Demography / Biopolitics
22. Epidemiology/Eco-epidemiology
23. Ecology
24. Micro-biology& Industrial microbiology
25. Medical & Health Geography

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