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STEM ENVIRONMENTAL EDUCATION:

A TRAINING COURSE FOR THE

SEB CENTENARY 2023

by Marina B.A. Minoli *

The project that forms the plot of the following contribution won the Centenary Award - awarded by the International Society for Experimental Biology (SEB - Lancaster University, UK). A scientific training path, conceived and created by the author, which has environmental education as its perspective, but documents how biosciences must refer to the historical and experimental dimensions for conceptual and cultural acquisition adequate to the complexity of the environmental reality.

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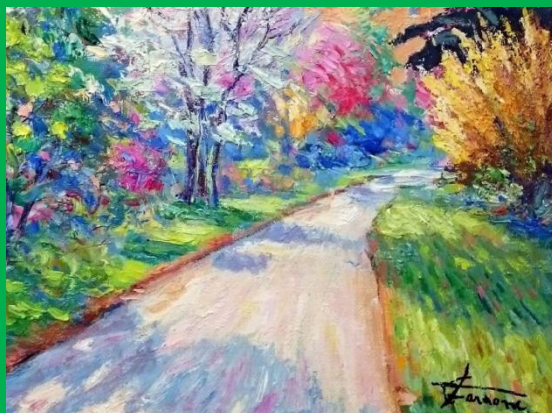
INTRODUCTION

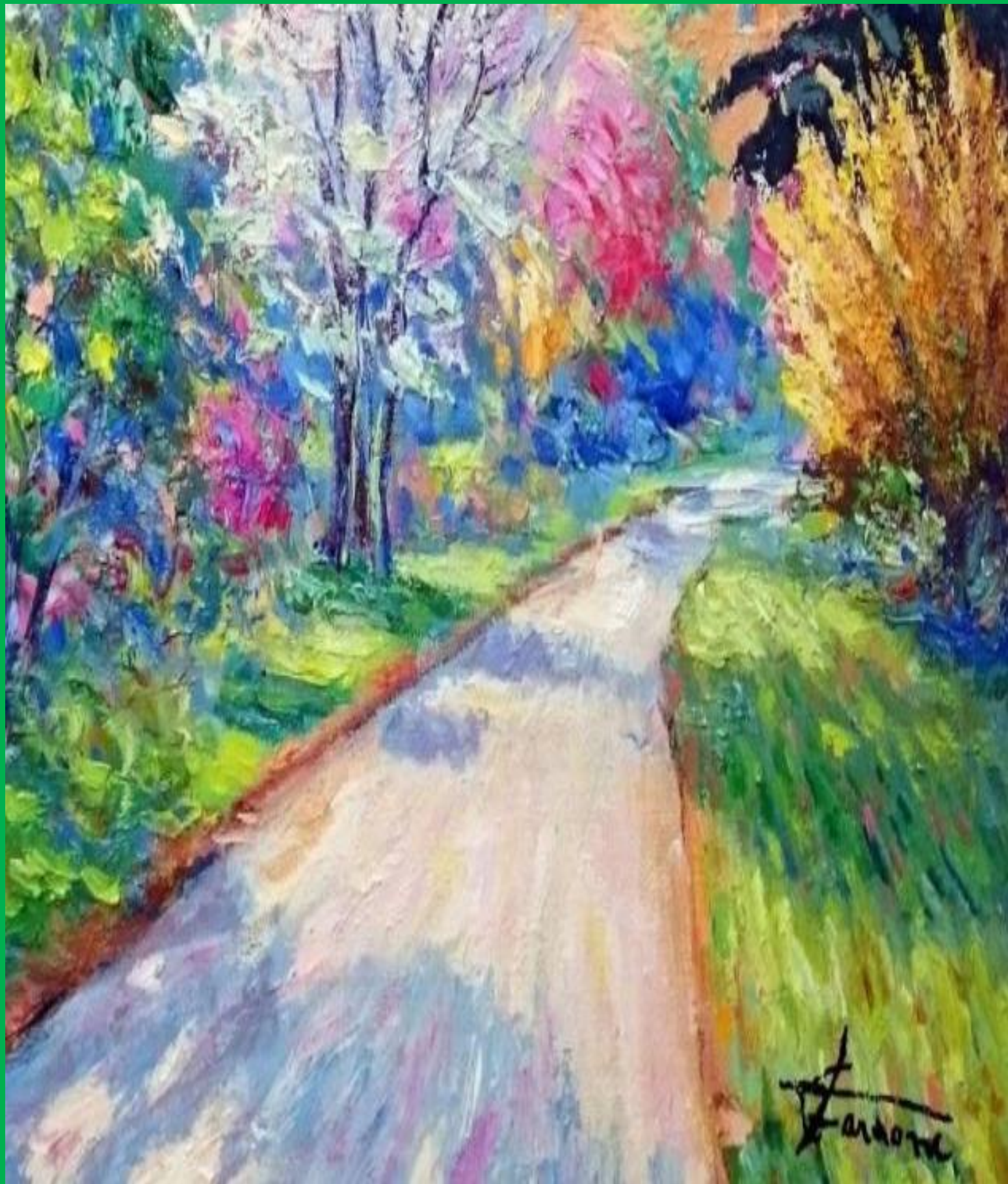
In the spring of 2023 - the year of the centenary of the foundation (1923.2023) of the prestigious International Society for Experimental Biology -



I created a STEM environmental educational itinerary and I led two days of virtual meetings with different thematic webinars also with two invited speakers, I was furthermore speaker in the talks of a cultural path which I illustrate in essential points in this contribution.

The general theme emerges from the title: "From Elements of Historical and STEM Experimental Bioscience to modern Environmental Education", but the reports outlined and exemplified the many complex problems linked to the methodologies with which the environment is studied and the EE. The main aim was to arouse interest and passion for Biosciences by referring to natural history and modern experimental sciences as part of an innovative conception of Environmental Education which implies interconnections and contaminations between different disciplines and in particular promotes critical thinking in the analysis of some cultural aspects of the topic. In fact, the fundamental concern of all the meetings was to encourage reflection in order to be able to distinguish what is perceived as truth, which is therefore thought to be true (BIAS) but in reality is a distortion of reality, from real knowledge which instead derives from acquired facts, accurate observations evaluated over time, fundamental for activating environmental citizen literacy based on interdisciplinary learning.





Beyond the culture of images to educate critical thinking Environmental issues are an excellent opportunity for individual and collective maturation, for cultural awareness not to follow the fashions of the moment, beyond homogenized banalizations and widespread spectacularisations, but to activate a motivated involvement in reasoned multidisciplinary paths. A broad perspective allows us to integrate information and approaches from the history of science (scientists who were pioneers in understanding environmental changes in the history of the Earth and precursors of innovative multidisciplinary study approaches) with data from modern interdisciplinary experimental research, considering the fundamental principle of balance as the guiding element.

BIOSCIENCE STEM ENVIRONMENTAL EDUCATION

- BIOSCIENCE – Between Natural History and Experimental Researches
- STEM ENVIRONMENTAL
- EDUCATION: TASTE OF DISCOVERY WITH DEEP KNOWLEDGE

CRITICAL THINKING

CRITICAL THINKING SKILLS

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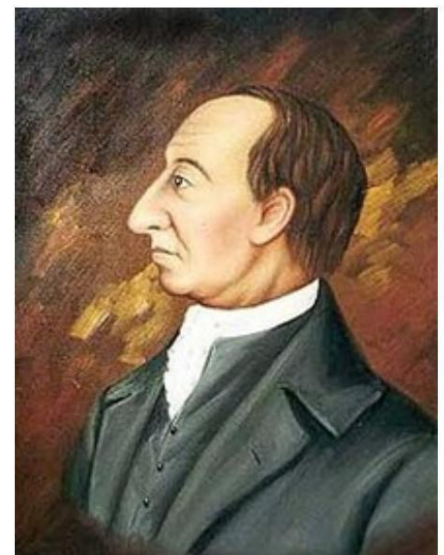
One of the objectives of the initiative that I conceived and implemented was to overcome some interpretative superficialities in Environmental Education to involve activating cultural contamination between humanistic and scientific disciplines, promoting in participants the awareness of the need to always analyze with care and with critical thinking of all data and information, to research in depth the causes and effects of events over time, to compare more reliable data in a comparative way to obtain reliable even if not definitive conclusions (Quantitative Biology Science).

History of sciences for a reasoned environmental culture



William Stapp (1929-2001)

In American scientific culture, William Stapp of Michigan University (USA), considered the father of Environmental Education, in 1969 believed that for adequate environmental education it was important to train citizens who also had good knowledge of biophysics, who had the ability to solve environmental problems, especially motivated to work towards their solution. In learning, observational action and the problem solving approach in dealing with biotic and abiotic aspects of the environment are underlined as fundamental to promote awareness , skills and reasoned participation at different levels to cultivate widespread environmental literacy.



James Hutton, portrait (1726-1797)

Promoter of the idea of the Memory of the Earth

Starting from a brief historical analysis of environmental studies, we verify that already in 1785 the Scottish geologist James Hutton published a text entitled Theory of Earth in which he combined the need to establish a balance between man's action on Nature and the response of the latter to such human action. James Hutton, proposing the idea that what we can observe and describe today derives as a direct consequence from what occurred in the past, defined the basis of the Theory of Actualism. Our planet is equipped with a Memory: every testimony of the Earth as an integrated system is written in its evolutionary history.

A subsequent document that made this idea official was the Declaration international rights to the Memory of the Earth developed in 1991 by UNESCO -

Digne, France. The document reports in nine points the fundamental directives for the safeguard and protection of natural environments, urging awareness of the uniqueness of planet Earth, (Marina Minoli, "Environmental Education for climate change: From historical Natural Science to Modern Interdisciplinary didactics", 9th International Conference New Perspectives in Science Education, 3/2020).

Anticipator of environmental changes

Numerous study trips to different continents and in different unexplored environments inspired the evolution of the scientific thought of Alexander Von Humboldt, naturalist, explorer, geographer and botanist; German scientist, author of widely disseminated scientific books including the treatise Kosmos. Von Humboldt was a multifaceted figure, a forerunner in understanding the climate changes that had characterized the history of planet Earth. Von Humboldt proposed the innovative idea of a "general equilibrium" of Nature, a natural order in the Earth system in all its components, organic and inorganic, in which each part could only be understood as part of a whole.

He also developed a series of models for studying plants not only as an object of observation but in relation to temperature, humidity, latitude, altitude and living conditions, founding Phytogeography. Alexander Von Humboldt proposed in a pioneering way the need for a transition from the then widespread contemplative aesthetics to the scientific observation derived from the use of adequate instruments (enhancing the then nascent observation with microscopes which has now evolved with the advanced techniques of Microscopic bioimaging) which Humboldt regarded as an extension of the senses.



Alexander Von Humboldt, portrait
(1769-1859)

Forerunner of cultural interdisciplinarity

The "Gaia Hypothesis", proposed by the Scottish chemist James Lovelock in 1970 and co-developed with the American biologist Lynn Margulis, represents a first approach to considering the environment as an integrated structure. The fundamental principle of Gaia is the consideration that all organisms - organic components - and all structures non-living - inorganic components - are integrated and self-regulated wholes in the "mutual balance" necessary to maintain a homeostasis of planet Earth.

According to this hypothesis all ecosystems contribute at the level of hydrosphere, geosphere, atmosphere, biosphere to the regulation of chemical characteristics -physics of the planet; living and non-living systems closely connected that modify and shape each other. A preview of modern Biogeoscience, a recent discipline with approaches integrated by the contributions of different experimental sciences, to initiate a systemic study of the Earth.



James Lovelock (1919-2022) and Lynn Margulis (1938- 2011)
in January 2000 at the University of Valencia

Elements common to the three naturalists

In the analysis of the elements that we can find common to the three scientists there are two aspects. First of all, the important interconnections between a modern vision of Nature in a systemic relationship between organic and inorganic components in the context of mutual and dynamic integration. Secondly, the concept of "dynamic equilibrium" as a fundamental condition for matter and life at different levels (chemical, physical, biological). We recall in particular the condition of "chemical equilibrium" described in Le Chatelier's Principle: "A chemical system at equilibrium reacts to the variations to which it is subjected in such a way as to cancel the effects and reach a new equilibrium", but above all the condition of "biological balance" with

the homeostasis of living things as a set of all self-regulatory processes that keep the internal conditions of biological systems stable in relation to external changes in the environment.

HOMEOSTASIS FUNDAMENTAL CONDITION OF THE LIVING

HOMEOSTASIS IS A DYNAMIC, CHEMICAL – PHYSICAL EQUILIBRIUM DUE TO FACTORS THAT COMPETE EACH OTHER



CONSTANT PARAMETERS SUCH AS ACIDITY, TEMPERATURE, CONCENTRATION OF SOLUTES PREVENTS SERIOUS DAMAGE TO THE PROTEIN STRUCTURES WITH LOSS OR MODIFICATION BY DENATURING OF THE CONFORMATION AND THEREFORE ALSO OF THE FUNCTION OF PROTEINS IN CELLS OF ANIMAL AND PLANTS

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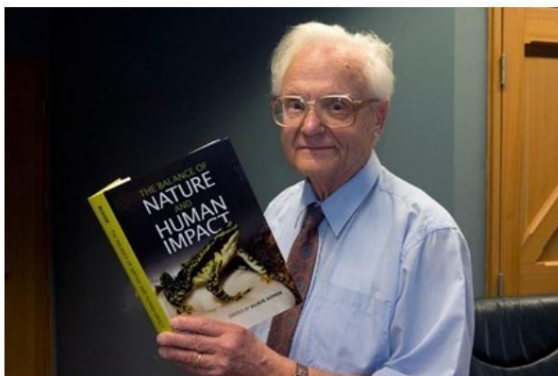
In the 20th century, other scientists proposed clarifications regarding the general concept of the condition of "environmental balance" which is interesting to know in order to have a more comprehensive overview of the topic.

In 1992 Stuart Leonard Pimm, a British-American biologist from Duke University, North Carolina, published the essay *Balance of Nature?*, proposing in relation to the concept of balance not so much the idea of a static condition of « Balance of Nature" but of flow and continuous change unpredictable change in the evolution of ecosystems.

The German biologist Klaus Rohde (1932-...), professor emeritus of the University of New England in Australia, published the essay *The Balance of Nature and Human impact* in 2013, believing that Nature is in a mostly static condition; in every era species have appeared and become extinct with the climate changes that have occurred throughout the history of Planet Earth and ecosystems have always adapted dynamically although in the past the changes occurred over long periods of time while very quickly now.



Stuart Leonard Pimm (1949-...)



Klaus Rohde (1932-...)

«Model» organisms for the environment

How can we study and observe, also with students, the effects of different conditions of rapid and unexpected environmental stress events on metabolism and on the interactions of different factors? «Model organisms» can be an effective response to create, at different cultural levels, experimental innovation in environmental education. A model organism is chosen by scientists to study particular biological phenomena with the aim of obtaining useful information also for other organisms with different degrees of complexity. Normally they are organisms accessible for molecular biology studies and some of them can also have applications in the environmental sector.

All model organisms must have precise characteristics: small size, short reproduction times, easy genome sequencing, possibility of genome manipulation. In particular, two organisms useful for studying interactions with the environment are *Caenorhabditis elegans* (a nematode worm) and *Arabidopsis thaliana* (a Brassicaceae plant).



MODEL ORGANISMS FOR ENVIRONMENT

- CAENORHABDITIS ELEGANS (NEMATODE) - WORM



- ARABIDOPSIS THALIANA (BRASSICACEAE) – SMALL PLANT



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C. elegans has a life cycle that depends on environmental conditions in relation to temperature. The *C. elegans* genome was completely sequenced in 1988; 40% of genes are present in humans. A theoretical-experimental learning path with *C. elegans* together with students is very interesting to study the effects of different stress conditions in model organisms and to learn about scientific research methods for the environment (PBE - Place Based Education approaches with Hands-On practices and Real-world learning). An educational-experimental path that promotes the following training actions: thinking independently (inquiry), collect, analyze, synthesize and evaluate information (data), activate discussions in the territorial community (civics), and create knowledge and solutions based on new ones ideas (innovation).

Using plant model organisms, it is interesting to understand how plants react to different external stimuli, studying for example ion transport also in relation to the concentration of the calcium ion in the regulation of the biochemical cycles of the plant. If a plant cell is stressed it sends a signal throughout the plant through changes in calcium concentration. This signal appears to be different depending on the stimulus received and many scientists wonder why not all cells are designed to receive this particular signal. In some recent experimental research, specimens of the model plant organism *Arabidopsis thaliana* are also used in which the environmental effects at the cellular level are examined in relation to the physiology of the entire plant.

How plants react to environmental stress

Plant stress can be defined as the set of external conditions that influence the development, growth and productivity of a plant. In response to this situation, two types of alterations can generally occur in the plant: modification of gene expression and modification of metabolism at the cellular level. There are various types of stress: biotic, if determined by an external pathogenic organism (for example parasites, fungal toxins) or abiotic if determined by

environmental, chemical or physical excesses or deficits. If stress conditions are reached progressively over time, the plant can self-induce adaptive physiological changes (acclimation).

A stress condition that alters the metabolic balance of plants, causing possible damage to proteins, lipids and DNA, is that caused by an overproduction of oxidizing chemical species called reactive oxygen species (ROS, oxygen compounds with high oxidizing activity). There are numerous factors currently studied which determine an increase in an anomalous concentration of ROS in plants, which are not counterbalanced by antioxidant substances, including herbicides, intense radiation, heavy metals, conditions of water shortage, high concentrations of ozone, high temperatures.

(Marina Minoli, "Elements of didactic innovation about oxidative stress condition for health education in High School", in *International Conference New Perspectives in Science Education*, 3/2018 - Congress Acts in Libreria Universitaria Book, Padua, 4/2018)

Interesting studies also emerge at an international level regarding an evergreen plant characterized by red berries, the *Taxus Baccata* of the conifer order widespread especially in northern Europe. It is a plant with slow growth and is very long-lived, an "environmental biosensor" which allows interesting observations at a macroscopic level as growth is correlated to the increase in temperature; it can in fact be considered a "growth model" plant for its rapid response to climate change.

TAXUS BACCATA L.
(PINALES – CONIFERS)

- HIGHER TEMPERATURES CORRELATED WITH GROWTH REDUCTION ESPECIALLY IN THE LAST DECADES
- REGRESSION WITH PHYSIOLOGICAL STRESS DETERMINED BY LACK OF WATER
- VERY WIDESPREAD SURVIVING IN TERTIARY INTERGLACIAL PERIODS
- PLANT THAT PREFERS CLIMATE WITH LIMITED DAILY AND SEASONAL THERMAL EXCURSIONS

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This plant is remembered above all in the British tradition for the particularly elastic and resistant wood used in the construction of bows, also the bow in the stories of the mythical character Robin Hood of English culture, a plant also cited by the Scottish writer Arthur Conan Doyle as True Wood in *The Song of Bow*.

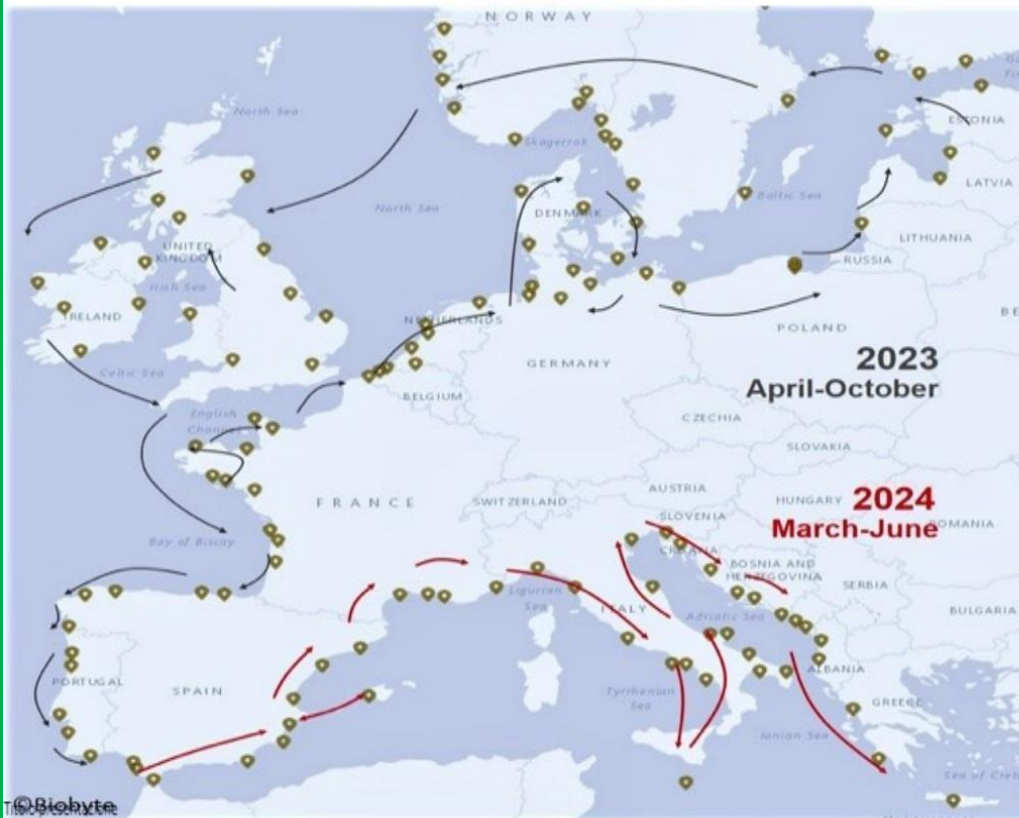
Botany, or rather Plant Science in the modern definition which includes the idea of complexity of this discipline, therefore turns out to be a science with high educational value for understanding the concept of evolution and change at different biological levels, also for studying emerging elements from modern interdisciplinary research relating to the environment; in particular, modern Phenology allows us to understand the responses in the reproductive and vegetative cycles of plants to climate change and allows us to carry out interesting active research works even with groups of secondary school students.

Trec project: innovative research for the marine environment

A large and interesting project for the environment is the one promoted by the European Molecular Laboratory of Heidelberg (EMBL) called *Traversing European Coastlines (TREC)*: it started in April 2023 with completion expected in spring 2024.

As part of TREC, groups of researchers will travel the European sea coasts with mobile laboratories to study the different coastal places and the effects of climate change at the molecular level and of phenotypic plasticity in the different organisms that populate them, the adaptation capacity of individual organisms and of communities. Microorganisms will also be studied, in particular bacteria and fungi; the changes in interaction between species and environment favor the emergence of new pathogenic microorganisms.

A scientific project which therefore involves molecular biologists, ecologists, oceanologists, chemists, engineers, data analysts from different nations and which may also involve some local communities in a path of scientific citizenship. 120 coasts of 46 regions will be studied with 22 European countries involved in two years, first in Northern Europe and in 2024 in Southern Europe, as seen in the following image.



The research will be conducted within a new concept of Bioscience, Planetary Biology research which involves animals, plants, fungi and individual communities in systemic investigations to understand how they interact and react by identifying the broad interconnections between living different levels of complexity.

Environmental humanities and experimental sciences

From the analysis of the different international lines of study on environmental education in recent years, it is highlighted that the scientific approach alone, even if derived from the integration of different STEM disciplines, is not sufficient to address these complex issues.

In different cultural contexts we are increasingly convinced that Environmental Humanities Integrated with Experimental Science are necessary to promote integrated analysis at different levels to try to respond in a constructive to different environmental challenges. Environmental humanities are a very broad multidisciplinary field that integrates History, Environmental Philosophy, Linguistics, Environmental Politics and Human Anthropology, to promote a dialogue between different research methods.

In conclusion we should be aware that there is much scientific data collected up to now in environmental sciences, but there are few real certainties and numerous difficulties for an effective interpretation and understanding of a correlation between data

and complex biological and climatic events. In agreement with international bioscientific research groups, I am convinced that, even in environmental research, living organisms should not be analyzed and studied at different levels by reducing and considering them as a pure sum of data and constituent parts; in fact, I believe that it is always important to have an exhaustive knowledge of the different biochemical and physiological interactions to try to correctly interpret the complex responses to different environmental conditions in a difficult process of systemic understanding.

«Complex learning also to educate about scientific doubt, about overcoming the idea of certainty of the knowledge obtained which must always be reconsidered in relation to other scientific knowledge, compared and evaluated in a broad general context of the functionality of organisms.» (*Marina Minoli, Educating in the knowledge of systems biology, Nuova Secondaria pp. 79-82, Studium Editore, Rome, 9/2018*).

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