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Geophysiology and Parahistology of the Interactions of Organisms with the Environment

by
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Dedicated to the 800th birthday of FRIEDRICH II. VON HOHENSTAUFEN (26.12.1194- 13. 12. 1250) and to the 200th birthday of CHRISTIAN GOTTFRIED EHRENBERG (19.04.1795 - 27.06.1876)

Abstract
Ecology and Global Ecology (GE) are terms by which the relations between the organism (or living matter as a whole) and the environment (or Earth as a whole) have been treated for almost a century. Geophysiology and PARAHISTOLOGY (PH) are terms slowly replacing older scientific thoughts jointly with an increasing number of modifications and alterations of the Darwinian Evolution (DE) concept. Somehow Geophysiology and Parahistology seem to describe evolution in a non-Darwinian domain. According to V. I. VERNADSKY (1929,1930,1988) -the great Russian naturalist and biogeochemist- the biogeochemical processes on Earth are controlled by the force of living matter rather than by species associations developing in and with individual ecosystems as expressed by darwinian evolutionary terms. He also claimed that GOETHE was incorrectly regarded as a predecessor of DE by some authors (including DARWIN) and that "Natur" (nature) and "Lebendige Natur" (the totality of creatures) are two very different things for GOETHE.

Detailed analyses of microbial mat systems in the German Wadden Sea and in artificial hypersaline WINOGRADSKY columns have shown that the totality of creatures and matter around them i.e. the "lebendige Natur" sensu Goethe or "living matter" sensu Vernadsky of such environments control to a considerable extent the structure, stability, and (geo-) morphology of sediments and thereby the geological structure of the living Earth. These structures do not follow the rules of sedimentation formulated by the laws of STOKES. They represent growth structures (Aufwuchs), whose physics and dynamics are controlled by complex fractal systems. The factors controlling the ultimate shape and stabilisation potential of the eventually resulting rocks and fossils are comparable to tissue development in macroorganisms. Also, certain microbial associations in the sub-recent and in the fossil record may be compared to metazoan tissues. Chemical gradients in the sedimentary column, regulated by the interplay of living matter and sluggish (slow-reactive to non-reactive) compounds, combine to create a pattern of porosity and structure of the resulting deposits that clearly indicates microbial influences and especially those of extracellular polymeric substances on the morphology and texture. The combined effects of microbiota or living matter on the sedimentary record are described as parahistology of sediments in analogy of the histology of tissue on a geological scale. This conceptual living tissue made up of microbially generated rocks and ore deposits cycled through metabolic processes and forced into tissue-like structures by microbial biofilms and mats may extend down to the upper mantle of Earth and far up into the stratosphere when Earth is regarded as a living entity over geological periods. We may have to conceive Earth as a living specimen, which is breathing at a frequency of thousands of years instead of the normal physiological breathing rate af man or an insect. Macroorganisms in all terrestrial systems represent the transport and logistic media, which, however, utterly depend on myriads of intra-, inter-, and extracellular microbial symbiotic partners.

Geophysiology -as a new scientific view of life process controlled biogeomorphogenetic and biogeochemical cycles- is presented in the context of a life field theory suggested by KRUMBEIN (1983) and an evolutionary field theory suggested by CRAMER (1989). The latter theories are related to physiological thoughts of FRIEDRICH II. VON HOHENSTAUFEN and to the "microgeology" of C G. EHRENBERG (EHRENBERG, 1854; KANTOROWICZ, 1992; MASSON, 1993). The factors controlling the preservation of organic material and biogenic structures in rocks are discussed on the background of "climate change" and "global change" theories. Geophysiology and parahistology are introduced as new terms in a time where environment-organism relationships are increasingly studied on a global scale including physiological time scales by far exceeding individual darwinian organismal life times.

Instead of an Introduction: - What is at the basis of mutual organism-environment influences- ?

Organism-environment relations have been described for about 5000 years in not always precise but still scientific terms (as a reference cf. to MANN, 1990, quoting IMHOTEP or DARWIN, 1979, p.53 quoting ARISTOTLE). Over the last (and short) period of 125 years, interactions between organisms and the environment, however, have been discussed on the basis of two paradigmatic terms: (1) Darwinian Evolution (sensu HUXLEY, HAECKEL, MAYR, and others) and (2) Ecology or Ecosystem Research (sensu HAECKEL, HUTCHINSON, ODUM). The terms Darwinian Evolution (DE) and Ecosystem Research (ER) were first filled with scholarly and scientific terminologies and life, then they culminated and started a decline. They were sociologically and socially exploited and, finally politically undermined. This was associated with a declined public respect to the defenders of DE and ER. This process is also reflected in the change of professional assignment: IMHOTEP was regarded as a god, PLATO as a citizen, politician, philosopher, mathematician and (with respect to the daedalic nature of his thought) also as an engineer. With Christianity came the theologists and physico-theologists, physiologists, natural philosophers (FRIEDRICH II., ALBERTUS MAGNUS, Patron of science of the Catholic church, NEWTON, LEIBNITZ, BUFFON, KANT.); finally the "scientist" appeared. This neotype represents on average a kind of degradation professional prostitution of the ideal man of wisdom.

New paradigmatic terms and approaches like "Geophysiology", "Gaia-hypothesis", "Noosphere-concept", "Life-field-theory" attempt nowadays to account for two phenomena of the turn of the millenium, namely (1) apparently uncontrolled logarithmic growth and expansion of one Darwinian species (Homo sapiens) at the cost of other Darwinian "species" and of the "environment" and (2) the fact, that a single individuum of the same species of living matter or the sum of organisms of Earth is capable of looking at Earth with its own eyes from space and learns to perceive it as a living planet by its own physiological means (eye, ear, heart, and - soul). In this context a Darwinian species is each single organisms in Aristotelian terms, while Earth represents a non-Darwinian species representing the process of life itself in which myriads of „generations“ or „representations“ of bacteria , mice and man are included and not singled out in an ecological network sense.

It was and is, however, the view of alternative lines of thinking in natural history that DE for example "is difficult to accept in view of the constancy of microbial forms over geological periods" (EHRENBERG, 1864 as quoted by EHRENBERG, 1905). It should be regarded not as a scientific concept but rather as hypothetical answer to apocalyptic views of the medieval time being replaced by a new "evolutionary concept" (ape-man-angel), in reaction to the deterministic Newtonian world (VERNADSKY, 1988). These views were and are supported by other scientists and scientific lines of thought. KRUMBEIN & SCHELLNHUBER (1992) and ZAVARZIN (1993) maintain that the organism-environment relationship -as summarized by the scholastic Darwinian view postulating a game between stochastic mutations and their coincidental selection following outer or inner stresses on and changes of the environment- represents an ambiguous combination of DE and ER. It does, however, not present an adequate view of the physiology of Earth and ist breathing rate (KRUMBEIN, 1990). KRUMBEIN (1989) also claims, that ER is an awkward term which should better be re-assigned and annotated as **natural economy**. ZAVARZIN (1993) criticizes the DE model inasmuch as he rejects the existence of the species as a vehicle of evolution while he accepts the genus as being part of a drifting equilibrium within community and ecosystem. KRUMBEIN (1983, 1993 a, b) goes further and suggests to replace the genus concept by the totality of living matter or the "genetic diversity", in agreement with VERNADSKY (1926, 1937, 1944) and EHRENBERG (1864 quoted by his daughter in 1905) . The notion that "organisms or living matter create the environment which in turn demands and selects for new organismal organization in an inseparable mutual dialogue within one entity, namely the living skin of the Earth or Earth itself" (KRUMBEIN & SCHELLNHUBER, 1992, KRUMBEIN & DYER, 1985) rules out that genetic events such as mutation and selection according to DE theories regulate the patterns of the living world. On the contrary: Earth has to be regarded as a living species in a non-Darwinian domain.

The recently proposed "life field theory" (KRUMBEIN, 1983, 1993a) or "evolutionary field theory" (CRAMER, 1989) were at least in part already maintained by BUFFON (1749), HERDER (1784), HUMBOLDT (1844), and last not least by VERNADSKY (1937, 1944). The latter stated: "Living matter is the sum of all organisms. Living matter, soil and rock are peculiar natural bodies. The fundamental property of biogeochemical energy is the growth of free energy of present and bygone biospheres with the progress of geological time". KRUMBEIN (1983) added that the growth of free energy can be related to information as a part of living (structured) energy and that the relationship between free energy, bound energy, and accumulated and transmitted information is regulated by changing forces from outside the living system of Earth. GOETHE calls this Earth „die Natur". KRUMBEIN (1983) stated: "Life forms an integral part of the basic principles of the universe as we understand it today. This implies a "field theory" of life which means that any kind or quality of life which is extinguished will produce new kinds and qualities of life to continue the basic principle. Life consists of acceleration and retardation of chemical reactions and of the embodying of continua of space and time into a special reference system, in non-linear reaction networks. If one wonders how life emerged and covered the planet Earth early in the Precambrian, one must ask of the physicists, how is matter destroyed and transformed into energy and how does energy create matter. In other words: the question of the reality of space and time in an objective sense is the same as the question of the reality of life in space and time. As EINSTEIN told us: 'only theory can tell us which experiments are to be meaningful'. Life is a regularity of nature".

Life and living matter thus are inseparable from the physical world. Both must be treated physiologically. Therefore, new paradigmatic sets of terms and propositions, along with empirical data to support these propositions have been forwarded recently. The latter have also been analyzed philosophically by WITTGENSTEIN (1974, p. 542): " Wenn die Begriffsbildung sich aus den Naturtatsachen erkären läßt, sollte uns dann nicht, statt der Grammatik, dasjenige interessieren, was ihr in der Natur zugrunde liegt? - Uns interessiert wohl auch die Entsprechung von Begriffen (*wie DE oder ER, insert of the author of this article*) mit sehr allgemeinen Naturtatsachen."

In this context of "Begriffe" or "terms" credit should be given especially to the originator of DE, namely C. DARWIN. Most researchers know, but tend to forget, that he never used the word evolution, avoiding it carefully in his book on „The Origin of Species". DARWIN also believed, that the theory of descendence or of the origin of species by organism-environment interaction through selection of arbitrary internal changes by stochastic changes of the environment was expressed simultaneously by LAMARCK, GOETHE,, and ERASMUS DARWIN between 1794 and 1795. CHARLES. DARWIN) adds that G. SAINT-HILAIRE, according to his son, in about 1795 expressed the strong view "that the same forms have not perpetuated since the origin of all things". „Geoffrey seems to have relied chiefly on the conditions of life, or the 'monde ambiant' as the cause of change". Neither DARWIN, nor KANT, nor GOETHE or SAINT-HILAIRE, however, seriously considered anything remotely resembling the term "genetic code" or "DNA", i.e. a constantly self-replicative powerful force of life innate in each organism (type, species, genus or more precise, the total genetic diversity). It is very astonishing that this period mentioned by DARWIN has had not only BUFFON (1707-1788) as a brilliant ancestor but also another personality, who was never regarded as a natural scientist, but rather as a theologist, linguist, or culturologist namely J. G. HERDER (1744-1803). If we read Herder properly, we have to revise the introductory remarks of DARWIN about the evolution of the descendence theory, and our thoughts about chaos theory, environment-organism-relations and other thoughts. This needs some introductory explanation. As pointed out above, two conflicting views were emerging from the Newtonian revolution, i.e., the deterministic view of the facts of nature (laws of nature): (1) the "descendence/selection theory" of DARWIN and his predecessors and (2) the "genetic discourse theory" or "life field theory" of KRUMBEIN (1983) and those on whom he bases. Both DARWIN and VERNADSKY righteously claim GOETHE as a fervent partisan of their theories. HERDER, however, is neglected by both. We must go back 20 years in time, making a snap-shot of AD 1774 instead of 1794. HERDER, who originally studied philosophy and natural philosophy with KANT (still in his pre-critic stage) in Königsberg, has become an independent theologist on his way to Weimar. He is 30 years old. KANT -his main critique- is 50 years old, J. HUTTON (1788), the originator of the "theory of Earth as a super-organism", is 48, LAVOISIER 31, LAMARCK in his 30th year, and GOETHE a 25 years old „youngster“ (in our terms). The master of all, BUFFON, is 67 years old.

We have to analyze the psychological and sociological situation precisely in order to understand what it means, that HERDER (1774) published the first outline of his theory of climate, environment and ascendence of man. In his 1784 edition he clearly predicts evolution, molecular biology as a tool of nature, the organism-environment relation as a dialogue and thus a theory closer to VERNADSKY and our present views than to DARWIN and his scholastic followers (see the above descriptions of organism-environment relations in the DE and in the "Life field" context).

It must further be mentioned at this point that the terms *field* and *climate* are both derived from astrology, a fact well known to the scientists of the Newtonian and Darwinian age but almost completely suppressed by the modern technologically oriented scientific disciplines. In order to be clearly understood: The modern scientist sees himself as an exact researcher and the astrologist as a scharlatan!

At this place one section from the work of HERDER (1784) is quoted first in the German language, then in literal english translation and finally in an modern english transformation using the knowledge of the "meaning" of words in the 18th Century (a technical dictionary of 1788 e.g., says: "Physiology or Physicks, or Natural Philosophy is the science of the phenomena and processes of natural bodies“). On this basis the narrative of HERDER sounds astonishingly post-modern, even if one considers the admitted fact, that the quotation is not in the full context of the thought and flow of narrative of the time 225 years ago.

Quotation 1 (Original)

"Das Klima ist ein Chaos von Ursachen, die einander sehr ungleich, also auch langsam und verschiedenartig wirken, bis sie etwa zuletzt in das Innere eindringen und dieses durch Gewohnheit und Genesis selbst ändern. Die lebendige Kraft wiedersteht sehr lange, stark, einartig, und nur ihr selbst gleich; da sie indessen doch nicht unabhängig von äußeren Leidenschaften ist, so muss sie sich ihnen auch mit der Zeit bequemen. "

Quotation 2 (literal english translation)

The climate is a chaos of causes, which are unequal and thus act slowly and in a differentiated way until they finally penetrate into the interior and change it by habit and genesis itself. The living force withstands very long, strong, and unifold, equal only to itself; since it (the living force), however, is not independent from the exterior passions, it must accomodate itself with time to the latter.

Quotation 3 (modern scientific english)

"The fluctuating and changing environment (or climate) consists of a multitude of causes which are unequal and thus act slowly and differently until they penetrate into the interior of the organism (s) and change the latter by adaptation and mutation. The genome withstands this pressure of the environment for a long time, strong in its speciation and self-replicatory power; since the genome, however, is not totally independent from environmental influences, it must be altered necessarily with time. "

HERDER subsquently expends some thought on the negative aspects of the dialogue between man and environment, deploring massive environmental destruction and species extinction by fatal colonisation of the America's by

Europeans, a thought he doubtlessly inherited from BUFFON (KRUMBEIN, 1989).

One conclusion from this quotation is that DARWIN, (1979) overlooked one of his predecessors. Another conclusion is that the subject of a dialogue between genome or genetic diversity and the environment manifested in the constant reshaping of the organism by the environment as expressed by KRUMBEIN & DYER (1985) bases on HERDER, as the latter on BUFFON.

HERDER himself was based on the views of BUFFON and KRUMBEIN (1993a, b) interpreted them recently in that way that living matter or "die lebendige Natur" or "the totality of organisms" itself creates its global environment including or sub-ordinating climate as one part of the (changing) environment. Environment and climate in turn shape and restructure or support the genetic diversity or living matter.

Summarizing these historical remarks on the life field theory: Present-day knowledge and historical analysis allow us to state that "the organism" and "the environment" are inseparable sub-units of a whole, which HUTTON regarded as a "super-organism", Goethe as "die Natur" (viewed independently from "der Kosmos") and what we like to regard as the "physiology of the Earth" (in the embracing sense of the above mentioned technical dictionary of the 18th Century claiming synonymity between physics and physiology). DE and ER thus would become obsolete or should be transferred to astronomical or „astrological“ interplanetary or interstellar systems

Geophysiological and parahistological methods

Before introducing and defining the new paradigmatic terms and theories it is useful to mention the empirical and analytical sets of data and informations that can potentially support new approaches to basic yet changing questions in the discourse between organism and environment:

Aquatic microbiology and geomicrobiology play an important role in the discussion concerning the equilibrium of global biogeochemical cycles, which are critical for short and long-term prognoses of global change. Global changes in the geochemical cycles would in turn drastically alter climatic and atmospheric equilibria on Earth. The International Geosphere-Biosphere-Program (Global Change Program), together with the International Global Sedimentology Program are focussing on whether or not man-made perturbances of atmospheric, aquatic and sedimentary cycles influence Earth's climate and the geochemical balance as a whole. Scientists persuing this question doubtlessly consider themselves (along with their social and physical environment) as outside of DE and ER terminologies. They feel themselves more or less as external enemies or as external „doctors" of the system, to which they, however, inseparably belong.

Thus the term "geophysiology" is used in this context in a way that does not exclude man as the "destroyer", "gardener" or "doctor" of the world's physiology/physics, but includes him into the physiology of living matter on Earth (die "lebende Natur" or totality of creatures in the sense of GOETHE). The term geophysiology in contrast to a reductionist view of biologically "powered" biogeochemical cycles more appropriately describes the discourse between living and sluggish or inert matter than the terms DE or ER. Geophysiological reactions range from the world-embracing biofilms and microbial mats to very complex symbioses and their chemical, physical, regulatory and even psychological impacts on the Earth as a whole as well as on sediments and their places of genesis - namely the aquatic environment. Parahistology of Earth as derived from tissue histology may describe the tissue of Earth as an entity of living matter including atmosphere, hydrosphere, pedosphere, and those parts of the lithosphere we can currently reach (e.g. 10.000 m deep continental bore-holes and about 1000 m deep bore-holes below the ocean bottom with samples and one order of magnitude further down based on circumstantial evidence). Life thrives everywhere or at least controls the turnover of materials in those parts of the Earth we know or believe to know.

Microbial processes span physiological, biochemical, geomicrobiological, and biogeochemical single cell processes in the microbial cell environment and in smallest biotopes to masses and fluxes at the global level. These mass and energy transfers involve planetary climatic, geochemical, and geological (or biogeomorphogenetic) dimensions. The single cell processes, however, sum up to dimensions of millions of years and a turnover of several Earth masses in geophysiological time intervals. At least four to eight orders of magnitude in time, mass, space and energy dimensions are altered biologically in these geophysiological reactions. For the participants of this 29th European Marine Biological Symposium the tremendous speed and turnover potential of biological processes may perhaps be illustrated as follows: The chances that any of the Vienna 29th Symposium participants in the moment of this lecture inhales a molecule of carbon dioxide that was exhaled during the first "yellow submarine competition" on the second Marine Biological Symposium by any of the participants are higher than 99% (KRUMBEIN, 1990).

The status of our lakes, seas, and coastal environments depends to a much greater scale on microbial and geomicrobiological reactions than thought. Clearly, most of the exploited ore deposits of the deep sea and of shallow marine coastal environmentsalong with petroleum and gas deposits, are accumulated by biological catalytic and symbiotic processes. We know that viable (and also infectuous) germs may survive hundreds and thousands of years in sediments. We have just learned that one of the major forces and systems of sea-floor spreading and continental growth, the submarine lavas and basaltic glasses, are attacked by bacterial communities reaching down several hundred meters into the sub-oceanic rocks, releasing large amounts of cations and -even more important- huge masses of liquid water which is bound in the glass and its matrix (THORSETH et al. , in press) We know that microbial systems and especially intertidal microbial mats can switch very fast from anoxygenic to oxygenic photosynthesis and from respirative to fermentative pathways. We further know that complex plowing, digging, gardening, and farming systems of a highly co-operative symbiotic character reign the bottoms of practically all oceans, seas and lakes: the extent equals or exceeds the impacts of human farming on parts of the terrestrial surface. We also learned that the outer borders or limits of organisms may be regarded with new eyes and treated with similarly new terms. If we use examples like the termite hills, the biofilm communities of the intestinal tracts of termites and cattle and try to transfer them to the mutual influences organisms excert on their environment and vice versa we feel more and more that terms like inside and outside, skin, epidermis, single cell, community, symbiont and even environment become very debatable and vague. Man is a walking reef, an elephant can be a sukkah hut, and the Serengeti is the intestinal tract of Africa. Finally, the swarms of fishes moving unnoticed through the Dardanelles are comparable to white blood bodies swimming to a site of cancer production in a human body.

Our present knowledge of biofilms and microbial mats, of coral reefs or mollusc banks etc. reveals that the borderlines between individual organisms, organismal symbiosis, communities, and environments become vague to non-existing on these scales. If we compare the complex and highly motile communities of Beggiatoa arachnoidea or other deep sea species, the elegant networks of Thiovolum majus in decaying marine algae aggregates, the walking "forests" of the myxobacterium Stigmatella aurantiaca or other phenomena and processes on the eukaryotic cell and organism level involving many examples of sudden outbursts of higher structuration, changes from motility of myriads of single cells in a coordinated way to complete desintegration we soon realize that the classical borderlines between the organism or the organisms and their environment have to be discarded. The sceptical reader may need perhaps a few more examples:

Who has never mused about the precision and beauty of the flight of a flock of sparrows or pigeons or a cluster of bees hanging in a tree when swarming. Who can supress a cry of joy when encountering a swarm of coral fish or mackerel during a SCUBA-dive? How can one not marvel at structures that man would call green potatoes laying on the bottom of a cold lake, when these potatoes turn into 8000 cyanobacterial trichomes behaving exactly like a flock of sheep held together by another 1000 trichomes behaving like shepherd dogs and wandering over the agar plate like comets pass through the skies (the latter being directed by stellar forces and the former by the light of an electrical bulb?). Biofilms of huge dimensions, created from myriads of individual cells shape the relic of a rabbit, or a former tree's trunk. Is it not the case that such biofilms, when coating a ships hull change its speed and direction - and its interaction with the marine environment? These biofilms are, however, created by trillions of individual cells and cell clones which in turn 'know' nothing of any environment. Further we know that the outer boundaries of individual organisms are modified, even falsified to an extent, that we are only beginning to understand. The examples of a single fungal clone covering hundreds of hectars of forest soil and "infecting" or better "influencing" thousands of trees, or the example of the many pheromones which regulate communication among trees, insects, mammals further demonstrate the necessity of the holistic approach to the dialogue between living matter and sluggish (reactions at lower turnover speed) material on Earth.

All material transfers, many of the material transformations, and a great deal of material transportations are organized by bacterial food-webs although macroorganisms furnish important transport and intermediate reservoir functions (Table 1). The dynamics of living matter in the marine and shallow-water sedimentary environment, however, is apparently not energy or nutrient dependent. On the contrary, viruses, phages and predatory bacteria, ekto- and endosymbioses of prokaryotes and eukaryotes regulate practically all energy and matter flows in aquatic systems on a scale that is „wiser“ than the uncontrolled expansion of the only "so-called" self-reflective part of living matter, namely mankind. Mankind is disqualifying itself as a system. The transfer of information, energy, and substance across the borderlines, however, is organized mostly through eukaryotic macroorganisms as a whole, if one needs to separate this lineage of genetic diversity so totally from prokaryotic genetic diversity. Eukaryotic genetic diversity may be a key element in the interplay between the availability of energy and building blocks of tissue and their exhaustion by logarithmic growth of individul clones.

The coupling of fossil matter with recent living matter and biogeochemical processes is virtually controlled by microbiota. The dimensions of this energy and mass transfer are still poorly understood. Geomicrobiology is understood as the microbiology of geogenic processes. Microbial biofilms are involved in the production of marine snow, the formation of sedimentary rocks, ore deposits, marine and terrestrial biocorrosion, and also -as crucial trigger mechanism- in the evolution of new and ever changing environmental conditions including weather and the long term average of the latter, namely climate. Microbial influences on weather and climate may, however, be unimportant in comparison to energy and matter that is microbially structured in a meaningful way in order to balance an increasing energy pressure on Earth excerted by an energetically expanding sun.

Geophysiology as an emerging science

C. G. EHRENBERG (1854), whose 200th birthday we celebrated in 1995, alluded in his book „Microgeology“ the forvces of the invisible microbial life on Earth "which is capable of creating and destroying soils and rocks". J. R. MAYER (1845) was among the first to state that huge amounts of sun energy are constantly trapped and transformed into reduced chemical compounds and useful static and kinetic energy by the living skin of Earth. Even LUCRETIUS (ca. 56 BC, 1973) expressed the view that Nature takes care of her business with the aid of invisible small particles. Erroneous interpretations have insinuated that Lucretius was talking of "atoms". Doubtlessly, however, LUCRETIUS was referring to both, more and less than the "BOHR atomic" model or hypothesis. (For the knowledgeable reader it is added that the BOHR atom model is a theory of the same quality as the BRONSTEDT acid/base model or theory). From this perspective, the "daedalic nature" of LUCRETIUS has to be regarded as a theory concerning the totality of invisible life particles, reactive and sluggish particles and other forces acting on this planet . LUCRETIUS did not decide or define whether small invisible particles are living bacteria or atoms! For him and for us the question remains, how many planets among all planets need to bear life in order to maintain life as a regularity of nature (a question that also is important for the interpretation of GOETHES's "Natur" and "lebendige Natur" in juxtaposition to "der Kosmos"). The view of nature of LUCRETIUS is a one of a growing, a productive and of an organisational and even mental control of life as expressed much later in the views of BUFFON as well as in those of T. DE CHARDIN and VERNADSKY (1929) who coined the terms biosphere and noosphere simultaneously acting on this planet in order to keep it alive. No wonder that one of the two plans which GOETHE conceived during his stay in Sicily without ever finishing them was a re-writing of the daedalic poem of LUCRETIUS (the second was the re-writing of HOMER's narrative about NAUSIKAA). Both tasks turned out to be impossible even for a man of his format.

Today have begun to understand how fossil microbial and macroorganismal biospheres that have ruled Earth exclusively over more than 3 500 million and 500 million years, respectively, and are still dominate it today, are interconnected with the present day shape and morphology of the surface of Earth, its water cover, climate and biogeochemical cycles. In these potentials we learn to see that the impact of life on the inert or sluggish (non-reactive) matter is never direct, as we would like to see it and is never directly intelligeable for the short-sighted human minds and communities which tends to think, e.g., of climate catastrophies, of irreversible and catastrophical changes. This view was already heavily criticized by KANT (KRUMBEIN, 1993 a,b). Nature, according to LUCRETIUS, BRUNO, VERNADSKY, RIEDL (1975, 1982), and others runs its affairs in a way that spans wider areas, spaces, and time periods as a human mind can usually grasp. This was expressed most beautifully in the Joseph legend of the Bible (based on the "scientist" IMHOTEP) and in the associated novel by TH. MANN. Josephus interprets the dreams of the Pharaoh's servants (limited space/time scale of organism-environment relations) and later the dreams of the Pharaoh/god himself (involving the space/time level of the then known global change system) ion a way which resembles our present discussions. KRUMBEIN and DYER (1985) used a "fairy tale" to describe the impact of living matter on planetary processes by using the Pharaoh's dreams and their interpretation by Josephus, the son of Jacob. The authors produced a scenario of transport and transfer of millions of tons of living matter and sluggish matter over thousands of miles from Mesopotamia to Abyssinia via a locust-swarm crossing the Persian Gulf, transferred down the Nile as fertilizers to Egypt and then transported back into Asia with the prosperous people of Israel exiling from Egypt. Thus the harvest of the king's of Babylon was taken away by locusts, washed dwon the Nile and brought back to Asia by an exiling people.

Huge geological reservoirs of energy, nutrients, and reducing power (useful also as electron acceptors and donators) are being constantly organized and re-organized by microbial activities. The macroorganisms and their evolutionary oscillations may serve as control factors, triggers, and necessary ornamentations or transport agents in the mass balance that is basically organized by microbes. The possibility exists, however, that all living matter is also involved on the informational and logistic level -not only animals and man. The mainly microbially organized reservoirs are recycled in time spans and metric dimensions reaching from several hundred thousand to millions of years and masses of up to 10^{25} g- which equals the Earth crust.

Thus we must see the Pharaoh's dream and the interpretations of Josephus interpretation in connection with the other biblical statement that thousand years are like one day in the view of god (or the living force). The principles that rule these cycles physically are by no means different from those ruling the marked annual cycles in temperate regions i.e. between peaks of primary production and accumulation of organic matter and its turnover in fall and winter through respiratory and fermentative pathways. Therefore microbial processes and biological processes in general reach geological scales in terms of time and space. The coupling of recent microbial sedimentary processes with fossil deposits and reservoirs (and thus fossil environments) has so far been underestimated in its importance for the equilibration of the present-day global environments. One cannot build a sky-scraper without foundations and one cannot feed a city like St. Petersburg without organizing a lot of food and energy reservoirs for the winter. The time and space dimensions of human planning or uncomparable with the time and space scales of the living Earth taking care of itself. This connection of recent and fossil biospheres needs to be carefully studied on a global and historical geological scale.

The junction of modern continental margins, oceans, their sediments and underground with ancient sediments and rocks is best represented in the highly productive, partially hypersaline, sea-marginal lagoonal environments. Information and knowledge about deep sea environments and the life processes going on in hundreds of meters of sediments and rocks below the deep sea bottom, however, give us other examples of the geophysiological power of global processes.

One example is the aforementioned microbial attack on volcanic glasses of the deep sea bottom; this process not only releases large amounts of nutrients reaching masses of global importance but also millions of tons of liquid water formerly bound in the volcanic glass thus furnishing a replenishment of the most important vehicle of all life processes, namely the aquatic skin of the planet.

Today, we have begun to think about the a new (yet very old) concept and era in natural history, i.e., the creation and understanding of a unifying concept of life as the controlling factor of past and present geochemical physiological, and biogeomorphogenetic processes on Earth. One of the increasingly used terms in this approach is **geophysiology**.
Huge geological reservoirs of energy, nutrients, and reducing power (useful also as electron acceptors and donators) are being constantly organized and re-organized by microbial activities. The macroorganisms and their evolutionary oscillations may serve as control factors, triggers, and necessary ornamentations or transport agents in the mass balance that is basically organized by microbes. The possibility exists, however, that all living matter is also involved on the informational and logistic level -not only animals and man. The mainly microbially organized reservoirs are recycled in time spans and metric dimensions reaching from several hundred thousand to millions of years and masses of up to 10^{25} g- which equals the Earth crust.

Physiology is regarded usually as the science of the normal functions and processes of living natural bodies, although LOVELOCK (1989) committed an apparent error in defining physiology as a part of medicine and thus ascribing the role of a "planetary doctor" to mankind. In the 18th century, however, the terms physiology and physics were still synonymously used to denominate the science of the phenomena (structures) and processes (functions) of natural bodies. Later -in the 19th century- physics became more or less restricted to permanently or momentarily non-animated (sluggish and inert) natural bodies, while physiology was restricted to the study of living natural bodies. Derived from this, geophysiology can be defined as the physiology of Earth or the science and study of the normal phenomena and processes of Earth as a living natural body (KRUMBEIN &

SCHELLNHUBER, 1990). Geophysiology thus treats (preferentially macromolecular, biochemical-catalytic, or microbial-energetic) processes, which are capable of influencing the dynamics of the Earth's crust through large-scale biological impacts on the composition and dynamics of the atmosphere, hydrosphere, and the lithosphere as a whole. In this frame, Darwinian Evolution (DE), Ecosystem Research (ER) and Global Ecology (GE) tend to fuse into geophysiology or metabolism of the Earth.

The coupling of fossil and recent microbial global phenomena, processes, and reservoirs is becoming increasingly visible, comprehensible, and important to understand since man, as a species and phenomenon of nature in his ever increasing global expansion, is deeply influencing these structures by changing them globally on the scale of biogeochemical cycles because the phenomena and processes of human activities interfer with fossil biogeochemical cycles and their dimensions in time and space through exploitation of fossil energy, electron and material deposits much faster than the normal biogeochemical turnover mechanisms account for. The self-reflectiveness of man, however, may be one of the greatest challenges of DE, ER and geophysiology. It is difficult for us to imagine that mankind is also deeply rooted in and bound to biogeochemical and biogeomorphogenetic processes on a global (spatial) and geological (historical) scale, although this thought was quite natural for scientists like KANT (KRUMBEIN, 1993 a,b).

The geophysiological dimension of microbial systems

The microbiologist learns by experiments on a very small scale. Clearly microbial physiology and molecular biology alone will not provide answers unless we extend our work into the field and set up field field experiments or at least laboratory models of the world around us capable of describing the conditions in large scale sections of the entire metabolic system of Earth. Work in the marine system directly and in the geochemical laboratories of lagoons and lagoonal environments is of high priority in order to understand the work of nature and man's role in it. Only on the basis of field studies, laboratory model systems, the understanding of each single microorganism occurring and acting in the marine system and model calculations and verifications of the microbial impact we will be able to extrapolate properly from the singled out microbial case study to the global processes. In the past these experiments were often based on physiology, but the instrumentarium is increasingly dominated by biochemical, biogeochemical and molecular genetic or molecular ecologic techniques. This complex narrative should consequently be closed by another historical remark: Physiology was started in the modern world by Friedrich II. of Hohenstaufen 800 years ago (see footnote).

The first physiological experiments reported in "modern" times stem from a great personality. This man was a political and army leader, law-maker, statesman, poet, scientist, an etiologist (his observations on the flight of birds have only been matched and over-ruled in this very century and his guidelines for breeding and cultivating animals are still precisely followed today (as those of DARWIN). In addition he loved life and art (and women). He is regarded as the creator of the poetic form of the sonet according to the most illustrious poets and scientists of the so-called Renaissance, namely DANTE and PETRARCA . His 800th birthday was celebrated 1994 - the year of this Symposium. He - FRIEDRICH II. von HOHENSTAUFEN, Caesar of the Roman Empire, King of both Sicilies and of Jerusalem - designed experiments on fish longevity, on the physiology of the human body and on the best way to get informations from the deep sea or how to breed and educate animals. Microbiology or geomicrobiology, however, were beyond the reach of his great mind.

The first microbiological laboratory experiments aiming at microbial ecology under field conditions and vice versa were developed by S. N. WINOGRADSKY and later VAN NIEL (BROCK, 1993; PALLERONI, 1993). Both scientists had great impact on the development of modern microbial field work. VERNADSKY (1929, 1930), in his textbooks on the biosphere and on the marine biogeochemistry was, however, the first to provide a global interpretation of geomicrobiological processes and their impact on general geochemical cycles and mass transfers. His idea of the expansion velocity of life is to be understood only in the context of the planetary turnover of materials and energies -from the atmosphere through the sea and its sediments into the huge reservoirs of sedimentary and metamorphic rocks-on a geological scale of masses and time. Two benchmarks in these developments were the books of KUZNETSOV on the role of microorganisms in the material cycles in lakes (KUZNETSOV, 1959) and on "Geological Microbiology" (KUZNETSOV, 1962). These works describe the organism-environment in a more global view than the terminologies of DE and ER.

Several years ago we chose subtropical lagoons and lagoonal environments as excellent field sites for geophysiological investigations (KRUMBEIN, 1971; KRUMBEIN & COHEN, 1974; KRUMBEIN, 1982). One such site is the Bardowil lagoon between Gaza and the Suez Canal, another one the Nile Delta itself with its large contributions of sediments, nutrients and chemical input from the African continent (TAHER, 1994). Such lagoons and sabkha environments were also studied in the Gulf of Aqaba (FRIEDMAN & KRUMBEIN, 1985). Natural and man-made laboratories of this kind were further found in the salt gardens of Lanzarote, Malta, the "Salins de Giraud" near Marseille, and in the northernmost salt gardens of the world in the region of Batz-Guérande in Bretagne. We further expanded these studies into silicoclastic microbial mat systems of the North Sea and model salt systems in the laboratory at a scale of 2x2 m and a water depth of only several centimeters.

The biogeochemical and geophysiological potential of such marginal coastal systems is apparent in their high biological productivity coupled with high sedimentation rates and high nutrient supply from continental biodegradation of rocks and/or pollution. More than 95% of the present-day calcium carbonate or potential limestone production is going on in sub-tropical to tropical lagoonal environments, while this productivity may be ultimtely deposited in deeper waters. These environments are characterized by a high adaptability of microorganisms and by extremely high organic productivities, which in turn by decay processes lead to enormous accumulations of biogenic minerals such as calcium carbonate, sulfides, phosphates, and iron minerals. Interestingly, past and present production and burial of calcium carbonate (limestone) is matched in a 5:1 ratio by the production and burial of organic carbon compounds (gas, petroleum, tar, coal, kerogen) -the energy sinks and reservoirs of terrestrial nature or terrestrial natural processes.

Intensive field studies, isolation of novel microorganisms, and laboratory and field experiments in such "Sabkha-Systems" and in the less intensively producing microbial mats of the North Sea enabled the analysis of certain key geophysiological and geochemical relations. We were able to show the potential of anoxygenic photosynthesis of cyanobacteria (KRUMBEIN & COHEN, 1974). We emonstrated microbial beachrock formation and degradation which is a general principle along all shores of the warmer seas (KRUMBEIN, 1979). The coexistance of high concentrations of oxygen with relatively excessive amounts of hydrogen sulfide within the multiply layered system of hypersaline microbial mats was shown (KRUMBEIN et al., 1979) and reportetd light penetration into such systems through salt directed light channeling of up to 7 cm (GERDES et al., 1985). Later methanogenesis in hypersaline systems was shown by us (GIANI et al., 1984) long before it was generally accepted that methanogenesis extends even into these systems which are usully under the influence of excessive sulfate concentrations. Finally the potential of aerobic nitrogen fixation in coastal microbial mat systems by non-heterocystous filamentous cyanobacteria (*Oscillatoria limosa)* and the potential of the same organism and others for fermentative pathways under exclusion of oxygen in anoxic conditions in the microbial mats was demonstrated (STAL & KRUMBEIN, 1981; HEYER & KRUMBEIN, 1991). The environmental impact of these processes must be called global in geological space and time scales.

The conclusion of the long debate on calcification in microbial mats is that practically all layered (laminated) and oolithic or oncolithic carbonate rocks in Earth’s history were generated in lagoonal microbial mat systems. The biogeochemistry of lagoons, however, also includes the potential formation of large deposits of iron and other metal sulfides, iron oxide deposits, and of the biggest phosphate deposits of the world (KRUMBEIN, 1974, KRUMBEIN, 1979, KRUMBEIN et al., 1977, GERDES & KRUMBEIN, 1987, DAHANAYAKE et al., 1985, DAHANAYAKE & KRUMBEIN, 1985, DAHANAYAKE & KRUMBEIN, (1986).

Carbon dioxide, water, oxygen and hydrogen, calcium and sulfate, phosphate, dinitrogen, iron, and more or less large amounts of accessory elements are gradually incorporated into organic matter and metal sulfides as ideal reservoirs of energy and electrons, while the sulfides, phosphates, and partially also nitrogen-rich compounds serve as nutrient reservoirs for the ever-growing biological presence on this planet.

The physiological reactions and biochemical pathways of oxygenated and anoxic systems are very similiar, and the co-existence of respiratory and fermentative pathways can clearly be demonstrated in aquatic and terrestrial microbial mat systems. Every electron acceptor for respiratory chains has been shown to exist in such sediments; all fermentative processes, including the inorganic fermentation or disproportioning of thiosulfate have recently been demonstrated (Jorgensen, 1990). The same inorganic fermentation processes may also be found in the future for the disproportioning of iron salts, such as Fe_2O_3 into FeS and Fe_3O_4.

Microbial mats and biofilms played an important role in Earth's history through stromatolite and biolaminite formation and continue to play this role in regulating the composition and oxidation status of the most important elements of the atmosphere (oxygen, nitrogen, carbon dioxide, methane, and many other trace compounds). The following also hint at the enormous importance of biofilms and microbial mats: the transformation of the most important elements of the hydrosphere (water itself being split and fused biologically in enormous amounts); the oxidation and reduction of carbon, iron, sulfur, nitrogen; the precipitation of calcium and potassium in the form of more or less soluble salts; and the oxidation and reduction status of the most important elements of the Earth's crust (reduced sulfides, oxidized carbonates of calcium and of iron, siliceous compounds, etc.) Furthermore, microbial mats serve as attractors and filters for polluting and poisonous man-made substances. They represent sensitive biological membranes or geomembranes. Their highly complex structure serves as a sorption and organisation site for many processes and compounds on a global scale. Therefore it seems legitimate to state that biofilms or microbial mats are sub-systems of global change and global structuration, which cannot be underestimated compared with eukaryotic control systems. The views of the microbiologists and "botanical" or "zoological" physiologists therefore must be combined into a single, global geophysiological approach.

Fractal physics and biogeomorphogenetic principles with respect to organism-environment relations

In the past, the biogeochemical and parahistological potential of microbial mat systems was very difficult to analyze because descriptors for their sorptive and structural potential were lacking. Viscosity, porosity, pore volumina, and adhesional factors were practically impossible to define in these highly structured, porous, "mesoscopic" systems. They cannot be described by a characteristic dominant length, but exhibit structuredness on all scales. Neither is it possible to describe such objects by the geometry of a classical, differentiated mathematical approach, nor will it be possible to explain their genesis and dynamics in the frame of traditional linear, reversible physics. The usually successful approaches - absolutely structurally organized or totally amorphous - are not applicable; a quantum mechanistic, exact consideration is as useless as a thermodynamic-mechanical one in every-day scales.

These biogeochemically operating, highly structured microbial mat systems, however, are amenable to so-called fractal-calculus, by which a defined mathematical description and classification of highly structured objects seems possible. In connection with the modern approaches to the characterization of topological and compositional disorder, fractal-calculus may enable a precise geometrical analysis of such complex systems as microbial mats and the highly porous sedimentary rocks derived from them .

The recognition of fundamental morphogenetic principles in the framework of the physics of non-linear dynamic systems and self-propelled irreversible processes may help us to understand the complex biogeochemical reactions of such systems as well. We have the potential to calculate and model complex bacterial colonies and even more complex biofilms and microbial mats. These morphogenetic approaches will eventually enable us to better understand and analyze the apparently non-thermodynamic biogeochemical processes in such systems (KRUMBEIN & SCHELLNHUBER, 1990). All these phenomena (e.g., marine snow, fecal pellets, microbial mats in shallow water systems and especially in confined lagoon environments) require further elaboration and modeling. This is especially important, because biofilms and microbial mats apparently represent the "factories" for the biogeochemical turnover of the most important compounds of the atmosphere, hydrosphere, and lithosphere.

The following questions may sooner or later be modeled and solved by the application of fractal-calculus and dynamic systems physics to microbial mats in lagoon environments and elsewhere:

- transport, filter capacity
- origin, structure, and diagenesis of microbial mats
- mat geometry and dynamics
- biogenic accumulation of metals and their agglomerations in the water column
- interaction of microorganisms with macromolecules and solid surfaces
- expansion and distribution of pollutants
- natural distribution and fixation of energy and matter in bioactive sediments
- natural global balances between sediment, water column, and underlying sedimentary systems
- experimental build-ups and models for the incorporation of life processes of benthic organisms into the physics and chemistry of benthic systems
- Initiation of plate tectonics by fractionation of reduced (coal, oil, kerogen) and oxidized carbon compounds (limestone, dolomite, marble)
- Biocorrosion and biodegradation of rock and mountains by biofilms and microbial mats

The immediate problems and questions regarding the impact of microbial life on the marine and terrestrial environments, however, relate to some basic questions of microbiology itself. These questions are multiple and require more careful analysis:

- Is the wax and wane of microbial mats energy- and nutrient-dependent?

- How do viruses and phages interact with structured microbial mats and their biogeochemistry?
- How can we precisely model nutrient and light relations in phototrophic microbial mats?
- How does lateral transport in such complex systems interfer with vertical transport?
- How is the transport itself organized? Macroorganisms and burrowing? Microbes? Diffusion ?
- How are the diffusional processes of oxygen and other compounds related to the physiological activity of microbial mats?
- Does the exchange rate in microbial mats depend on grazing and burrowing animals, and to what extent?

Many of these points are not satisfactorily settled and it may take some time before we can derive accurate global geophysiological models from the case studies of lagoon microbial mat systems and their biogeochemistry.

Climatic relations and conclusions

The comparative biogeochemistry of aquatic and terrestrial as well as tropical and temperate microbial mats can help us to understand ongoing processes in different parts or organs of the whole body of Earth. This includes the view that on the organisational level of biofilms the reactive surface between atmosphere and biofilms as well as between hydrosphere and biofilms is dominated by the interactive surface area soil/rock biofilm to atmosphere rather than hydrosphere/atmosphere. We are taught that 70% of the Earth's surface is covered by water. If we consider, however, that the space of exchange between microbiota and atmosphere is in the order of magnitude of $250\mu m^2$, then the fractal dimension will yield a reactive surface of soil and rock microflora of Earth with the atmosphere which is perhaps 1000 to 10 000 times higher than that of the oceanic surface with the atmosphere (KRUMBEIN, 1995). The features of energy-, gas- and nutrient-exchange of biofilms or the exchange through the parahistologically defined skin of Earth that clearly seem to increase or decrease from north to south or from 10 000 m depth in the ocean to 8000 m high above NN with respect to our present knowledge are e.g.:

1) availability and penetration depth of light,
2) concentration of important chemical species,
3) organic compound and calcium carbonate production and decomposition,
4) mineral, rock, and mountain formation and destruction (especially sulfides/oxides and phosphates),
5) gradients from oxic to anoxic and from oxigenic to anoxigenic,
6) nutrient turnover,
7) trapping capacity of microbial systems,
8) coupling of organic and inorganic geochemical cycles,
9) structuration and communication,
10) transport capacity and speed, and finally
11) horizontal and vertical mass transfer on the scale of biologically driven plate tectonics.

Many of these processes are triggered and controlled by temperature and climate in general, many of them by light or both, others by completely different factors, that we do not yet fully understand. The geomicrobiologist and geophysiologist, however, increasingly studies his topics under the assumption that even climate and its regulators (such as polar caps, orogenesis, biocorrosion and bioerosion, oceanic currents, etc.) are firmly controlled by living matter. The great physicist, aphorist, and sarcast LICHTENBERG gave expression of this approach in his "Sudelbücher" by saying:

"Hätte ich zu Värdohüs keinen Kirschkern in die See geworfen, so hätte der Tropfen Seewasser, den sich Mynheer am Kap von der Nase wischte, nicht genau an dem Ort gesessen."

"If I had not thrown the cherry-stone into the Sea at Värdohüs, the drop of sea-water which Mynheer at the Cape wiped from his nose would not have been situated exactly at this spot."

Between 1930 and 1990 it was generally deemed necessary to study the relations of animal and microbe communities among each other and with the surrounding physico-chemical environment using mainly "ecological" techniques within the frame of DE, ER, and GE.

New geophysiological and molecular techniques, in combination with the physics of dynamic systems are necessary to understand microbial and biophysical processes in the fractal dimension of marine sediments as well as in the continental parts of the geophysiological reactions. Geophysiology and parahistology hint at reactions that are not ruled by the laws of diffusion or by metabolic rates. The goal is to test field observations in laboratory models, in model calculations, and finally to extrapolate from these data the global biogeochemical processes assumed to control the dynamisation of global biogeochemical pathways. For example the geophysiological basis of the biogenic formation of sedimentary rocks and ore deposits and its bearing on life processes of later epochs has to be analysed. The biogenic accumulations of chemical compounds, which are often locked into the sedimentary rock crust for millions of years, must have a severe impact on the availability of energy, electron donors and acceptors, and nutrients for life processes; this will further affect the biological control of geologic, hydrologic, climatic, and last not least geomorphogenetic cycles which - in turn - will control the amount and transfer speed of biologically important geochemical cycles. In recent work, WACHENDÖRFER (1991) and KRUMBEIN (1993 a, b) have approached the complex relationship between living matter and the environment using the new term parahistology. It can further be demonstrated that the accumulation of sedimentary rock systems, their transportation through space and time, as well as their deterioration (biocorrosion, bioerosion, biodecomposition) leads to relationships between living matter and terrestrial environment via climate interlocking, this may even involve orogenetic processes and the vax and wane of such huge land masses as the Tibet Massif. All these processes must be included into the geophysiological dialogue between the parahistological living tissue of Earth and her sluggish or inert internal and/or external environment. Environment here includes outer space, sun energy input, and decreasing energy output of the Earth's interior. A calculation of all material losses and gains during Earth's history will make the comparison with a single organism even more plausible, inasmuch as losses of gases and gains of extraterrestrial dust are also biologically influenced (ANDERSON, 1984,

KRUMBEIN & SCHELLNHUBER, 1990, 1992; KRUMBEIN, 1993 a b; KRUMBEIN, 1995). Thus we have reasons to state that Earth really acts as an organsm, as it is fed by external sources of energy and matter and excretes its metabolic products into space as waste energy and waste material. In the context of geophysiology, episodic events or catastrophes as discussed by BOERO (1994 and this volume) may be regarded as a faster or slower breathing, faster or slower running, or even a jump of an animal.

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