



ENVIRONMENTAL HEALTH FOUNDATION

From Humic Substances in Academia To The Needs Of International Commerce

What Are YOU Going To Do With What YOU Have?

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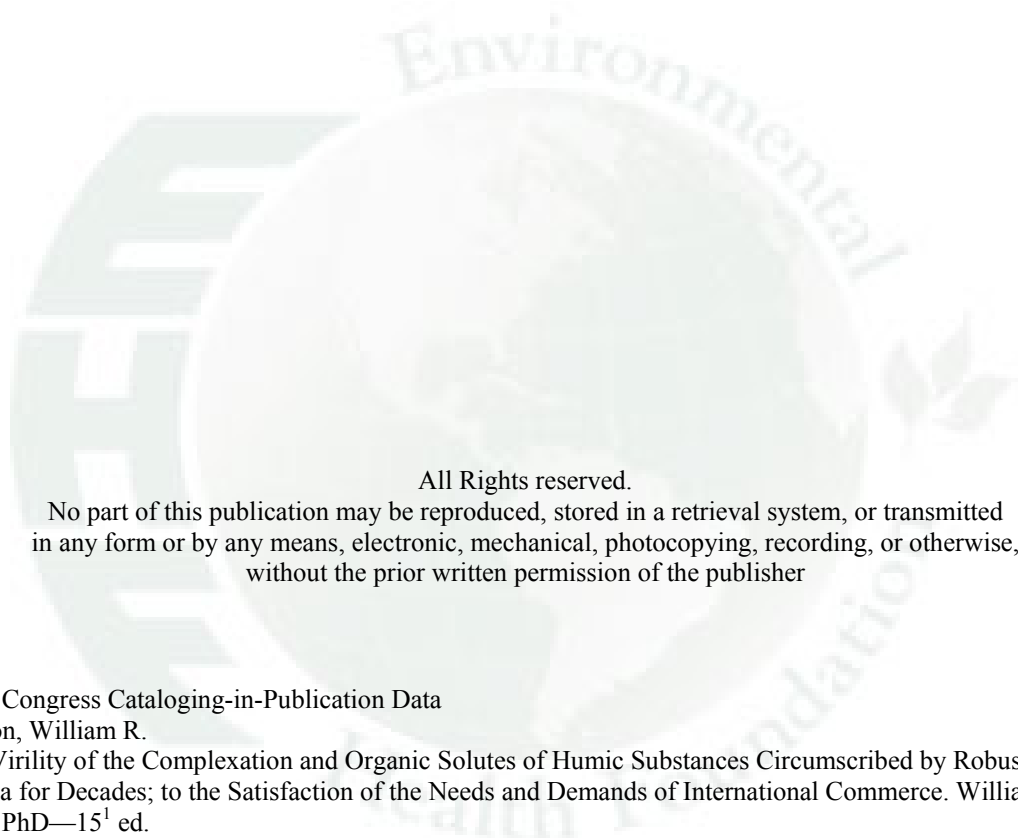
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From the Virility of the Complexation and Organic Solutes of Humic Substances Circumscribed by Robustious Academia for Decades; to the Satisfaction of the Needs and Demands of International Commerce

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Two fundamental precepts are presented herein which appear to be opposite ends of an axis.

First, consider the exactness of the discipline of chemistry; consider the many decades of intense re-research by some of the most outstanding scholars in the world; consider as evidence the vast accumulation of information that defines some of the attributes and characteristics of humic substances; consider the challenge that there are still facets of this subject, that are yet to be discovered; consider the expenditure of money, time, effort and reputation to further this inquiry; consider the following examples which constitute the first precept of this abstract ("Precept One"). The examples presented by Precept One are quotes from HS Seminar V (held March 21 through 23, 2001), identified by page number.

Page 25 "Heterocyclic compounds must be abandoned as major constituents of HSs, as ¹⁵N NMR shows that N occurs overwhelmingly as amide." "Breakdown comprises oxidation of the 3-C side-chain (most commonly at C-1), Demethylation of OME groups and depolymerization and cleavage of aromatic rings."

Page 26 "... the scanning transmission x-ray microscope at beamline X-1 A... allows combination of NEXAFS and imaging to investigate the spatial heterogeneity of NOM with high resolution (>30NM). ... the NEXAFS spectra of NOM have been interpreted only qualitatively and a quantitative approach is still missing."

Page 29 "... we have computed the minimum geometry of two 'representative' fulvic acid type structures using the PM3 semi-empirical quantum chemistry approximations. Where SYBYL and MM+ molecular mechanics give emphasis to aromatic stacking in these structures and, as an extension, a helical geometry for polymers, PM3 calculations give a more open quasi-hemispherical structure that resembles a half tennis ball."

Page 33 "This paper discusses the interrogation of Laurent Ian Fulvic Acid (LFA) by a series of NMR Techniques (1D Techniques; ¹³C Spectra with apt and inept, 2D Techniques TOSCY, HSQC, HSQCTOCSY, NOESY, ROESY, and Multinuclear ¹H, ¹³C, ¹⁴N, ¹⁵N, ¹⁹F, ³¹P)."

The functional aspects of this abstract's second precept present the antithesis of theories represented herein as Precept One. International commerce needs and demands a credible means for quantifying the pronouncements and theories of Precept One. The challenge posed by this abstract is to unite synergistically the profound theories exemplified by Precept One with the needs and demands of international commerce. This abstract proposes a discussion of several working models to affect pragmatic applications of the theories exemplified by Precept One.

PRECEPT ONE: Understand The Humic Substance Material And Learn To Communicate Its Merits.

CARBON AS STORED ENERGY¹

As many as 100,000 different kinds of molecules can be found in living cells. The death and decomposition of living cells transforms these molecules into many more kinds of molecules. Thus, many thousands of organic compounds are found in sedimentary deposits. This carbon build-up varies from year to year, but it is calculated that the annual, primary oceanic productivity would range from 1.5 to 12.6 x 10¹⁰; in other words, 1.25 trillion tons of carbon compounds are produced annually in the oceans alone.² In addition, approximately 750 billion tons of atmospheric carbon dioxide are produced. The airborne carbon dioxide is circulated both vertically and horizontally by winds.³

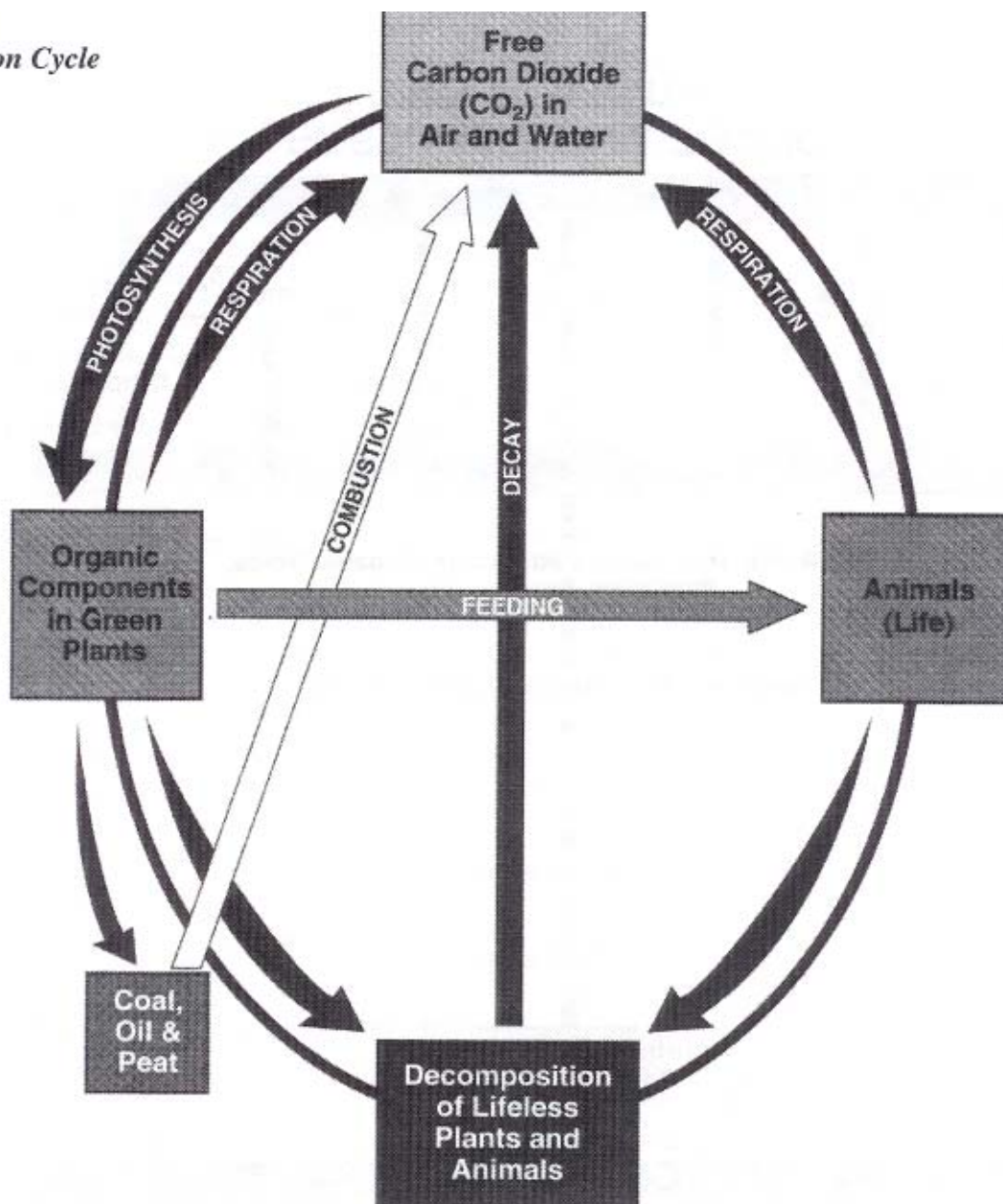
About 18% of the carbon in sedimentary rocks is of organic origin, and the balance of 82% is made up of inorganic carbonate carbon.⁴ Most of this carbon has been consumed through biochemical and geochemical processes and converted to carbon dioxide. Only a small percentage is preserved to form geochemical fossils.

The unique molecular structure of carbon allows it to combine with other elements to form an enormous number of organic compounds. Carbon ranges in form from carbon dioxide as a gas; to carbon in the solid form of peats, Leonardites, lignites, coals, shales and bitumens; to its perfect crystalline state as a diamond. It also includes inorganic compounds such as limestone and baking soda (sodium bicarbonate), for example.

The complex carbon cycle on spaceship earth circulates carbon between living organisms and the non-living surroundings. Various scientific investigations have outlined different schemes for this carbon cycle. Bolin et al. diagramed a comprehensive outline of this scheme, and Figure A is a simplified explanation modified from Collier's Encyclopedia.^{5,6}

The carbon "power pack" is joined to the element hydrogen and is an essential component of the basic compounds that make up plant and animal cells. For humans, for example, carbon makes up approximately 18% of body weight. This measurement is more difficult to calculate for plant life, but it is estimated that green plants absorb about 220 billion tons of carbon dioxide annually.

Figure A
The Carbon Cycle



THE MAJOR PROCESSES OF THE CARBON CYCLE

The process of photosynthesis is one of spaceship earth's universal phenomena. It is carried out on land and within the marine environment by all those living organisms containing chlorophyll.

During the life cycle, all living organisms experience a certain period of growth and then all of them eventually die. The physical remains of the dead organisms then experience intense transformations brought about by a multitude of microorganisms. This is the genesis of humification, the breakdown of organic matter into humic material. While the microorganisms are involved in decay and disintegration, many compounds containing carbon are completely mineralized, releasing carbon dioxide to the atmosphere. This completes the carbon dioxide cycle.

Figure B
Humification

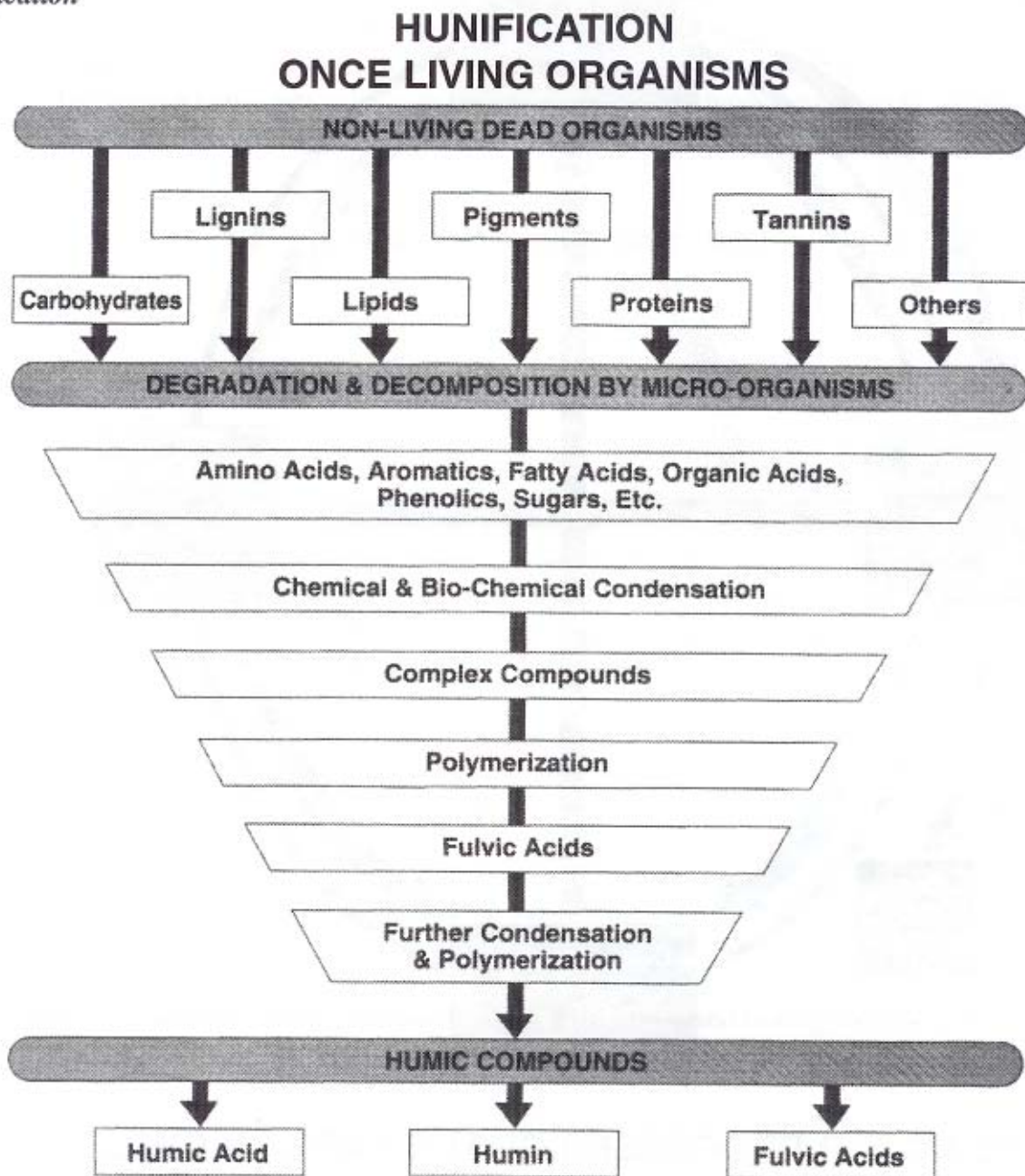


Figure B illustrates the progression of the humification process. Because some carbonaceous compounds are relatively resistant to the disintegrating activity of microorganisms, one should not assume that all compounds containing carbon are mineralized completely nor instantaneously. The process includes a series of reactions caused by enzymes, which are initiated by a variety of microorganisms. In some cases, this action causes the complex polymers of carbohydrates, proteins, lipids, lignins, tannin, polyphenols, and includes a complex accumulation of aliphatic and aromatic matter (that is, matter with special chemical properties), blended together in a way that does not cause the loss of its original individuality or identity. The reactions of polymerization and polycondensation develop larger and more condensed molecules. As the process of humification takes place, the newly combined molecules resist degradation and breakdown by microorganisms. Humic compounds do experience a high degree of stability; however, there remains that percentage

which continues to change slowly over time. These "lay-away" modifications are affected by several environmental factors, including:

1. The nature of the original mineral makeup;
2. The origin, nature, and source of the organic substances;
3. The population of microorganisms;
4. Variations of oxygen content;
5. pH conditions;
6. Thermal history;
7. Pressure from overburden weight;
8. Soil salinity;
9. Humic compound compaction; and
10. Overall water availability.⁷

Each of these factors plays an important role in bringing about the lay-away modifications of humic compounds. These transformations over time may be minor in some situations, while very profound in other cases. The continued changes over time may be defined in several general categories:

1. Diagenesis
2. Catagenesis
3. Metagenesis

DIAGENESIS

Diagenesis is the stage of change over time that represents the less advanced development of sedimentary organic matter and involves low-temperature transformation of organic compounds. This activity typically takes place in low-temperature waters, soils, and relatively deeply buried sediments. During diagenesis, it is primarily biochemical reactions that consume and produce organic compounds. This stage is divided into early diagenesis, when organic matter loses mainly nitrogen, and long-term diagenesis, when organic matter loses mainly oxygen. The diagenesis of organic substances yields many different materials. Peat, Leonardite, lignites, bituminous coals, and anthracite are terrestrial products of the transformation of organic matter deposited under semi-aerobic conditions.

Diagenesis takes place over a period of many million years. In early diagenesis, the vigorous transformation instigated by microorganisms functions most actively in the upper layers of sediment and declines gradually relative to depth. On the other hand, chemical reactions, occurring slowly when compared to the microbial activity, continue from early diagenesis through late diagenesis.

With further development, these complexes result in the formation of complex organic matter known as fulvic acid, which has been determined to be a low-molecular-weight humic material. Fulvic acid, depending upon its molecular make-up, may or may not be water-soluble. It is always soluble in acids.⁸ Humic acid, on the other hand, does not dissolve in water or acid, but it does dissolve in base or alkaline solutions.

Humic and fulvic acids are the major substances produced during the early diagenesis of organic matter.

There are basic differences between fulvic acid and humic acid. Fulvic acids are made up of low-molecular-weight polymeric compounds. Humic acids contain high-molecular-weight polyacids. Fulvic acids may be an intermediate product between plankton matter and humic acids.

If the oxygen supply is depleted, anaerobes become vigorously involved. Under these conditions, nitrates, phosphates, and sulfates become the principal and terminal acceptors of the electrons generated in the degradation of organic matter.⁹ Methane is the most important byproduct of anaerobic bacterial activity.

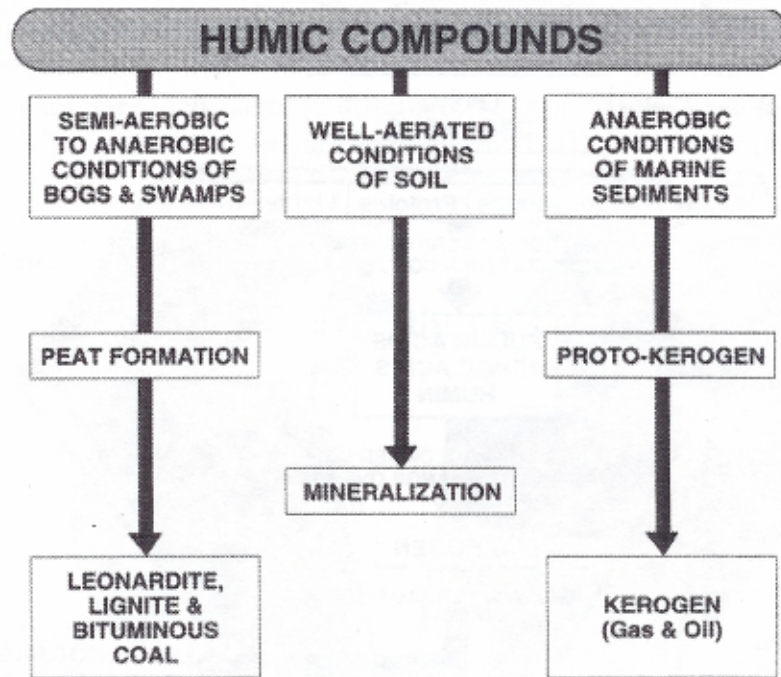
The results of several investigations suggest that anaerobic degradation retards the process of humification.¹⁰ The carbon content of humic acids developed under sustained anaerobic conditions is generally low and quite similar to the composition of fulvic acids extracted from marine sediments of normal environments. Humic substances collected from anoxic marine sediments consist of more low-molecular-weight fulvic acids than high-molecular-weight humic acids.¹¹ Humic acids are the most abundant form of extractable organic matter in reducing sediments, while fulvic acids are more common in oxidizing environments.¹²

Oxidative circumstances favor the speedy mineralization of organic matter without much preservation. For example, in well-aerated soils, approximately 80 to 90% of the deposited organic material can easily be lost. In marshy and swampy areas with heavy vegetation, the heavy accumulation of organic matter encourages the development of semi-aerobic and acidic conditions.

If the rate of build-up of organic material exceeds the rate of microbial decay, semihumified and semidecayed peat beds develop. Following this stage, with further change over a prolonged time involving proper time-temperature conditions, these peat beds begin to change to leonardites, lignites, and various forms of coal.

An overview of the transformation order of successions is illustrated in Figure C. Because of the inclusion of diversified plant types, some coalification products are rich in lignin, some in tannins, some in resins, as well as other various combinations of compounds.

Figure C
Humic Compounds



CATAGENESIS

The transformations of diagenesis, characterized by their low temperature conditions and low to moderate overburden compression, are gradually replaced by a new phase of transformations called catagenesis. This middle stage of development of sedimentary organic matter involves thermal transformation of organic compounds that occurs as a result of increasing geothermal temperatures in sediments buried more deeply.

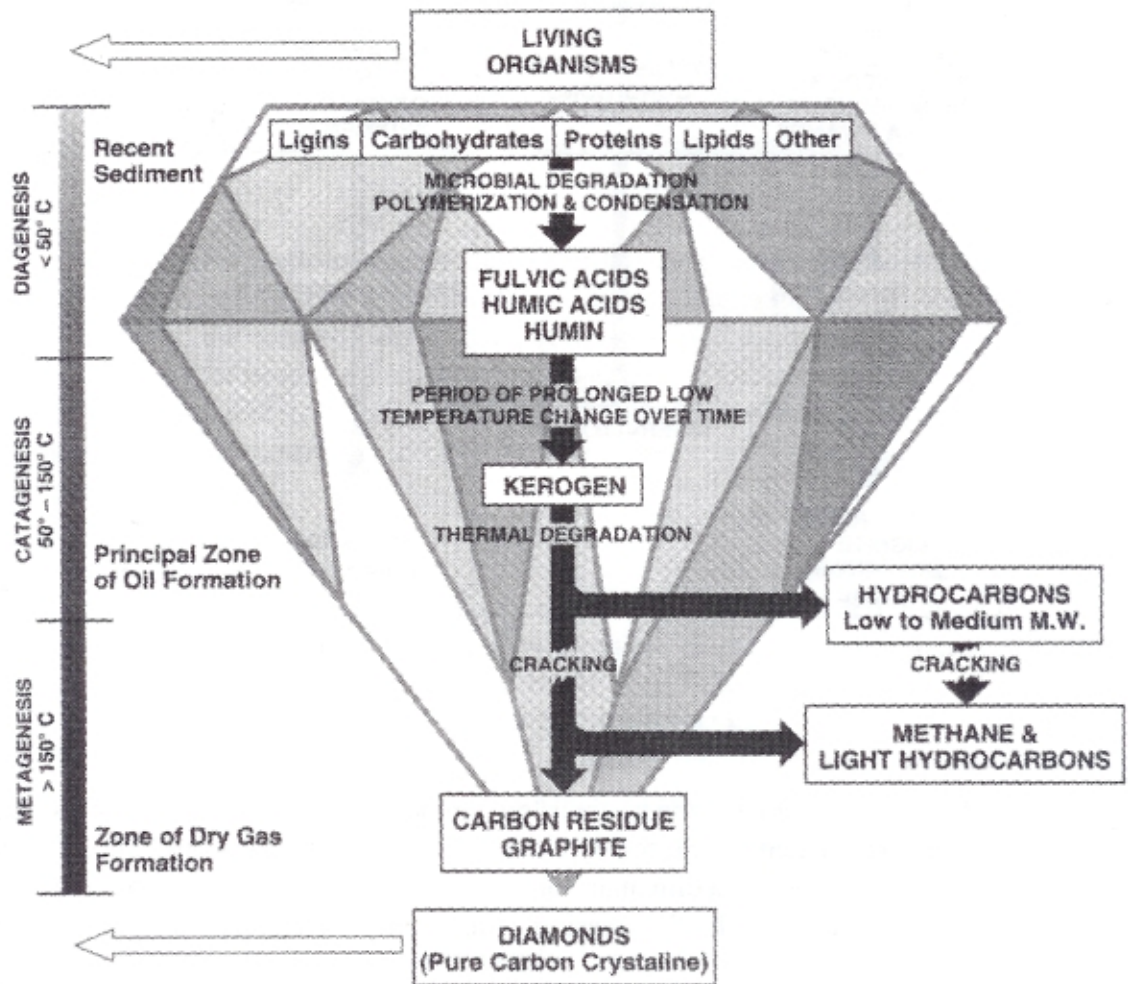
METAGENESIS

With increasing depth of burial and geothermal heat rising to 150° C to 300° C, the high temperatures and pressures cause rocks and their interred organic matter to undergo additional physiochemical transformation. Upon the completion of the principal stage of oil formation completion, the rock strata first become dehydrated then crystalline. At this point, the strata no longer produce hydrocarbons. Thus, the liquid hydrocarbons previously generated go through extensive "cracking" of the carbon-carbon bonds occurring during metagenesis. The primary result is the conversion to dry gas or methane. As a result of the prolonged release of hydrocarbons, the residual organic matter becomes depleted of hydrogen.

Progressing to the extreme of metagenesis, the process produces diamonds further down in the terrestrial depths. Here the pressure and the temperature are extremely high. Over a period of time, perhaps several hundred million years, organisms that once lived in surface waters become carbon residues following many geochemical transformations.¹³ Figure D indicates the progression.

Figure D
Transformations of Humic Compounds

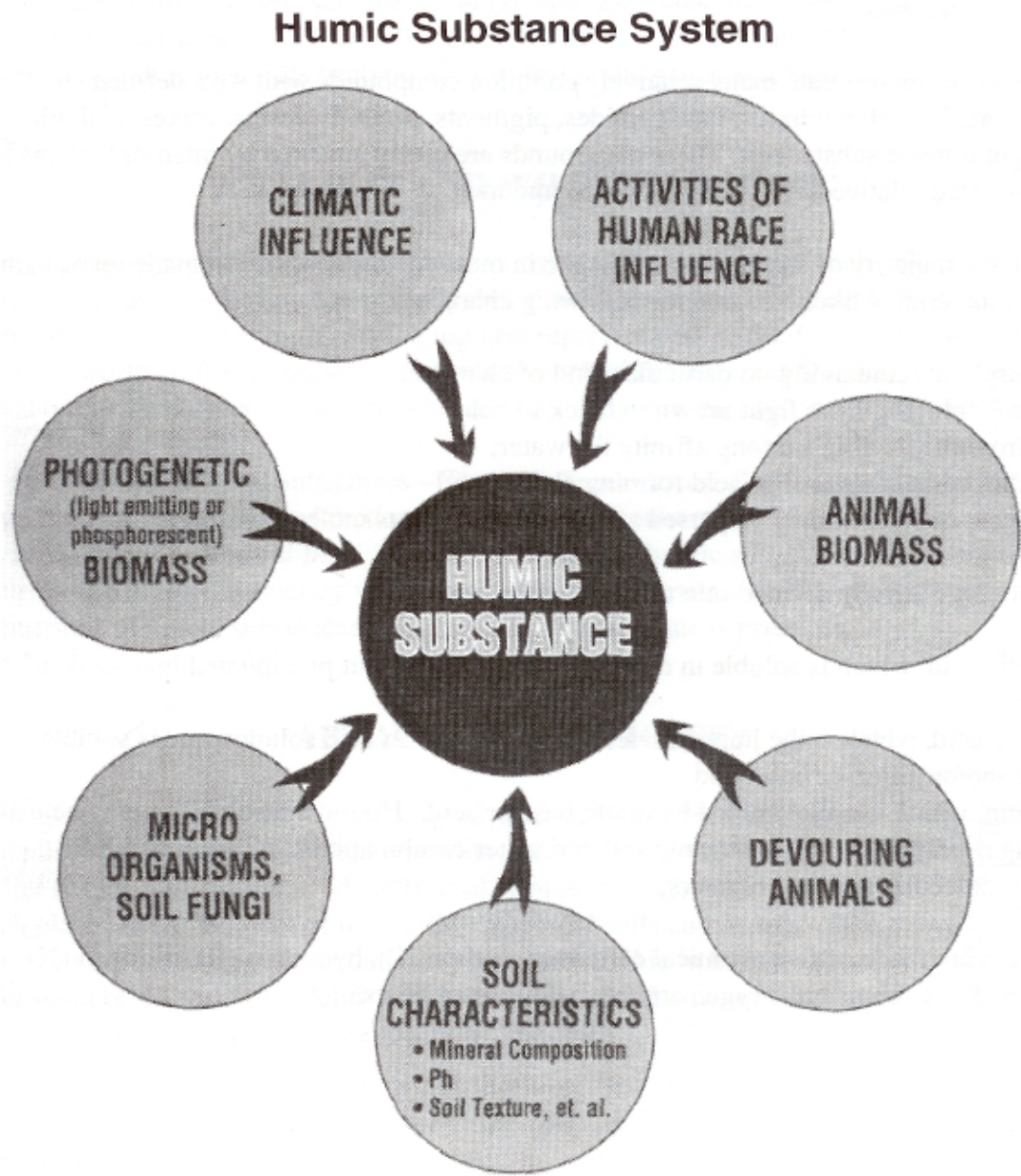
Transformations of Humic Compounds



HUMIC SUBSTANCE

Humic substance includes naturally occurring, biogenic, heterogeneous organic substances. These generally can be characterized as being yellow to black in color and of high molecular weight, while having refractory characteristics. Different authors may generalize these terms somewhat, although the content of their work expresses their intent or difference of opinion relative to these definitions more specifically. Figure E illustrates the dominant developmental factors in the humic substance system.

Figure E
Humic Substance System



DOMINANT DEVELOPMENT FACTORS IN THE HUMIC SUBSTANCE SYSTEM

Let's review some material already presented: Organic substance in soil, peats, leonardite, and water is made up of a mixture of plant and animal remains in various degrees of decomposition. Also involved are various substances created biologically or synthesized chemically from a combination of breakdown products and microorganisms, small animals, and their decomposing materials. This combination of organic substances is divisible into two categories:

- 1, Nonhumic substances; and
2. Humic substances

Nonhumic substances incorporate many relatively common compounds with well-defined structures including amino acids, carbohydrates, fats, peptides, pigments, proteins, resins, waxes, and other lowmolecular-weight organic substances. These compounds are easily attacked by microorganisms in the soil and are converted relatively quickly to other compounds.

By comparison, the majority of the organic substance in most soils and waters is made up of humic substance. This material is likely to have the following characteristics:

1. Amorphous, containing no particular kind of character;
2. Usually ranging from light brown to black in color;
3. Hydrophilic, having a strong affinity for water;
4. Acidic, containing acid or acid forming ability; and
5. Polydispersed or widely dispersed substances of various molecular weights.

Humic substances are usually divided into three general groups:

1. Humic acid, which is soluble in dilute alkaline solution but precipitated in a weak acid solution;
2. Fulvic acid, which is the humic material that remains in acid solution and is soluble in both acid and/or water, or base; and
3. Humin, which is not extracted by dilute base or acid. Humin's insolubility may be caused by being rigidly fixed within organic soil and water combinations. It is composed of high-molecular weight polymers.

Humic substances are made of five chemical elements: carbon (C), hydrogen (H), nitrogen (N), oxygen (O), and sulphur (S). Carbon and oxygen are the major components.

PRECEPT TWO: Humic substance, "What will it do?" "What is it worth?" and "How will you be involved?"

On the back cover of the book, Humic Substances: Structures, Models and Functions, edited by E.A. Ghabbour and G. Davis 2001, we find this summarizing statement: "Humic substances, the remarkable brown biomaterials in animals, coals, plant sediments, soils and waters, are crucial components of the carbon cycle and other life processes. Thus, greater knowledge and understanding of these versatile materials is of great importance to the productivity, health and safety of the world's ecosystem, humans, land and water."

We agree wholeheartedly with this statement and go on to ask, what are some of the specific uses of these various humic substances; "What will it do?" "What is it worth?" and "Are you interested in helping these outstanding materials become more useful to the general public?"

WHAT IS IT AND WHAT WILL IT DO?

On the cover of this paper you will find two boxes or grids. The left side of each grid is numbered one through ten and pertains to the functions briefly described in each part of the grid. Across the top of each grid are ten divisions, A through J. The top grid represents people and suggests some of the monetary values or "worth" different societies attribute to each of the different function, or careers of these people based on the public's value-view of what they do. This is used as a comparison for the lower grid.

The lower grid, labeled "Humic Substances – *The Pure Supermixture*," (a term coined by Dr. Patrick MacCarthy), includes 100 possible functions, attributes and connections associated with various humic substances as described in this publication. What will various humic substances do (or not do)?– i.e., what is their "worth?" Here, monetary values cannot be readily assigned. The authors' assertion is that, since the functions of humic substances seem countless, their value is priceless.

ABSOLUTE SPECIFICITY?

1-A All humic substance is not "created equally," at least it does not represent constant identical duplication. As indicated earlier, humic substances are made up of animal matter (which animals, from where?), coal (which stages?), plant sediments (from which plants and which part of this earth?) and local soils and waters. Thus we find no extended continuity of a chemical system identifiable in humic sub-stances. We observe no absolute fidelity of a framework of selfsameness or duplication within this humic material from one location to another.

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THE CARBON CYCLE AND LIFE

1-B Organic matter is the remainder or residue of formerly living plant and animal life; however, most of it is plant material. In the case of land plant materials, favor-able climatic and weathering conditions along with the action of numerous strains of soil-borne microorganisms or bacteria cause rot or decomposition.

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1-C Water plays a dominant role in the cycle of life. The oceans of spaceship earth are a perfect habitat for many living organisms. Subject to the various conditions present in the water of the sediment, the amount of organic carbon preserved may range from as low as 0.1% to as much as 4% or more.

1-D On spaceship earth, the accumulation of organic matter may be affected by: (a) moisture, (b) temperature, (c) pH, (d) aeration, (e) microbial activity and (f) chemical reactions.

1-E Organic compounds may be involved in the weathering of rocks, degradation of various minerals, the processing of soil, and the formation of metal ores.

1-F Amino acids may have been combined randomly giving rise to proteins. Catalytic reactions were responsible for the generation of new and additional compounds.

1-G It is possible that these new compounds may have provided a structural base for the development of energy sorting compounds, including DNA, RNA, and ATP.

1-H DNA (deoxyribonucleic acid), the nucleic acid found in the nucleus of cells, is responsible for transmitting hereditary characteristics and for building proteins. All of the enzymes that catalyze biochemical reactions are proteins. The DNA thus contains the blueprint specifications for all of the biochemistry and structure of a cell.

1-I RNA (ribonucleic acid) is a nucleic acid found in the cytoplasm of all living cells. RNA often functions by carrying the genetic code from the nucleus of the cell to the cytoplasm where most cellular functions take place. RNA in some way affects the linking of amino acids into protein molecules.

1-J ATP (adenosine tri-phosphate) serves as a source of ENERGY for physiological reactions. ATP is a major carrier of phosphate and electrical energy in general biological systems.

2-A Organic (pertaining to or derived from living organisms) matter includes all compounds of carbon other than the inorganic carbonates.

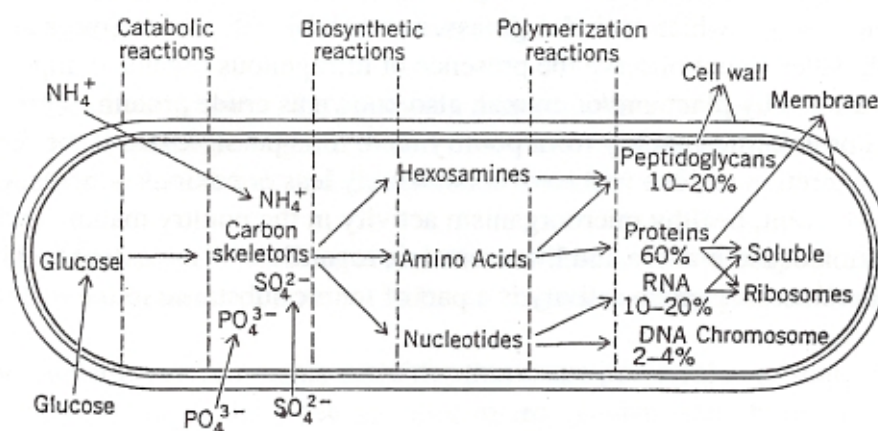
HUMIFICATION

2-B Only those microorganisms capable of (a) utilizing, (b) transforming, and (c) producing phenols are directly responsible for the synthesis or manufacturing of humus, as concluded by researcher F.J. Stevenson.¹⁴



2-C Authors Varadachari and Gohsh of Calcutta University, India, proposed that lignins and carbohydrates, the chief sources of carbon for the microorganisms, are first broken down by extracellular enzymes into smaller units.¹⁵ Thus the more soluble units are absorbed into the microbial cell. These together with oxidizing enzymes are exchanged into the environment where they are polymerized by a free radical mechanism.

2-D Mechanical depiction of a biochemistry schematic:
Generalized Flow Diagram for the Synthesis of the Bacterial Cell Components.¹⁶



Generalized Flow Diagram for the Synthesis of the Bacterial Cell Components
J. Mendelsohn and R. McQuinn. Biochemistry of Bacterial Growth. John Wiley, 1975.

2-E Of what is a bacterial cell composed?

Component

Component		Total Cell Weight
* Water (H ₂ O)	approximately	70%
* Protein	over 3,000 different protein molecules	15%
* DNA (Deoxyribonucleic Acid)	one or two kinds	1% ^c
* RNA (Ribonucleic Acid)	some 1,000 different molecular species	6%
* Carbohydrates	perhaps 50 different kinds (glucose plus)	3%
* Lipids	approximately 50 different kinds	2%
* Building Blocks or Molecules of Intermediary Metabolism	500 different kinds	2%
* Inorganic Ions	approximately 12 kinds (trace minerals)	1%
		100%

2-F Observe the functions of 2-D and 2-E and consider the suggested design. In an example of animal and poultry manure, even after remediation, the toxic amounts of nitrogen and phosphorus, have actually made available more usable nitrogen and phosphorus for the soil in usable form.¹⁷

2-G Microorganism activity in one acre of soil expends about the same amount of energy in soil preparation, as 10,000 people would burn for the same work, for the same period of time.¹⁸

POULTRY DIGEST

2-H Example of Humic Substance in the making: Poultry manure and litter include a load of matter determined by the volatile solids relative to the bird's unburned feed. An analysis shows that these volatile solids include cellulose, cell wall plant material, and a complex group of gummy polysaccharides partially digested, somewhere between sugar and more cellulose. Complicate this conglomeration further with lignin, a cellulose that takes on a "woody tissue" characteristic, pasted with a collection of lipid residue, which includes greasy, non-soluble fats and triglycerides that are not always compatible with water. Next observe the presence of nitrogenous organic compounds of highmolecular-weight synthesized by plant and/or animal, also known as crude protein. This represents the remainder – the unused or unburned energy from poultry feed. It is possible that if the feed is more efficiently burned, this excretion residue will have considerably less obnoxious odor, as well as a better feed conversion.¹ In any event, healthy microorganism activity in the poultry manure and litter can accelerate the humification of the manure and litter remains, regardless of the extent to which the poultry feed is digested. That microorganism activity is a part of humic substance in the making.

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FDA ANIMAL DIVISION

2-I Promoting animal health by including enzymes in their feed can enhance enzymatic action in their manure and thus, in any soil to which the manure (once it is composted) is added. Such enzymatic action in the soil further develops healthy microbial life in the soil. Any enzymes added to animal feed must be designed and chosen to match the ingredients in the diet. HOW does this benefit odor reduction? Anaerobic fermentative decomposition (the burning of feed or "fuel within the furnace") of an animal's diet may involve beneficial and balanced enzymolysis fermentation, or on the other hand it may use an incomplete or negative system of enzymolysis fermentation referred to as putrefaction.²⁰

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2-J The incomplete system of fermentation, or putrefaction, leaves more complex compounds less broken down and thus less usable. The putrefaction process produces ammonia, hydrogen sulfide, mercaptan, indole, and other partially reduced but negative substances. This production of negative enzyme-suppressive substances occurs through secondary metabolism while releasing odoriferous gases and heat. This incomplete system of putrefaction is also responsible for the production of inorganic substances and may to some degree include a compatibility toward pathogens.²⁰

3-A The balanced and specifically designed enzymolysis fermentation incorporated into the CI products, involves the production or liberation of more available amino acids, alcohols, sugars, organic acids and esters, while assisting in the solubilization of inorganic nutrients. This process may also have a positive effect on the production of Competitive Inhibitors, vitamins, hormones and various biogenic substances through secondary metabolism.²⁰

MICROBIAL ACTION

3-B Some microorganisms like a more specific selection of organic compounds, and others have the ability to find a source of energy and food value for their metabolic survival from a large menu of carbon compounds.



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3-C Through humification, complex polymers are disintegrated into simpler segments. Then the microorganisms remanufacture or recombine those simple segments or units into altogether different sequences, thus forming a complete series of new and different complex polymers and eventually forming humic molecules.

3-D Under favorable circumstances, the following four categories of microorganisms are present in very large numbers. For example, one gram of soil (one cubic centimeter) may contain 300,000 algae, four billion bacteria, one million fungi, and 20 million actinomycetes.²¹

3-E All of the above microorganisms are of significant value in the decomposition of organic materials. This process releases elements of nutrient value and captures nitrogen from the atmosphere.

3-F Soil microorganisms perform many activities that make powerful contributions to our ecosystem. The fertility level of the soil depends so heavily upon microorganism activity that if they were to fail, life for higher plants and animals would cease.

3-G Soil microorganisms are so versatile in their diet that they can actually attack and decompose almost any complex matter. In this process, they transform carbon into new protoplasm and thereby create the energy required for their metabolic functions.

3-H In spite of the high degree of complexity and diversity found in organic compounds manufactured in the cell, all compounds, even the complex polymers, are disintegrated by the microbial population and their enzymes.

3-I Each enzyme is involved in a specific role, following particular steps in a well-defined process on a substrata backdrop or stage. These critical enzymes play a unique role in the biochemistry of organisms in the full range of life, from bacteria to humankind.

3-J Numerous soil bacteria are capable of producing an abundance of extracellular polysaccharides that perform many functions such as adhesion, protection against dehydration, ion exchange and selection, tolerance to metals, and recognition and immunization protection against predators.²²

4-A Soil bacteria may continue to manufacture high-molecular-weight humic-like substances intracellularly. These substances are then released in the soil after the microorganisms die and their cells have disintegrated. At that point, the high-molecular-weight compounds represent the first stages of their own humification, followed by extracellular microbial degradation to humic acids, fulvic acids, and finally to carbon dioxide and water.²³

4-B In addition to functioning as a reserve of energy, soil humic substances can form stable complexes with some metals and thus influence the availability of these complexes to plants and microorganisms.²⁴

4-C The basis of the nitrogen cycle involves the mineralization of nitrogen bound in organic molecules and then the immobilization of inorganic nitrogen by its transformation to organic compounds. Nitrogen functioning as a macronutrient has a powerful influence on the growth of microorganisms, plants, and eventually on animals.²⁵

SOIL DEVELOPMENT FOR PLANT GROWTH

4-D Except for a plant's invagination of nutrients by absorption, plants seldom can take up substances of high or low-molecular weight. Because the majority of soil organic matter consists of high-molecular-weight materials, the value of soil microorganisms becomes apparent. Soil microorganisms breakdown high-molecular-weight material, and thereby these biodegradable substances can better serve as a major food source for plants.

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4-E Soil microorganisms stimulate the rebuilding of the soil and often have been observed to do so at a more rapid rate than many other known methods such as crop rotation, mulching, and other soil treatments. Under favorable conditions of moisture, temperature, and the proper balance of soil microorganisms, the following influences can be observed:

4-F One: Faster and more thorough decomposition of crop residue and other organic materials.

4-G Two: Granulation of the soil, decreased crusting, and a decrease in massive clodding (as observed on some untreated soils) facilitating easier plowing, cleaner harvesting of root crops, and development of stronger and deeper plant root systems.

4-H Three: Increased crop quality and yield: (a) plants better able to withstand disease; (b) faster and greater germination percentages; (c) more evenly spaced stands of crop; (d) faster fruiting; and (e) notable improvement in flavor and texture of many fruits and vegetables.

4-I Four: Greater response in soils previously treated with fertilizers and then treated with additional cultured microorganisms, indicating better utilization of many soil compounds.

4-J Five: These effects have been observed to increase as the growing season progressed even though one might expect soil nutrients to decrease in availability.²⁶

LIVING CELLS & CHEMICAL COMPOSITION

5-A The living cells of all organisms are capable of manufacturing a variety of heterogeneous and highly complex compounds. This collection of individual compounds by living organisms is incredibly large. The chemical composition of both marine and terrestrial living matter is highly valuable and depends upon many possible factors.

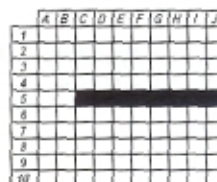


5-B Knowledge of the chemical composition of the biomass helps us understand the action of humification. Chemical humification in process.

1981: THE IHSS HUMIC & FULVIC STANDARD

5-C A COLLECTION OF STANDARD HUMIC SUBSTANCES ESTABLISHED IN 1981.

P. MacCarthy, Colorado School of Mines; R.L. Malcolm, U.S. Geological Survey; M.H.B. Hayes, University of Birmingham, U.K.; R.S. Swift, Lincoln College, N.Z.; M. Schnitzer, Agriculture Canada; and W.L. Campbell. U.S. Geological Survey.



5-D INTRODUCTION: The need to establish an international collection of standard humic and fulvic acids from a variety of environments, and the benefits that would result from such a collection, have been discussed in the past (1-4). The purpose of this paper is to report on the successful completion of this task by the International Humic Substances Society (IHSS) and to describe typical results relating to some of the ensuing materials. The samples consist of humic substances isolated from three solid earth materials (soil, peat, and leonardite) and from one stream. The suite of isolated humic substances is actually composed of two classes of materials: (1) Standard humic substances which have been isolated by a carefully defined isolation and "purification" procedure from specifically designated source materials; and (2) Reference humic substances, which refer to humic substances extracted from the above source materials by procedures other than the standard methodology, or to humic substances isolated from other source materials, in both cases under the supervision of the IHSS. In addition to the isolated humic and fulvic acids, large quantities of the three bulk solid samples from which the standard humic substances were extracted are included in the collection.

5-E MATERIALS AND METHODS: The three solid earth materials and the stream from which the standard humic substances were isolated are described as follows: (1) Soil from a mollic epipedon near Joliet, Illinois, U.S.A.; (2) peat obtained at Belle Glade Research Station, Everglades, Florida, U.S.A.; (3) leonardite from an oxidized coal seam at the Gascoyne Mine, Bowman County in southeastern North Dakota, U.S.A.; and (4) stream water from the Suwannee River, near Fargo, Georgia, U.S.A.

5-F Standard humic and fulvic acids were extracted from the soil, peat, and from the stream water. Standard humic acid only was obtained from the leonardite because of the very small amount of fulvic acid present. Reference humic substances were also extracted from some of these source materials in addition to their isolation from other substrates. The bulk solid materials were air-dried, and then sieved to remove pebbles and gross fibrous matter. They were then homogenized prior to removing samples for extraction, and the remainder was stored.

5-G Humic and fulvic acids from the bulk solid earth materials were extracted and "purified" by a multi-step procedure, based upon sodium hydroxide extraction, that was formulated by an international group of humic substances researchers. (It should not be construed that this procedure is being recommended or endorsed by the IHSS as the best method for extracting humic substances. It is simply the method which was chosen by the working group in 1981, on the basis of information that was then available, as being most suitable for these particular materials and for the specific purposes of this venture). The stream humic and fulvic acids were isolated by a procedure essentially the same as that described in reference (5).

5-H All extracted materials were freeze-dried in the hydrogen form and were then homogenized. The samples are being characterized by a variety of methods including: (1) Elemental analysis (C, H, O, N, P, S trace metals, and ash); (2) infrared spectroscopy; (3) Proton and Carbon-13 NMR spectroscopy; (4) functional group analysis; and (5) amino acid and carbohydrate content.

5-I LEONARDITE: Leonardite is produced by the natural oxidation of exposed lignite, a low-grade coal. The IHSS sample was obtained from the Gascoyne Mine in Bowman County North Dakota, U.S.A.

ELLIOTT SOIL: The Elliott soil is typical of the fertile prairie soils of the U.S. states of Indiana, Illinois, and Iowa. Our sample was obtained near Joliet, Illinois. Below is some of the text from the official soil series description. For more information see the USDA-NRCS soil series description. Elliott series.

PAHOKEE PEAT: The Pahokee peat is a typical agricultural peat soil of the Florida Everglades. Our sample was obtained from the University of Florida Belle Glade Research Station. The Pahokee series consists of very poorly drained soils that are 36 to 51 inches thick over limestone. Pahokee soils formed in organic deposits of freshwater marshes.

Characteristics of Soil and Leonardite Materials Used in the Preparation of HISS HA and FA Samples

	Elliott Soil	Pahokee Peat Soil	Leonardite
Moisture %	1.52	7.1	10.9
Ash %	na	15	13
C%	2.9	45.7	49.2
N%	0.25	3.13	0.90
H%	na	4.74	4.52

5-J RESULTS AND DISCUSSION: The existence of this collection of standard humic substances makes possible, for the first time, the critical comparison of the experimental results of humic substances researchers throughout the world. Samples of the standard and reference humic substances, and of the original solid earth materials, are available from the IHSS on a cost-reimbursable basis. Unique features of the collection are: (1) It is accessible to researchers worldwide; (2) all materials originated from carefully chosen and specified locations;

(3) all samples have been isolated by carefully controlled and supervised procedures that are fully documented; (4) all materials (both the isolated humic sub-stances and the bulk solids) have been thoroughly homogenized; and (5) availability of the three bulk solids allows the comparison of different extractive methods.

2001: A SUBSEQUENT POINT OF VIEW

6-A Patrick MacCarthy Department of Chemistry and Geochemistry, Colorado School of Mines, Golden, CO (excerpts from) THE PRINCIPLES OF HUMIC SUBSTANCES: AN INTRODUCTION TO THE FIRST PRINCIPLE.²⁷ The chemical nature of humic substances can be rationalized on the basis of the following statement, which will be referred to as the First Principle of humic substances. Humic substances comprise an extraordinarily complex, amorphous mixture of highly heterogeneous, chemically reactive yet refractory molecules, produced during early diagenesis in the decay of biomatter, and formed ubiquitously in the environment via processes involving chemical reaction of species randomly chosen from a pool of diverse molecules and through random chemical alteration of precursor molecules. This principle describes the fundamental molecular nature and origin of humic substances by addressing the questions: what are humic substances, and when, where, and how are they formed?

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6-B Corollary A. Humic substances are devoid of a regularly recurring, extended skeletal entity. Corollary A states that there is no long-range chemical order recognizable in humic substances, and that there is no identifiable backbone or skeletal structure that could be regarded as uniquely characteristic of these materials.

6-C Corollary B. Humic substances cannot be purified in the conventional meaning of purity. There is an overwhelming body of evidence from separation studies indicating that humic substances comprise an enormously complex mixture. **In** attempts to isolate pure humic substances, virtually every method of separation has been applied, ranging from classical methods such as fractional precipitation²⁸ to the more modern separation techniques including chromatography of all types, electrophoresis and field-flow fractionation. In all separation studies, the fractions obtained still consisted of very complex mixtures and no material has ever been isolated in significant amounts that could be described as a pure, or reasonably pure, humic substance. For example, as early as 1963 Dubach and Mehta²⁹ stated: "... in spite of intensive efforts involving most diverse methods, no discrete fractions have ever been isolated from humic substances." In 1985, Perdue³⁰ stated that "... humic substances are indisputably a highly complex mixture that has thus far been essentially unresolvable into significant amounts of pure components."

It appears that molecules in a humic system differ gradually from one another in their chemical and physical properties in a continuous manner, thereby accounting for the inability to separate these materials into pure components. For example, in 1964, Dubach et al.³¹ pointed out that the methods used to characterize the fractions... show rather a continuous variation," and in 1965 Felbeck³² stated that at the present time there has been no evidence presented to indicate that a definite fraction has ever been isolated from a humic substance.

Each fraction can be refractionated into subfractions by some other technique, and this can be repeated, apparently, ad infinitum." Swift, in 1985, stated that humic sub-stances consist of "a broad spectrum of related molecules, each one differing almost imperceptibly from the next in terms of one or other of its properties."³³ These many observations relating to the inability to separate humic substances into pure or reasonably pure fractions, with no reports to the contrary, testify to the highly complex and heterogeneous nature of humic substances.

6-D Dr. MacCarthy²⁷ explains Corollary B further: The combination of data from fractionation and structural investigations on humic substances indicates that these substances are, or approach, supermixtures in their complexity. It is thus clear why humic substances cannot be purified in the conventional meaning of purity, as stated in Corollary B. The wording in Corollary B could be replaced with the following: Humic substances comprise a supermixture. Considering humic substances as a supermixture focuses attention on their extreme multicomponent and structurally chaotic nature. With this view of humic substances it is possible to concentrate on the true nature of these materials during structural studies and while conducting experimental investigations on these materials. A humic sub-stance (that is, a sample free of nonhumic materials) may be considered "pure" in the context of humic substances; however, the meaning of purity in that context must be distinguished from the conventional chemical definition of the term. The supermixture character of humic substances imposes constraints on the qualitative and quantitative analysis of these materials that will be examined in more detail else-where.

6-E Corollary C. The essence of humic substances resides in the combination of their extreme molecular heterogeneity and pronounced chemical reactivity. Corollary C recognized those unique features that are essential to humic substances from both a chemical and an ecological point of view.

6-F Corollary D: Humic substances from different sources display a remarkable uniformity in their gross properties. Corollary D provides the basis for considering humic substances as a unique class of materials.

6-G Corollary E: It is not possible to write a molecular structure, or set of structures, that fully describes the connectivity within molecules of a humic substance. Corollary E addresses the nebulous nature of the molecular structure concept when applied to humic substances.

6-H There are recurring structural units in humic structures. However, numerous studies on higher molecular weight humic substances have failed to identify a regularly repeating structural unit or set of units that could be considered characteristic of these materials.²⁷ In 1989 Hayes et al. stated that, "there is no evidence for regularity in the structures of humic macromolecules."³⁴ According to Stevenson "... each fraction (humic acid, fulvic acid, etc.) came to be regarded as being made up of a series of molecules of different sizes, few having precisely the same structural configuration or array of reactive functional groups."³⁵ One of the more intriguing statements in this context dates back to 1963 when Dubach and Mehta speculated that "perhaps no two molecules of humic substances are exactly alike." There have been many similar statements in the intervening literature. For example, in 1976 Gjessing³⁶ commented that "every molecule of humus could be different" and in 1985 Stevenson stated that it "is probably safe to say that few, if any, humic molecules will be precisely the same."³⁷

6-I The term mixture does not adequately convey the enormity of the challenges posed by these systems and such extremely complex mixtures will be referred to herein as supermixtures. A supermixture is defined in conceptual terms as a mixture having a degree of complexity and heterogeneity equivalent to that of a large ensemble of molecules where no two molecules are identical, where the molecules are essentially devoid of a regularly recurring, extended skeletal entity and display a high degree of molecular diversity. A supermixture has both a high multiplicity and a high diversity, and it generally would be polydisperse.²⁷

6-J Dr. MacCarthy adds: The First Principle offers a simple rationale for what appear to be disparate and frustrating observations relating to the fractionation, structural nature and formation of humic substances. The inability to purify humic substances is a direct consequence of their intrinsic molecular heterogeneity, which in turn results from the molecular nonspecificity in the processes that generate these materials. Thus, it is not surprising in view of the First Principle that: (i) no unique molecular structure, discrete skeletal entity or repeating, extended molecular unit has been identified in humic substances, and (ii) no one has succeeded in purifying these materials. In fact, it becomes evident that the conventional concepts of purity and unique structures are foreign to humic substances. Not only do humic substances comprise an extraordinarily complex mixture of structurally randomized molecules as outlined in the First Principle, but such molecular heterogeneity, randomness and complexity, in combination with their chemical reactivity, in fact constitute the very essence of these materials. It is these features that distinguish humic substances from all other natural materials, as stated in Corollary C.²⁷

POWERFUL GROWING MEDIUM

7-A Christman and Gjessing commented that the ecological significance of the biological effects of humic substances become more meaningful when we consider the overall impact or influence of these humic materials on the productivity and fertility of soil and water ecosystems.³⁸ In addition to facilitating the dissolution of most otherwise insoluble metallic salts, humic substances are involved in a variety of reactions in soils, sediments, and water with major nutrients such as ammonia, nitrates, phosphates, and silicates.

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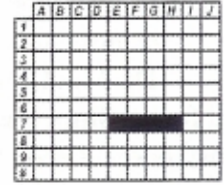
7-B Research indicates that these interactions not only considerably increase the retention and residence time of the nutrients in the growing media, but also enrich and biologically condition the growing media. This has a profound influence on the biological production process.

7-C When a growing medium is enriched with humic material, both direct and indirect effects can be observed on the growth of plants.^{39,40,41,42} Indirect effects result because humic materials act as suppliers and regulators of plant nutrients. The indirect processes are concerned mainly with modifications of physical and chemical components of the soil and generally take place outside the plant. The direct effects involve entry of the humic material through the plant roots, and the metabolic processes of the plant are affected.^{43,44}

7-D Generally speaking, the productivity or crop yield of soil enriched with humic materials increases. The high-molecular-weight humic materials, humic acids, alter the physical characteristics of the soil, while the low-molecular-weight humic substances, fulvic acids, are involved in chemical reactions in the soil that in turn influence plants' metabolic processes.

PHYSICAL CONDITIONS OF SOIL ENRICHED WITH HUMIC MATERIALS

7-E Desirable structure, texture, and looseness or friability and crumbliness, of particular importance in tight clay soils.



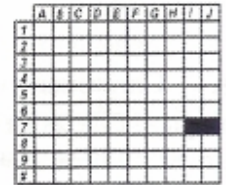
7-F Adequate drainage, suitable aeration, heat adsorption, and water holding capacity.

7-G Buffering properties (that is, the prevention of rapid changes in soil acidity and alkalinity, which is accomplished by the humic substance readily assisting the soil in accepting or donating free hydrogen ions).

7-H Openness for easy surface absorption of water, thus reducing surface water runoff and soil erosion, and soil water accumulation.

MECHANICAL CONDITIONS OF SOILS ENRICHED WITH FULVIC ACIDS

7-I A more favorable medium for plant root system development, which is especially important in the production of root crops.



7-J A desirable environment for beneficial microorganism development.

SOIL CHEMICAL ACTIVITY PROMOTED BY HUMIC AND FULVIC MATERIALS

8-A Active disintegration of soil rock, thus releasing additional supplies of important plant nutrients.



8-B Soil chemical reactions that convert a number of important plant elements, including chemical compounds available for plant root uptake (for example, the conversion of phosphorus into a form available for plant use, the chelating of soil iron compounds to a form suitable for plant utilization in leaf chlorophyll development - yellowing of leaves, known as chlorosis, is the result of iron starvation, generally speaking).

8-C A reduction of the "locking up" of P205 (phosphorus) in the soil, especially soil with a clay base.

8-D The liberation of carbon dioxide from soil calcium carbonate, thus increasing the availability of this important plant nutrient through plant roots for carbohydrate synthesis.

8-E The neutralization of soil chemical substances that may cause plant toxicity.

8-F A high ion exchange capacity in soils. This benefit allows better retention and utilization of various elements, including minerals and soil nitrogen, by preventing excess losses of these ingredients through drainage water leaching from plant root zone areas. In the presence of an adequate amount of humic substance, the plant food nutrients are held in the soil and made available to the plant roots upon demand.

8-G The storage of plant nutrients. The gradual decomposition of organic matter-humic substance by soil microorganism actions results in the availability of: (a) carbon dioxide; (b) nitrogen as ammonia quickly changed to nitrites and nitrates by bacteria; and (c) phosphorus and other elements essential for plant growth, such as sulphur and potash.

8-H Through soil biochemistry and microorganisms, the high-molecular-weight organic materials are broken down, making up to 5,000 calories per gram of energy available to be used by plants until further biodegradation takes place.⁴⁵

8-I A retardation of the growth of soil organisms injurious to plants.

8-J The promotion and conversion (chelation) of a number of elements into "food" forms; nutrient uptake is thus available to plants.

BIOCHEMICAL VALUES

9-A The following general effects of humic and fulvic materials in the soil have been claimed by plant botanists, plant physiologists, and horticulturists around the world:

1. Improved plant cellular growth and division, including accelerated growth due to the presence of auxin type reactions.
2. Effective development of plant circulatory systems.
3. The most favorable functioning of plant respiration and transpiration systems.
4. The decrease of plant stress and premature deterioration.

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PRAGMATIC RESULTS

9-B As a result of the factors listed above, plant growth is stimulated, as reflected in these observations:

1. Improved seed germination.
2. Greater growth of fibrous roots.
3. Increases in legume root nodule formation (numbers and size).
4. Greater resistance to insects.
5. Greater plant resistance to drought and effects of frost damage.

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MINERAL-ENZYME CONNECTION

9-C Soil enriched with humic and fulvic materials and healthy microbial life produces fruits and vegetables rich in enzymes, vitamins and minerals. Mineral elements and trace mineral elements are made bio-available through chelation - an enzyme process wherein they are surrounded by and bonded to amino acids - which are proteins. Once chelated, they can be transported into the blood stream for use by the body.

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9-D Water soluble trace minerals can:

1. Partnership with enzymes as cofactors,
2. Help regulate fluid and electrolyte balance, and
3. Contribute rigidity to a body's skeletal framework.

9-E Other mineral enzyme cofactors:

1. Regulate the function of muscles and nerves, and
2. Work synergistically with vitamins, hormones, peptides, and other substances to regulate the body's metabolism.

ORGANIC SOIL CONDITIONING SUMMARY OF HUMIC SUBSTANCE FUNCTIONS

9-F Humic substance is the end product of decayed matter and usually contains large quantities of trace minerals. It contains up to 5,000 calories per gram, providing energy that can be used for plant growth.

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9-G Humates (metal complexes of humic acid) supply growing plants with food. They also act in other important ways to make soil more productive and fertile. For example, humic substance increases the water holding capacity of soil; therefore, it helps plants resist droughts and produces better crops in reduced water conditions.

9-H Humic substance breaks up unproductive clay soils, turning them into profitable soils. Humic acid stimulates seed germination and viability, and root respiration, formation, and growth.

9-I Humic substance helps retain water-soluble inorganic fertilizers, releases them, as needed, to the growing plants, and helps prevent soil leaching. Thus, humic acid reduces other fertilizer requirements. It fosters improved drainage, increases soil aeration and increases yields in crops such as cotton, potatoes, wheat, rice, tomatoes, corn, beets, etc.

9-J Humic acids increase the protein and mineral contents of most crops. Humates establish a desirable environment for microorganism development. Humic substances produce thicker, greener, and healthier crops.

ORGANIC SOIL CONDITIONING - SUMMARY OF FULVIC FUNCTIONS AS WATER SOLUBLE TRACE MINERALS

10-A Assists in seed germination and growth.
Improves development of roots and shoots.
Resistance of plants to fungal attack is improved.

10-B Metal complexing and nutritional physiology are enhanced.
Enhances uptake of nutrients.
Stimulates plant metabolism.

10-C Improves chelation and beneficially effects the plant growth cycle.
Positive effects on plant RNA & DNA.
Catalysts in plant respiration.

10-D Increases metabolism of proteins.
Increases activity of multiple enzymes.
Enhances permeability of cell membranes.

10-E Enhances cell division and cell elongation.
Assists chlorophyll synthesis.
Increases drought tolerance.

10-F Increases growth and yield of crops.
Assists denitrification by microbes.
Improves pH buffering capacity,

10-G Displays a special chemical affinity for balance.
Participates in synthesis of new minerals.
Promotes chemical weathering of inorganic substances.

10-H Silicate decomposition by hydrogen ions of fulvic acids.
Aids in the creation of fertile new soil.

10-I Affords ability to scavenge heavy metals.
Detoxifies various pollutants.

10-J The effects listed in this section are of economic value in that they contribute to increased yields and to improved crop quality, including the storage life of perishable crops. Many different facets of life also may be affected in positive ways.

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SO... WHAT IS THIS INCREDIBLE HUMIC SUBSTANCE WORTH?

The 100 functions briefly described in the foregoing paper strongly support the assertion that "Humic Substance and the Pure Supermixture" are priceless. Defining a standard that quantifies the contents of humic substances or fulvic substances has proven to be a daunting task. This task certainly can be likened to the metaphor of the three blind men who were asked to examine and describe an elephant. One man felt the trunk of the elephant and gave great detail. The second man wrapped his arms around the front leg of the elephant and his explanation was quite different from that of the first man. The third blind man took the tail of the elephant and summarized, "it is a very unusual rope." Marketing humic and fulvic materials could be more effective if standards for both humic and fulvic substances could be established. In the absence of such standards, however, the authors warn neophytes to the wonders of humic and fulvic materials to be aware of this absence of quantifying standards.

The authors of this paper greatly appreciate the diligent experimentation and analysis of the "Humic Substance and the Pure Supermixture." These efforts, together with the efforts of the agricultural industry, are forming a knowledge base about humic and fulvic materials and their respective functions. This growing knowledge base inspires a genuine respect for the "gift" of these substances and a renewed determination to continue exploring and discovering the vast reaches of their separate and collective contributions.

From this backdrop there remains a logical farm boy conclusion. One may not understand all there is to know about this subject, this "gift," but you must face the reality of: What are you going to do with what you do understand?

REMEMBER GEORGE WASHINGTON CARVER

George Washington Carver was a black man, born of slave parents in Diamond, Missouri (1860-1943). George Washington Carver was inducted into the Hall of Fame/Inventor Profile, 1990. Dr. Carver was an agricultural chemist who developed crop rotation methods for conserving plant nutrients in the soil. Carver discovered hundreds of new uses for crops. His research with agricultural products allowed the development of **325 products from peanuts, 108 applications for sweet potatoes, and 75 products derived from pecans. His industrial application from agricultural products, included a rubber substitute and over 500 dyes and pigments from 28 different plants.** It is reported that in 1927 he was responsible for the **invention of a process for producing paints and stains from soybeans.**

George Washington Carver received his B.S. degree in 1894 from the institution now known as Iowa State University, and his M.S. in agriculture in 1897. Carver was bestowed an honorary doctorate from Simpson College and he was made a member of the Royal Society of Arts in London, England. He received the Spingarn Medal in 1923. In 1943, U.S. President Franklin D. Roosevelt dedicated \$30,000 for a national monument honoring Carver's accomplishments.

The following is a list of some of the synthetic products developed by Dr. Carver.

Adhesives	Flour	Metal Polish	Shaving Cream
Axel	Fuel Briquettes	Milk Flakes	Sugar
Grease	Ink	Mucilage	Synthetic Marble
Bleach	Instant Coffee	Paper	Synthetic Rubber
Buttermilk	Insulating Board	Rubbing Oils	Talcum Powder
Cheese	Linoleum	Salve	Vanishing Cream
Chili Sauce	Mayonnaise	Soil Conditioner	Wood Stains
Cream	Meal	Shampoo	Wood Filler
CreosoteDyes	Meat Tenderizer	Shoe Polish	Worcestershire Sauce

A GIANT CHALLENGE FOR EACH ONE OF US

The research summarized and presented in this paper is a valuable resource from which the agricultural industry has gleaned direction and credibility in its efforts to develop methods for producing more nutritious food using fewer chemicals. Results of those efforts are illustrated in the pages following this conclusion. The challenge facing both scientists and leaders in the agricultural industry is to continue learning about "Humic Substance and the Pure Supermixture," and to continue developing multiple means for maximizing the benefits of their contributions. Using the list of 100 functions in this paper as a springboard, the authors of this paper challenge each of its readers to remember George Washington Carver, and ask: Are you interested in helping these priceless materials and their countless benefits become available for use by the general public?

Hear again the paraphrase of Oliver Wendell Holmes used in John F. Kennedy's Presidential Inaugural Address of January 20, 1961, which rang out "Ask not what your country can do for you, but what you can do for your country." The authors suggest today that as trustees of spaceship earth, that our paraphrase might be: "Ask not what else shall I discover about humic substances, but how do I translate this information to use for the general public." Here in lies wealth and comfort. "What does it do?" and "What is it worth?" What will you do with what you have?

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