Publications of the Exobiology Program for 1991

A Special Bibliography
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Introduction

The Exobiology Program, located within the Solar System Exploration Division, Office of Space Science and Applications of the National Aeronautics and Space Administration, is an integrated program designed to investigate and understand those processes related to the origin, evolution, and distribution of life in the universe.

This report contains a listing of 1991 publications resulting from research supported by the Exobiology Program. Our intent in compiling this bibliography is twofold: to provide the scientific community with an annual publication listing (as we have done since 1975) of current NASA-supported research in this field, and to stimulate the exchange of information and ideas among the scientists working in the different areas of the program.

The Exobiology Program is broad in scope, covering the following subject areas: Cosmic Evolution of Biogenic Compounds, Prebiotic Evolution, Early Evolution of Life, Evolution of Advanced Life, Solar System Exploration, Exploration Exobiology, Search for Extraterrestrial Intelligence, and Planetary Protection.

**Cosmic Evolution of Biogenic Compounds** focuses on understanding the cosmic history of the biogenic elements (C, H, N, O, P, S) and their compounds in the galaxy and early solar system and understanding the mechanisms of their incorporation (evolution) into organic compounds. This includes: (1) tracing the physical and chemical pathways of the biogenic elements and their compounds from their origins in stars to their incorporation in pre-planetary bodies; (2) determining the kinds of measurements that can be made on the biogenic elements and their compounds to develop theories about solar system formation and prebiotic evolution, and the origin of life; and (3) determining the ways in which the physical and chemical properties of the biogenic elements and their compounds may have influenced the course of events during the formation of the solar system and component bodies.

**Prebiotic Evolution** seeks to understand how the evolutionary sequence leading from simple chemicals to living systems occurred during the development of the Earth and other planets. Research and analysis falls into two major areas: (1) the consequences of planetary evolution on the physical environment of the Earth and planets, including the importance of the physical-chemical processes associated with the development of dynamic planetary surfaces, and (2) the evolution of molecules and molecular systems focusing on energetics, dynamics, and synthesis of chemicals and chemical systems to determine mechanisms by which these systems acquired biological attributes under the constraints imposed by the physical environment.

**Early Evolution of Life** focuses on the nature and history of primitive organisms, relating their evolution to those forces that shaped the evolution of the Earth. The evolutionary record occurs in two forms: the familiar fossil record in rocks, in which phylogeny is deduced from morphology, and in the genome of extant organisms, where mutational events, the driving force of evolution, are expressed in sequences found in the organism's nucleic acids, or the gene products. Thus, studies use the geological record and the molecular record in living organisms to determine when and in what setting life first appeared, to determine the characteristics of the first successful living organisms, to understand the phylogeny and physiology of primitive organisms, to understand the evolution of energy-transducing systems, and to understand what determines the rate of mutation (evolution).

**Evolution of Advanced Life** examines the influence of astrophysical, stellar, and solar system impact events on the evolution of advanced life on Earth, with specific regard to their role in species extinctions. Research in this area focuses on understanding the role of extinction in evolution and the physical conditions that cause extinction of species.
Cosmic Evolution of Biogenic Compounds
Allamandola*, L.J.
Analysis of frozen volatiles.

Allamandola*, L.J.
Interstellar organics and possible connections with the carbonaceous components of meteorites and IDPs (Abstract).

Allamandola*, L.J.
The nature of interstellar/precometary ices.

Allamandola*, L.J.; Sandford, S.A.; Tielens, A.G.G.M.; Herbst, T.
Methanol in the sky with diamonds (Abstract).

Allamandola*, L.J.; Sanford, S.A.; Schutte, W.A.; Tielens, A.G.G.M.
Laboratory and observational study of the interrelation of the carbonaceous component of interstellar dust and solar system materials (Abstract).

Anicich*, V.G.; Arakelian, T.; Hanner*, M.S.
Quantification of UV stimulated ice chemistry: CO and CO$_2$ (Abstract).

Banin*, A.; Blake*, D.F.; Benshlomo, T.
Detection of nanophase lepidocrocite (γ-FeOOH) in iron-smectite Mars soil analog materials (MarSAM) (Abstract).

Imaging Jupiter's aurorae from H$_3^+$ emissions in the 3-4 μm band.

Battlo, F.; LeRoy, R.C.; Parvin, K.; Freund*, F.; Freund, M.M.
Positive holes in magnesium oxide: Correlation between magnetic, electric, and dielectric anomalies.

Battlo, F.; Desgranges, L.; Freund*, F.
Anomalous thermal expansion and large polaron conductivity in magnesium oxide single crystals (Abstract).
Eos. Transactions, American Geophysical Union 72(44, Suppl.): 529-530, 1991. (GWU 16095)

Physical conditions along the Orion Molecular Cloud ridge (Abstract).

Clathrate hydrate formation in amorphous cometary ice analogs in vacuo.
Fredericks, J.R.; Gibson*, E.K., Jr.; Hartmetz, C.P.
Trapped lunar volcanic gases within Apollo 15 glass spherules (Abstract).

Freund*, F.; Battlo, F.; LeRoy, R.C.
Electrical conductivity of olivine revisited (Abstract).
*Eos. Transactions, American Geophysical Union* 72(44, Suppl.): 529, 1991. (GWU 16096)

Crystal-field-driven redox reactions: How common minerals split $H_2O$ and $CO_2$ into reduced $H_2$ and $C$ plus oxygen (Abstract).

Freund*, F.; Masuda, M.M.; Freund, M.M.
Highly mobile oxygen hole-type charge carriers in fused silica.

Gibson*, E.K., Jr.; Hartmetz, C.P.
Carbon-bearing phases and volatiles in interplanetary dust particles (Abstract).

Gibson*, E.K., Jr.; Hartmetz, C.P.
Volatile species in interplanetary dust particles and aerogels (Abstract).

Gibson, J.E.; Pillinger, C.T.; Gibson*, E.K., Jr.
Carbon content of silica aerogel: A material proposed as a medium for collection of cosmic dust grains (Abstract).

Griffith, C.A.; Owen*, T.; Wagener, R.
Titan's surface and troposphere, investigated with ground-based, near-infrared observations.

Hartmetz, C.P.; Gibson*, E.K., Jr.; Blanford, G.E.
Analysis of volatiles present in interplanetary dust and stratospheric particles collected on large area collectors.

Hartmetz, C.P.; Gibson*, E.K., Jr.; Blanford, G.E.
*In situ* extraction and analysis of volatile elements and molecules from carbonaceous chondrites.

Herbst, E.; DeFrees*, D.J.; Talbi, D.; Pauzat, F.; Koch, W.; McLean, A.D.
Calculations on the rate of the ion-molecule reaction between $NH_3^+$ and $H_2$.

Interstellar HNO: Confirming the identification.
Madden, S.C. (Irvine, W.M. = P.I.)
Results of a galactic survey for the ring molecule cycloprenylidene (C₃H₂).

McConville, P.; Reynolds, J.H.; Epstein*, S.; Roedder, E.
Implanted ³He, ⁴He, and Xe in further studies of diamonds from Western Australia.

Abundance and chemistry of interstellar HOCO⁺.
Astronomy and Astrophysics 244: 470-476, 1991. (GWU 14756)

Minh, Y.C.; Irvine*, W.M.
Interstellar H₂S: Probe of grain surface chemistry.

Minh, Y.C.; Irvine*, W.M.
Upper limits for the ethyl-cyanide abundances in TMC-1 and L134N: Chemical implications.

The ortho to para ratio for ketene in TMC-1.

Detection of a new carbon-chain molecule, CCO.

Owen*, T.; Bar-Nun, A.; Keinfeld, I.
Cometary impacts on the early Earth: Evidence from heavy noble gases (Abstract).
Eos. Transactions, American Geophysical Union 72(44, Suppl.): 59, 1991. (GWU 16098)

Pauzat, F.; Ellinger, Y.; McLean, A.D. (DeFrees, D.J.; Löwel, G.H. = P.I.)
Is interstellar detection of higher members of the linear radicals C₄CH and C₄N feasible?
Stone, J.; Hutcheon, I.D.; Epstein*, S.; Wasserburg, G.J.
Si, C and N isotopes in SiC from Orgueil and Murchison: H- and He- burning components in presolar grains (Abstract).

Talbi, D.; DeFrees*, D.J.
Ab initio study of C + H3+ reactions.

Talbi, D.; DeFrees*, D.J.; Egolf, D.A.; Herbst, E.
Calculations concerning the reaction C + H3+ → CH+ + H2

Tarter*, J.; Saykally, R.
Measurement of the spectral signature of small carbon clusters at near and far infrared wavelengths (Abstract).

Tielens, A.G.G.M.; Allamandola*, L.J.; Sandford, S.A.
Laboratory, observational and theoretical studies of interstellar ices.

Interstellar solid CO: Polar and nonpolar interstellar ices.

Trafton, L.M.; Lester, D.F.; Ramseyer, T.F.; Salama, F.; Sandford, S.A.; Allamandola*, L.J.
A new class of absorption feature in Io's near-infrared spectrum.

Trice, J.P.; Becker, J.F.; Sauke, T.B.; Freund*, F.
Kinetic 12C/13C fractionation during isothermal degassing of arc-fusion grown magnesium oxide (Abstract).
Eos. Transactions, American Geophysical Union 72(44, Suppl.): 523, 1991. (GWU 16097)

Chemical gradients in the Orion Molecular Cloud (Abstract).

Villac, H.O.; Loew*, G.H.
Properties of selective type-I benzodiazepine receptor ligands.

Watson, L.L.; Ihinger, P.D.; Epstein*, S.; Stolper*, E.M.
Hydrogen, carbon and oxygen isotopic composition of volatiles in Nakhla (Abstract).

Whang, E.-J.; Freund*, F.
Carbon segregation from calcium oxide single crystals (Abstract).
Eos. Transactions, American Geophysical Union 72(44, Suppl.): 530, 1991. (GWU 16094)
Prebiotic Evolution
Arrhenius*, G.
Sources and geochemical evolution of cyanide and formaldehyde (Abstract).

Barak, D.; Shibata, M.; Rein*, R.
Structural investigation of protein kinase C inhibitors.

Evolution of isotopic signatures in lunar-regolith nitrogen: Noble gases and N in ilmenite grain-size fractions from regolith breccia 79035 (Abstract).

Betts, J.N.; Holland*, H.D.
The oxygen content of ocean bottom waters, the burial efficiency of organic carbon, and the regulation of atmospheric oxygen.

Bishop, J.L.; Pieters, C.M.; Edwards, J.O.; Coyne*, L.M.; Chang*, S.
Spectroscopic analyses of Fe and water in clays. A Martian surface weathering study (Abstract).

Blank, J.G.; Stolper*, E.M.; Zhang, Y.
Diffusion of CO₂ in rhyolitic melt (Abstract).
*Eos. Transactions, American Geophysical Union* 72(17, Suppl.): 312, 1991. (GWU 16105)

Chu, B.C.F.; Orgel*, L.E.
Binding of hairpin and dumbbell DNA to transcription factors.

Chyba, C.; Sagan*, C.
Electrical energy sources for organic synthesis on the early Earth.
*Origins of Life and Evolution of the Biosphere* 21: 3-17, 1991. (GWU 14820)

Chyba, C.F. (Sagan, C. = P.I.)
The heavy bombardment and the origins of life (Abstract).
*Eos. Transactions, American Geophysical Union* 72(44, Suppl.): 59, 1991. (GWU 14818)

Chyba, C.F.; Sagan*, C.; Brookshaw, L.; Thomas, P.J.
Terrestrial accretion of prebiotic volatiles and organic molecules during the heavy bombardment.

Chyba, C.F.; Sagan*, C.; Thomas, P.J.; Brookshaw, L.
Terrestrial production vs. extraterrestrial delivery of prebiotic organics to the early Earth (Abstract).

Coyne*, L.
Reflectance signature of trapped holes in montmorillonites using near infrared reflectance analysis (NIRA) and EPR.
Egli, M.; Williams, L.D.; Gao, Q.; Rich*, A.
Structure of the pure-spermine form of Z-DNA (magnesium free) at 1Å resolution.

Egli, M.; Williams, L.D.; Gao, Q.; Rich*, A.
X-ray crystal structures of nucleic acids and their complexes with mono and bis-intercalators (Abstract).

Ferris*, J.P.; Guillemin, J.C.

Fox*, S.W.
Nonrandom protein in prelife → life transition (Abstract).

Fox*, S.W.
Origins of life and biomedicinals from thermal proteins (Abstract).
Abstract of paper presented at the 201st National Meeting of the American Chemical Society, Biopolymers Symposium, Atlanta, GA, April 18-19, 1991, 1 p. (GWU 15073)

Fox*, S.W.
Synthesis of life in the lab? Defining a protoliving system.

Fox*, S.W.; Bahn, P.R.
Self-sealing artificial skin comprising copoly-alpha-amino acid (Patent).

Fox*, S.W.; Ruecknagel, P.; Braunitzer, G.
Molecular bases for unity and diversity in organic evolution (Abstract).

Gao, Q.; Williams, L.D.; Egli, M.; Rabinovich, D.; Chen, S.-L.; Quigley, G.J.; Rich*, A.

Harada, K.; Orgel*, L.E.
The cyclization of arabinosyladenine-5'-phosphorimidazolide.

Harang, E.A.; Baltscheffsky, H.; Deamer*, D.W.
Production of ATP and PPI in R. rubrum chromatophores using ferrocyanide illumination to produce chemiosmotic proton gradients (Abstract).

Hefti, F.; Junard, E.O.; Knüsel, B.; Strauss, W.L.; Strang, P.F.; Przybylski, A.; Vaughan, G.; Fox*, S.W.
Promotion of neuronal survival in vitro by thermal proteins and poly(dicarboxylic) amino acids.
Kanavarioti*, A.; Rosenbach, M.T.  
Catalysis of hydrolysis and nucleophilic substitution at the P-N bond of phosphoimidazolide-activated nucleotides in phosphate buffers.  

The structural studies of endotoxin neutralizing protein (Abstract).  

Kerridge*, J.F.  
Interstellar precursors in synthesis of meteoritic organic matter (Abstract).  

Kerridge*, J.F.  
Isotopic analysis of cometary organic matter.  

Kerridge*, J.F.  
Isotopic constraints on the origin of meteoritic organic matter (Abstract).  

Kerridge*, J.F.; Bochsler, P.; Eugster, O.; Geiss, J.  
Modelling the evolution of N and $^{15}$N/$^{14}$N in the lunar regolith (Abstract).  

Optical properties of tholin from H$_2$O/C$_2$H$_6$ (6:1) ice, and comparison with Titan tholin, kerogen and meteoritic organics (Abstract).  

Khare*, B.N.; Thompson, W.R.; Sagan*, C.; Arakawa, E.T.; Miesse, C.; Gilmour, I.  
Optical constants of kerogen from 0.15 to 40 $\mu$m: Comparison with meteoritic organics.  

Lacey*, J.C.; Thomas, R.D.; Staves, M.P.; Watkins, C.L.  
Stereoselective formation of bis($\alpha$-aminoacyl) esters of 5'-AMP suggests a primitive peptide synthesizing system with a preference for L-amino acids.  
*Biochimica et Biophysica Acta*  1076: 395-400, 1991. (GWU 12269)

Lacey*, J.C., Jr.  
Chemistry of aminoacylation of 5'-AMP and the origin of protein synthesis (Abstract).  

Landry, B.; Allen, M.; Yung*, Y.L.  
Troposphere-stratosphere interactions in a one-dimensional model of Jovian photochemistry.  

Levine*, J.S.  
The biosphere as a driver for global atmospheric change.  

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Morowitz*, H.J.
A window in time for the first evolutionary radiation (Abstract).

Morowitz*, H.J.; Deamer*, D.W.; Smith, T.
Biogenesis as an evolutionary process.
*Journal of Molecular Evolution* 33: 207-208, 1991. (GWU 14043)

Interaction between the left-handed Z-DNA and polyamine: The crystal structure of the d(CG)₃ and N-(2-aminooethyl)-1,4-diamino-butane complex.

Orgel*, L.E.
Template polymerization of nucleotide analogues (Abstract).

Oró*, J.
Origen y evolucion de la vida. (Spanish)

Oro*, J.; Lazcano, A.
On the origin and early evolution of biological catalysis and other studies on chemical evolution (Abstract).

Oró*, J.; Mills, T.; Lazcano, A.
Comets and the formation of biochemical compounds on the primitive Earth: A reappraisal (Abstract).

Pohorille*, A.; Benjamin, I.
Molecular dynamics of phenol at the liquid-vapor interface of water.

Pohorille*, A.; Wilson, M.; MacElroy*, R.D.
Structure and functions of water-membrane interfaces and their role in proto-biological evolution (Abstract).

Ponnamperuma*, C.
Studies on the origin of the genetic code (Abstract).

A possible relationship between enantiomeric structure of an amino acid and its association with its anticodon nucleotide (Abstract).

Shibata, M.; Zielinski, T.J.; Rein*, R.
A molecular dynamics study of the effect of G - T mispairs on the conformation of DNA in solution.


Sokalski, W.A.; Shibata, M.; Barak, D.; Rein*, R.

Stolper*, E.; Newman, S.
The role of water in the petrogenesis of Mariana trough magmas (Abstract).
Eos. Transactions, American Geophysical Union 72(44, Suppl.): 239, 1991. (GWU 16102)

Stribling, R. (Deamer, D. = P.I.)
High performance liquid chromatography of oligoguanylates at high pH.

Stribling, R.; Miller*, S.L.
Attempted nonenzymatic template-directed oligomerizations on a polyadenylic acid template: Implications for the nature of the first genetic material.

Stribling, R.; Miller*, S.L.
Template-directed synthesis of oligonucleotides under eutectic conditions.

Plasma discharge in N2 + CH4 at low pressures: Experimental results and applications to Titan.
Icarus 90: 57-73, 1991. (GWU 14821)

Thompson, W.R.; Sagan*, C.
Titans's condensates and tholins: Surface interactions (Abstract).

Usher*, D.A.; Kozlowski, M.; Zou, X.
Catalytic RNA and synthesis of the peptide bond (Abstract).

Valverde, V.; Lazcano, A.; Gariglio, P.; Or6*, J.
Interacción de reverso transcriptasas virales con cationes divalentes. (Spanish)

Velasco, A.M.; Medrano, L.; Or6*, J.; Lazcano Araujo, A.
Caracterizacion de un sitio funcional conservado en reverso transcriptasas celulares y virales (Abstract). (Spanish)
Zuotein-1, a putative Z-DNA binding protein in yeast Saccharomyces cerevisiae (Abstract).

Zhang, X.; Kang, C.-H.; Rich*, A.
The structural studies of left-handed Z-DNA (Abstract).

Zhang, Y.; Stolper*, E.M.
Water diffusion in a basaltic melt.

Zhang, Y.; Stolper*, E.M.
Water diffusion in a basaltic melt (Abstract).
Eos. Transactions, American Geophysical Union 72(17, Suppl.): 312, 1991. (GWU 15324)

Zhang, Y.; Stolper*, E.M.; Wasserburg, G.J.
Diffusion of a multi-species component and its role in oxygen and water transport in silicates.

Zhang, Y.; Stolper*, E.M.; Wasserburg, G.J.
Diffusion of water in rhyolitic glasses.
Early Evolution of Life
Allen, M.E.; Friedmann*, E.I.
Scanning electron microscopy of cryptoendolithic microorganisms in Antarctic rocks: Distribution along ecological gradients (Abstract).
In: *Abstracts, 91st Annual Meeting of the American Society for Microbiology*, Dallas, TX, 1991, p. 190. (GWU 14803)

Asmerom, Y.; Jacobsen, S.B.; Knoll*, A.H.; Butterfield, N.J.; Swett, K.
Strontium isotopic variations of Neoproterozoic seawater: Implications for crustal evolution.

Awramik*, S.M.
Nonmarine stromatolites and the search for early life on Mars (Abstract).

Awramik*, S.M.; Kusky, T.M.; Vanyo, J.P.
Inclined stromatolites as recorders of geophysical data (Abstract).
*Eos. Transactions, American Geophysical Union* 72(17, Suppl.): 270, 1991. (GWU 16106)

Barth, A.L.; Stricker, J.A.; Margulis*, L.
Search for eukaryotic motility proteins in spirochetes: Immunological detection of a tektin-like protein in *Spirochaeta halophila*.

Bauer, J.E.; Haddad, R.I.; Des Marais*, D.J.

Blankenship*, R.E.; Causgrove T.P.; Alden, R.G.; Trost, J.T.
Primary photochemistry in heliobacterial reaction centers (Abstract).

Blankenship*, R.E.; Causgrove, T.P.; Cheng, P.; Brune, D.C.; Trost, J.T.; Alden, R.G.
Energy transfer and trapping in green photosynthetic bacteria and heliobacteria (Abstract).

Heliobacterial reaction centers as models for photosystem (Abstract).

Buchanan*, B.B.
Regulation of CO₂ assimilation in oxygenic photosynthesis: The ferredoxin/thioredoxin system.

Buchanan*, B.B.
Thioredoxin and evolution (Abstract).

Buchanan*, B.B.
Thioredoxins: Photosynthetic proteins as regulatory prototypes for nonphotosynthetic systems (Abstract).
*Plant Physiology* 96(1, Suppl.): 43, 1991. (GWU 11817)
Des Marais*, D.J.; Canfield*, D.E.
Have stromatolites recorded changes in atmospheric carbon dioxide levels? (Abstract)
Eos. Transactions, American Geophysical Union 72(17, Suppl.): 165, 1991. (GWU 14885)

Des Marais*, D.J.; Truesdell, A.H.

Dracheva, S.; Williams, J.C.; Van Driesche, G.; Van Beeumen, J.J.; Blankenship*, R.E.
The primary structure of cytochrome c-554 from the green photosynthetic bacterium Chloroflexus aurantiacus.

Eglinton, T.I.; Fry, B.D.; Freeman, K.H.; Hayes*, J.M.
Stable carbon isotopic composition of individual products from flash pyrolysis of kerogens (Abstract).

Fairchild, I.J.; Knoll*, A.H.; Swett, K.
Coastal lithofacies and biofacies associated with syndepositional dolomitization and silicification (Draken Formation, Upper Riphean, Svalbard).
Precambrian Research 53: 165-197, 1991. (GWU 1303)

Fox*, G.E.
Exploration of RNA structure spaces (Abstract).

Francois, L.M.; Walker*, J.C.G.
Modelling the Phanerozoic carbon cycle and climate: Constraints from the \(^{87}\text{Sr} / ^{86}\text{Sr}\) isotopic ratio of seawater (Abstract).
Eos. Transactions, American Geophysical Union 72(17, Suppl.): 158, 1991. (GWU 16107)

Freeman, K.H.; Hayes*, J.M.
The relationship between \(^{13}\text{C}\) in organic carbon and atmospheric pCO\(_2\) and estimation of pre-Miocene CO\(_2\) levels (Abstract).
Eos. Transactions, American Geophysical Union 72(17, Suppl.): 166-167, 1991. (GWU 16108)

Freeman, K.H.; Wakeham, S.G.; Hayes*, J.M.
Predictive isotopic biogeochemistry of lipids from the Black Sea and Cariaco Trench (Abstract).

Friedmann*, E.I.; Ocampo-Friedmann, R.
Strategies of xerophytic algae (Abstract).

Grant, S.W.F.; Knoll*, A.H.; Germs, G.J.B.
Probable calcified metaphytes in the latest Proterozoic Nama Group, Namibia: Origin, diagenesis, and implications.

Green, L.S.; Yee, B.C.; Buchanan*, B.B.; Kamide, K.; Sanada, Y.; Wada, K.
Ferredoxin and ferredoxin-NADP reductase from photosynthetic and nonphotosynthetic tissues of tomato.
Huppe, H.C.; Picaud, A.; Buchanan*, B.B.; Miginiac-Maslow, M.
Identification of an NADP/thioredoxin system in *Chlamydomonas reinhardtii*.
*Planta* 186: 115-121, 1991. (GWU 14750)

Jahnke*, L.L.
The effects of oxygen on the evolution of microbial membranes (Abstract).

Jasper, J.P.; Hayes*, J.M.; Prahl, F.G.
Photosynthetic fractionation of $^{13}$C and estimates of $pCO_2$ on the scale of $10^3$-$10^8$ years (Abstract).

Jasper, J.P.; Hayes*, J.M.; Prahl, F.G.; Mix, A.; Wakeham, S.G.; Crusius, J.; Anderson, R.F.
Isotopically-driven estimates of dissolved $CO_2$ and equilibrium $pCO_2$ from late Quaternary sedimentary records in the equatorial Pacific and Black Sea (Abstract).
*Eos. Transactions, American Geophysical Union* 72(44, Suppl.): 272, 1991. (GWU 16103)

Jasper, J.P.; Prahl, F.G.; Mix, A.; Hayes*, J.M.
Photosynthetic $^{13}$C fractionation and estimated $CO_2$ levels in the eastern equatorial Pacific (MANOP Site C) at over the last 255,000 years (Abstract).
*Eos. Transactions, American Geophysical Union* 72(17, Suppl.): 167, 1991. (GWU 16110)

Jukes*, T.H.
Random Walking: Chimps, gorillas, orangs and us.

Jukes*, T.H.
Early development of the neutral theory.

Jukes*, T.H.
Mars as a new abode for microbial life.
*Journal of Molecular Evolution* 32: 355-357, 1991. (GWU 14911)

Jukes*, T.H.; Osawa, S.
Recent evidence for evolution of the genetic code.

Jurtshuk, R.J.; Blick, M.; Bresser, J.; Jurtshuk, P., Jr.; Fox*, G.E.
16S rRNA in situ hybridization technique for differentiating closely related gram positive organisms, *Bacillus polymyxa* and *Bacillus macerans* (Abstract).
In: *Abstracts, 91st Annual Meeting of the American Society for Microbiology*, Dallas, TX, 1991, p. 244. (GWU 15367)

Kasting*, J.F.
Box models for the evolution of atmospheric oxygen: An update.

Kasting*, J.F.
$CO_2$ condensation and the climate of early Mars.
Lanyi*, J.K.
Archaebacterial rhodopsin sequences: Implications for evolution (Abstract).

Liebl, U.; Blankenship*, R.E.; Vermaas, W.F.J.
Cloning of the reaction center gene from *Helio bacterillus mobilis* (Abstract).

Lowe*, D.; Byerly, G.
Powerline Road section across the central Barberton Greenstone Belt.

Lowe*, D.R.
Geology of the Barberton Greenstone Belt: An overview.

Lyons, W.B.; Des Marais*, D.J.
The stable isotope biogeochemistry of carbon and nitrogen in Lake Hoare, Antarctica (Abstract).
*Eos. Transactions, American Geophysical Union* 72(17, Suppl.): 109, 1991. (GWU 14888)

Marcus, F.; Chamberlain, S.H.; Chu, C.; Masiarz, F.R.; Shin, S.; Yee, B.C.; Buchanan*, B.B.
Plant thioredoxin h: An animal-like thioredoxin occurring in multiple cell compartments.

Margulis*, L.
Big trouble in biology: Physiological autopoiesis versus mechanistic Neo-Darwinism.

Margulis*, L.
Come nasce la vita. (Italian)

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Gaia, a new look at the Earth's system.

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Paster, B.J.; Dewhirst, F.E.; Weisburg, W.G.; Tordoff, L.A.; Fraser, G.J.; Hespell, R.B.; Stanton, T.B.; Zablen, L.; Mandelco, L.; Woese*, C.R.
Phylogenetic analysis of the spirochetes.

Popp, B.N.; Hayes*, J.M.; Chicarelli, M.I.; Eckardt, C.B.; Maxwell, J.R.
Carbon and nitrogen isotopic analyses of porphyrins from the Triassic Serpiano Oil Shale (Abstract).
*Eos. Transactions, American Geophysical Union* 72(17, Suppl.): 158, 1991. (GWU 16112)

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Appendix
## Principal Investigators

<table>
<thead>
<tr>
<th>Name</th>
<th>Affiliation</th>
<th>Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>Louis J. Allamandola</td>
<td>NASA, Ames Research Center</td>
<td>Mail Stop 245-6, Moffett Field, CA 94035</td>
</tr>
<tr>
<td>Vincent Anicich</td>
<td>NASA, Jet Propulsion Laboratory</td>
<td>California Institute of Technology</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4800 Oak Grove Drive, Pasadena, CA 91109</td>
</tr>
<tr>
<td>Gustaf Arrhenius</td>
<td>Scripps Institution of Oceanography</td>
<td>Mail Code A-020, University of California, San Diego La Jolla, CA 92093</td>
</tr>
<tr>
<td>Frank Asaro</td>
<td>Lawrence Berkeley Laboratory</td>
<td>University of California, Berkeley, CA 94720</td>
</tr>
<tr>
<td>Stanley M. Awramik</td>
<td>Department of Geological Sciences</td>
<td>University of California, Santa Barbara, CA 93106</td>
</tr>
<tr>
<td>Amos Banin</td>
<td>San Francisco State University Foundation</td>
<td>1640 Holloway Avenue, San Francisco, CA 94132</td>
</tr>
<tr>
<td>Albert Betz</td>
<td>Space Sciences Laboratory</td>
<td>University of California, Berkeley, CA 94720</td>
</tr>
<tr>
<td>John Billingham</td>
<td>NASA, Ames Research Center</td>
<td>Mail Stop 239-22, Moffett Field, CA 94035</td>
</tr>
<tr>
<td>David F. Blake</td>
<td>NASA, Ames Research Center</td>
<td>Planetary Biology Branch, Mail Stop 239-4, Moffett Field, CA 94035</td>
</tr>
<tr>
<td>Geoffrey A. Blake</td>
<td>Division of Geological and Planetary Sciences</td>
<td>California Institute of Technology 17-25, Pasadena, CA 91125</td>
</tr>
<tr>
<td>Robert E. Blankenship</td>
<td>Center for the Study of Early Events in Photosynthesis</td>
<td>Arizona State University, Tempe, AZ 85287</td>
</tr>
<tr>
<td>Stuart Bowyer</td>
<td>Department of Astronomy</td>
<td>Space Sciences Laboratory, University of California Berkeley, CA 94720</td>
</tr>
<tr>
<td>John C. Briggs</td>
<td></td>
<td>1260 Julian Drive, Watkinsville, GA 30677</td>
</tr>
<tr>
<td>Bob Buchanan</td>
<td>College of Natural Resources</td>
<td>Department of Plant Biology, University of California Berkeley, CA 94720</td>
</tr>
<tr>
<td>Theodore Bunch</td>
<td>NASA, Ames Research Center</td>
<td>Mail Stop 239-4, Moffett Field, CA 94035</td>
</tr>
<tr>
<td>Donald E. Canfield</td>
<td>Department of Earth and Atmospheric Sciences</td>
<td>Georgia Institute of Technology, Atlanta, GA 30332</td>
</tr>
<tr>
<td>Glenn Carle</td>
<td>NASA, Ames Research Center</td>
<td>Mail Stop 239-12, Moffett Field, CA 94035</td>
</tr>
<tr>
<td>Sherwood Chang</td>
<td>NASA, Ames Research Center</td>
<td>Mail Stop 239-4, Moffett Field, CA 94035</td>
</tr>
</tbody>
</table>
Principal Investigators

Heinrich D. Holland
Department of Earth & Planetary Sciences
Hoffman Laboratory
Harvard University
20 Oxford Street
Cambridge, MA 02138

John F. Kerridge
Institute of Geophysics and Planetary Physics
University of California
405 Hilgard Hall
Los Angeles, CA 90024

Marsha Hollander
Department of Chemistry
George Mason University
4400 University Drive
Fairfax, VA 22030

Bishun N. Khare
Laboratory for Planetary Studies
Center for Radiophysics and Space Research
Space Sciences Building
Cornell University
Ithaca, NY 14853

John R. Holloway
Departments of Chemistry and Geology
Arizona State University
Tempe, AZ 85287

Andrew H. Knoll
Botanical Museum
Harvard University
26 Oxford Street
Cambridge, MA 02138

William M. Irvine
Five College Radio Astronomy Observatory
University of Massachusetts
619 Lederle Graduate Research Center
Amherst, MA 01003

Daniel R. Kojiro
NASA, Ames Research Center
Mail Stop 239-12
Moffett Field, CA 94035

Linda Jahnke
NASA, Ames Research Center
Mail Stop 239-4
Moffett Field, CA 94035

Robert Kretsinger
Department of Biology
University of Virginia
Charlottesville, VA 22901

John R. Holloway
Departments of Chemistry and Geology
Arizona State University
Tempe, AZ 85287

James C. Lacey, Jr.
Department of Biochemistry
Room 520 CHSB
University of Alabama
Birmingham, AL 35294

Anastassia Kanavarioti
Department of Chemistry
University of California
Santa Cruz, CA 95064

Janos K. Lanyi
Department of Physiology and Biophysics
California College of Medicine
University of California
Irvine, CA 92717

James F. Kasting
Department of Geological Sciences
503 Deike Building
Pennsylvania State University
University Park, PA 16802

James G. Lawless
NASA, Ames Research Center
Mail Stop 242-4
Moffett Field, CA 94035
**Principal Investigators**

**Margaret Race**  
College of Natural Resources  
101 Giannini Hall  
University of California  
Berkeley, CA 94720

**Michael R. Rampino**  
Department of Applied Science  
26-36 Stuyvesant Street  
New York University  
New York, NY 10003

**David M. Raup**  
Department of Geophysical Sciences  
University of Chicago  
5734 South Ellis Avenue  
Chicago, IL 60637

**Robert Rein**  
Roswell Park Memorial Institute  
Building CCC, Suite 218  
666 Elm Street  
Buffalo, NY 14263

**Alexander Rich**  
Department of Biology  
Massachusetts Institute of Technology  
Cambridge, MA 02139

**L.J. Rothschild**  
NASA, Ames Research Center  
Mail Stop 245-3  
Moffett Field, CA 94035

**Jonathan Roughgarden**  
Department of Biological Sciences  
Stanford University  
Stanford, CA 94305

**Ted L. Roush**  
NASA, Ames Research Center  
Mail Stop 245-3  
Moffett Field, CA 94035

**John D. Rummel**  
Program Manager, Exobiology  
NASA Headquarters  
Code SBR  
Washington, DC 20546

**Carl Sagan**  
Center for Radiophysics  
and Space Research  
Laboratory for Planetary Studies  
Space Sciences Building  
Cornell University  
Ithaca, NY 14853

**Thomas Scattergood**  
NASA, Ames Research Center  
Mail Stop 239-4  
Moffett Field, CA 94035

**J. William Schopf**  
Department of Earth & Space Sciences  
3806 Geology Building  
University of California  
Los Angeles, CA 90024

**J. John Sepkoski, Jr.**  
Department of Geophysical Sciences  
University of Chicago  
5734 South Ellis Avenue  
Chicago, IL 60637

**Thomas C. Shen**  
NASA, Ames Research Center  
Mail Stop 239-12  
Moffett Field, CA 94035

**Edward M. Stolper**  
Professor of Geology  
California Institute of Technology  
Pasadena, CA 91125

**Jill Tarter**  
NASA, Ames Research Center  
Mail Stop 239-22  
Moffett Field, CA 94035

**Peter Tsou**  
California Institute of Technology  
NASA, Jet Propulsion Laboratory  
4800 Oak Grove Drive  
Pasadena, CA 91109

**David Usher**  
Department of Chemistry  
Baker Laboratory  
Cornell University  
Ithaca, NY 14853
S

Principal Investigators

SETI Investigators

NASA, Ames Research Center
SETI Project
Mail Stop 244-11
Moffett Field, CA 94035

NASA, Jet Propulsion Laboratory
SETI Program
California Institute of Technology
4800 Oak Grove Drive
Pasadena, CA 91109

Peter Backus
David H. Brocker
D. Kent Cullers
L.J. Deutsch
John Dreher
Chris Hlavka
J.L. Huntington
Jane Jordan
J.R. Marshall
D.E. Schwartz
Richard Stauduhar
L.D. Webster

P. Asmar
D.J. Burns
M.J. Flanagan
C.F. Foster
M.F. Garyantes
R. Gosline
M.J. Grimm
Samuel Gulkis
E.B. Jackson
Michael J. Klein
S.M. Levin
E.T. Olsen
H.C. Wilck
G.A. Zimmerman