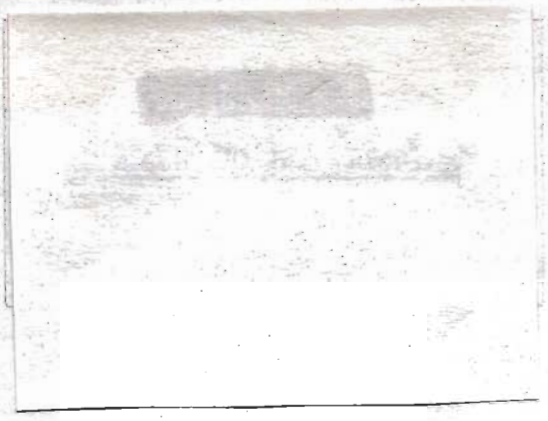

BULLETIN OF THE SANTA FE INSTITUTE

Volume 1, Number 1 June, 1986

The Bulletin of the Santa Fe Institute will be a quarterly publication. The distribution includes SFI Trustees, Officers, Advisors, workshop organizers and participants, past and potential donors, and leaders in universities, industry and government. Address correspondence to the editors, Peter Carruthers, David Pines, and L. M. Simmons, Jr. Until January 1987 please note that David Pines will be at Los Alamos. The main office address of the SFI is:

Santa Fe Institute
P.O. Box 9020
Santa Fe, N.M. 87501

The Institute has a limited number of copies of Emerging Syntheses in Science: Proceedings of the Founding Workshops of the Santa Fe Institute, edited by David Pines. They are available on request from the main office.

CONTENTS

1986 CALENDAR OF EVENTS

June 12	Self-Similarity and Scaling Workshop Planning Meeting, Chicago
June 25	SFI Presentation at Carnegie Corporation, New York
July 17-25	Adaptive Neural Nets Workshop, Los Alamos and Santa Fe
July 26	Board of Advisors and Program Committee Meeting, Santa Fe
July 28-August 8	Complex Adaptive Systems Workshop, Santa Fe
August 7	Exploratory Meeting on International Finance as a Complex System, Santa Fe

FUTURE WORKSHOP PROGRAM DISCUSSED AT THE MEETING OF THE BOARD OF ADVISORS

The following list of workshops was discussed at the March 9, 1986 meeting of the Board of Advisors and presently constitutes the immediate agenda of the Santa Fe Institute. Some will definitely occur, others are in the planning stage, while others are in a still earlier stage of formulation. Here we give only a list of titles and contact persons.

Adaptive Neural Networks	A. Lapedes
Interdisciplinary Aspects of Complex Adaptive Systems	J. Cowan and M. Feldman
Self Similarity and Scaling	P. Carruthers
International Finance as a Complex System	G. Cowan
Structure, Dynamics, and Functions of Proteins	H. Frauenfelder
Foraging, Food, Population, Range Management, and Ecology	R. McC. Adams
Sequencing the Human Genome	G. Bell
Human Heterogeneity and the Consequences for Public Policy of Advances in the Sequencing of the Human Genome	M. Bitensky
Mechanisms of Gene Expression	T. Puck
Stability and Sustainability in International Security Affairs	L. Rosen and J. Rubel
New Approaches to Economics	
Archeology, Archeometry, and the Disappearance of Cultures	D. Schwartz

PLANNED SANTA FE INSTITUTE PRESENTATION AT THE CARNEGIE CORPORATION

We have the opportunity to present the concept of the Santa Fe Institute, together with plans and financial requirements, to a select group of potential donors in the Carnegie Board Room on June 25. Institute representatives participating in the presentation include R. Adams, P. Anderson, G. Cowan, M. Feldman, M. Gell-Mann, and D. Pines.

A principal item in the presentation will be the two-year development plan that follows. This plan was produced by an ad hoc committee consisting of P. Carruthers, G. A. Cowan, D. Pines, and L. M. Simmons, Jr. It is designed to establish the Institute as a physical and intellectual reality as soon as possible. At the time of writing we are optimistic that the necessary land (item 2 below) will be donated in the near future. In addition to the estimated $1,030K budget required to implement the action items in Year One, we note the critical need to raise $1,000K for initial construction.

TWO-YEAR DEVELOPMENT PLAN

Year One (July 1, 1986-June 30, 1987)

1. Staff a full-time Santa Fe facility. ($100K)
2. Establish the Santa Fe campus.
3. Develop a coordinated campus plan, with architectural studies for initial buildings. ($200K)
4. Conduct a capital gift campaign for the initial building. ($100K)
5. Hold at least three workshops in Santa Fe. ($120K)
6. Initiate a contract-funded research program.
7. Establish a research network on complex adaptive systems. ($50K)
8. Initiate a Visiting Fellows Program. ($150K)
9. Initiate a publication program, including the Bulletin of the Santa Fe Institute. ($60K)
10. Conduct studies of computer and communication needs and begin acquisition of microcomputers and scientific work stations. ($150K)
11. Appoint an Executive Vice President. ($100K)
12. Initiate a Presidential search.

Total Cost $1,030K

TWO-YEAR DEVELOPMENT PLAN

Year Two (July 1, 1987-June 30, 1988)

1. Appoint a President.
2. Launch a full-scale development campaign.
3. Make initial (visiting) faculty appointments
4. Expand to a year-round Visiting Fellow program.
5. Select the first group of Postdoctoral Fellows.
6. Complete construction of the first building on the permanent site, with occupancy by January, 1988.
7. Conduct five or more workshops in Santa Fe.
8. Expand the contract-funded research program.
9. Acquire a major minicomputer and upgrade microcomputers.
10. Establish three or more active research networks.

CONNECTION BETWEEN BIOLOGICAL EVOLUTION AND COMPUTER ADAPTATION

Marcus Feldman

Mathematicians, physicists, biologists, and behavioral scientists have a common interest in the quantitative study of adaptation. The processes that physicists, biologists and behavioral scientists believe to occur, as neural networks accommodate information or as organisms adapt genetically to environmental challenges, seem to have a common mathematical framework which has been called "complex adaptive systems". In the first half of this century population geneticists worked hard to predict mathematically how natural selection should alter a population's genetic state. Their most elegant finding agreed with Darwin's qualitative rule that the average fitness of the population should increase. With the advent of more careful definitions of fitness that include fertility, mortality, mate choice, etc., the mathematical prediction of evolution has become extremely complex. Physicists have seen areas of overlap between these complex models and mathematics arising in their own field. The time is ripe for collaboration.

Of great interest to both biologists and physicists are questions about the origin of life. Recent experimental and theoretical studies have focused on the simplest self-replicating molecules in a laboratory environment. The trajectories followed by these molecules as they compete share many of the properties of the models of adaptation, mentioned above, in evolutionary genetics. Computer scientists have recently become deeply involved in theories of adaptation in pursuit of computer models of intelligent organisms. A promising approach treats the strings of zeroes and ones that comprise computer instructions as though they were DNA-like, and subject to similar rules. These rules include mutation, breakage and rejoining, and, of course, natural selection. This last occurs by deciding whether one instruction does a task better than another, and retaining it if it does while discarding it if it does not. The result is a genetic algorithm for adaptation among a set of instructions; the computer program adapts.

Related to this question of artificial intelligence is one of the major issues in behavioral evolution. We refer to the events surrounding the transition from an information storage and transmission system that was entirely based in DNA to organisms with culture, i.e., the ability to store and transmit non-biological information via non-genetic methods. Much controversy surrounds this question because, as it is central in modern speculation about social organization, it provides an excellent example of a complex adaptive system. All of these phenomena share a common

mathematical framework even though their fields of origin may overlap very little. By pursuing this commonality in the unique environment of the Santa Fe Institute, we anticipate significant progress for each field.

REPORT ON THE SUPERSTRING WORKSHOP

Richard Slansky

The Santa Fe Institute sponsored a three-day meeting (November 8-10, 1985) to discuss the exciting current developments in superstring theory. An outstanding group of mathematicians and physicists were assembled by Murray Gell-Mann (CalTech) and Richard Slansky (Los Alamos), to discuss questions of mutual interest related to the formulation of string theory. The so-called superstring is at present the only serious candidate for a unified quantum field theory of all the forces of nature and all the elementary particles of which matter is composed. The theory gives promise of reconciling Einstein's general relativity with quantum mechanics, and of unifying Einsteinian gravity with the theories of the other forces, including the electroweak and strong interactions. The mathematical problems presented by superstring theory are so complex that their solution is expected to require the combined efforts of the best mathematicians and theoretical physicists.

This workshop had a somewhat unusual style. The twenty-five participants were able to meet as an informal discussion group. There were short reviews of work already completed, but mainly people described work in progress and their expectations for the successes and failures of various approaches to string theory. All this was done in a lively dialogue. For example, one of the major topics discussed was the use of noncommutative geometry in the formulation of superstrings: E. Witten proposed a formulation of open bosonic string theory, while I. Singer emphasized some of the general features of noncommutative geometry and why it might be expected to be useful in formulating physical law.

The workshop received support from the Santa Fe Institute, the National Science Foundation and the Department of Energy.

PREVIEW OF WORKSHOP ON ADAPTIVE NEURAL NETWORKS

Alan Lapedes

The Santa Fe Institute will join with the Center for Nonlinear Studies (Los Alamos National Laboratory) in sponsoring a nine-day workshop, organized by Alan Lapedes (Los Alamos), on the interdisciplinary aspects of neural networks. A class of complex adaptive systems, neural networks are massively parallel systems that are thought by many to be a strong contender for the next generation of super fast and intelligent cognition systems. There exists the fascinating possibility that understanding these artificial systems will be useful in comprehending the nature of true biological intelligence. Cross-fertilization of ideas between physicists, mathematicians, neurophysiologists, computer scientists and hardware experts is the goal of the workshop. Topics to be discussed include the adaptive properties of neural networks that can learn, as well as networks that can solve difficult optimization problems such as the classic Travelling Salesman Problem. Indeed, recent research has shown that these two classes of problems are closely related. We hope that bringing together researchers whose interests span many disciplines will stimulate new advances in the rapidly developing area of massively parallel "intelligent" systems. Among those who will take part in the workshop are: John Dehker (AT&T Bell Labs), John Hopfield (CalTech and SFI trustee), Eric Mjolsness (Yale), Terry Sejnowski (Johns Hopkins), Ronald Williams (UCSD), Helga Sertorio (Torino), and Alan Yuille (MIT).

The workshop will be at the J. Robert Oppenheimer Study Center (Los Alamos) on July 17-18, and at the School for American Research (Santa Fe) from July 20 to July 25. It is being supported by the Department of Energy and the Santa Fe Institute.

PREVIEW OF WORKSHOP ON COMPLEX ADAPTIVE SYSTEMS

Jack Cowan and Marcus Feldman

Twenty-five scientists, from fields as diverse as population biology, theoretical physics, psychology, computer science, mathematics, and political science, will discuss interdisciplinary aspects of complex adaptive systems in a two-week Santa Fe Institute workshop organized by Santa Fe Institute Trustees Jack Cowan (Chicago) and Marcus Feldman (Stanford). The workshop will be at the School for American Research from July 28 to August 9. It has been made possible by a substantial grant from the Alfred P. Sloan Foundation.

Complex adaptive systems are systems comprising large numbers of coupled elements the properties of which are modifiable as a result of environmental interactions. To put it another way, complex adaptive systems process information, and can modify their internal organization in response to such information. In general, complex adaptive systems are highly nonlinear and are organized on many spatial and temporal scales. Their investigation is important for an understanding of many physical, biological, and social phenomena and for the design and construction of new instruments, especially computers and robots. The theory of evolution provides a good example of how these problems originate in natural science. The theory is concerned with adaptive changes over time in the distribution of phenotypes within one or more populations.

A recent approach to computer learning developed by Holland involves an evolutionary conceptualization similar to that proposed above. Instructions are regarded as symbolic strings that are subject to breakage and reunion (recombination), limited mutation, and evaluation as to function according to criteria that are input and that may change (this corresponds to natural selection). We will conduct a thorough study of adaptation as applied to genotypes, organismic phenotypes, and chemical species. Topics to be explored include the relationship of the Eigen-Schuster theory of chemical "hypercycles", and of Kauffman's adaptive chemical networks, to conventional evolution theory, and the role of embryological constraints in development and evolution. We will also review the current status of the theory of nonlinear dynamical systems, focusing on topics such as stability and bifurcations, both local and global, many-body problems, chaos, spin-glass dynamics, neural network dynamics, and the relevance of all these subdisciplines for a theory of adaptive dynamical systems.

Finally, we will examine current developments in cellular automata theory and in high-level heuristic programming, both for pattern recognition and related problems and for computer learning. Cellular automata theory may help to provide a bridge between conventional dynamical systems (including neural networks and spin-glasses) and computer-based algorithms that solve problems recursively. The interfaces between hard-wired approaches to pattern recognition via neural networks and the adaptive programming approach pioneered by Holland and others will be explored.

PREVIEW OF EXPLORATORY MEETING ON INTERNATIONAL FINANCE AS A COMPLEX SYSTEM

George Cowan

An informal one day meeting will be held at Rancho Encantado on August 7 to explore this topic. The participants will be John Reed, Chairman of the Board and Chief Executive Officer of Citicorp; two members of his staff; Kenneth Rogoff of the Social Systems Research Institute of the University of Wisconsin; Larry Smarr, Director of the National Center for Supercomputer Applications at the University of Illinois; Jerry Geist, Chairman of the Board of Public Service Company of New Mexico, which is providing support for this meeting; Philip Anderson of Princeton University and Vice Chairman of the SFI Board of Advisors; two dynamical systems theorists, yet to be selected; and four members of the SFI Board of Trustees: Robert McCormick Adams, who suggested the meeting and helped to organize it, George Cowan, David Pines, and Murray Gell-Mann.

The objective of the meeting is to assess the possible applications of the modern mathematical tools relevant to complex systems, such as dynamical systems theory and other nonlinear mathematical techniques, to the construction of macroeconomic models dealing with aspects of international finance. The discussion will touch on the main features of world capital holdings, flows and indebtedness; the character and limitations of the current generation of macroeconomic models; the character and limitations of modern nonlinear dynamical systems theory and its relation to the construction of useful models in the physical, behavioral and biosciences; problems of economic data availability and accuracy; and potential contributions of emerging developments in computing

hardware and software and in new mathematical concepts. The group will try to assess possible synergisms and recommend next steps.

PREVIEW OF PLANNING MEETING ON SELF SIMILARITY AND SCALING

Peter Carruthers

Many of the vital themes of the Institute center on recent advances in the study of problems involving self similarity in mathematics and the physical sciences. A planning meeting including F. Browder, P. Carruthers, M. Gell-Mann and I. Singer will be held in Chicago on June 12 with the intent of organizing a workshop of about 25 people in the late fall or early winter of 1986. Possible topics include the following: fractal structures and their generation; fractal sets in mathematics; scaling behavior near critical points (including the transition to chaos); fundamental laws of science and their scaling behavior; modular systems and their application to economic, social, and biological systems; cellular automata (including modeling of turbulent flows). The subject is so large that considerable selection will be necessary. Input about subject matter and potential participants is desired.

PREVIEW OF PLANNING MEETING ON THE STRUCTURE AND DYNAMICS OF PROTEINS

Hans Frauenfelder

Proteins, the machines of life, are complex dynamic systems. In many properties, such as the classification of their states, substates, and motions, they may resemble glasses. Their experimental exploration requires essentially every tool available to physicists and chemists, from Xray diffraction using synchrotron radiation to specific heat measurements at very low temperatures. Their theoretical understanding may well be based on a combination of large scale computer modeling with theories of complex systems involving concepts such as ultrametricity. The theoretical treatment may link proteins to physical systems such as spin glasses and glasses, as well as to immunology and evolution. A concerted

effort could involve the collaboration of biologists, chemists, mathematicians, and physicists from many different fields. A planning meeting organized by Hans Frauenfelder, an SFI Advisor, will be held in the late fall or early winter.

ELECTION RESULTS FROM THE ANNUAL MEETING OF THE BOARD OF TRUSTEES

The Board of Trustees met on March 8, 1986 at La Posada in Santa Fe. A substantial expansion of the Board membership was approved, with emphasis placed on experience in business and public affairs.

Incumbents reelected to three-year terms:

Harold Agnew	Gian-Carlo Rota
Jack Campbell	Douglas Schwartz
Jack Cowan	Isadore Singer
Edward Knapp	Anthony Turkevich

New Members:

One-year terms:	Two-year terms:	Three-year terms:
Robert Craig	John Hopfield	David Z. Robinson
James Modrall	Carl Kaysen	J. I. Staley
Tom Lang	Sydney Stein, Jr.	George Stranahan

OFFICERS OF THE CORPORATION

Chairman, Board of Trustees:	David Pines
Vice-Chairman, Board of Trustees:	Robert McC. Adams
President:	George A. Cowan
Vice-Presidents:	Peter Carruthers
	John Rubel
	L. M. Simmons, Jr.
Secretary:	Nicholas C. Metropolis
Treasurer:	Arthur H. Spiegel

SANTA FE INSTITUTE COMMITTEES

Executive Committee:

George A. Cowan and David Pines, Cochairmen
Robert McC. Adams
Peter Carruthers
Murray Gell-Mann
Edward Knapp
John Rubel
George Stranahan

Executive Finance Committee:

George A. Cowan
David Pines
Arthur H. Spiegel

Program Committee:

Murray Gell-Mann, Chairman
Robert Mc. Adams
Felix Browder
Peter Carruthers
George Cowan
Jack Cowan
Marcus Feldman
John Hopfield
Carl Kaysen
David Pines
David Z. Robinson
Isadore Singer

Organization, Structure, and Governance:

John H. Rubel, Chairman
Peter Carruthers
L. M. Simmons
George Cowan

Nominating Committee:

Edward Knapp, Chairman
Robert McC. Adams
Peter Carruthers
George Cowan
Murray Gell-Mann
David Pines
John Rubel
George Stranahan

Committee on Fund-Raising Tactics and Strategy:

George Stranahan, Chairman
Jack Campbell
Robert Craig
John Rubel
J. I. Staley
Arthur H. Spiegel

Building Facilities:

L. M. Simmons, Jr., Chairman
George Cowan, ex-officio
Darragh Nagle
David Pines, ex-officio
Richard Slansky

Talent Identification and Data Base Implementation:

Richard Slansky, Chairman
Robert McC. Adams
P. W. Anderson
Murray Gell-Mann
David Pines
L. M. Simmons, Jr.

Computer Acquisition and Network Implementation:

David Campbell, L. M. Simmons, Jr., and Richard Slansky

Workshop Coordination and Planning (Executive Committee for Board of Advisors):

Philip W. Anderson
David Campbell, Chairman
Peter Carruthers
Murray Gell-Mann
David Pines
L. M. Simmons, Jr.

Bulletin Coeditors:

Peter Carruthers, David Pines, and L. M. Simmons, Jr.

Public Relations: Peter Carruthers

Publications:

David Campbell, Peter Carruthers, and David Pines.