REPORT TO THE US DEPARTMENT OF ENERGY
1998 COMPLEX SYSTEMS SUMMER SCHOOL

I. INTRODUCTION

For the past eleven years a group of institutes, centers, and universities throughout the country have sponsored a summer school in Santa Fe, New Mexico as part of an interdisciplinary effort to promote the understanding of complex systems. The goal of these summer schools is to provide graduate students, postdoctoral fellows and active research scientists with an introduction to the study of complex behavior in mathematical, physical, and living systems. The Center for Nonlinear Studies supported the eleventh in this series of highly successful schools in Santa Fe in June, 1998.

II. PROGRAM

The format of the school consisted of four hours of course lectures and a one-hour seminar each day. The rest of each day was set aside for discussion sessions, laboratory projects, and informal interactions. Laboratory facilities included computer workstations, experimental equipment, and software provided by the sponsoring institutions and the individual lecturers.

Lecturers and topics for 1998 were:

Week One

Stability and Turbulence
Charles Doering, Mathematics, University of Michigan

Stability is usually considered a property of stationary, relatively "simple" states of a hydrodynamic system. Turbulence is the antithesis, characterized by instabilities and complex dynamics. There is, however, a heuristic connection between the two concepts which bears some similarities to the modern concept of self-organized criticality. In recent years this connection has been placed on a rigorous mathematical footing. In this series of lectures, the connection between stability concepts and turbulence dynamics was explored both in terms of physically motivated arguments and in terms of rigorous mathematical analysis.

Adaptive Social Systems
John Miller, Social and Decision Sciences, Carnegie Mellon University

This series of talks will explored issues surrounding adaptation and complexity in some fundamental economic and social systems. The systems explored included basic markets and auction institutions, games of cooperation, and political models of party competition. These systems will be analyzed through the integration of both adaptive computational

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and more traditional theoretical techniques.

Week Two

The Satisfiability Problem

Toniann Pitassi, Computer Science, University of Arizona

The satisfiability problem is the original and quintessential NP-complete problem. Pitassi discussed this famous problem, and its importance to computer science, artificial intelligence, logic, economics and cryptography.

Models of Cortical Population Codes

Richard Zemel, Psychology, University of Arizona

Zemel investigated current models of population codes in terms of three main questions: 1) Interpretation: how can the underlying encoded quantity be inferred from a set of neural activities? 2) Generation: how can the observed tuning curves arise from the afferent synapses? 3) Information: what information about external correlates is contained in the population code, and how does this information influence behavior? He explored the mathematical techniques and assumptions used in models that address these three questions, and discussed the computation consequences of the different models.

Week Three

Molecular Evolution and the Past, Present and Future of Proteins

Frances Arnold, Chemistry and Chemical Engineering, California Institute of Technology

Steven Benner, Chemistry, University of Florida at Gainesville

Benner began these the lectures by describing a Markovian model for divergent evolution in protein sequences, a model similar to that implemented by nearly all computer tools used to analyze genomic sequences. He then introduced chemistry into the analysis, showing how a purely informatic model fails to describe adequately the divergent evolution of real proteins in real organisms struggling to survive, get married, and have children in real environments

Arnold then described how we can mimic key processes of Darwinian evolution--mutation, recombination and selection (or screening)--to evolve a wide variety of protein functions on the time scale of weeks. Many of the molecular solutions that arise from these experiments are unanticipated and provide unique insights into the molecular mechanisms of protein folding and function.

Week Four

Form and Motion in Physics and Biology

Ray Goldstein, Physics, University of Arizona

Adriana Pesci, Physics, University of Arizona

These lectures covered an interrelated set of topics in the areas of nonlinear dynamics and pattern formation. Both theoretical and experimental methods for the study of how patterns emerge from structureless continua were explained. Examples were drawn from soft condensed matter physics, biological physics, fluid dynamics, and astrophysics. Common theoretical notions developed include geometrical aspects of the motion of surfaces and interfaces, the dynamics of pattern competition, the structure and importance of variational principles, and the role of numerical computations.

III. OUTCOMES

Participant Evaluations

Written participant evaluations of each year's school are solicited on a weekly basis during the program and at its conclusion. Evaluations to date have been consistently positive in response to the content and quality of the lectures, and to the format and administrative coordination of the schools.

Participants' Research Careers

The successes of the summer schools must also be judged by long-term effects. Attendees of past schools are routinely polled to learn what influence their attendance had on their subsequent careers and research. For many past attendees the School appears to have played an instrumental role in helping them to choose their present research and goals. Some became aware of techniques from other fields that have helped them solve research problems; others became aware of new problems that changed the course of their research up to that point. Many report specific benefits. Some find the school instrumental in obtaining postdoctoral positions in the fields and institutions of their choice. Many author papers directly stemming from the summer research. Some begin long-term collaborations with other participants.

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1998 Complex Systems Summer School Schedule

May 31-June 5

Sunday afternoon
(King Hall, College of Santa Fe)

1:00-8:00 p.m. Registration

6:00-8:30 Welcoming reception

Monday
(All lectures and seminars take place in the Forum. Computer Laboratory is on the lower level of the Forum. Summer school office is on the lower level of the Forum.)

8:45 a.m. Introduction to the 1998 Complex Systems Summer School
Daniel Stein, Co-director

9:00 Stability and Turbulence
Charles Doering, Mathematics, University of Michigan

10:30 Break

10:45 Adaptive Social Systems
John Miller, Social and Decision Sciences, Carnegie Mellon University

12:15 p.m. Lunch, Cafeteria

1:30 Introduction to the Santa Fe Institute (SFI)
Erica Jen, Vice President for Academic Affairs, SFI

2:00 Introduction to CSSS computer facilities and support
Tim Carlson, System Manager, SFI and Sam Brannen, Summer School Program Coordinator

Tuesday
a.m. Same morning lecture schedule throughout this week

1:30 p.m. Introduction to Santa Fe
Andi Sutherland, Events Coordinator, SFI

2:30 UNM Registration (Lobby of the Forum)

Wednesday
Free afternoon

Thursday

4:00 p.m. Open house and reception at the Santa Fe Institute

Friday
Free afternoon

June 8-12

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Monday

9:00 a.m. The Satisfiability Problem
Toniann Pitassi, Computer Science, University of Arizona

10:30 Break

10:45 Models of Cortical Population Codes
Richard Zemel, Psychology, University of Arizona

12:15 p.m. Lunch, cafeteria

1:30 Quenched Disorder and Its Applications I
Daniel Stein

Tuesday

a.m. Same morning lecture schedule throughout this week

1:30 p.m. Quenched Disorder and Its Applications II
Daniel Stein

Wednesday

1:30 p.m. Toolkit on Computational Complexity
Cris Moore

Thursday

2:00 p.m. Talk by SFI Research Professor James Crutchfield at the Santa Fe Institute

Friday

p.m. Free afternoon

June 15-19

Monday

9:00 a.m Global Objective Functions and Local Learning Rules
Barak Pearlmutter, Computer Science, University of New Mexico

10:45 a.m. Molecular Evolution and the Past, Present and Future of Proteins
Frances Arnold, Chemistry and Chemical Engineering, California Institute of Technology
Steven Benner, Chemistry, University of Florida at Gainesville

12:15 p.m. Lunch, cafeteria

1:30 p.m. Experimental Demonstrations of Pattern Formation
Robert Ecke, Los Alamos National Laboratory

Tuesday

a.m. Same morning lecture schedule throughout this week

p.m. Free afternoon

Optional trip to the Ghost Ranch; participants in the course will see a working paleontology operation, where the most ancient fossils of dinosaurs, emerging right after the Permian extinction, are being excavated and studied. Led by Steven Benner.

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Wednesday	
p.m.	Free afternoon
8:00	Public lecture: Unnatural Selection: Proteins of the Future Frances Arnold at the James A. Little Theater
Thursday	
2:00 p.m.	Talk by Christian Reidys at the Santa Fe Institute
Friday	
p.m.	Free afternoon

June 22-26

Monday	
9:00 a.m.	Form and Motion in Physics and Biology Ray Goldstein, Physics, University of Arizona Adriana Pesci, Physics, University of Arizona
10:30	Break
10:45	Nonlinear Resonances, Optimal Dendritic Structures, Singular Motion, and Other Paradigms in Complexity Alfred Hubler, Physics, University of Illinois at Urbana-Champaign, associate director of the Center for Complex Systems Research of the UIUC, Santa Fe Institute
12:15 p.m.	Lunch, cafeteria
p.m.	Free afternoon
Tuesday	
a.m.	Same morning lecture schedule throughout this week
p.m.	Free afternoon
Wednesday	
p.m.	Free afternoon
Thursday	
2:00 p.m.	Toolkit on Computational Complexity Chris Moore at the Santa Fe Institute
Friday	
12:15 p.m.	Concluding remarks Daniel Stein
12:30	Farewell barbecue

1998 Complex Systems Summer School

May 31-June 26, 1998
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