

**Dynamical Psychology:
Complexity, Self-Organization and Mind**

**Dynamical Psychology:
Complexity, Self-Organization and Mind**

Written by
Jay Friedenberg

Cover images were provided by Genaro Martinez, and reproduced with permission.

Dynamical Psychology: Complexity, Self-Organization and Mind

Written by: Jay Friedenber

Library of Congress Control Number: 2009924499

ISBN13: 978-0-9817032-9-9

© 2009 ISCE Publishing.

All rights reserved. No part of this publication may be reproduced, stored on a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, microfilming, recording or otherwise, without written permission from the publisher.

Printed in the United States of America

CONTENTS

CHAPTER 1

Introduction—What Is This Book About?

Dynamics, Complexity, Self-Organization and Mind.....	15
Networks and Neurodynamics.....	16
Levels of Organization, Fractals and Noise	17
Dynamical Psychology and Cognition	18
An Ecological Approach	18
Models and Recommendations	19
Classical Science vs. the Dynamical Approach.....	19
Linearity and Independence	20
Causality and Rules.....	21
Change and Bifurcation	22
Order and Energy	23
Reduction and Emergence	24
Reductionism	24
<i>Problems with Reductionism</i>	25
<i>Bénard Cells</i>	26
Emergence	27
<i>Problems with Emergence</i>	29

CHAPTER 2

Systems and Complexity

Systems	31
Types of Systems	31
<i>Ordered Systems</i>	31
<i>Chaotic Systems</i>	32
<i>Random Systems</i>	33
The Edge of Chaos.....	33
Complex Adaptive Systems.....	34
Complexity.....	36
Complexity and Order	36
Entropy and Complexity	37
A Complexity Metric.....	38
Complexity from Simplicity	40
Complexity and Parts	41
Information and Complexity	44
Algorithmic Information Content.....	44
Computational Complexity.....	45

Complexity and the Nervous System.....	47
Complexity Science.....	49
A Critique of Complexity Science.....	50

CHAPTER 3

Self-Organization

Self-Organization	53
Features of Self-Organization.....	53
Self-Organization and Leadership.....	54
Self-Organization and Complexity.....	55
The Process of Self-Organization	56
Feedback.....	56
Information Transfer.....	57
Stigmergy.....	58
Alternatives to Self-Organization	59
Self-Organized Criticality	61

CHAPTER 4

Dynamical Systems

The Dynamical Systems Approach	65
Nonlinearity	65
Predictability	65
State Space and Trajectories.....	68
Attractors.....	69
Dimensionality and Lyapunov Exponents	72
Landscapes and Mental Trajectories.....	72
Ghosts and Rivers	75
Control and Order Parameters.....	76
The Logistic Equation and Bifurcation	76
Order out of Chaos.....	79
Hysteresis	79
Catastrophe Theory	80

CHAPTER 5

Networks

Boolean Networks	83
Biological Meaningfulness and Boolean Networks.....	86
Network Science	87
Random Graphs.....	88
Random-Biased Networks	90
Hierarchical Networks	92

Centrality.....	93
Hierarchies and Control.....	94
<i>Hierarchies and the Brain</i>	96
Small-World Networks	98
It's a Small World After All.....	98
Ordered and Random Connections.....	98
Egalitarians and Aristocrats.....	100
The Power and Development of Hub-based Webs.....	101
Neuroscience and Networks.....	103
Small-World Networks and Synchrony.....	103
Small-World Networks and Collective Computation.....	104
Percolation	105
Percolation and Psychology.....	106
The Future of Network Science	107

CHAPTER 6

Neurodynamics

Neural Oscillation	109
Neural Coding	110
Single-Neuron Codes.....	110
Multiple-Neuron Codes.....	110
Synchrony and Coding.....	112
Neural Synchrony	113
Neural Coupling	114
Metastability	115
Dynamics and Metastability.....	116
Connectivity and Metastability.....	117
Nonlinear Dynamics and EEG	119
Is the Brain Chaotic?.....	119
Neural Dynamics During Different Brain States.....	120
<i>Normal Resting-States</i>	120
<i>Perceptual States</i>	120
<i>Emotional States</i>	120
<i>Cognitive States</i>	121
<i>Sleeping States</i>	121
<i>Development</i>	121
<i>Epilepsy</i>	122
<i>Alzheimer's Disease and Dementia</i>	122
Dynamics and Olfaction	123

CHAPTER 7

The Fractal Mind

Fractals and Dimensionality	125
Fractal Dimensionality and Magnitude Estimation.....	127
Perception of Fractal Stimuli	130
Fractals and Visual Aesthetics	130
The Fractal Brain	131
Levels of Analysis and the Brain	132
Mind-Brain Interaction in Complex Systems	133
Fractal Geometry and Human Nature	134

CHAPTER 8

Statistical Mechanics and Noise

Statistical Mechanics and Magnetism	137
A Statistical Mechanics of the Mind	140
Noise	141
Characteristics of Noise	141
Why Nervous System Noise is Important	142
Sources of Nervous System Noise	142
Major Types of Noise	143
<i>Pink Noise and Neural Processes</i>	145
<i>Pink Noise and Cognitive Processes</i>	146
Noise as Therapy.....	148

CHAPTER 9

Dynamics and Psychology

Dynamics and Psychology	151
The Failure of Psychology to Adopt the Dynamical Approach	151
Hypothesis Testing.....	153
Development	154
Traditional and Dynamical Accounts of Development	154
The Time Course of Development	155
Social Behavior	156
Dynamics in Social Psychology	156
Dyadic Processes.....	157
Hysteresis in Relationships	157
Dynamics of Romantic Relationships	158
Cellular Automata Models of Social Influence	160
Industrial and Organizational Psychology	161
Organizational Change.....	161
The Dynamics and Structure of Organizational Change	161

Organizational Decision Making	162
Work Performance	163
Leadership Emergence	164

CHAPTER 10

Personality, Pathology, and Therapy

A Model of Personality Self-Organization.....	168
Psychopathology.....	169
Psychosis and Dynamics.....	169
Dynamical Disease.....	170
Psychological Disorders.....	171
Traditional versus Dynamical Views of Abnormality	172
Defenses.....	172
Specific Disorders.....	173
Anxiety Disorders.....	173
Mood Disorders.....	175
Dissociative Identity Disorder.....	177
Schizophrenia.....	177
Learning Disabilities, Self-Organization, and Multi-Component Cognition.....	178
Dynamical Therapy.....	179
Group Therapy.....	180
<i>Order and Disorder in Group Therapy.....</i>	<i>180</i>
<i>Complex Adaptive Systems and Group Therapy.....</i>	<i>181</i>

CHAPTER 11

Cognition

Cognition and Dynamics.....	183
Representation.....	183
Symbolic Dynamics.....	185
Concepts.....	186
Supervised and Unsupervised Learning.....	187
Concept Formation.....	187
Dynamical vs. Classical Cognitive Science.....	189
The Continuity of Mind.....	189
Modularity vs. Distribularity.....	189
Component-Dominant vs. Interaction-Dominant Dynamics.....	190
Internalism vs. Externalism.....	191
Situated vs. Embodied Cognition.....	191
Feed-forward vs. Recurrent Pathways.....	192
Cyclical Processes in Cognition.....	192
The Perceptual-Cognitive Loop.....	192
The Thought-Perception-Action Triad.....	193
Edge of Chaos and Cognitive Function.....	194

CHAPTER 12

Cognitive Processes

Cognitive Processes and Dynamics.....	197
Perception.....	197
<i>Ambiguous Figures.....</i>	<i>197</i>
<i>Glass Patterns.....</i>	<i>198</i>
<i>Apparent Motion.....</i>	<i>199</i>
Attention.....	200
<i>Attention and the Structure of Time.....</i>	<i>200</i>
Memory.....	201
<i>Stability and Plasticity in Memory Processes.....</i>	<i>201</i>
Language.....	203
<i>The Lexicon.....</i>	<i>203</i>
<i>Syntax.....</i>	<i>204</i>
<i>Conversational Behavior.....</i>	<i>205</i>
Decision Making.....	206
<i>Decision Field Theory.....</i>	<i>206</i>
A Dynamical Model of Problem Solving.....	208

CHAPTER 13

Problem Solving and Evolution

Evolutionary Processes and Problem Solving.....	211
Problem Spaces and Search.....	211
Simulated Annealing.....	213
Genetics.....	213
Random Fitness Landscapes.....	214
Correlated Fitness Landscapes.....	217
The <i>NK</i> Model.....	217
An Expanded View of Evolution.....	218
Mental Landscapes and Problem Solving.....	219

CHAPTER 14

Mental Ecology

Mental Ecology.....	223
Homeostatic Environment Regulation.....	223
<i>Self-Regulation and the Brain/Mind.....</i>	<i>225</i>
Food Webs.....	226
<i>Webs and the Brain/Mind.....</i>	<i>226</i>
Species Defense.....	227
<i>Species Defense and Interference.....</i>	<i>228</i>
Species Competition.....	228
<i>Species Competition and Interference.....</i>	<i>229</i>

Species Deletion and Coherence	229
<i>Species Deletion and Filling In Processes</i>	230
Habitat Fragmentation	231
<i>Habitat Fragmentation and Brain Damage</i>	232
Conclusions	233

CHAPTER 15

Models

Modeling Complexity	235
General Features of Models	235
Broad Categories of Models	236
Process Models	237
Statical and Dynamical Models	238
More on Dynamical Models	239
Deterministic and Stochastic Models	240
Oscillatory Models	241
<i>Neural Oscillatory Models</i>	242
<i>An Oscillatory Model of Hippocampal Function</i>	242
<i>An Oscillatory Model of Attention</i>	244
<i>Conclusions Concerning Oscillatory Neural Models</i>	244
Models of Self-Organization	245
The Differential Equation Model	245
Cellular Automaton Models	247
<i>Cellular Automata and Computation</i>	249
Agent-Based Modeling	251
<i>Sugarscape</i>	252
<i>Evaluating Agent-based Models</i>	252
<i>Constrained Generating Procedures</i>	253
Modeling Chaotic Brain Activity	254
Control and Anti-Control of Chaos	254
Chaotic Computing	256
A Review of Dynamical Modeling	256

CHAPTER 16

Conclusions

A Summary	259
The Problem with Defining Emergent Levels	261
Carving Systems at their Joints	261
Alternate Conceptions of Emergent Levels	262
Aggregates Again	263
Informational Complexity and Emergence	263
An Empirical Approach	264
Evaluating the Reduction-Emergence Debate	264
The Interdisciplinary Approach	264

Multiple-Level Consideration.....	265
Redefining Parts and Wholes.....	266
The Unification of Psychology	266
Cognitive Science, Dynamical Systems, and Evolutionary Psychology ..	267
References.....	269
Index	291

CHAPTER 1

INTRODUCTION—WHAT IS THIS BOOK ABOUT?

Dynamics, Complexity, Self-Organization and Mind

The world is a complicated place. Obviously we haven't figured it all out yet. However, we certainly have come a long way. Modern science and technology have yielded a remarkable understanding and control of the physical universe. A person transported in time from the beginning of even the 19th century to now would be in awe of humankind's current achievements.

But let's not get carried away. There are still many fundamental mysteries that have yet to be solved. One of these is very close and personal. In fact, you are using it right now. It's called the human brain and much about the way it operates is still a mystery. Part of what makes the brain so hard to understand is its dynamic nature. Brains are never the same from one instance to the next. Messages are always being sent back and forth between billions of cells in an intricate dance. This activity is what gives rise to our mental selves. It underlies what we see, think, and feel.

It is difficult to get a handle on this activity in part because of its complexity. There are an estimated 100 billion neurons in the human brain. Each of these can have as many as ten thousand connections to other cells. At any given time, there are multiple patterns of activation that course through this network. These patterns are constantly changing in response to the environment and to each other.

This complexity is compounded by the fact that brain processes are simultaneously happening at many different spatial and temporal scales. At the level of the neuron, neurotransmitter molecules are being packaged, released and recycled, in some cases, many times a second. At the level of a society, brains make decisions that affect how we interact with each other. Is there an appropriate level of organization that we should study? One theme of this book is that we must study complex phenomenon at multiple levels. No level is privileged. What's more, we need to fathom the connectivity between these levels. No complex system can be fully understood by focusing only on one level, it is often the coordination and interaction between levels that yields new and interesting insights.

Another problem with studying complex systems has to do with organization. Many natural processes seem to develop and organize themselves. There is no single external "boss" to tell a brain how to grow or what to do. The brain figures it out on its own. This runs counter to traditional conceptions in psychology and cognitive science, where there is a central executive or processing unit that monitors ongoing functions, issues commands and generally keeps things operating smoothly.

When we look at nature, we can never seem to find this boss. Nature instead builds and operates using the principles of self-organization by which systems come into existence and function under their own command. The interaction of parts with each other and with the environment is enough to give rise to ordered behavior. These processes are an integral part of who we are. They are taking place in the chemical reactions inside our cells, governing how our cells grow and differentiate during development, and probably underlie mental and conscious phenomena. To explain the mind we therefore need to understand self-organization.

So far we have touched on several themes. These are change over time, intricacy, and how ordered behavior emerges and operates. Each of these themes corresponds to a particular scientific-theoretic approach; namely, dynamics, complexity, and self-organization. In this book, we discuss these approaches in great detail and then apply them to the study of mind. Separate chapters are devoted to each, where we first introduce the topic from a theoretical standpoint and then examine how it helps us to understand mind.

Networks and Neurodynamics

The brain is a network made up of units and connections between them. There are many other examples of complex networks, both natural and man-made. The society we live in is a network, made out of individuals that move around and exchange information. The Internet is also a network. In recent years we have seen the development of a new approach to the study of networks. Called network science, researchers in this discipline attempt to understand the abstract principles by which networks operate.

After introducing the ideas of dynamics, complexity, and self-organization, we therefore next turn our attention to the study of networks. We start by examining Boolean networks, whose nodes operate in a very simple way, but whose overall behavior when wired up together is quite complex. We then examine random graphs, whose nodes are connected randomly but which still display ordered and interesting behavior. Following this, we discuss how self-organizational processes can lead to ordered connectivity, even in networks that are mostly random to start.

One problem in networks is how activity gets coordinated, especially if there is no “leader”. How for example, does a message spread from one part of a net to another? We look at different ways that this can occur, along the way discussing networks like corporations and the human brain that show hierarchical organization.

A fascinating discovery, first noted by social psychologists some years ago, but only recently studied with more rigor, are small-world networks. In these nets, any two nodes can communicate with one another through a small number of connections, even though the number of nodes can be very large. In popular culture, this phenomenon is referred to as “degrees of separation”. We look at the scientific study of small-world networks and what the implications of these findings are for mental processing.

It turns out, perhaps not unsurprisingly, that brains are small-world networks. This makes sense, because animals need to react quickly in order to survive. If information has to flow through too many connections, reaction times are slow and the proverbial tiger will eat you before you can react quickly enough. A number of other interesting properties can be instantiated in small-world networks, including signal synchronization and collective computation.

With this foundational knowledge in mind, we turn next to the specifics of how brain networks operate. The focus is on dynamical activity inside neural networks, what we call neurodynamics. Neurons are oscillators because they exhibit repetitive wave activity. We look at neural oscillation and how this can code for information. Then we summarize some of the research on synchrony and coupling, the means by which brains coordinate their activity between different regions. Another interesting feature of brain networks is metastability, a state that allows both for pattern formation and dissolution. Metastability may explain many cognitive processes like memory and free association.

Levels of Organization, Fractals and Noise

Classical methods in science have been useful at getting nature to reveal her secrets. Traditional science adopts an analytical and reductionist approach. It takes a whole such as the brain and breaks it down into its component parts. Once we know what the parts are and how they work, we can then figure out how they combine and interact to produce the behavior of the whole they make up.

Unfortunately, many wholes in nature defy reductionist explanation. The behavior of these wholes, to borrow a phrase from the Gestalt psychologists, is “more than the sum of their parts”. There are several reasons for this. The sheer number of parts and the possible ways they can combine is vast in even moderately complex systems. Another obstacle has to do with our conception of what a whole is. Many investigators draw arbitrary lines around what they investigate. They agree to study a certain aspect of a whole, such as a neuron, person, or society, while neglecting that the “piece” they look at is both part and parcel of larger and smaller systems respectively.

The holistic emergent paradigm arose in reaction to these problems. In this approach, one takes care to examine interactions between levels and to consider any phenomenon in light of the other systems of which it is a part. In this book, we favor neither the reductionist or emergent perspectives. Rather, we advocate that both approaches are necessary to understanding complex systems. They must be used in conjunction with one another as part of a proper cognitive science. However, we spend more time examining the emergence perspective because it is newer and has yet to be applied in the same general and systematic way as its reductionist cousin.

A fractal is a pattern that is self-similar at different scales. Fractals exist everywhere in nature. We describe what fractals are and summarize some of the literature on psychology and fractals. This literature includes magnitude estimation, perception of fractal stimuli and aesthetic judgments. The brain has a very definite fractal organization, so we describe this activity and how it relates to mind and human nature.

A persistent problem in statistics and research methods is what to do with noise. Traditionally noise has been treated as error, the proportion of variance in the dependent variable that cannot be accounted for by the manipulation. A dynamical account views noise very differently. In this view, noise should be studied as it reflects some mechanism or aspect of the system under investigation. So we next describe sources of nervous system noise, different types of noise, including white, pink, and brown noise, and how they can account for neural and cognitive processes.

Dynamical Psychology and Cognition

The scientific study of how complex systems like the brain change is called dynamical systems theory, although it is has also been referred to as chaos theory. This relatively new paradigm provides us with a novel theoretical orientation and a set of tools and techniques that we can apply to things like the mind and understand them better. Unfortunately, psychologists do not seem ready for it just yet. In the section on dynamics and psychology we mention a number of reasons for this. We then summarize dynamical theory and practice for several major areas of the discipline, including development, social behavior, and industrial and organizational psychology. The amount of research that has gone into clinically relevant fields requires a separate chapter on personality, pathology and therapy.

Perhaps the greatest application of dynamical ideas in psychology has occurred in the cognitive area. There is much to talk about here. The dynamical approach forces us to rethink our traditional notions of representation, concepts and learning. We contrast classical views in cognitive science with the dynamical approach. Classical cognitive science advocates a mind that is modular, component-dominant, closed and feed-forward. The dynamical account sees mind instead as distributed, interaction-dominant, open, and recurrent. The recurrence theme is a particularly important one, so we describe several theories of cyclical processes in cognition.

This is followed by an in-depth analysis of studies in different areas of cognition. Each area corresponds to a distinct form of cognitive processing. We cover visual perception, including perception of ambiguous figures, Glass patterns and apparent motion. Then we look at attention in a temporal context. Following this we examine dynamical processes in memory, looking at the stability-plasticity issue. Language has been analyzed from the dynamical perspective, so we look at dynamics and the lexicon, syntax, and conversation. This chapter ends with a discussion of human decision-making and problem solving.

An Ecological Approach

People are not the only systems capable of problem solving. The process of biological evolution can viewed as a continuous solution to the problem of adapting organisms to an ever-changing environment. We discuss evolution in terms of optimization on a fitness landscape. This model is not complete however, without the introduction of self-organization. The key ingredients of selection, variation, and reproduction explain how evolutionary change happens. But the

tendency for the world to form into ordered and stable forms is necessary to produce the structures upon which such change acts.

Evolutionary optimization on a fitness landscape can also serve as a model of human problem solving. We outline some of the work on human cognitive problem solving such as analogical reasoning, functional fixedness, insight learning, means-end analysis, heuristics and their relation to optimization processes.

The analogy between dynamic processes in ecological and human systems does not stop here. Ecological systems can be viewed as dynamical systems. They have web-like structures, consist of multiple differentiated competing/cooperating units, and play an active role in regulating themselves and their environments. Both ecologies and the mind defend against intruders and reorganize themselves after damage. It seems that similar underlying forces are at work in both, and perhaps in all complex systems with a given nature.

Models and Recommendations

A hallmark of the dynamic approach is the use of models. These are created and run in order understand some aspect of a complex real world system. Models of course cannot capture every aspect of a system, but if done correctly, they can reveal many interesting features and processes. Models are best used in concert with empirical methods. Experimental validation of a model is a crucial technique that all researchers should practice.

There are many sorts of models. Traditional cognitive science models are either static or fail to capture important dynamical aspects of the process under consideration. We briefly summarize some of the basic types of models, including deterministic and stochastic, oscillatory, differential equation, cellular automata, and agent-based models. Examples are given for how some of these can be used to model brain activity and cognitive processes. We then present the advantages and disadvantages of various models and of modeling in general.

To conclude, we summarize the salient points made in this book and analyze the concept of emergence levels. We then evaluate the reduction-emergence debate and make suggestions for how to deal with some of the issues raised. The book concludes with a discussion of how the dynamical approach can serve to unify psychology and cognitive science.

Classical Science vs. the Dynamical Approach

Before describing the dynamical approach in any depth we need to first compare it to classical notions in science. The dynamical systems approach represents a sharp break with these views (Goerner, 1995). In this section we will summarize the classical scientific perspective and show how it contrasts with the ideas of dynamical systems theory. Table 1.1 shows a summary of these differences. Many of these distinctions are discussed in greater detail in other sections throughout the book. We introduce them here now to provide the reader with an overview.

Assumption	Classical Science View	Dynamical Systems View
System's Output	Linear	Nonlinear
System's Parts	Independent	Interdependent
Methodological Approach	Analytic	Holistic
System	Closed	Open
Causality	Linear	Circular
Prediction	Complete	Limited
Change	Slow and Gradual	Can be Fast and Rapid
How Order Arises	Unspecified or Agents	Spontaneously
Philosophical Perspective	Reduction	Emergence

Table 1.1 A comparison of the differences between the classical and dynamical views of science.

Linearity and Independence

Historically, scientists have focused on *linear* explanations, where the output of a system is proportional to its inputs. This type of relationship assumes a simple sort of system whose processes can be measured and understood. Of course, most if not all systems in nature are *nonlinear*. Outputs in this case are not proportional to inputs. A small input to a complex system can produce a small, moderate or even large effect. The processing taking place in these systems is intricate, convoluted and difficult to explain.

The parts of a system are in many cases assumed to be independent in the classical view. *Independence* assumes that a part functions with little regard for what is occurring in other parts of the system. It is compartmentalized, insulated or “boxed off” from the rest of the system to which it belongs. The cognitive science postulation of separate modules in the brain is a good example of independence. These modules are dedicated to processing specific information. When they receive an input, they crank through a computational routine uninfluenced by other modules. The result is that we always know what the result will be regardless of the overall state of the system. We discuss modules in greater detail later.

Modularity makes the brain easier to understand and model, but it throws the baby out with the bath water, since it fails to account for complex interactions between modules. The dynamical systems view can account for this. It sees the parts of a system as *interdependent*. In interdependent systems a processor in one location may be monitored, modulated or regulated by other processors. In this case, a processor's performance is dependent on the state of the entire system. The way it operates in one state is different from the way it might operate when the system is in another state.

If we assume independence, then a system can be understood *analytically*. One can examine the behavior of the different pieces of a system and then

put these separate descriptions together to explain the behavior of the whole. This is the reductionist approach. However, this approach often fails. Many systems in nature, including the human brain, resist reductionist explanations. This suggests that they function in a holistic manner. A system is *holistic* if it cannot be broken down piecemeal. Each piece relies on the parts around it to function properly. In the words of the gestalt psychologists, “the whole is greater than the sum of its parts”. Emergence is a property of these kinds of systems.

Systems in the traditional view are considered closed. That is, the system as a whole is assumed to be shut-off from the larger world around it. So when considering the brain as a *closed system* we treat it as distinct from the body in which it is embedded. The dynamical systems view instead sees the brain as an *open system* that cannot be considered independent of its surroundings. The brain is part of a body that is in turn part of the world. Treating the brain as an open system means taking into account “external” factors such as hormones from the body or visual stimuli from the outside world. It also postulates a two-way street between brain and its context, where the brain influences the environment and the environment also influences the brain. We discuss open and closed systems later in the section on the continuity of mind.

Causality and Rules

The independence approach has a linear view of causality, where variables affect others in a sequential manner. The best way to conceive of this is as a chain of arrows where variable A affects B, which then affects variable C, etc. (Figure 1.1). The dynamical systems view is that variables can have all sorts of causal relations that act concurrently. Much of this occurs as the result of feedback, where a variable’s output at one point in time can alter the future activity of both itself and many other variables. We can diagram this type of *circular causality* by showing loops and networks as shown in Figure 1.1.

The difference between linear and circular causality is to some extent reflected in the serial vs. parallel processing approaches in cognitive science. In the serial approach, information processing happens one step at a time. Information processing must finish in one module before it can be passed on, as is the case in most contemporary computer architectures. In the connectionist or parallel-distributed processing perspective, streams of information are processed simultaneously. There is no need to wait for one unit to finish before proceeding.

Dynamical systems takes a long-term view of system action, since feedback can alter not just what happens in the immediate moment following a cause, but over the entire future course of the system’s behavior. Feedback mechanisms can promote the maintenance of homeostasis, but they more often produce increases, decreases, oscillations, fluctuations, and other sorts of dynamic processes that change with time. So while the traditional view sees short-term immediate effects, the dynamical systems view sees long-term dynamical effects.

The classical view in science was that the world operated according to deterministic rules. These rules can be summarized in general as the laws of physics and more specifically as the laws that govern each of the different branches of

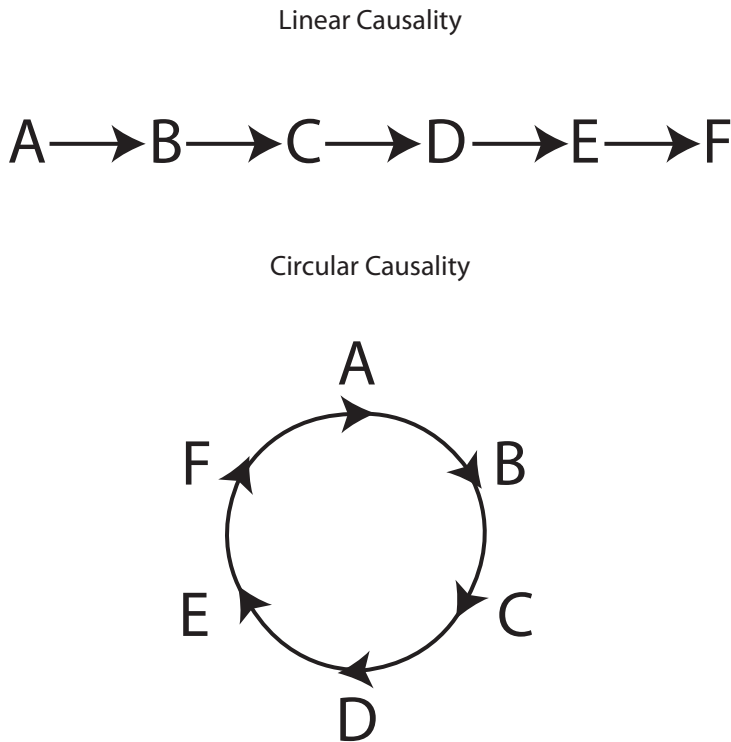


Figure 1.1 *The classical view in science is that causality is linear. The dynamical perspective allows for circular causality.*

science like chemistry and biology. If we can know these laws and have sufficient information as to the state of a system, then we can predict with accuracy what the system will do far into the future. We have *complete predictability*. Knowledge of physical law and conditions not only enables prediction, it implies also that complete understanding and control of a system are possible.

Dynamical systems theory also acknowledges that there are deterministic rules that govern a system's behavior. However, these rules and knowledge of starting conditions are not sufficient to allow complete prediction. The more accurate our knowledge of a system's starting state, the longer we can predict its future course. Eventually over time though, the behavior will diverge from our prediction no matter how accurate our starting observations. This is because the system is sensitive to initial conditions. Whereas the classical science view postulates long-term predictability, the dynamical systems view acknowledges only *limited predictability*. It allows for only partial understanding and control.

Change and Bifurcation

Change in the traditional view occurs gradually and slowly. In natural selection, for example, it was believed that species evolved continuously over long time periods and many generations. Evidence is now available though, that supports faster evolutionary change. This theory, called punctuated equilibrium, states that species evolution can happen fairly quickly, in a short time period with a smaller number of generations.

The dynamical systems perspective allows for such sudden and rapid change. Oftentimes, it is driven by the system's arrival at a *critical point*. These are conditions where a system undergoes a complete and dramatic alteration. For example, water molecules undergo a phase transition when they reach 100° C / 212° F. At this point they transform from water to steam and exhibit many new properties.

Chaotic systems can reach what is called a *bifurcation*, where they can switch to one of two alternate states. A state in this sense is large-scale or macroscopic. The bifurcation is a sizeable qualitative change in behavior. In perception of ambiguous figures such as the Necker cube, the perceptual organization can alternate back and forth between each possibility. The transition from one to the other can be considered as a bifurcation. We should also mention that there is an entire field devoted to the study of rapid change, called catastrophe theory. This discipline tells us that a particular combination of conditions, such as temperature and the degree to which steel is flexed, can give rise to dramatic alterations such as the collapse of a bridge.

Order and Energy

Perhaps one of the most important differences between the classical and chaotic perspectives is their view of order. The traditional science view has difficulty explaining how order in the universe comes to exist. It is accounted for by various factors such as accident, anomaly, or certain “agents of order” such as selfish genes, the human brain, or life itself (Goerner, 1995). According to the supernatural and unscientific view of vitalism, there is a mysterious force, vital spark or energy that creates phenomenon such as life and consciousness.

To a classical scientist, the world is passive and directionless. As we mention elsewhere, it acts much like a giant machine or clock that inexorably ticks away following known physical laws. How then, does order and organization emerge from this machine? According to the principle of self-organization, certain systems spontaneously organize themselves. Numerous examples of this are evident in nature. For instance, in chemistry, there are autocatalytic reactions that sustain themselves based on the amount of available precursor molecules. In biology, we see emergent behaviors when birds flock and fish school. Consciousness and cognition may also be examples of self-organization. This provides a very different conception of the universe, one that is active and directed toward the creation of ordered, complex structures and processes. The idea that natural ordered processes can arise from disorder is not entirely new and was proposed early in the 20th century (Schrödinger, 1944).

Another important distinction between the classical and dynamical systems views has to do with equilibrium. Systems that are in equilibrium have a homogenous distribution of energy and are incapable of driving processes. A process in this sense means any activity that requires energy. In biological organisms energy-requiring processes include locomotion and cognition that rely on metabolism. Self-organizing systems in contrast are *far-from-equilibrium*. They have a large energy concentration that has built up. This energy concentration creates a pressure to flow and drive operations.

According to thermodynamics, energy in any system always “seeks” to flow as fast as possible (Odum, 1988). It turns out that structured energy flow moves more quickly than that which is less structured. For example, energy flow is faster in a chimpanzee than it is in an amoeba because the chimpanzee is more structured and ordered. We can therefore see the creation of order and organization in the universe as driven by energy flow. This property of dissipative efficiency then could cause systems to become more ordered with time. If we plot energy flow over the time course of the evolution of life we see a dramatic increase. Energy flow, measured as metabolic rate, gets faster as organisms evolved over several billion years on earth (Swenson, 1989).

Energy flow can also explain why reorganization occurs within a given system (Goerner, 1995). If the pressure to flow builds up, energy cycles faster and faster within the system. The energy eventually reaches a limit on how fast it can flow. If this limit is reached and the resistance to flow is still less than the pressure driving the flow, a reorganization takes place. A bifurcation occurs and the pattern restructures itself into a more efficient configuration that can dissipate energy better.

A good example of this are Rayleigh-Bénard cells. If a thin layer of silicon oil is heated in a pan, the oil particles at first move randomly. As the temperature is increased, this pattern no longer dissipates heat well. There is a sudden reorganization into hexagonal-shaped cells where particles rise in the center of each cell and fall near its edges. This new arrangement is better at dissipating heat. If the temperature is increased further even more complex arrangements, such as rotating spiral patterns develop.

Reduction and Emergence

We have already mentioned reduction and emergence. Whereas reduction is analytic and seeks to break wholes into parts, emergence is holistic and seeks to build wholes out of parts and part interactions. Reduction is part of the classical approach while emergence is more recent. In what follows, we introduce these perspectives in greater detail and discuss the problems that are inherent in each.

Reductionism

In a general sense, *reductionism* is the belief that everything about a whole can be explained entirely by understanding its parts. If we can understand all there is to know about the parts that make up a system, then this enables us to completely understand the whole that they make up. In reduction we attempt to say that a given phenomenon X is “nothing more than” or “nothing above and beyond” phenomenon Y. X thus becomes reduced to Y.

Silberstein (2002) describes two types of reduction. *Ontological reduction* is concerned with the nature of reality and posits that everything in the universe consists of the fundamental constituents of reality, some basic particles or entities, or is determined by them. *Epistemological reduction* is concerned with descriptions of reality and posits that scientific theories or common sense

conceptions can be reduced to other scientific theories or conceptions about the fundamental features of the world.

In ontological reduction, the things that need to be related are real-world items such as entities, events, and properties. For instance, we might want to relate the property “heat” from thermodynamics to a more basic global description derived from the properties of individual molecular elements, as is done in statistical mechanics. In epistemological reduction, the things that are being related or reduced are representational items like theories, concepts, models, frameworks, and schemas. A theory in biology for example, might be reduced to another theory in chemistry.

Inherent in the notion of reductionism is the idea of *levels of analysis*. In this view, natural phenomena can be analyzed at different levels of spatial and temporal scale. Usually these two are correlated, with things happening faster at smaller sizes. We can take a given phenomena, such as the mind, and examine it from the large scale of psychology, which examines abstract concepts such as thoughts and emotions, all the way down to the quantum scale of subatomic particles. Because each level contains different phenomena and is organized and operates differently, there are distinct disciplines that have developed to study each. From large to small, we could study the mind from the disciplines of psychology, biology, chemistry, and physics, with multiple sub-disciplines in-between each of these.

Problems with Reductionism

Reductionism was one of the major goals of the traditional scientific endeavor. At one point, it was thought that even the largest scale phenomena could all be reduced to physics. Each level of explanation would eventually reduce to the one below it like the floors of a collapsing building until we would be left with nothing but the “basement”. Sociology could be explained by psychology, which could be explained by biology, which could be explained by chemistry, and so on. Findings from modern scientific investigation however suggest that this goal is untenable.

One of the central problems with reductionism is that there are very few actual cases of successful inter-theoretic reduction, where the explanatory constructs of one discipline are explained by those beneath it. Examples of failed or incomplete cases concern the reduction of thermodynamics to statistical mechanics, of thermodynamics to quantum mechanics, and of chemistry to quantum mechanics. In the last instance, the concept of a molecule cannot be accounted for using quantum formulations.

These are troubling because they come from the physical sciences. Reduction is even more problematic in the social sciences. It is not at all clear for example how to link the “hard” problems of consciousness, i.e., those that explain the subjective character of mind, with the “easy” problem of neural states. There are no clear linkages between mental or psychological terms like “perceptions”, “thoughts” and “feelings” to particular physical brain states and processes.

It is very difficult to start with the characteristics and properties of parts and use them to explain the features of the whole, even in simple systems that

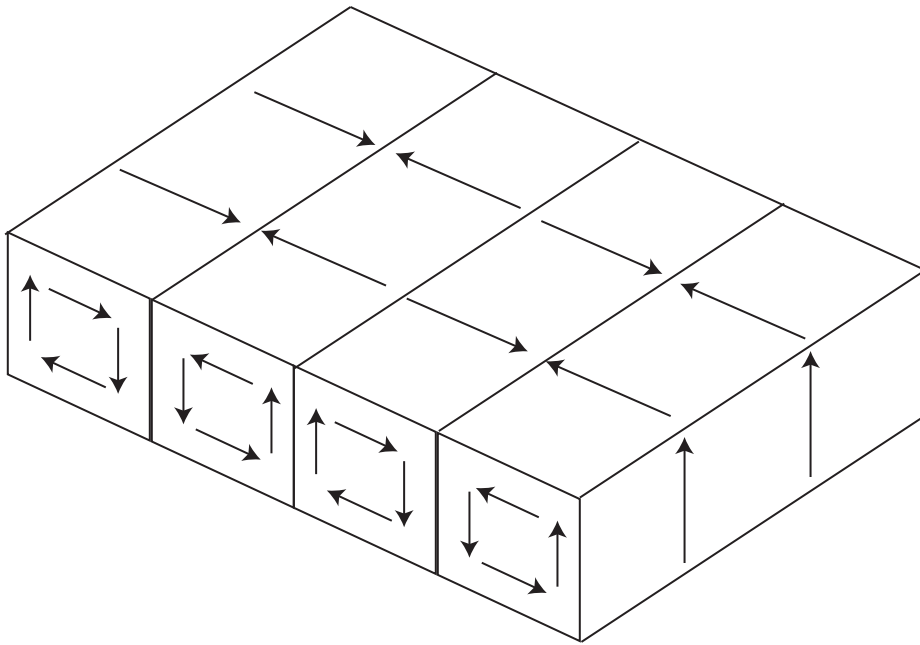


Figure 1.2 *Order from disorder: liquid molecules spontaneously transition into Bénard cells from random motion when heated.*

are just aggregates of a single kind of part. Take water for example. It is made up of the molecule H_2O . But knowledge of this molecule alone does not easily explain the interesting changes that take place when we heat large numbers of them. In this situation, the system undergoes dramatic qualitative changes, turning from ice to water to gas.

Many natural systems are like this. Their behavior doesn't change slowly, gradually, or predictably with a change in conditions, but instead undergoes dramatic alterations. These critical shifts produce a whole new organization, one that is best explained by resorting to different concepts and principles. It may seem disconcerting, but many phenomena in nature act this way. It is as if somebody flipped a switch that changed all the rules, forcing us to constantly come up with a new explanatory language. The failure of reductionism has cast doubt on whether the sciences can be united and has in part contributed to the current popularity of the emergence movement.

Bénard Cells

To show how difficult reductionism is, we will describe one phenomenon in detail. A Bénard cell is a convection cell, a region where gas or liquid matter rolls about upon itself. These cells appear spontaneously in a liquid layer that is progressively heated from below (Figure 1.2). Why should these ordered patterns appear, as it were, out of "nowhere"? It seems that a simpler outcome would be simply to have the liquid molecules move faster and faster, continuing to bump into each other in random fashion as more heat is applied.

The answer has to do with how temperature spreads in a medium. At lower temperatures, heated molecules can get rid of their heat through dissipa-

tion. They simply transfer the heat to neighboring molecules, rising from the bottom layers where it is hottest to the top layers where it is cooler. But at a critical value of temperature, this movement cannot get rid of enough heat. A new movement pattern develops consisting of the Bénard cells. These are more efficient at reducing heat because hot particles near the bottom move quickly to the top, lose their heat near the surface, and then plunge back down to heat up once more. The Bénard cells in this capacity can be thought of as a heat “conveyer belt”.

From a global perspective, the liquid has spontaneously organized itself into a new and more ordered spatial configuration. Instead of random motion, we see cyclical motion. When viewed from above the cells form into a variety of shapes depending on the geometry of the container and can be in long cylinder-like forms or more spherical shapes. A three-dimensional perspective shows that the direction of flow within a cell alternates clockwise and counterclockwise directions every other cell. This preserves the same flow direction at cell borders, again maximizing the efficiency with which the heat passes out of the liquid.

The Bénard cells seem to emerge spontaneously from the liquid system. They are considered an example of self-organization, where order can arise naturally from disorder. Much of the order we see throughout the natural world is of this sort. It can be seen in weather patterns, chemical reactions, biological development and even human societal organizations.

For our purposes, Bénard cells provide us with a simple but useful guide for understanding how mind and consciousness might arise from the brain. It could be that mental properties are the result of self-organizing principles at work in the brain. Just as the dissipation of heat, the liquid structure and the geometry of the container create a context that gives rise to rolling convection, energy laws, neural structure, function and other properties naturally give rise to mind. The challenge for cognitive science is to describe how this happens.

Emergence

The concept of *emergence* is that the features of a whole or complex are not completely independent of the parts that make them up. They are said to go beyond the features of those parts or emerge from them. Many phenomenon in the natural world seem to be emergent. In fact, emergence has been used to explain almost everything from the big bang to mind. Table 1.2 outlines a fairly comprehensive list (Morowitz, 2002). Just as was the case with reduction, there is both ontological and epistemological emergence. The first is concerned with real world items such as parts/wholes, properties, events/processes, laws and entities. The latter deals with concepts, theories, models, frameworks, and states of a system (Silberstein, 2002).

Holland (1998) describes several features of emergence. Emergent systems are made up of interacting parts. The function of these systems is rule governed. These rules are invariant even though the parts or components of which they are made do change over time. In fact, the states or processes of these systems are in constant flux; we say they are dynamic. Their dynamic and constant-

Step	Process	Description
1.	The Primordium	Origin of the universe
2.	Large-Scale Structure	Structured matter like galaxies
3.	Stars	Formation of stars like our sun
4.	The Elements	Creation of chemical elements
5.	Solar Systems	Matter organized around suns
6.	Planets	Condensation of planetary bodies
7.	The Geospheres	Geological structures like rocks, water, and gas
8.	The Biosphere	Chemical combinations, replication, autocatalysis
9.	The Prokaryotes	Primitive biological cells
10.	The Eukaryotes	Cells with organelles
11.	Multicellularity	Multicellular organisms like plants, animals and fungi
12.	Neurons	Cells allowing the transmission of information
13.	Protostomia and Deuterostomia	Evolution of animals with single and dual gut openings
14.	Vertebrates	Animals with brains
15.	Fish	Various forms of fish in aquatic environment
16.	Amphibians	Transition to land-based life
17.	Reptiles	Animals with shelled eggs
18.	Mammals	Emergence of these major terrestrial vertebrates
19.	Arboreal Animals	Forest-Dwelling Animals fill this ecological niche
20.	Primates	Enlarged cerebral cortex, extended maternal care and training of young
21.	The Great Apes	Adaptation to savannah ecology
22.	Hominids	Full bipedal locomotion, cooperative food acquisition, and increased cognitive skill
23.	Toolmakers	Creation of effective instruments for altering the environment
24.	Language	Cultural transmission of information
25.	Agriculture	Domestication of animals and plant cultivation
26.	Technology and Urbanization	Applied mathematics and city-dwelling
27.	Philosophy	Efforts at self-understanding
28.	The Spiritual	Attempts to ascribe meaning to other emergences

Table 1.2 *Natural processes attributed to emergence in the temporal order in which they occurred (from Morowitz, 2002).*

ly changing nature gives rise to novelty; a non-stop parade of new patterns or behaviors that are difficult if not impossible to predict.

There is another sense in which things change but stay the same in emergent systems. Holland (1998) calls this persistence. This is where patterns of interaction persist despite a continual turnover of their constituent parts. He cites as an example the standing wave in front of a rock in a white-water river. The water molecules making up the wave are constantly changing, but the global wave pattern remains. So we can say that although the rules and particular patterns of emergence are invariant, their parts are always on the move.

Emergent systems, even though they are complex, demonstrate regularity. Under certain conditions, the system will show patterned behavior. Although the system may not repeat itself exactly, it can be shown to act similarly in a given situation. A random process would not be like this. Random processes cannot be predicted and cannot be guaranteed of acting in similar ways in a given context. Emergent systems are therefore not random or stochastic.

Problems with Emergence

Like reduction, emergence is not without its own set of difficulties. To start, a philosophical account of emergence doesn't count as an explanation. It merely says that if one thing cannot be reduced to another then it must be something more than what it is made of. In most cases there is no attempt to say exactly what happens. What is needed is some sort of explanation or theoretical account of how this something extra comes into being. Given this explanatory vacuum, some may come to equate emergence with magical, mystical, or theological workings. If relationships between parts are considered important in emergent phenomena, then a theory is needed that explains how relational processing gives rise to emergent properties.

REFERENCES

- Abraham, F. D. (1995). "A postscript on language, modeling, and metaphor," in F. D. Abraham and A. R. Gilgen, (eds.), *Chaos Theory in Psychology*, ISBN 0-275-95140-5, pp. 311-336.
- Abraham, F. D. (2002). "Chaos, bifurcations, and self-organization: Dynamical extensions of neurological positivism and ecological psychology," in A. Combs, B. Goertzel, and M. Germino (eds.), *Mind in Time: The Dynamics of Thought, Reality, and Consciousness*, ISBN 1572732563, pp. 111-144.
- Abraham, F. D., Abraham, R. H. and Shaw, C. D. (1990). *A Visual Introduction to Dynamical Systems Theory for Psychology*, ISBN 0942344097.
- Aftanas, L. I. and Golocheikine, S. A. (2002). "Non-linear dynamic complexity of the human EEG during meditation," *Neuroscience Letters*, ISSN 0304-3940, 330(2) : 143-146.
- Aftanas, L. I., Lotova, N. V., and Kosharov, V. I. (1998). "Non-linear dynamical coupling between different brain areas during evoked emotions: An EEG investigation," *Biological Psychology*, ISSN 0301-0511, 48(2): 121-138.
- Aftanas, L. I., Lotova, N. V., Kosharov, V. I., Popov, S. A., and Makhen, V. P. (1997). "Nonlinear forecasting measurements of human EEG during evoked emotions," *Brain Topography*, ISSN 0896-0267, 10(2): 155-162.
- Aks, D., Spott, J. C. (1996). "Quantifying aesthetic preference for chaotic patterns." *Empirical Studies of the Arts*, ISSN 0276-2374, 14: 1-16.
- Albert, R., Jeong, H. Barabasi, A. (1999). "Diameter of the world wide web," *Nature* ISSN: 0028-0836, 10(September): 40, 130-131.
- Alexander, D. M. (1993). "A neural architecture with multiple scales of organization," in P. Leong, and M. Jabri (eds.), *Proceedings of the Fourth Australian Conference on Neural Networks*, ISBN 0867586508, pp. 157-160.
- Alexander, D. M., Globus, G. G. (1996). "Edge-of-chaos dynamics in recursively organized neural systems," in E. M. Cormac and M. I. Stamenov, (eds.), *Fractals of Brain, Fractals of Mind: In Search of a Symmetry Bond*, ISBN 1556191871, pp. 31-74.
- Anderson, J. R. (1985). *Cognitive Psychology and Its Implications (2nd ed.)*, ISBN 978-0716701101.
- Anderson, R. S. (1990). "Eolian ripples as examples of self-organization in geomorphological systems," *Earth-Science Reviews*, ISSN 29: 77-96.
- Anderson, C. M. and Mandell, A. J. (2002). "Fractal time and the foundations of consciousness: Vertical convergence of 1/f phenomena from ion channels to behavioral states," in E. M. Cormac and M. I. Stamenov (eds.), *Fractals of Brain, Fractals of Mind: In Search of a Symmetry Bond*, ISBN 1556191871, pp. 75-126.
- Anokhin, A. P., Birbaumer, N., Lutzenburger, W., Nikolaev, A., Elger C. E., and Lehnertz, K. (1996). "Age increases brain complexity," *Electroencephalography and Clinical Neurophysiology*, ISSN 1388-2457, 99(1): 135-144.

- Atkinson R. C., and Shiffin R. M., (1971). "The control of short term memory," *Scientific American*, ISSN 0036-8733, 225: 82-90.
- Atlan, H. (1983). "Information theory: Basic elements and recent developments" in R. Trappl (ed.) *Cybernetics: Theory and Applications*, ISBN 0891161287, pp. 9-41.
- Baddeley, A. D. (1992). "Working Memory," *Science*, ISSN 0036-8075, 255: 556-559.
- Baggot, J.E. (1992). *The Meaning of Quantum Theory*, ISBN 019855575X.
- Bak, P. (1996). *How Nature Works: The Science of Self-Organized Criticality*, ISBN 0387987385.
- Bak, P., Tang, C. and Wiesenfeld, K. (1987). "Self-organized critically: An explanation for $1/f$ noise," *Physical Review Letters*, ISSN 0031-9007, 59: 381-384.
- Bar-Yam, Y. (1997). *Dynamics of Complex Systems*, ISBN 978-0201557487.
- Barabási, A. L. (2002). *Linked: The New Science of Networks*, ISBN 0738206679.
- Baran, P. (1964). "Introduction to distributed communications networks," in report Memorandum RM-3240-PR (RAND Corporation, Santa Monica, CA), available for download at: <http://www.rand.org/publications/RM/baran.list.html>
- Barkely, R. A. (1997). "Behavioral inhibition, sustained attention and executive functions: Constructing a unified theory of ADHD," *Psychological Bulletin* ISSN 0079-2993, 121: 65-94.
- Barton, S. (1994) . "Chaos, self-organization and psychology," *American Psychologist*, ISSN 0003-066X, (January): 5-13.
- Bascompte, J. and Solé, R. V. (1996). "Habitat fragmentation and extinction thresholds in spatially explicit models," *Journal of Animal Ecology*, ISSN 0021-8790, 65: 465-473.
- Bateson, G. and Bateson, M. C. (1990). *Angels Fear*, ISBN 1572735945.
- Bennett, C. (1988). "Dissipation, information, computational complexity, and the definition of organization," in D. Pines (ed.), *Emerging Syntheses in Science*, ISBN 978-0201156867, pp. 215-231.
- Bernander, O., Douglas, R. J., Martin, K. A. C., Koch, C. (1991). "Synaptic background activity determines spatial-temporal integration in pyramidal cells," *Proceedings of the National Academy of Sciences*, ISSN 0027-8424, 88: 11569.
- Bickle, J. (2001). "Understanding neural complexity: A role for reduction," *Minds and Machines*, ISSN 0924-6495, 11: 467-481.
- Biederman, I. (1987). "Recognition-by-components: A theory of human image understanding," *Psychology Review*, ISSN 0033-295X, 94: 115-147.
- Bollt, E., Stanford, T., Lai, Y., Zyczkowski, K. (2000). "Validity of threshold crossing analysis of symbolic dynamics from chaotic time series," *Physical Review Letters*, ISSN 0031-9007, 85: 3524-3527.
- Bonin, V., Mante V. and Carandini, M. (2006). "The statistical computation underlying contrast gain control," *Journal of Neuroscience*, ISSN 0270-6474, 26(23): 6346-6353.

- Borisyuk, R., Borisyuk, G. and Kazanovich, Y. (2001). "Temporal structure of neural activity and modeling of information processing in the brain," in S. Wermter, J. Austin and D. Willshaw (eds.), *Emergent Neural Computational Architectures Based on Neuroscience: Towards Neuroscience-Inspired Computing*, ISBN 978-3540423638, pp. 237-254.
- Borisyuk, G., Borisyuk, R., Khibnik, A. and Roose, D. (1995). "Dynamics and bifurcation of two coupled neural oscillators with different connection types," *Bulletin of Mathematical Biology*, ISSN 1522-9602, 57(6): 809-840.
- Borisyuk, R. M., Borisyuk, G. N. Kazanovich, Y. B., Strong, G. (2000). "Oscillatory neural networks: Modeling binding and attention by synchronization of neural activity" in D. S. Levine, V. R. Brown and V. T. Shiry (eds.), *Oscillation in Neural Systems*, ISBN 0805820663, pp. 261-284.
- Borisyuk, R. and Borisyuk, G. (1997). "Information coding on the basis of synchronization of neuronal activity," *BioSystems*, ISSN 0303-2647, 40(1-2): 3-10.
- Borisyuk, R. and Hoppensteadt, F. (1998). "Memorizing and recalling spatial-temporal patterns in an oscillator model of the hippocampus," *BioSystems* ISSN 0303-2647, 48(1): 3-10.
- Borisyuk, R. and Hoppensteadt, F. (1999). "Oscillatory model of the hippocampus: A study of spatiotemporal patterns of neural activity," *Biological Cybernetics*, ISSN 0340-1200, 81(4): 359-71.
- Bossomair, T. and Green, D. (1998). *Patterns in the Sand: Computers, Complexity, and Everyday Life*, ISBN 0738201723.
- Brabender, V. (1997). "Chaos and order in the psychotherapy group," in F. Masterpasqua and P. Perna (eds.), *The Psychological Meaning of Chaos: Translating Theory into Practice*, ISBN 1557984298, pp. 225-252.
- Braspenning, P. J. (1995). "Neural cognidynamics," in P. J. Braspenning, F. Thnijnman, and A. Weijtjers (eds.), *Artificial Neural Networks: An Intro to ANN Theory and Practice*, ISBN 3540594884, pp 247-272.
- Breakspear, M. (2002). "Nonlinear phase desynchronization in human electroencephalographic data," *Human Brain Mapping*, ISSN 1065-9471, 15(3): 175-198.
- Breakspear, M. and Terry, J. R. (2002). "Detection and description of non-linear interdependence in normal multi-channel human EEG data," *Clinical Neurophysiology*, ISSN 1388-2457, 113(5): 735-753.
- Brooks, R. A. (1991). "Intelligence without representation," *Artificial Intelligence*, ISSN 0004-3702, 47: 139-159.
- Brooks, R. J. (2002). *Flesh and Machines: How Robots Will Change Us*, ISBN 037572527X.
- Brown, A. L., Bransford, J. D., Ferrara, R. A., and Campione, J. C. (1983). Learning, remembering and understating. In J. H. Flavell and E. M. Markman (eds.), *Handbook of Child Psychology*, ISBN 0471272878, pp. 77-166.
- Buchman M. (2002). *Small Worlds and the Groundbreaking Theory of Networks*, ISBN 0393324427.
- Busemeyer, J. R. and Townsend, J. T. (1993). "Decision field theory: A dynamic-

- cognitive approach to decision making in an uncertain environment,” *Psychological Review*, ISSN 0033-295X, 100(3): 432-459.
- Bütz, M. R. (1990). “Chaos: An omen of transcendence in the psychotherapy process,” presented at the *Symposium on Chaos and Psychology*, Springfield, MA.
- Bütz, M. R. (1997). *Chaos and Complexity: Implications for Psychological Theory and Practice*, ISBN 1560324198.
- Calaprice, A. (2005). *The New Quotable Einstein*, ISBN 0691120757.
- Camazine, S. and Deneuburg, J. L. (2001) *Self-Organization in Biological Systems*, ISBN 0691012113.
- Carver, C. S. and Scheier, M. F. (1994). “Situational coping and coping dispositions in a stressful transaction,” *Journal of Personality and Social Psychology*, ISSN 0022-3514, 66: 148-195.
- Chaitin, G. (1987). *Information, Randomness & Incompleteness: Papers on Algorithmic Information Theory*, ISBN 9971504790.
- Chappell, M. and Humphreys, M. (1994). “An auto-associative neural network for sparse representations: Analysis and application to models of recognition and cued recall,” *Psychological Review*, ISSN 0033-295X, 101(1): 103-128.
- Chino, C., Cronin, T. W., and Osorio, D. (2000). “Color signals in natural scenes: Characteristics of reflectance spectra and effects of natural illuminants,” *Journal of the Optical Society of America A*, ISSN 1084-7529, 17: 218-224.
- Chung S. H., Raymond S. A. and Lettin, J. Y. (1970). “Multiple meaning in single visual units.” *Brain, Behavior, and Evolution*, ISSN 0006-8977, 3: 12-101.
- Clark, A. (1996) “Happy couplings: Emergence and explanatory interlock,” in M. Boden (ed.), *The Philosophy of Artificial Life*, ISBN 0198751559, pp. 262-281.
- Clark, A. and Chalmers, D. (1998). “The extended mind,” *Analysis*, ISSN 0003-2638, 58: 7-19.
- Clayton, K. and Frey, B. (1997). “Studies of mental noise,” *Nonlinear Dynamics, Psychology, and Life Sciences*, ISSN 1090-0578, 1(3): 173-180.
- Cohen, A. H. (1992). “The role of heterarchical control in the evolution of central pattern generators,” *Brain, Behavior, and Evolution*, ISSN 0006-8977, 40(2-3): 112-124.
- Colarusso, C. A. and Nemiroff, R. A. (1987). “Clinical implications of adult development theory,” *American Journal of Psychiatry*, ISSN 1535-7228, 144: 1263-1270.
- Colwell, K. A. (2003). “Emergence and evolution of silence networks for commercializing radical innovations: The case of nanotechnology.” Unpublished doctoral dissertation, University of Oregon.
- Combs, A. and Winkler, M. (1995). “The nostril cycle: a study in the methodology of chaos science,” in R. Robertson and A. Combs (eds.), *Chaos Theory in Psychology and the Life sciences*, ISBN 0805817360, pp. 51-60.
- Condon, W. S. and Ogston, W. D. (1967). “A segmentation of behavior.” *Journal Of Psychiatric Research*, ISSN 0022-3956, 5: 221-235.

- Coveny, P. and Highfield, R. (1995). *Frontiers of Complexity. The Search for Order in a Chaotic World*, ISSN 0571179223.
- Cutting J. E. and Ganin, J. J. (1987). "Fractal curves and complexity," *Perception & Psychophysics*, ISSN 0031-5117, (Oct): 42(4), 365-370.
- DeMaris, D. (2000). "Attention, depth gestalts, and spatially extended chaos in the perception of ambiguous figures," in D. Levine and V. Brown (eds.), *Oscillations in Neural Systems: The International Neural Networks Society Series*, ISBN 0805820663, pp. 239-260.
- Dennett, D. (1991). *Consciousness Explained*, ISBN 0316180653.
- Derrickson-Kossmann, D., Drinkard, L. (1997). "Dissociative disorders in chaos and complexity," in F. Masterpasqua and P. A. Perna (eds.), *The Psychological Meaning of Chaos: Translating Theory Into Practice*, ISBN 1557984298, pp. 117-146.
- Diederich A. (2003). "MDFT account of decision making under time pressure," *Psychonomic Bulletin and Review*, ISSN 1069-9384, 10(1): 157-166.
- Dittman, A., T. and Llewellyn, L. G. (1969). "Body movement and speech rhythm in social conversation," *Journal of Personality and Social Psychology*, ISSN 0022-3514, 11(2): 98-106.
- Dobrunz, L. E. and Stevens, C. F. (1997). "Heterogeneity of release probability facilitation, and depletion at central synapses," *Neuron*, ISSN 0896-6273, 18: 995.
- Drake, J. A., (1990). "The mechanics of community assembly and succession," *Journal of Theoretical Biology*, ISSN 0022-5193, 147: 213-233.
- Duncker, K. (1945). "On Problem Solving," *Psychological Monographs*, ISSN 0096-9753, 58: 1-112.
- Edwards, F. A. (1995). "LTP – A structural model to explain the inconsistencies," *Trends in Neuroscience*, ISSN 0166-2236, 18: 250-255.
- Elman, (1998). "Language as a Dynamical System," in R. F. Port and T. van Gelder (eds.), *Mind as Motion: Exploration in the Dynamics of Cognition*, ISBN 0262661101.
- Epstein, J. M. (1999). "Agent-based computational models and generative social science," *Complexity*, ISSN 1076-2787, 4(5): 41-60.
- Epstein, J. M. and Axtell, R. L. (1996). *Growing Societies: Social Science From the Bottom Up*. ISBN 9780262550253.
- Erdős, P. and Rényi, A. (1959). "On random graphs," *Publicationes Mathematicae*, ISSN 0033 - 3883, 6: 290-297.
- Ermentrout, G. B. and Edelstein-Keshet, L. (1993). "Cellular automata approaches to biological modeling," *Journal of Theoretical Biology*, ISSN 0022-5193, 160: 97-133.
- Estes, W. K. (1959). "The statistical approach to learning theory," in S. Koch (ed.), *Psychology: A study of a Science. Vol. 2. General Systematic Formulations, Learning and Special Processes*, ISBN 9657328799, pp. 380-491.
- Fell, J., Klaver, P., Lehnertz, K., Grunwald, T., Schaller, C., Elger, C. E. and Fernandez, G. (2001). "Human memory formation is accompanied by rhinal-hippocampal coupling and decoupling," *Nature Neuroscience*, ISSN 1097-6256, 4(12): 1259-1264.

- Ferri, R., Chiaramonti, R., Elia, M., Musumeci, S. A., Rgazzoni, A. and Stam, C. J. (2003). "Nonlinear EEG analysis during sleep in premature and full-term infants," *Clinical Neurophysiology*, ISSN 1388-2457, 114(7): 1176-1180.
- Ferri, R., Elia, M., Musumeci, S. A. and Stam, C. J. (2001) "Non-linear EEG analysis in children with epilepsy and electrical status epilepticus during slow-wave sleep (ESES)," *Clinical Neurophysiology*, ISSN 1388-2457, 112(12): 2274-2280.
- Ferri, R., Parrino, L., Semerieri, A., Terzano, M. G., Elia, M., Musumeci, S. A., Pettinato, S. and Stam, C. J. (2002). "Non-linear EEG measures during sleep: Effects of the different sleep stages and cyclic alternating patterns," *International Journal of Psychophysiology*, ISSN 0167-8760, 43(3): 273-286.
- Festinger, L, Schachter, S. and Back, K. (1950). *Social Pressures in Informal Groups, Volume 5*, ISBN 0804701733.
- Field, D. J. (1994). "What is the goal of sensory coding?," *Neural Computation*, ISSN 0899-7667, 6: 559-601.
- Fodor, J. (1983). *The Modularity of Mind*. ISBN 0262060841.
- Folkman, S. and Lazarus, R. S. (1985). "It changes it must be a process: Study of emotion and coping during three stages of a college examination," *Journal of Personality and Social Psychology*, ISSN 0022-3514, 48: 150-170.
- Forrest, S. B. and Haff, P. K. (1992). "Mechanics of wind ripple stratigraphy," *Science* ISSN 1095-9203, 255: 1240-1243.
- Freeman, W. (1990). "Searching for the signal and noise in the chaos of brain waves," in S. Krasner (ed.), *The Ubiquity of Chaos*, ISBN 0871683504, pp. 47-55.
- Freeman, W. J. (1987). "Simulation of chaotic EEG patterns with a dynamic model of the olfactory system," *Biological Cybernetics*, ISSN 0340-1200, 56(2-3): 139-150.
- French, R. M. (1999). "Catastrophic interference in connectionist networks," *Trends in Cognitive Sciences*, ISSN 1364-6613, 3(4): 128-135.
- Friedenberg, J. and Silverman, G. (2006). *Cognitive Science: An introduction to the Study of Mind*, ISBN 1412925681.
- Friston, K. J. (1997). "Transients, Metastability, and Neuronal dynamics," *Neuroimage*, ISSN 1053-8119, 5: 164-171.
- Friston, K. J. (2000). "The labile brain. I. Neuronal transients and nonlinear coupling," *Philosophical Transactions of the Royal Society of London*, ISSN 0261-0523, 355: 215-236.
- Friston, K. J. (2001). "Brain function, nonlinear coupling, and neuronal transients," *The Neuroscientist*. ISSN 1073-8584, 7(5): 406-418.
- Gaik, W. (1993). "Combined evaluation of inter-aural time and intensity differences: Psychoacoustic results and computer modeling," *Journal of the Acoustical Society of America*, ISSN 0001-4966, 94(1): 98-110.
- Gaka V. and Meyer A. D. (2005). "The diffusion of corporate venture investing programs: What do perspective adopters observe?" Working Paper, *INSEAD*.
- Gallagher, R. and Appenzeller, T. (1999). "Complex systems viewpoints article," in R. Gallagher and T. Appenzeller, T. (eds.), *Science*, ISSN 0036-8075,

- 284: 79-109.
- Gammaitoni, L., Hanggi, P. and Marchesoni, F. (1998). "Stochastic resonance," *Review of Modern Physics*, ISBN 0034-6861, 70: 223-287.
- Gardner, M. (1971). "On cellular automata, self-reproduction, The garden of Eden and the game of life," *Scientific American*, ISSN 0036-8733 (February): 224(2): 112-117.
- Gell-Mann, M. (1994). *The Quark and the Jaguar: Adventures in the Simple and the Complex*, ISBN 0716727250.
- Gentry, T. A. (1995). "Fractal geometry and human understanding," in F. D. Abraham and A. Gilgen (eds.), *Chaos Theory in Psychology*, ISBN 0275951405, pp. 145-155.
- German, T. P. and Defeyeter, M. A., (2000). "Immunity to Functional Fixedness in Children," *Psychonomic Bulletin and Review*, ISSN 1069-9384, 7: 707-712.
- Gibson, J. J. (1986). *The ecological Approach to visual perception*, ISBN 0898599598.
- Gick, M. C. and Holyoak, K. J. (1980). "Analogical Problem Solving," *Cognitive Psychology*, ISSN 0010-0285, 12: 306-355.
- Gilden, D. L. (1997). "Fluctuations in the time required for elementary decisions." *Psychological Science*, ISSN 0956-7976, 8: 296-301.
- Gilden, D., L., Thornton, T., and Mallon, M. W. (1995). "1/f noise in human cognition," *Science*, ISSN 0036-8075, 267: 1837-1839.
- Gilden, D. L., Schmucker, M. A. and Clayton, K. (1993). "The perception of natural contours," *Psychology Review*, ISSN 0033-295X, 100: 460-478.
- Glass, L. and Perez, R. (1973). "Perception of random dot interference patterns," *Nature*, ISSN 0028-0836, 246: 3603-362.
- Globus, G. G. (1992). "Towards a non-computational cognitive neuroscience," *Journal of Cognitive Neuroscience*, ISSN 0898-929X, 4(December): 299-310.
- Goerner, S. (1995). "Chaos, evolution, and deep ecology," in R. Robertson and A. Combs, (eds.), *Chaos Theory in Psychology and the Life Sciences*, ISBN 0805817360, pp. 17-38.
- Goertzel, B. (1994). *Chaotic Logic*, ISBN 0306446901.
- Goertzel, B. (2002). "Chance and Consciousness," in A. Combs, B. Goertzel and M. Germine (eds.), *Mind in Time: The Dynamics of Thought, Reality, and Consciousness*, ISBN 1572732563, pp. 46-84.
- Goertzel, B. (2002). "On the algebraic structure of consciousness," in A. Combs, B. Goertzel and M. Germine (eds.), *Mind in Time: The Dynamics of Thought, Reality, and Consciousness*, ISBN 1572732563, pp. 13-46.
- Goldstein, E. B. (2002). *Sensation and Perception*, ISBN 0534539645.
- Goldstein, J. (2001). "Emergence, radical novelty, and the philosophy of mathematics," in W. Sulis and I. Trofimova (eds.), *Nonlinear Dynamics in the Life and Social Sciences*, ISBN 1586030209, pp 133-152.
- Goldstein, J. (2002). "The singular nature of emergent levels: Suggestion for a theory of emergence," *Nonlinear Dynamics, Psychology, and Life Sciences*, ISSN 1090-0578, 6(4): 293-307.

- Gonzalez, M.C., Hidelgo C.A. and Barabasi, A. (2008). "Understanding individual human mobility patterns," *Nature*, ISSN: 0028-0836, 453: 779-782.
- Gordon, P. C., Hendrick, R., Johnson, M., and Lee, Y. (2006). "Similarity-based interference during language comprehension: Evidence from eye-tracking during reading," *Journal of Experimental Psychology: Learning, Memory, and Cognition*, ISSN 0278-7393, 32: 1304-1321.
- Govindan, R. B., Narayanan, K., Gopinathan, M. S., Pradhan, N., Sreenivasan, R. and Dwivedi, P. (1999). "The spectrum of unstable periodic orbits of the human brain," in N. Pradhan, P. E. Rapp and R. Sreenivasan, (eds.), *Nonlinear Dynamics and Brain Functioning*, ISBN 1560726482, pp. 345-377.
- Graham, C. H. (1965). "Perception of movement" in C. Graham, (ed.), *Vision and Visual perception*, ISBN 0471321702.
- Graham, D. J., Chendler, D. M. and Field, D. J. (2006). "Can the theory of 'whitening' explain the center-surround properties of retinal ganglion cell receptive fields?" *Vision Research*, ISSN 0042-6989, 46(18): 2901-2913.
- Grassberger, P. (1986). "Do climatic attractors exist?," *Nature*, ISSN 0028-0836, 323: 609-612.
- Gray, C. M., Kornhuber, H. H. and Singer, W. (1989). "Oscillatory responses in cat visual cortex," *Nature*, ISSN 0028-0836, 338: 334-337.
- Green, C. D. and Vervake, J. (1996). "What kind of explanation if any is a connectionist net?" in C. W. Tolman, F. Cherry, R. van Hezewijk, and I. Lubek (eds.), *Problems of Theoretical Psychology*, ISBN 189669117X, pp. 201-208.
- Grossburg, S. (1980). "How does a brain build a cognitive code?" *Psychology Review*, ISSN 0033-295X, 87(Jan): 1-51.
- Guastello, S. J. (1981). "Catastrophe model of equity in organizations," *Behavioral Science*, ISSN 0005-7940, 26(January): 63-74.
- Guastello, S. J. (1987). "A butterfly catastrophe model of motivation in organizations: Academic performance [Monograph]," *Journal of Applied Psychology*, ISSN 0021-9010, 72(May): 165-182.
- Guastello, S. J. (1992). "Population dynamics and workforce productivity," in M. Michaels, (ed.), *Proceedings of the Annual Chaos Network Conference: The Second iteration*, Urbana, IL: People Technologies, pp. 120-127.
- Guastello, S. J. (2001). "Nonlinear Dynamics in Psychology," *Discrete Dynamics in Nature and Society*, 6(1): 11-29, available for download at: <http://www.hindawi.com/GetArticle.aspx?doi=10.1155/S1026022601000024&e=cta>.
- Guastello, S. J. (2007). "Nonlinear dynamics and leadership emergencies," *The Leadership Quarterly*, ISSN 1048-9843, 18(4): 357-369.
- Guastello, S. J. and Bond, R. W. (2007). "A swallowtail catastrophe model for the emergence of leadership in coordination-intensive groups," *Nonlinear Dynamics, Psychology, and Life Science*, ISSN 1090-0578, 11(2): 235-251.
- Guastello, S. J., Dooley, K. J. and Goldstein, J. A. (1995). "Chaos, organizational theory, and organizational development," in F. D. Abraham and A. R. Gilgen (eds.), *Chaos Theory in Psychology*, ISBN 0275951405, pp. 268-276.
- Gupte, N. and Amritkar, R. E. (1996). "Enhancing chaos in chaotic maps and

- flows,” *Physical Review A*, ISSN 1094-1622, 54, 4580-4585.
- Gurney, K. (1997). *An Introduction To Neural Networks*, ISBN 1857285034.
- Gutman, S. E. Gilroy, L. A. and Blake, R. (2007). “Spatial grouping in human vision: Temporal structure trumps temporal synchrony,” *Vision Research*, ISSN 0042-6989, 47(2): 219-230.
- Hannah, T. (1990). “Does chaos theory have application to psychology? The example of daily mood fluctuations,” *Network*, 8(3): 13-14.
- Hartman, H. (2000). “Symmetry breaking and the origin of life” in Y. Bar-Yam (ed.), *Unifying Themes in Complex Systems: Proceedings of the International Conference on Complex Systems*, ISBN 0813341221, pp. 248-257.
- Hayashi, H. and Ishizuka, S. (1999). “Synchronization of neurons during complex and irregular activity in both neuronal network and real tissue,” in N. Pradhan, P. E. Rapp and R. Sreenivasan, *Nonlinear Dynamics and Brain Functioning*, ISBN 1560726482, pp. 379-400.
- Heath, R. A. (1993). “A nonlinear model for human associative memory based on error accumulation,” in P. Leong and M. Jabri (ed.), *Proceeding of the Fourth Australian Conference on Neural Networks*, ISBN 0805832009, pp. 130-133.
- Heath, R. A. (2000). *Nonlinear Dynamics. Techniques and Applications in Psychology*, ISBN 0805831991.
- Hebb, D. O. (2002). *The Organization of Behavior*, ISBN 978-0805843002.
- Hegde, J. and Felleman, D. J. (2007). “Reappraising the functional implications of the primate visual anatomical hierarchy,” *The Neuroscientist*, ISSN 1073-8584, 13: 416-421.
- Heiby, E. M. (1991). “Implications of chaos theory for the study of depression,” presented at the *American Psychological Association National Convention*, San Francisco, CA.
- Heiby, E. M. (1995a). “Assessment of behavioral chaos with a focus on transitions in depression,” *Psychological Assessment*, ISSN 1040-3590, 7: 10-16.
- Heiby, E. M. (1995b). “Chaos theory, nonlinear dynamical models, and psychological assessment,” *Psychological Assessment*, ISSN 1040-3590, 7: 5-9.
- Hobson, J. A. and Pace-Schott, E. F. (2002). “The cognitive neuroscience of sleep: Neuronal systems, consciousness and learning,” *National Review of Neuroscience*, ISSN 1471-003X, 3(9): 679-693.
- Hock, H. S., Kelso, J. A. S., Schöner, G. (1993). “Bistability, hysteresis, and loss of temporal stability in the perceptual organization of apparent motion,” *Journal of Experimental Psychology: Human Perception and Performance*, ISSN 0096-1523, 19(1): 63-80.
- Holland, J. H. (1995). *Hidden Order. How Adaptation Builds Complexity*, ISBN 0201407930.
- Holland, J.H. (1998). *Emergence: From Chaos to Order*, ISBN 0192862111.
- Hopfield, J. J. (1982). Neural networks and physical systems with emergent collective computational properties.” *Proceedings of the National Academy of Sciences*, ISSN 0027-8424, pp.2254-2258.
- Horgan, J. (1995). From complexity to perplexity: Can science achieve a unified

- theory of complex systems?" *Scientific American*, ISBN 0036-8733, 284: 104-109.
- Hubel, D. H. (1982). "Exploration of the primary visual cortex, 1955-1978," *Nature*, ISSN 0028-0836, 7(October): 299, 515-524.
- Hubel, D., Wiesel, T. (1979). "Brain Mechanisms of Vision," *Scientific American*, ISSN 0036-8733, 241: 150-162.
- Hull, C. L. (1943). *Principles of Behavior*, New York, NY: D. Appleton and Company.
- Ishai, A., Underleider, L. G., Martin, A., Schouten, J. L. and Haxby, J. V. (1999). "Distributed Representation of objects in human ventral visual pathway," *Proceedings of the National Academy of Sciences*, ISSN 0027-8424, 96(16): 9379-9384.
- Jaffe, J., and Feldstein, S. (1970). *Rhythms of dialogue*. ISBN 0123798507.
- Jeong, J., Chae, J. H., Kim, S. Y. and Han, S. H. (2001). "Nonlinear dynamic analysis of the EEG in patients with Alzheimer's disease and vascular dementia," *Journal of Clinical Neurophysiology*, ISSN 07360258, 18: 58-67.
- Jones, M., Boltz, M. (1989). "Dynamic attending and responses to time," *Psychological Review*, ISSN 0033-295X, 96(3): 459-491.
- Kaas, J. H. (1982). "Why do sensory systems have so many subdivisions?" in W. Neff (ed.), *Contributions to Sensory Psychology, Volume 7*, ISBN 0121518019, pp. 201-240.
- Kahneman, D. (1973). *Attention and Effort*, ISBN 0130505188.
- Kahneman, D. and Tversky, A. (1979). "Prospect Theory: An analysis of decision under risk," *Econometrica*, ISSN 0012-9682, 47(2): 263-291.
- Kampen, N. G. (1987). "Some theoretical aspects of noise," in C.M. Van Vliet (Ed.), *Ninth International Conference on Noise in Physical Systems*, ISBN 9971503972, pp. 3-10.
- Kaneko, K. (1992). "Focus issue on coupled map lattices," *Chaos*, ISSN 1054-1500, 2: 279-408.
- Kauffman, S. A. (1993). *The Origins of Order: Self-Organization and Selection in Evolution*, ISBN 0195058119.
- Kauffman, S. A. (1995). *At Home in the Universe: The Search for the Laws of Self-Organization and Complexity*, ISBN 0670847356.
- Kelso, J. A. (1995). *Dynamic Patterns: The Self-Organization of Brain and Behavior*, ISBN 0262112000.
- Kelso, J. A. S., Case, P., Holroyd, T., Horvath, E., Rączaszek, J., Tuller, B. and Ding, M. A. (1994). "Multistability and metastability in perceptual and brain dynamics," in M. Stadler and P. Kruse (eds.), *Multistability in Cognition*, Berlin, Germany: Springer-Verlag.
- Kenrick, D. T. (2001). "Evolutionary psychology, cognitive science and dynamical systems: Building an integrative paradigm," *Current Directions in Psychological Science*, ISSN 0963-7214, 10(1): 13-17.
- Kenrick, D. T., Li, N. and Butner, J. (2000). "Dynamical systems and the mating game," *Behavioral and Brain Sciences*, ISSN 0140-525X, 23(4): 607-608.
- King, R., Barchas, J. D. and Huberman, B. A. (1983). "Theoretical psychopathology: An application of dynamical systems theory to human behavior,"

- in E. Basar, H. Flohr, H. H. Haken, and J. Mandell (eds.), *Synergetics of the Brain*, Heidelberg: Springer-Verlag.
- King, R., Barchas, J. D. and Huberman, B. A. (1984). "Chaotic behavior in dopamine neurodynamics," *Proceedings of the National Academy of Sciences of the United States of America (Neurobiology)*, ISSN 1091-6490, 81: 1244-1247.
- Kingsbury M. and Finlay, B. (2001). "The cortex in multidimensional space: Where do cortical areas come from?," *Developmental Science*, ISSN 1363-755X, 48: 135-152.
- Klatzky, R. L. (1980). *Human Memory: Structures and Processes*, ISBN 0716711133.
- Knill, D. C., Field, D. and Kersten, D. (1990) "Human discrimination of fractal images," *Journal of the Optical Society of America A*, ISSN 1084-7529, 7(6):1113-1123.
- Kobayashi, T., Misaki, K., Nakagawa, H., Madokoro, S., Ihara, H., Tusda, K., Umegawa, Y., Murayama, J. and Isak, K. (1999). "Nonlinear analysis of the sleep EEG," *Psychiatric Clinical Neuroscience*, ISSN 0940-1334 53(2): 159-161.
- Kobayashi, T., Madokoro, S., Wada, Y., Misaki, K., Nakagawa, H. (2001). "Human sleep EEG analysis using the correlation dimension," *Clinical Electroencephalography*, ISSN 1388-2457, 32(3): 112-118.
- Koch, C. and Crick, F. (1990). "Towards a neurobiological theory of consciousness," *Sem Neuroscience*, ISSN 2: 263-275.
- Koch, C. and Segev, I. (1998). *Methods in Neuronal Modeling: From Ions to Networks*. ISBN 0262112314.
- Koch, C. and Laurent G. (1999). "Complexity and the Nervous System," *Science*, ISSN 0036-8075, 284: 96-98.
- Köhler, W. (1976). *The Mentality of Apes*, ISBN 0871401088.
- Köhler, W. (1965). *Dynamics in Psychology*, ISBN 0871400871.
- Kolb, B., and Whishaw, I. Q., (1996). *Fundamentals of Human Neuropsychology*, ISBN 0716723875.
- Kondakor, I., Brandeis, D., Wackmann, J., Kochi, K., Koenig, T., Frei, E., Pascual-Margui, Yagy, T., and Lehmann, D. (1997). "Multichannel EEG fields during and without visual input: Frequency domain model source locations and dimensional complexities," *Neuroscience Letters*, ISSN 0304-3940, 226(1): 49-52.
- Kosslyn S. M. (1980). *Image and Mind*, ISBN 067443659.
- Kruse, P. and Stadler, M. (1990). "Stability and instability in cognitive systems: Multistability, suggestion and psychosomatic interaction," in Haken, H. and Stadler, M. (eds.), *Synergetics of Cognition*, ISBN 3540519297, pp. 201-215.
- Kryukov, V. I. (1991). "An attention model based on the principle of dominantia" in A. V. Holden and Kryukov, V. I. (eds.), *Neurocomputers and Attention I. Neurobiology, Synchronization and Chaos*. ISBN 0471935050, pp. 319-352.
- Kukkarni, D. R., Parikh, J. C. and Pratap, R. (1999). "Simulation and modeling of evoked response electroencephalograph signal," *International Journal of*

- Modern Physics*, ISSN 0218-2718, 10(4): 759-776.
- Kumar, T., Zhau, P., and Glaser, D. A. (1993). "Comparison of Human performance with algorithms for estimating fractal dimension of fractional Brownian statistics," *Journal of the Optical Society of American A, Optic Image and Science*, ISSN 0740-3232, 10(6): 1136-1146.
- Kunda, Z., and Thagard, P. (1996). "Forming impressions from stereotypes, traits, and behaviors: A parallel- constraint- satisfaction theory," *Psychological Review*, ISSN 0033-295X, 103: 284-308.
- Kuramoto, Y. (1984). *Chemical Oscillations, Waves, and Turbulence*. ISBN 978-0486428819.
- Kurian, G. and Joseph, K. B. (1999). "Control of Chaos in neural networks by altering the thresholding function," in N. Pradhan, P. E. Rapp and R. Sreenivasan (eds.), *Nonlinear Dynamics and Brain Functioning*, ISBN 1560726482, pp. 49-51.
- Lago-Fernandez, L. F., Huerta, R. Corbacho, F. and Siguenza, J. A. (2000). "Fast response and temporal coherent oscillations in small-world networks," *Physical Review Letter*, ISSN 1079-7114, 84(12): 2758-2761.
- Lakoff, G. (1987b). "Cognitive models and prototype theory," in U. Neisser (ed.), *Concepts and Conceptual Development: Ecological and Intellectual Factors in Categorization*, ISBN 0521322197, pp. 63-100.
- Lakoff, G. (1987b). *Women, Fire, and Dangerous Things: What Categories Reveal About the Mind*, ISBN 0226468044.
- Lamberts, J., van den Broek, P., Bener, J., van Egmond, J., Dirksen, R., Coenen, A. (2000) "Correlation dimension of the human electroencephalogram corresponds with cognitive load," *Neuropsychobiology*, ISSN 1423-0224, 41: 149-153.
- Langton, C. G. (1990). "Computation at the edge of chaos: Phase transitions and emergent computation," *Physica D: Nonlinear Phenomena*, ISSN 0167-2789, 42(1-3): 12-37.
- Langton, C. G. (1992). "Life at the edge of chaos," in C.G. Langton, C. Taylor, J. D. Farmer, and S. Rasmussen (eds.), *Artificial life II: Santa Fe Institute Studies in the Sciences of Complexity*, ISBN 0201525712, pp. 41-91.
- Lashley, K. S. (1950). "In search of the engram," *Society of Experimental Biology Symposium, No. 4: Psychological Mechanisms in Animal Behavior*, London: Cambridge University Press, 4: 454-482.
- Laskoski, G. M. (1990). "Addressing scaling and plasticity problems with a biologically motivated self-organizing network," *Proceedings of the IEEE International Conference on Neural Networks*, ISSN 1098-7576, 2: 355-360.
- Latora, V. and Marchiori, M. (2001). "Efficient behavior of small-world networks," *Physical Review Letters*, ISSN 0031-9007, 87: 198701.
- Le Van Quyen, M. (2003). "Disentangling the dynamic core: A research program for neurodynamics at the large scale," *Biological Research*, ISSN 0100-879X, 36(1): 67-86.
- Le Van Quyen, M., Martinerie, J., Navarro, V., Baulac, M. and Varela, F. J. (2001). "Characterizing neurodynamic changes before seizures," *Journal of Clinical Neurophysiology*, ISSN 1388-2457, 18(3): 191-208.

- Lovelock, J. (2000). *Gaia: A New Look at Life on Earth*, ISBN 019217665X.
- Levy, W. and Wu, X. B. (2000). "Some randomness benefits a model of hippocampal function," in P. Arhem, C. Blomberg and H. Liljenstrom (eds.), *Disorder Versus Order in Brain Function: Essays in Theoretical Neurobiology*, ISBN 9810240082, pp. 221-238.
- Lewin R. (1999). *Complexity. Life at the Edge of Chaos*, ISBN 0226476553.
- Lewin, K. (1947). "Frontiers in group dynamics," *Human Relations*, ISSN 0018-7267, 1: 5-41.
- Lewin, K. (1951). *Field Theory in Social Science*, New York: Harper.
- Lewis, M. D. (1995). "Cognition-emotion feedback and the self-organization of developmental paths," *Human Development*, ISSN 0018-716X, 38: 71-102.
- Lewis, M. D. and Junyk, N. (1997). "The self-organization of psychological defenses," in F. Masterpasqua and P. A. Perna, (eds.), *The Psychological Meaning of Chaos: Translating Theory Into Practice*, ISBN 1557984298, pp. 41-74.
- Liebovitch, L. and Todorov, A. (2000). "What causes ion channel proteins to open and close?," in P. Arhem, C. Blomberg and H. Liljenstrom (eds.), *Disorder Versus Order in Brain Function: Essays in Theoretical Neurobiology*, ISBN 9810240082, pp. 83-106.
- Liljenström, H. and Wu, X. B. (1995). "Noise-enhanced performance in a cortical associative memory model," *International Journal of Neural Systems*, ISSN 0129-0657, 6: 19-29.
- Lloyd, J. E. (1983). "Bioluminescence and communication in insects. *Annual Review of Entomology*, ISSN 0066-4170, 28: 131-160.
- Loftus, E. F. (1975). "Leading questions and the eyewitness report," *Cognitive Psychology*, ISSN 0010-02857, 7(4): 560-572.
- Logie, R. H., Zucco, G., and Baddeley, A. D. (1990). "Interference with visual short term memory," *Acta Psychologica*, ISSN 0001-6918, 75(1): 55-74.
- Loring, D. W., Struss, E., Hermann, B. P., Perrine, K., Trenerry, M. R., Barr, W. B., Westfield, M., Chelune, G. J., Lee, G. P., and Mendor, K. J. (1999). "Effects of anomalous language representation on neuropsychological performance in temporal lobe epilepsy," *American Academy of Neurology* ISSN 1080-2371, 53(2): 260-264.
- Losada, M., and Markovitch, S. (1990). "Group analyzer: A system for dynamic analysis of group interaction," in B. Shriver (ed.), *Proceedings of the 23rd Annual Hawaii International Conference on System Sciences*, ISBN 0818620099, pp. 101 - 110.
- Lutzenberger, W., Elbert, T., Birbaumer, N., Ray, W. J. and Schupp, H. (1992). "The scalp distribution of the fractal dimension of the EEG and its variation with mental tasks," *Brain Topography*, ISSN 0896-0267, 5: 27-34.
- Markram, H. (1997). "A network of tufted layer 5 pyramidal neurons," *Cerebral Cortex*, ISSN 1047-3211, 7(6): 523-533.
- Marks-Tarlow, T. (1995). "The fractal geometry of human nature," in R. Robertson and A. Combs (eds.), *Chaos Theory in Psychology and the Life Sciences*, ISBN 0805817360, pp. 275-284.

- McClelland, J. L. Rumelhart, D. E., and the PDP Research Group. (1987). *Parallel Distributed Processing, Vol 2: Psychological and Biological Models*, ISBN 978-0262631105.
- McDonald, J. and Ward, L., M. (1998). "Nonlinear dynamics of event-related human brain activity," Unpublished manuscript, University of British Columbia.
- Messick, D. M., and Liebrand, V. B. G. (1997). "Individual heuristic and the dynamics of cooperation in large groups," *Psychological Review*, ISSN 0033-295X, 102(1): 131-145.
- Meyer A. D. (1982). "Adapting to environmental jolts," *Administrative Science Quarterly*, ISSN 0001-8392, 27(4): 515-537.
- Meyer A. D., Gaba, V. and Colwell, K. A. (2005). "Organization far from equilibrium: Non-linear change in organizational fields," *Organization Science*, ISSN 1526-5455, 16(5): 456-473.
- Meyer-Lindenberg, A. (1996). "The evolution of complexity in human brain development: An EEG study," *Electroencephalography and Clinical Neurophysiology* ISSN 1388-2457, 99(5): 405-411.
- Micheloyannis, S., Flitzanis, N., Papanikolaou, E., Bourkas, M. Terzakis, D., Arvanitis, S., Stam, C. J. and Simos, P. G. (2002). "Ongoing electroencephalographic signal study of simple arithmetic using linear and non-linear measures," *International Journal of Psychophysiology*, ISSN 0167-8760, 44(3): 231-238.
- Milgram, S. (1967). "The small world problem," *Psychology Today*, ISSN 0033-3107, 2: 60-67.
- Miller, G. A. (1956). "The magical number seven, plus or minus two: Some limits on our capacity for processing information," *Psychological Review*, ISSN 0033-295X, 101(2): 343-352.
- Molle, M., Marchall, L., Pietrowsky, R., Lutzenburg, W., Fehm, L., Born, J. (1995). "Dimensional complexity of the EEG indicates a right fronto-cortical locus of attention control," *Journal of Psychophysiology*, ISSN 0167-8760, 9: 45-55.
- Mormann, F., Kreuz T., Andrezjak, R. G., David, P., Lenertz, K. and Elger, C. E. (2003) "Epileptic seizures are preceded by a decrease in synchronization," *Epilepsy Research*, ISSN 0920-1211, 53(3): 173-185.
- Morowitz, H. J. (2002). *The Emergence of Everything: How the World Became Complex*, ISBN 019513513X.
- Muller, V., Lutzenberger, W., Preissel, H., Pulvermuller, F. and Birbaumer, N. (2003). "Complexity of visual stimuli and non-linear EEG dynamics in humans," *Cognitive Brain Research*, ISSN 0926-6410, 16(1): 104-110.
- Murray, J. D. (1981). "A prepattern formation mechanism for animal coat markings," *Journal of Theoretical Biology*, ISSN 0022-5193, 88: 161-199.
- Muzalevskaya, N. I., Uritsky, V. M., Korolyov, E. V., Reschikov, A. M. and Timoshinov, G. P. (1993). "Stochastic control of living systems. Normalization of physiological function by magnetic field with 1/f power spectrum," in P. H. Handel and A. L. Chung (eds.), *Noise in Physical Systems and 1/f Fluctuations*, ISBN 1563962705, pp. 724-727.

- Newell, A. (1991). *Unified Theories of Cognition*, ISBN 0674920996.
- Newtson, D. (1994). "The perception and coupling of behavior waves," in R. R. Vallacher and A. Nowak (eds.), *Dynamical systems in Social Psychology*, ISBN 1572303530, pp. 139-167.
- Nezlek, J. B. (1993). "The stability of social interaction," *Journal of Personality and Social Psychology*, ISSN 0022-3514, 65(5): 930-941.
- Nezlek, J. B. and Wheeler, L. (1984). "Rochester interaction record analysis package," *Psychological Documents*, ISSN 0021-843X, 14(6): 2610.
- Nicolis, J. S. and Tsuda, I. (1985). "Chaotic dynamics of information processing," *Bulletin of Mathematical Biology*, ISSN 1522-9602, 47(3): 343-365.
- Noam, G. G., Powers, S. I., Kilkenny, R. and Beedy, J. (1990). "The interpersonal self in life-span developmental perspective: Theory, measurement, and longitudinal case analyses," in P. B. Baltes, D. L. Featherman and R. M. Lerner (eds.), *Life-span development and behavior*, ISBN 0805815078, pp. 59-104.
- Noelle-Neumann, E. (1984). *The Spiral of Silence: Public Opinion - Our Social Skin*, ISBN 0226589366.
- Novikov, E., Novikov, A., Shannahoff-Khalsa, D., Schwartz, B. and Wright, J. (1997). "Scale-similar activity in the brain," *Physical Review E*, ISSN 1063-651X, 56(3): R2387-R2389.
- Nowak, A., and Lewenstein, M. (1996). "Modeling social change with cellular automata," in R. Hegselmann, K. Troitzch, and U. Muller (eds.), *Modeling and Simulation in the Social Sciences from the Philosophy of Science Point of View*, ISBN 0792341252, pp. 249-285.
- Nowak, A., and Vallacher, R. R. (1998). *Dynamical Social Psychology*, ISBN 1572303530.
- Nowak, A., Lewenstein, M. and Szamrej, J. (1993). "Social transitions occur through bubbles," *Scientific American*, ISSN 0036-8733, 12: 16-25.
- Nowak, A., Szamrej, J., and Latane, B. (1990). "From private attitude to public opinion: A dynamic theory of social impact," *Psychological Review*, ISSN 0033-295X, 97: 362-376.
- Odum, H. T. (1988). "Self-organization, transformity, and information," *Science*, ISSN 0036-8075, 242: 1132-1139.
- Osborne, A. R. and Provenzala, A. (1989). "Finite correlation dimension for stochastic systems with power-law spectra," *Physica*, ISSN 0031-8949, 35D: 357-381.
- Otmakhov, N., Shirke, A. M. and Malinow, R. (1993). "Measuring the impact of probabilistic transmission on neuronal output," *Neuron*, ISSN 0896-6273, 10: 1101-1111.
- Ott, E., Grebogi, C., and Yorke, J. A. (1990). "Controlling chaos," *Physical Review Letters*, ISSN 0031-9007, 64: 1196-1199.
- Paine, R. T. (1966). "Food web complexity and species diversity," *American Naturalist*, ISSN 0003-0147, 100: 65-75.
- Palus, M. (1996). "Nonlinearity in normal human EEG: Cycles, temporal asymmetry, nonstationarity and randomness, not chaos," *Biological Cybernetics*, ISSN 0340-1200, 75(5): 386-396.

- Parekh, N., and Sinha, S. (1999). "Suppressing spatiotemporal chaos in coupled map lattices using constant pinnings," in N. Pradhan, P. E. Rapp and R. Sreenivasan, (eds.), *Nonlinear Dynamics and Brain Functioning*, ISBN 1560726482, pp. 77-.
- Pelli, D. G. (1981). Effects of visual noise. Ph.D. Thesis. Cambridge University.
- Pereda, E., Manas, S., De Vera, L., Garrido, J. M., Lopez, S. and Gonzalez, J. J. "Non-linear asymmetric interdependencies in the electroencephalogram of healthy term neonates during sleep," *Neuroscience Letters*, ISSN 0304-3940, 337(2): 101-106.
- Peschl, M. F. (1997). "The representational relation between environmental structures and neural systems: Autonomy and environmental dependency in neural knowledge representation," *Nonlinear Dynamics, Psychology, and Life Sciences*, ISSN 1090-0578, 2(November): 99-121.
- Pettigrew, A. G., Bleasel, A. F. (1994). "Developmental and properties of spontaneous oscillations of the membrane potential in inferior olivary neurons in the rat," *Developmental brain research*, ISSN 0165-3806, 65(1): 43-50.
- Phelan, S. E. (2001). "What is complexity science, really?" *Emergence: Complexity and Organization*, ISSN 1521-3250, 3(1): 120-136.
- Pons, T. P., Garragty, P. E. Ommaya. A. K., Kass, J. H., Taub, E. and Mishlan, M. (1991). "Major cortical reorganization after sensory differentiation in adult macaques," *Science*, ISSN 0036-8075, 252: 1857-1860.
- Port, R. F. and van Gelder, T. (1998). *Mind as Motion: Exploration in the Dynamics of Cognition*, ISBN 0262661101.
- Post, W. M., and Pimm, S. L. (1983). "Community assembly and food web stability," *Mathematical Biosciences*, ISSN 1547-1063, 64: 169-192.
- Pradhan, N. and Dutt, D. N. (1993). "Use of running fractal dimension for the analysis of changing patterns in electroencephalograms," *Computers in Biology and Medicine*, ISSN 0010-4825, 23(5): 381-388.
- Raeymaekers, L. (2002). "Dynamics of Boolean networks controlled by biologically meaningful functions," *Journal of Theoretical Biology*, ISSN 0022-5193, 218(3): 331-341.
- Ramachandran, V. S. (1992). "Blind spots." *Scientific American*, ISSN 0036-8733, 266: 86-91.
- Ramaswamy, R., Sinha, S., and Gupte, N. (1999). "Enhancement and maintenance of chaos using adaptive anti-control," in N. Pradhan, P. E. Rapp and R. Sreenivasan (eds.), *Nonlinear Dynamics and Brain Functioning*, ISBN 1560726482, pp. 113-120.
- Rapoport, A. (1957). "A contribution to the theory of random and biased nets," *Bulletin of Mathematical Biophysics*, ISSN 0007-4985, 19: 257-271.
- Rapp, P. E., Zimmerman, I. D., Albano, A. M., Deguzman, G. C. and Gressbaum, N. N. (1989). "Dynamics of spontaneous neural activity in the simian motor cortex: The dimension of chaotic neurons," *Physics Letters*, ISSN 0015-9018, 110: 99-118.
- Ray, T. S. (1991) "Approach to the synthesis of artificial life," in C. Langton, C. Yaylor, J. D. Farmer and S. Rasmussen (eds.), *Artificial Life II*. ISBN 0201525704, pp. 341- 408.

- Read, S., J., and Miller, L.C. (eds.), (1998). *Connectionist Models of Social Reasoning and Social Behavior*, ISBN 0805822168.
- Redies, C. (2007). "A universal model of esthetic perception based on the sensory coding of natural stimuli," *Spatial Vision*, ISSN 1568-5683, 21: 97-117.
- Reeke, G. N. Jr., and Edelman, G. M. (1984). "Selective networks and recognition automata," *Annals of the New York Academy of Sciences*, ISSN 0077-8923, 426: 181-201.
- Reicher, G. M. (1969). "Perceptual recognition as a function of meaningfulness of stimulus material," *Journal of Experimental Psychology*, ISSN 0096-3445, 81: 274-280.
- Rieke, F., Warlund, D., de Ruyter van Steveninck, R. and Bialek, W. (1996). *Spikes: Exploring the Neural Code*, ISBN 0262681087.
- Rinaldi, S. and Gragnani, A. (1998). "Minimal models for dyadic processes: A review," in F. Orsucci (ed.), *The Complex Matters of the Mind*, ISBN 9810233396, pp. 87-104.
- Robinson, C. (1998). *Dynamical Systems: Stability, Symbolic Dynamics, and Chaos*, ISBN 0849384958.
- Rourke, B. P., and Conway, J. A. (1997) "Disabilities of arithmetic and mathematical reasoning: Perspectives from neurology and neuropsychology," *Journal of Learning Disabilities*, ISSN 1354-4187, 30(1): 34-46.
- Rusbult, C. E. (1980). "Commitment and satisfaction in romantic associations: A test of the investment model," *Journal of Experimental Social Psychology*, ISSN 0022-1031, 16: 172-186.
- Rusbult, C. E. (1980). "A longitudinal test of the investment model: The development (and deterioration) of satisfaction and commitment in heterosexual involvement," *Journal of Experimental Social Psychology*, ISSN 0022-1031, 45: 101-117.
- Rusbult, C. E. and Martz, J. M. (1995). Remaining in an abusive relationship: An investment model analysis of nonvoluntary dependence," *Personality and Social Psychology Bulletin*, ISSN 1552-7433, 21: 558-571.
- Sabelli, H. C. and Carlson-Sabelli, L. (1990). "Psychogeometry: The dynamics of behavior," presented at the *34th Annual Meeting of the International Society for the Systems Sciences*, Portland, Oregon: ISSS, pp. 769-775.
- Sabelli, H. C., Carlson-Sabelli, L. and Javaid, J. I. (1990). "The thermodynamics of bipolarity: A bifurcation model of bipolar illness and bipolar character and its psychotherapeutic applications," *Psychiatry*, ISSN 0033-2747, 53: 346-368.
- Sabelli, H. C., Carlson-Sabelli, L., Patel, M., Levy, A. and Diez-Martin, J. (1995). "Anger, fear, depression, and crime: Physiological and psychological studies using the process method," in R. Robertson, and A. Combs (eds.), *Chaos Theory in Psychology and the Life Sciences*, ISBN 0805817360, pp. 65-88.
- Sathian, K., Zangaladze, A., Hoffman, J., and Grafton, S. (1997). "Feeling with the mind's eye," *Neuroreport: An International Journal for the Rapid Communication of Research in Neuroscience*, ISSN 0959-4965, 8: 3877-3881.
- Saunders, P. T. (1980). *An Introduction to Catastrophe Theory*, ISSN 052123042X.

- Sammer, G. (1996). "Working-memory load and dimensional complexity of the EEG," *International Journal of Psychophysiology*, ISSN 0167-8760, 24: 173-182.
- Shadlen, M.N., Newsome W.T. (2001). "Neural basis of a perceptual decision in the parietal cortex (area LIP) of the rhesus monkey," *Journal of Neurophysiology*, ISSN 0022-3077, 86(4): 1916-1936.
- Scannell, J. W. (1997). "Determining cortical landscapes," *Nature*, ISSN 0028-0836, 386(April): 452-452.
- Scannell, J. W. and Young, M. P. (1999). "Neuronal population activity and functional imaging," *Proceedings in Biological Science*, ISSN 1939-0084, 266(1422): 875-881.
- Schall, J. D. (2003). "Neural correlates of decision processes: Neural and mental chronometry," *Current Opinion in Neurobiology*, ISSN 0959-4388, 13(2): 182-186.
- Schank, R. and Abelson R. (1977). *Scripts, Plans, Goals, and Understanding: An Inquiry Into Human Knowledge Structures*, ISBN 0898591384.
- Schiff, S. J., Jerger, K., Duond, D. H., Chang, T., Spano, M. L. and Ditto, M. L. (1994). "Controlling chaos in the brain," *Nature*, ISSN 0028-0836, 370: 615-620.
- Schmid, G. B. (1998). "The six fundamental characteristics of chaos and their clinical relevance to psychiatry: A new hypothesis for the origin of psychosis," in F. Orsucci (ed.), *The Complex Matters of the Mind*, ISBN 9810233396, pp. 139-181.
- Schrodinger, E. (1944). *What is life? The Physical Aspect of the Living Cell*, ISBN 0521427088.
- Seeley, T. D. (1989). "Social foraging in honey bees: How nectar foragers assess their colony's nutritional status," *Behavioral Ecology and Sociobiology*, ISSN 1432-2013, 24: 181-199.
- Segal, G. (2000). *A Slim Book About Narrow Content*, ISBN 978-0262194310.
- Sheehan, S. (1982). *Is There no Place on Earth for Me?* ISBN 0395318718.
- Silberstein, M. (2002). "Reduction, emergence, and explanation," in P. Machamer and M. Silberstein (eds.), *The Blackwell Guide to the Philosophy of Science*. ISBN 0631221081, pp. 80-107.
- Singer W. (1996). Neural Synchronization: A solution to the binding problem? in R. Llinas and P. S. Churchland (eds.), *The Mind-Brain Continuum: Sensory Processes*, ISBN 0262121989, pp. 100-130.
- Singer, J. L. (1995). "Mental processes and brain architecture: Confronting the complex adaptive systems of human thought," in H. J. Morowitz and J. L. Singer (eds.), *The Mind, the Brain and Complex Adaptive Systems*, ISBN 0201409860, pp. 1-10.
- Sinha, S. (1999). "A 'Computing' Chaotic System," in N. Pradhan, P. E. Rapp and R. Sreenivasan (eds.), *Nonlinear Dynamics and Brain Functioning*, ISBN 1560726482, pp. 138-143.
- Sinha, S. and Ditto, W.L. (1998). "Dynamics-based computation," *Physical Review Letters*, ISSN 0031-9007, 81(10): 2156-5159.
- Skinner, B. F. (1953). *Science and Human Behavior*, ISBN 0029290408.

- Smetters, D. (2000). "Noise in neural computation," in P. Arhem, C. Blomberg and H. Liljenstrom (eds.), *Disorder Versus Order in Brain Function: Essays in Theoretical Neurobiology*, ISBN 9810240082, pp. 107-116.
- Smith, E. R. (1996). "What do connectionism and social psychology offer each other?" *Journal of Personality and Social Psychology*, ISSN 0022-3514, 70: 893-912.
- Smith, J. C. and Feldman, J. L. (1990). "Organization of oscillatory motor pattern generation networks in the mammalian central nervous system," *Proceedings of the IEEE International Conference on Neural Networks*, ISSN 1098-7576, 2: 651-656.
- Sole, R. and Goodwin, B. (2000). *Signs of Life: How Complexity Pervades Biology*, ISBN 0465019277.
- Solé, R. V., Bascompte, J. and Valls, J. (1992). "Stability and complexity in spatially-extended two-species competition," *Journal of Theoretical Biology*, ISSN 0022-5193, 159: 469-476.
- Spehar, B., Clifford, C. W. G., Newell, B. R. and Taylor, R. P. (2003). "Universal aesthetic of fractals" *Computers and Graphics*, ISSN 0097-8493, 27: 813-820.
- Spivey, M. (2007). *The Continuity of Mind*, ISBN 0195170784.
- Stam, C. J. (2003). "Chaos, continuous EEG, and cognitive mechanisms: A future for clinical neurophysiology," *American Journal of Electroneurodiagnostic Technology*, ISSN 1086-508X, 43(4): 211-227.
- Stam, C. J. (2005). "Nonlinear dynamical analysis of EEG and MEG: Review of an emerging field," *Clinical Neurophysiology*, ISSN 1388-2457, 116(10): 2266-2291.
- Stam, C. J., Jelles B., Achtereekte, H. A. M., Rombouts, S. A. R. B., Slaets, J. P. J. and Keunen, R. W. M. (1995). "Investigation of EEG non-linearity in dementia and Parkinson's disease" *Electroencephalography and Clinical Neurophysiology*, ISSN 1388-2457, 95(5): 214-224.
- Stam, C. J., Tavey D. L. J., Jelles B., Achtereekte, H. A. M., Slaets, J. P. J. and Keunen, R. W. M. (1994). "Non-linear dynamical analysis of multi channel EEG data: Clinical applications in dementia and Parkinson's disease," *Brain Topography*, ISSN 0896-0267, 7(2): 141-150.
- Stepien, R. A. (2002). "Testing for non-linearity in EEG signal of healthy subjects," *Acta Neurobiologiae Experimentalis*, ISSN 0065-1400, 62: 90-96.
- Sternberg, S. (1966). "High-speed scanning in human memory," *Science*, ISSN 0036-8075, 153(3736): 652-654.
- Stevens, C. F., Wang, Y. (1994). "Changes in reliability of synaptic function as a mechanism for plasticity," *Nature*, ISSN 0028-0836, 371: 704-707.
- Strogatz, S. (2003). *Sync: How Order Emerges from Chaos in the Universe, Nature, and Daily Life*, ISBN 0786887214.
- Sutton, R. S. and Barto, A. (1998) *Reinforcement Learning: An Introduction*, ISBN 0262193981.
- Swindale, N. V. (1980). "A model for the formation of ocular dominance stripes," *Proceedings of the Royal Society of London, Series B*, ISSN 0962-8452, 208: 243-264.

- Swenson, R. (1989). "Emergent evolution and the global attractor: The evolutionary epistemology of entropy production," *Proceedings of the 33rd Anniversary Meeting of the International Society for the Systems Sciences*, ISSN 0016-6588, 3: 46-53.
- Takakura, K., Kosugi, Y., Ikebe, J. and Musha, T. (1987). "1/f controlled transcutaneous electrical stimulation for pain relief," in C. M. Van Vliet (ed.), *Ninth International Conference on Noise and Physical Systems*, ISBN 9971503972, pp. 279-282.
- Tech, M. C. (1989). "Fractal character of the auditory neural spike train," *IEEE Transactions on Biomedical Engineering*, ISSN 0018-9294, 36(1): 150-160.
- Tesser, A. (1980). "When individual dispositions and social pressure conflict: A catastrophe," *Human Relations*, ISSN 0018-7267, 33: 393-407.
- Tesser, A., and Achee, J. (1994). "Aggression, love, conformity, and other social psychological catastrophes," in R.R. Vallacher and A. Nowak (Eds.), *Dynamical Systems in Social Psychology*. ISBN 1572303530, pp. 96-109.
- Theiler, J. (1991). "Some comments on the correlation dimension of 1/f noise," *Physics Letters*, ISSN 0015-9018, 115A: 480-493.
- Thelen, E. and Smith, L. B. (1994). *A Dynamic Systems Approach to the Development of Cognition and Action*, ISBN 026270059X.
- Toffoli, T. and Margolus, N. (1987). *Cellular Automata Machines*. ISBN 0262200608.
- Tononi, G. and Edelman, G. M. (1998). "Consciousness and complexity," *Science*, ISSN 0036-8075, 282: 1846-1851.
- Tononi, G., Sporns, O. and Edelman, G. M. (1996). "A complexity measure for selective matching of signals by the brain," *Proceedings of the National Academy of the Sciences*, ISSN 0027-8424, 93(8): 3422-3427.
- Torre, C. A. (1984). "Problem solving and decision-making: An integration of cognitive, affective, and pragmatic operations," presented at the *Second Biennial International Conference on Thinking*, Harvard University, (August).
- Torre, C. A. (1987). "Thinking, culture and education," presented at the *Third Biennial International Conference on Thinking*, University of Hawaii at Manoa, (January).
- Torre, C. A. (1995). "Chaos in the Triadic Theory of Psychological Competence in the Academic Setting" in F. D. Abraham and A. R. Gilgen (eds.), *Chaos Theory in Psychology*, ISBN 0275951405, pp. 279-294.
- Treisman, A. (1987). "Features and objects in visual processing," *Scientific American*, ISSN 0036-8733, 255(5): 114-125.
- Treves, A. and Rolls, E. T. (1994) "Computational analysis of the role of the hippocampus in memory," *Hippocampus*, ISSN 1050-9631, 4(3): 374-391.
- Tryon, W. W. (1995). "Synthesizing psychological schisms through connectionism," in F. D. Abraham, and A. R. Gilgen (eds.), *Chaos Theory in Psychology*, ISBN 0275951405, pp. 247-263.
- Tsuda I. (2001). "Toward an interpretation of dynamic neural activity in terms of chaotic dynamical systems," *Behavioral and Brain Science*, ISSN 0140-525X, 24: 793-841.

- Uttal, W. R. (1973). *The Psychobiology of Sensory Coding*, ISBN 1125942991.
- Vaadia, E. Haalman, I. Abeles, M., Bergman, H., Prut, Y., Slovin H. and Aertsen, A. (1995). "Dynamics of neuronal interactions in monkey cortex in relation to behavioral events," *Nature*, ISSN 0028-0836, 373: 515-518.
- Valdes, P., Bosch, J., Jimenez, J. C., Trujillo, N., Biscay, R. and Morales, F. (2001). "The statistical identification of nonlinear brain dynamics: A progress report," in N. Pradhan, P. E. Rapp and R. Sreenivasan (eds.), *Nonlinear Dynamics and Brain Functioning*, ISBN 1560726482, pp. 243-264.
- Van der Pol, B., van der Mark, J. (1927). "Frequency demultiplication," *Nature*, ISSN 0028-0836, 120: 363-364.
- Van der Malsburg, C. (1999). "The what and why of binding: The modeler's perspective," *Neuron*, ISSN 0896-6273, 24: 95-104.
- Van Orden, G. C., Holden, J. G. and Turvey, M. T. (2005). "Human cognition and 1/f scaling," *Journal of Experimental Psychology: General*, ISSN 0096-3445, 134(1): 117-123.
- Varela, F. J. (1995). "Resonant cell assemblies: A new approach to cognitive functions and neuronal synchrony," *Biology Research*, ISSN 0716-9760, 28: 81-95.
- Varela, F. J. (1999). "The specious present," in J. Petetot, F. J. Varela, B. Pachoud and J. M. Roy, (eds.), *Naturalizing Phenomenology*, ISBN 0804733229, pp. 266-316.
- Velazquez, J. L., Cortez, M. A., Carter, Snead III, O. and Wennberg R. (2003). "Dynamical regimes underlying epileptiform events: Role of instabilities and bifurcations in brain activity," *Physica D*, ISSN 0167-2789, 186: 205-220.
- Von Neuman, J. and Morgenstern, O. (1947). *Theory of Games and Economic Behavior*, ISBN 0691003629.
- Voss, R. F. and Clarke, J. (1975). "1/f noise in music and speech," *Nature*, ISSN 0028-0836, 258 (5533): 317-318.
- Ward, L. M. (2002). *Dynamical Cognitive Science*, ISBN 0262232170.
- Ward, L. M. and Richard, C. M. (2001). "1/f noise and decision complexity," Unpublished manuscript, Vancouver, Canada: University of British Columbia.
- Watts D.J. (2003). *Six Degrees: The Science of a Connected Age*, ISBN 0393041425.
- Watts, D. J. and Strogatz, S. H. (1998). "Collective dynamics of 'small-world' networks," *Nature*, ISSN 0028-0836, 393: 440-442.
- Weinberg, Gerald M. (1975). *An Introduction to General Systems Thinking*, ISBN 0471925632.
- Westheimer, G. (1991). "Visual Discrimination of fractal borders," *Proceedings of the Royal Society of London*, ISSN 0962-8452, 243: 215-219.
- Williams G. P. (1997). *Chaos Theory Tamed*, ISBN 0309063515.
- Winkler, M., Combs, A. L. and Daley, C. (1994). "A chaotic systems analysis of rhythm in feeling states," *The Psychological Record*, ISSN 0033-2933, 44: 359-368.
- Winkler, M., Combs, A. L., Dezern, D., Alstott, T., Burnham, J., Ran, B. and

- Walker, S. (1991). "Cyclicity in moods: A dynamical systems analysis," presented at the *Society for Chaos Theory in Psychology*, San Francisco, CA.
- Wolff, P. H. (1987). *The Development of Behavioral States and the Expression of Emotions in Early Infancy*, ISBN 978-0226905204.
- Wolfram S. (2002). *A New Kind of Science*, ISSN 1579550088.
- Wolpert, D. and Macready, W. (2000). "Self-dissimilarity: An empirically observable complexity measure" in Y. Bar-Yam (Ed.), *Unifying Themes in Complex Systems: Proceedings of the International Conference on Complex Systems*, ISBN 0813341221, pp. 625-643.
- Wong, R. (1999). "Retinal waves and visual system development," *Annual Review of Neuroscience*, ISSN 1471-003X, 22: 29-47.
- Wynn, T. (1999). "The Evolution of Tools and Symbolic Behaviour," in A. Lock, C. Peters (eds.), *The Handbook of Human Symbolic Evolution*, ISBN 0631216902, pp. 263-287.
- Xu, J., Tong, Q. and Liu, R. (1999). "Information transmission of human cerebral cortex and schizophrenia in N. Pradhan, P. E. Rapp and R. Sreenivasan (eds.), *Nonlinear Dynamics and Brain Functioning*, ISBN 1560726482, pp.
- Xu, Y., Shen, M., Tony, S., Thakor, N., Lee, Y., Zhu, Y. (1990). "The nonlinear dynamical analysis of the EEG in schizophrenia with temporal and spatial embedding dimension," *Journal of medical engineering & technology*, ISSN 0309-1902, 25(2): 79-83.
- Yagy, T., Wackermann, J., Shigeta, M., Jelic, V., Kinoshita, T., Kocki, K., Julin, P., Almkvist, O., Wahlund, L. O., Kondarkor, I. and Lehmann, D. (1997). "Global dimensional complexity of multi-channel EEG in mild Alzheimer's Disease and age-matched controls," *Dementia and Geriatric Cognitive Disorders*, ISSN 1420-8008, 8: 343-347.
- Zangaladze, A., Epstein, C., Grafton, S. and Sathian, K. (1999). "Involvement of visual cortex in tactile discrimination of orientation," *Nature*, ISSN 0028-0836, 401: 587-590.
- Zera, D. A. and Lucian, D. G. (2001). "Self-organization and learning disabilities: A theoretical perspective for the interpretation and understanding of dysfunction," *Learning Disability Quarterly*, ISSN 0731-9487, 24(2): 107-118.

INDEX

A

- A-Life simulations 184, 263
- ability 103, 107, 154-5, 160, 163-4, 178-9, 183, 226-7, 233, 236, 252, 260
- ABM (agent-based modeling) 55, 251-3
- abnormality 151, 172-3
- activation 15, 38, 75, 90, 94, 106, 112, 124, 132, 134, 173, 184-5, 203-4, 227, 233
- Activity States 85, 140, 195
- adaptive systems 50, 259
- Agents 34-6, 49-50, 55-6, 133, 157, 187-8, 206, 245, 251-4, 260
- aggregates 26, 37, 263
- AIC (algorithmic information content) 44-5, 264
- algorithms 44, 130, 211, 213, 240-1, 245
- alleles 213-15, 217-18
- alternatives 59, 61, 206-7
- ambiguous figures 73-4, 197-8
- animal populations 65, 76-7
- Ants 55, 58-9, 245, 249
- anxiety 167-8, 171, 173-5, 260
- Anxiety Disorders 173, 175
- atoms 33, 37, 55-6, 137-40
- attention 16, 18, 50, 75, 107, 109-10, 115, 121, 168-9, 173, 178-9, 187, 192-3, 200-1, 206, 244
- attraction, basin of 69, 77, 84, 159, 185, 187
- attractor basins 72, 74, 76, 173, 185, 189
- attractor points 77
- attractor states 124, 155, 164, 194, 262
 - stable 155, 167
- Attractors 61, 69-70, 72-4, 77-9, 84-7, 117, 124-5, 153, 155-6, 169, 173, 188, 197, 201-2, 260, 267
 - exotic 117
 - new 124, 156, 209
 - periodic 70-1, 77, 79, 84-5
 - personality 167, 173
 - strange 72-3, 117, 175, 201-2
- avalanches 61-3
- axons 57, 59, 103, 225, 246, 251

B

- basins 72-4, 77, 85-6, 159, 185
- behavior 16-17, 20-3, 31-3, 35-8, 41-2, 49-51, 55-7, 76, 78-81, 139-42,
152-5, 157-9, 169-72, 183-4, 253-5, 259-61
 - aggregate 35, 251
 - child's 155
 - complex 40, 49, 55, 62, 155-6, 259
 - emergent 23, 107, 247
 - global 38, 40, 137, 139, 252, 267
 - guide 61, 267
 - healthy pattern of 170
 - human 135, 241
 - maladaptive 171, 173
 - mating 81, 267
 - random 79, 225
 - social 18, 80, 151, 156-7
 - unrestricted sexual 267
- behavior surface 80-2
- Bénard cells 26-7, 264
- bifurcations 22-4, 53, 76-7, 79-80, 117, 122, 161, 164, 175, 177, 181,
208-9, 247, 256, 259-60, 262
- biological systems 53-5, 57, 225, 249
- biology 22-3, 25, 33, 41, 49, 139, 151, 236, 239, 249, 254, 261, 265, 267
- bipolar disorder 170, 175
- blueprints 54, 59-61
- Boolean networks 16, 83-6, 104
- boundaries 158-9, 190, 261
- brain 15-17, 20-1, 40-1, 47-8, 56-9, 103-4, 106-9, 113-15, 119-21, 131-3,
140-1, 189-92, 225, 227, 232-4, 259-63
- brain activity 115, 119-20, 134, 142, 146, 191, 265
- brain areas 103, 106, 110, 114-16, 121-2, 178-9, 261
- brain damage 224, 232-3
- brain dynamics, complex 120
- brain networks 17
- brain regions 40, 59, 115, 117-18, 120-2, 132, 195, 265
- brain states 109, 115, 120-1, 191
- Burst coding 110-11

C

- CA (cellular automata) 19, 53-4, 62, 153, 157, 160, 194, 235, 247, 249-50,
254, 260-1, 263, 267
- CA models 63, 160, 249
- catastrophe theory 23, 80, 82

- Causality 21-2, 192
 - circular 21-2
- cells 15-16, 24, 26-8, 47-9, 55-6, 96, 110-12, 114-15, 118, 131-2, 142-3, 154, 214, 247-9, 251-2, 261-2
 - glial 224-5
 - pyramidal 243
- cellular automata *see* CA
- central oscillator *see* CO
- central pattern generator (CPG) 154
- cgp 253-5
- chain, linear 242
- Chain of Command 92-3
- change 21-2, 26-7, 56-7, 65, 76-7, 80-1, 121-4, 152-3, 155, 160-2, 169-72, 205-6, 214-15, 238-9, 256-7, 259-61
- chaos 32-4, 66, 76-9, 109, 119, 125, 135, 146, 151-2, 169-70, 172, 174, 180, 194-5, 219, 254-5
 - edge of 33-4, 146, 183, 194-5, 219, 249
- Chaotic 33, 72, 79, 118-20, 123, 170, 174, 176, 201-2, 219, 225, 228, 241, 244, 249, 254-6
- Chaotic attractors 70, 72, 122, 124-5, 176, 178, 249
- chaotic behavior 68, 78-9, 119, 167, 194, 202, 241
- chaotic brain dynamics 119
- Chaotic systems 23, 32-4, 65-8, 79, 194, 219
- chemistry 22-3, 25, 34, 41, 49, 151, 213, 261, 265
- chromosomes 213-14
- circulatory system 227, 232
- Classical cognitive science 18, 189, 247, 250
- closed systems 21, 31, 42, 191
- closure, triadic 90-1
- clustering 100, 103, 160
- clusters 76, 106-7, 138, 160, 249
- CO (central oscillator) 244
- code 17, 45, 47-8, 55, 60, 96-7, 104, 110-12, 123, 142, 184-5, 213-14, 217, 232, 263
- Cognition 18, 23, 35, 65, 151, 154, 169, 183, 185, 187, 189, 191-5, 207, 221, 230-1, 233
- cognitive processes 17-19, 36, 56, 109, 146, 179, 194, 197, 199, 201, 203, 205, 207-9, 229, 254
- cognitive science 15, 17-19, 21, 27, 54, 60, 87, 183, 187, 189, 226, 236, 249, 267
- cognitive systems 146-7, 179, 183, 194-5, 226, 235-8
- coherence 180, 224, 229, 266
- command 15-16, 59-60, 92-3, 124
- community 162, 229
- Complex Adaptive Systems 34-5, 50, 162, 181, 259
- complex dynamical systems 76, 240

complex stimuli 111
complex systems 15, 17-20, 31, 33-4, 36, 38, 40, 45, 47, 49-50, 53, 56, 133, 145-6, 233-4, 259-62
Complexity 15-16, 31, 33, 35-45, 47-51, 53, 55-6, 72, 85, 118, 121-2, 125, 129-30, 148, 234-5, 254
complexity science 47, 49-50, 140, 235, 259, 261
components 27, 31, 53, 89, 133, 154-5, 169, 193, 205, 209, 249
Computational Complexity 45, 47, 259
Computational models 32, 40
computations 47, 55-6, 132, 146, 151, 184-5, 190-1, 193, 226, 237, 247, 249-50, 256, 262, 265
computer models 50, 62, 221, 224, 227, 236, 251-2, 259, 263
Computers 44-5, 47, 50, 93, 203, 221, 241, 249, 251
connections 15-17, 40, 44, 47, 59, 83, 86-7, 90-2, 96, 98, 100, 104-5, 115, 118-19, 140, 242
connectivity 15, 44, 48, 58, 98, 105, 115, 117-19, 132
consciousness 23, 25, 27, 55, 75, 79, 94, 107, 114, 178, 227, 242, 250
context 21, 27, 29, 34, 40, 48, 88, 96, 123, 151, 155-6, 186, 195, 203-4, 231, 264-5
control 15, 22, 32, 47, 49, 56-7, 94-5, 132, 142, 161, 164, 169, 181, 189, 194, 254-6
control parameters 76-80, 122, 160, 164, 200, 208-9, 260
control surface 80-1, 163-4
coordination 15, 57, 115, 138, 140, 157, 195
core apprehension 173-4
correlation 113, 115, 152, 198, 202
correlation dimension 118-19, 121-2
CPG (central pattern generator) 154
Curie temperature 138-9
cycles 72, 86-7, 113, 169, 192

D

Decision Field Theory 206-7
depth, logical 47, 263-4
deterministic rules 21-2, 241
development 16, 18, 58-61, 87, 92, 101, 120-1, 151, 154-6, 161, 171, 186, 260
DFT (Decision field theory) 206-8
Differential Equation Model 245-7
dimensional complexity 118, 121
Dimensionality 72, 118-19, 122, 125-7, 153, 159
dimensions 56, 68-9, 72, 74-5, 82, 118, 122, 125, 152, 158, 163, 175, 189, 204-5, 212, 215
disease 105-6, 169-70, 225

- disorder 23, 26-7, 33, 37-8, 59, 117, 135, 138, 141, 161, 169, 171-3, 177-8, 180-1, 198, 202
- disordered patterns 38-9
- dissociative identity disorders 177, 260
- Dynamic Psychology 16, 18, 20, 22, 24, 26, 28
- dynamical approach 18-19, 151, 153, 161, 266-7
- dynamical concepts 84, 135, 189, 197
- dynamical models 159, 176, 178, 194, 237-40, 247, 257, 260
- dynamical perspective 18, 22, 172, 186, 241
- dynamical systems 19-23, 61, 63, 65, 67, 69, 71-7, 79-81, 88, 114, 153-4, 156, 161, 175, 254, 267
- dynamical systems approach 19, 65, 151, 154, 237, 260
- dynamical systems perspective 23, 183, 186
- dynamical systems theory 18-19, 22, 116, 262, 267
- Dynamics 15-16, 18, 55, 75, 92, 116-20, 123, 132, 151, 153, 156, 158-61, 169-70, 197, 244, 267
- interaction-dominant 146, 190

E

- Ecological Approach 18, 191, 193, 266
- ecologies 19, 33, 49-50, 83, 223, 226, 229, 233, 261
- ecosystems 35-6, 223-5, 227-31, 234, 261
- EEG 119-23, 146, 148, 153
- emergence 20-1, 24, 27-9, 41, 115, 259-65
- emergent levels 261-4, 266
- emergent structures 90, 92, 249, 251, 264
- Emergent systems 27, 29
- emotional involvement 82, 158
- emotions 25, 36, 168-70, 173, 175, 177, 207
- encoding 202, 238
- Energy 23-4, 38, 69, 74, 177, 227, 252, 259
- energy flow 24, 227
- entities 24-5, 27, 31, 55, 193
- Entropy 37, 50, 262
- environment 15-16, 21, 31, 34, 48-9, 55-6, 58-9, 75, 155, 170-2, 183-4, 191-3, 211, 218-19, 223-7, 253-5
- Epilepsy 103, 106, 120, 122, 132, 173
- equations, logistic 65-7, 76-9
- equilibrium 23, 161, 172, 194
- events 25, 31, 65, 171, 173, 175, 199-201, 240, 253, 262
- evolution 18, 24, 28, 47, 53, 57, 159, 211, 213-19, 221, 223, 252, 259
- Evolutionary Psychology 267
- experience 42, 48, 58, 75, 114, 124, 135, 167, 169, 171, 186, 188, 221, 231
- extroversion 68-9, 159

F

- facilitator neuron 90-1
- feedback 21, 36, 49, 56-7, 59, 97, 115, 168, 170, 189, 220
 - negative 56-7, 220
 - positive 56-7, 162, 220
- firing 48, 57, 84, 103, 110, 112-13, 140, 251
- firing rate 48, 75, 86, 109, 113, 142, 178
- fitness 212, 215, 217-18, 259
 - rank order 215, 217
- fitness landscapes 18-19, 212-15, 217-19
- fitness values 214-15, 218
- flow 17, 23-4, 27, 75, 84, 88, 103, 105, 107, 132, 143, 152, 177, 192-4, 227, 237
- food webs 83, 223-4, 226
- Formal statical models 238
- formation 42, 57, 90-2, 114, 151, 177, 181, 186, 198, 203, 221, 262, 264
- fractal dimension 127, 130
- Fractal Mind 125, 127, 129, 131, 133, 135
- Fractals 17, 110, 125, 130, 134-5, 137, 146, 238
- fractional similarity dimensions 125, 127
- functional fixedness 19, 220
- functional role 202-3, 265
- functions 15-16, 21, 27, 31, 34, 36, 46-7, 56-8, 86-9, 92-4, 147, 189-90, 225, 232-3, 236, 265-6

G

- Game of Life 40, 248-9, 251
- generations 22, 47, 57, 208, 214-15, 219, 223, 248, 263, 267-8
- genes 60, 154, 185, 213-15, 217-18, 263
- Genetics 55, 58, 87, 211, 213
- genotypes 214-18
- geometry 27, 76, 92
- Gestalt psychologists 17, 21, 220-1
- global structure 100, 133, 253
- group dynamics 156
- groups 37, 54, 72, 90, 92, 94, 109, 117-18, 152, 159-60, 164, 177, 180-1, 231, 244, 263
 - creative 164
 - neural 118, 146, 260

H

Habitat fragmentation 224, 231-3
heat 25-7, 224
heuristics 19, 220-1
hierarchies 56, 92-6, 105, 184
hippocampus 106, 114, 118, 202, 232, 236, 242-3
human brain 15-16, 21, 23, 47-8, 60, 75, 86, 106, 131, 259-60
Hysteresis 79-80, 157-8, 198-200

I

Images 60, 113, 130, 151, 191-2, 247, 249
impulses 48, 75, 110, 112, 173, 246
individuals 16, 48, 58, 69, 76, 90, 94, 105-6, 134, 152, 157-9, 179, 184-6,
202, 205, 219-20
 normal 119-20, 175, 177
information flow 94, 96, 101, 194-5, 226, 245
Information Transfer 57-8, 253
inputs 20, 31-2, 49, 55, 65, 83, 85-7, 96, 110, 115, 124, 140, 202-3,
239-40, 243-4, 253-6
 synaptic 142
instability 117, 155, 170, 172, 180, 197
instructions 44, 54-5, 60, 154, 188, 214
inter-stimulus interval (ISI) 110, 199
interactions 15-17, 29, 31, 34-5, 37-8, 40-1, 49-50, 53, 56-7, 109, 115,
132-3, 154, 186, 189-93, 253-4
 agent 245, 252-3
interference 141-2, 228-9
Internal states 36, 123
Internet 16, 63, 83, 88, 98, 100-1, 125
iron atoms 137-8, 140
irritable bowel syndrome (IBS) 170-1
ISI (inter-stimulus interval) 110, 199
iterations 77, 125, 130, 169, 187, 248-9, 252, 255

J

jumps 55, 81, 99, 107, 163, 219

K

knowledge 22, 26, 32, 38, 42, 44, 50, 59, 108, 138-9, 151, 184, 221, 231

L

- landscape 72-6, 125, 130, 159, 173, 188, 197, 211, 213-15, 217-21, 252, 260
- language 18, 44, 47, 58, 75, 103, 178, 185-6, 197, 203-4, 260, 266
- lateral geniculate nucleus (LGN) 192
- laws 21-2, 27, 49-50, 239
- LD (Learning disabilities) 178-9, 260
- leaders 16, 54, 59-61, 93-4, 160, 164, 181, 260
- levels 15, 17, 25, 41-2, 44, 55-6, 92, 94-7, 109-10, 131-5, 137-8, 191-2, 239-40, 261-3, 265, 267-8
 - global 48, 53, 115, 121, 134, 137, 140, 265
 - local 115, 133-4, 137, 140, 253, 265
 - lower 96-7, 131-2, 227, 263
 - multiple 15, 40, 137, 161, 262, 264
- LGN (lateral geniculate nucleus) 192
- limbic system 124
- limit cycles 70-2, 79, 117, 158-9, 176
- links 25, 55, 83, 87-93, 98, 100-3, 162, 193, 198, 217, 226-8, 232, 256
- local information 40, 53-4, 58, 187, 253
- local interactions 40, 54, 133, 252-3
- local rules 40, 104, 249
- long-term potentiation (LTP) 90, 92
- loops 21, 69-70, 192-3
- LTP (long-term potentiation) 90, 92
- Lyapunov Exponents 72, 118-19, 130, 152, 175

M

- magnetization 137-40
- magnitude estimation 17, 127, 129
- mechanisms 18, 32, 51, 53, 62-3, 88, 94, 115, 121, 142, 172, 188-90, 198, 201, 245, 253-4
- memory 17-18, 35-6, 48, 55, 58, 87, 109-10, 114, 151, 177-9, 193-5, 201-3, 223-4, 228-32, 236-8, 265-6
 - modal model of 227, 237
- memory model 195, 202
- memory system 195, 202
- metastability 17, 109, 115-19
- mind 15-19, 25, 27, 107, 133-4, 140, 152, 180-1, 183, 188-9, 191-2, 223, 225-6, 237, 253, 265-6
- modeling 19, 50, 157, 227, 235, 237, 241
 - agent-based 55, 251
- Models
 - agent-based 19, 235, 252-3

cognitive 151, 227, 235, 237, 246
 mathematical 169, 207, 236, 238
 multi-agent 153, 157, 254
 neural 119, 245
 percolation 105-6
 statical 238
 traditional 194, 206, 256
 models of self-organization 235, 245
 molecules 25-6, 33-4, 37-8, 45, 55-6, 76, 132, 213, 225, 261-2
 monkeys 103, 232-3
 motion 18, 41, 80, 113, 190, 199-200, 235, 241
 multi-agent systems 157, 251, 254
 mutations 60, 214-15

N

natural systems 26, 50, 61, 81, 137, 264
 Necker cube 23, 74, 197-8
 neighbors 37, 48, 58, 83, 85, 103, 105, 109, 137, 140, 160, 190, 215, 248,
 251-2
 nearest 54, 99, 104, 139-40
 nervous system noise 18, 142
 nervous systems 42, 47-8, 59, 98, 142, 154, 173, 184
 net magnetization 137-9
 nets 16, 83-4, 88, 90, 98, 100, 106, 121
 network analysis 37, 162
 network models 108-9, 195, 254
 network science 16, 83, 87-8, 105, 107, 162, 259-61
 Network theory 107-8, 161
 Networks 15-16, 21, 43-4, 83-101, 103-8, 131-2, 162, 184-5, 187, 203-5,
 227-8, 234, 242, 244-5, 249, 260-2
 artificial 203, 224
 complex 16, 109
 computer 50, 83
 hierarchical 83, 92, 94-6, 132
 hub-based 102, 146
 propositional 224, 227
 random 87, 98-9
 random-biased 83, 90
 randomized 99
 small world 93, 118, 253
 small-world 16-17, 83, 98, 100-1, 103-5
 social 90, 105
 neural circuits 108-9, 132, 191, 232, 261
 neural complexity 48
 measure of 48

neural networks 17, 87, 90, 106, 123, 129, 173, 205, 224, 255
 artificial 83, 118, 131, 184, 203, 227-8
 traditional artificial 245, 256
neural oscillation 17, 109-10
neural pattern 115-16, 154, 202
neural synchrony 103, 109, 113-14, 132, 242
neural systems 48, 116, 118-19, 132, 184, 247
Neurodynamics 16-17, 48, 109, 111, 113, 115, 117, 119, 121, 123, 152
neuron level 48, 190, 267
neuron populations 113-14, 143, 181, 184, 246
neurons 40-2, 47-8, 54-5, 58-9, 83-6, 96, 103-4, 106, 108-14, 123-4,
 131-3, 140, 142-3, 146-7, 232-5, 265-7
 cortical 40, 58, 124
 hippocampal 202
 inhibitory 242-4
 input 110, 124
 single 75, 143, 244
Neuroscience 40, 103, 208, 235-6, 260-1, 263
neuroscientists 236, 265
neurotransmitter 75, 107
NK Model 217-18
nodes 16, 44, 83-90, 92-3, 98-101, 103-4, 108, 131, 137, 157, 162, 184-5,
 187, 203, 227, 243
Noise 17-18, 119, 130-1, 137, 139-43, 145-9, 152, 160, 237, 241
 brown 18, 144-5, 148
 internal 117, 141-2
nonchaotic attractors 70
nonlinear brain dynamics 122
nonlinear dynamical modelers 152
nonlinear dynamical systems 185
nonlinear dynamical systems approach 189, 262
nonlinear dynamical systems research 151
nonlinear dynamical systems theory 65
nonlinear equation 65-7, 153
Nonlinear relationships 65
nonlinearity 32, 65, 121, 198

O

observers 44, 113, 127-8, 130, 183, 191, 197, 200
obsessive-compulsive disorder (OCD) 175
OCD (obsessive-compulsive disorder) 175
opinion 76, 160
optima, local 211, 213, 215, 217-18, 220
order 19-20, 23, 26-7, 33-4, 36-8, 59-60, 76, 79, 117-19, 180, 197-8,
 200-2, 213-14, 240, 259, 262

Order Parameters 76, 80, 161, 257, 260, 262
 ordered behavior 16, 260
 ordered network 98, 103-4
 Ordered Systems 31-2, 34, 36, 38, 259
 organisms 24, 35-6, 47, 55-6, 60, 83, 124, 142-3, 154-5, 171, 184, 186-7,
 193, 214-15, 217-19, 223
 organization 15, 17, 23-4, 26, 32, 36-7, 53-4, 57, 61, 88, 90, 92, 131-2,
 161-4, 186, 261-3
 oscillations 21, 109-10, 134, 155, 242, 247
 oscillators 17, 103, 237, 241-2, 244
 oscillatory behavior 109, 202, 235, 237, 242
 Oscillatory models 109-10, 235, 241-2, 244, 260
 Outputs 20, 31-2, 49, 55, 65, 112, 123, 189-90, 192, 194, 203, 226, 244,
 253-5

P

Painful Attractor 174
 participants 114, 120-1, 130, 140-1, 146-8, 164, 197-8, 200-1, 207, 220,
 229, 231
 pathology 18, 167, 169, 171, 173, 175, 177, 179, 181
 pathways 57-9, 93, 103, 192, 209, 233
 perception 25, 34-6, 60, 65, 73, 80, 82, 114, 117, 120, 123-4, 191, 193-4,
 197-8, 225-6, 230-1
 percepts 74, 96, 181, 188-9, 193, 197-8, 200, 226, 231
 Perceptual-Cognitive Loop 192-4
 percolating cluster 106-7, 232-3
 personality 18, 151, 167-9, 171-3, 175, 177, 179, 181, 236
 personality self-organization 167-8
 personality traits 68-9, 171, 173
 phase transition 23, 34, 61, 138, 195
 physical system 33, 37, 55, 236
 physics 21, 25, 41-2, 55, 87, 137, 139, 151, 239, 261, 265
 pink noise 131, 144-8
 plasticity 58, 103, 109, 178, 201-3
 point attractor 70, 72, 77
 POPS (Process-Oriented PSYchiatry) 169
 populations 37, 48, 57, 76-7, 98, 106, 112, 114, 118, 162, 224-5, 229,
 231-2, 242-3, 267
 post-traumatic stress disorder (PTSD) 171, 175
 power 101, 128, 133, 145, 147, 235
 power law 62, 162
 power spectra 130, 145-8, 152
 power spectrum 145
 prediction 22, 35, 38, 49, 65, 67, 70, 153, 181, 201, 203, 239-40, 259
 probability 33, 38, 60, 100, 112, 143, 213, 231

problem solving 18, 57, 65, 121, 164, 178, 208, 211-12, 219-21, 260, 266
 human 19, 211, 219-21
Problem Spaces 211-12, 220-1
Process models 189, 226, 237-8
Process-Oriented PSYchiatry (POPSY) 169
properties 17, 21, 23-5, 27, 37, 49-50, 53, 79, 88, 104, 125, 133-5, 140,
 146, 261-4
psychological defenses 172, 174, 260
psychological disorders 119, 135, 169, 171-2, 175
psychology 15, 17-18, 25, 33, 65, 105-6, 135, 139, 151-3, 155, 157, 159,
 161, 163, 259-60, 266-7
Psychosis 169-70
psychotics 170
PTSD (post-traumatic stress disorder) 171, 175

R

Random Fitness Landscapes 214-15, 217-18
random graphs 16, 88-9
Random processes 29, 38, 45, 65, 68, 89, 240-1
Random Systems 33
randomness 33, 36-7, 45, 50, 92, 100, 177
Reduction 20, 24-5, 27, 29, 41, 148, 264-5
Reductionism 24-6, 36, 107, 137-8
regions 17, 26, 33, 36, 38, 72-3, 79, 81-2, 112-18, 121-2, 163-4, 167, 185,
 208, 220-1, 232-3
 exclusive 229
 hysteresis 80
 neural 48, 118-19, 227
 transition 195
regularities 29, 34-5, 45, 76, 191, 249
relationships 20, 29, 31, 36-7, 41, 62, 81-2, 87-8, 127, 133, 143, 157, 159,
 186, 226-7, 230-1
 linear 65
reorganization 24, 34, 61, 171-2, 224, 229, 234
representations 18, 48, 60, 96, 111-12, 123-4, 133, 151-2, 183-5, 189, 203,
 205, 233, 247, 265
 mental 60, 123, 183, 185
rule assignment 84-6
Rules 21-2, 26-7, 40-1, 49-50, 53-6, 61-3, 83-7, 104-5, 139-40, 184,
 204-6, 239, 247-9, 251-3, 259-60, 262-3
 generative 49
 grammatical 204
 logical 83
 syntactical 186, 204-5

S

- scales 17, 38, 42, 48, 62, 68, 118, 125-6, 128, 131-2, 135, 162, 191, 261
- schema 25, 34-6, 219
- schizophrenia 106, 170, 177, 260
- schizophrenics 107, 177-8
- science 17, 19-22, 26, 87-8, 156, 236-7, 259-60, 267
- search, visual 65, 246
- Search time 46, 65
- seizures 103, 106, 122, 132
- Self-Organization 15-16, 18, 23, 27, 53-61, 63, 79, 107, 178, 209, 219, 233, 259, 261
- Self-organized criticality *see* SOC
- self-organized systems 53, 172, 259
- Self-organizing systems 23, 53-4, 56-9, 179, 181, 245, 247, 249
- self-transcending constructions (STC) 263-4
- Semantic networks 227, 249
- sensitivity 66, 72, 130, 170, 174, 240
- sensory input 48, 124, 184
- signals 56-7, 83, 104, 108, 120, 124, 130, 140, 142, 192, 247
- similarities 62, 126, 129-31, 138, 169-70, 180-1, 188, 192-3, 202-3, 220, 233, 254
- similarity dimension 125-7
- Simulated Annealing 213
- sleep, stages of 119, 121-2
- Small World 98, 101
- SOC (Self-organized criticality) 51, 61-2, 146
- social influence 156-7, 160
- social psychology 76, 81, 153, 156, 263, 266
- societies 15-17, 35, 87-8, 108, 151, 157, 261
- space 36, 45, 48, 68-9, 72, 75-6, 125-6, 152, 189, 204-6, 211, 213-15, 217, 219-21, 260, 266-7
- species 22, 47-8, 53, 211, 219, 223-32
- stability 53, 109, 158, 161-3, 172, 201-2, 219, 226, 259
- state space 33, 68-70, 72, 75, 84, 86, 117, 153, 167, 169, 185-6, 189, 204-5, 209, 255, 260
- states 20, 22-3, 31-4, 68-70, 80, 84-7, 90, 104-5, 115-18, 143, 167-8, 197-8, 202-4, 238-40, 247-8, 254
- depressive 175
- manic 175
- ordered 138, 142, 194-5, 202
- possible 83-6, 161
- resonant 131
- spin 137, 140
- stable 167, 190, 197, 245
- statistical mechanics 25, 137, 140

STC (self-transcending constructions) 263-4
stimuli 36, 49, 56-8, 60, 74, 96, 112-13, 123-4, 127-30, 142-3, 146, 170-1, 188, 197-200, 231, 237-8
stimulus input 55-6, 75, 112, 151, 238
Stochastic Models 240-1
Stratified networks 131-2
Sugarscape 252
Symbolic Dynamics 185
symbols 151, 183, 185-6, 203
synapses 90, 103, 117-18, 124, 142-3, 188
synchronization 75, 109, 120-2, 201-2, 244
synchronize 112, 114, 140, 157, 200-1, 205, 266
synchrony 17, 94, 103-4, 112-14, 122, 205, 244, 260
system behavior 117, 253

T

teams, meta 95-6
temperature 23-4, 26-7, 34, 56, 61, 76, 129, 137, 139-41, 213, 223-5, 241
templates 59-61
therapy 18, 103, 148, 151, 167, 169, 171-3, 175, 177, 179-81
thermodynamics 24-5
thinking, disorganized 106-7
threshold 55, 90, 199, 206-7, 232-3, 251, 256
toroidal attractors 70-2
trace 58, 117, 188, 211, 241
Traditional neural networks 131, 256
Traditional science 17, 23, 49, 235
trajectories 68-70, 72, 74, 77, 84-6, 117-18, 155, 158-9, 175, 184-5, 188-9, 202, 205-6, 208-9, 260, 267
transient 115, 117, 167
transition function 239-40, 254-5
traveling salesman problem (TSP) 46
trees, phrase structure 204-5
triad 90-1, 193

U

units, functional 132, 190, 249
unpredictability, ordered 135
Unstable Periodic Orbits (UPOs) 122

V

values, initial 67
variables 18, 21, 31-2, 50, 68-9, 72, 76, 79-80, 137, 141, 152-3, 158, 163-4,
238-9, 252-3, 256-7
random 241
visual cortex 57, 113-14, 190
visual system 58, 96-7, 113, 115, 131, 133, 142, 188, 190-2, 197-200,
230-1, 236

W

weather 32, 65, 239
weather system 32
white noise 129, 144-5, 147-8
white noise model 147
wholes 17, 24, 36, 96-7, 192, 263, 266
world, real 35, 225, 239-40, 252-3, 257, 268
World Wide Web 83, 100-1

