

# Contents

<b>1</b>	<b>Introduction</b>	1
1.1	What Is Nonlinear Science?	4
1.2	An Explosion of Activity	9
1.3	Causes of the Revolution	13
<b>2</b>	<b>Chaos</b>	19
2.1	The Three-Body Problem	20
2.2	Poincaré's Instructive Mistake	21
2.3	The Lorenz Attractor	23
2.4	Other Irregular Curves	25
2.5	The KAM Theorem	30
2.6	More Early Discoveries of Low-Dimensional Chaos	34
2.7	Is There Chaos in the Solar System?	36
<b>3</b>	<b>Solitons</b>	43
3.1	Russell's Solitary Waves	43
3.2	The Inverse Scattering Method	46
3.3	The Nonlinear Schrödinger Equation	50
3.4	The Sine-Gordon Equation	51
3.5	Nonlinear Lattices	56
3.6	Some General Comments	58
<b>4</b>	<b>Nerve Pulses and Reaction-Diffusion Systems</b>	63
4.1	Nerve-Pulse Velocity	63
4.2	Simple Nerve Models	69
4.3	Reaction Diffusion in Higher Dimensions	72
<b>5</b>	<b>The Unity of Nonlinear Science</b>	79
5.1	The Provinces of Nonlinearity	79
5.1.1	Solitons and Reaction Diffusion	80
5.1.2	The KAM Theorem	83
5.1.3	Chaos	84
5.1.4	Reaction Diffusion and Chaos	85
5.2	Metatheories of Nonlinear Science	86
5.2.1	Cybernetics (C)	86

5.2.2	Mathematical Biology (MB) .....	88
5.2.3	General Systems Theory (GST) .....	93
5.2.4	Nonequilibrium Statistical Mechanics (NSM).....	94
5.2.5	Catastrophe Theory (CT) .....	95
5.2.6	Synergetics (S).....	96
5.2.7	Complex Adaptive Systems (CAS).....	97
5.3	Interrelations Among the Metatheories .....	98
<b>6</b>	<b>Physical Applications of Nonlinear Theory.....</b>	<b>101</b>
6.1	Theories of Matter.....	101
6.1.1	Mie's Nonlinear Electromagnetism .....	102
6.1.2	De Broglie's Guiding Waves and the Double Solution .	106
6.1.3	Skyrmions .....	107
6.1.4	Point vs. Extended Particles .....	108
6.2	Quantum Theory .....	110
6.2.1	Quantum Probabilities .....	111
6.2.2	Schrödinger's Cat .....	112
6.2.3	The EPR Paradox .....	113
6.2.4	Nonlocality and Quantum Entanglement .....	116
6.2.5	Bell's Inequality .....	117
6.2.6	Joint Measurability .....	119
6.2.7	Many Worlds? .....	120
6.2.8	Nonlinear Quantum Mechanics? .....	121
6.3	Quantum Energy Localization and Chaos.....	122
6.3.1	Local Modes in Molecules .....	122
6.3.2	Quantum Solitons .....	124
6.3.3	Quantum Inverse Scattering .....	125
6.3.4	Quantum Chaos? .....	126
6.4	Chemical and Biochemical Phenomena .....	127
6.4.1	Molecular Dynamics .....	127
6.4.2	Energy Localization in Biomolecules .....	128
6.4.3	Chemical Aggregates .....	131
6.4.4	Chemical Kinetics .....	132
6.5	Condensed-Matter Physics .....	132
6.5.1	Extrinsic Nonlinearity.....	133
6.5.2	Phase Transitions .....	133
6.5.3	Supersonic Solitary Waves .....	135
6.5.4	Discrete Breathers .....	136
6.6	Engineering Applications .....	138
6.6.1	Nonlinear Mechanical Vibrations .....	138
6.6.2	Vacuum Tube Electronics .....	139
6.6.3	Negative and Positive Feedback .....	140
6.6.4	Frequency-Power Formulas .....	142
6.6.5	Synchronization .....	142
6.6.6	Nonlinear Diffusion .....	143

6.6.7	Shock Waves and Solitons .....	145
6.6.8	Electronic Chaos .....	146
6.7	Optical Science.....	147
6.7.1	Lasers .....	147
6.7.2	Modulational Instability.....	149
6.7.3	Solitons on Optical Fibers .....	150
6.7.4	Pump–Probe Spectroscopy .....	150
6.8	Fluid Dynamics .....	152
6.8.1	Supersonic Waves .....	152
6.8.2	Shock Waves.....	153
6.8.3	Rayleigh–Bénard Cells .....	155
6.8.4	Plasma Waves .....	156
6.8.5	Rogue Waves .....	157
6.8.6	Coronets, Splashes and Antibubbles .....	160
6.8.7	Atmospheric Dynamics.....	162
6.8.8	Turbulence .....	164
6.9	Gravitation and Cosmology .....	165
6.9.1	General Relativity Theory .....	166
6.9.2	Nonlinear Cosmic Phenomena.....	170
6.9.3	Black Holes.....	172
6.9.4	Tests of GRT .....	174
6.9.5	A Hierarchy of Universes? .....	177
<b>7</b>	<b>Nonlinear Biology .....</b>	<b>181</b>
7.1	Nonlinear Biochemistry .....	182
7.1.1	Fröhlich Theory .....	182
7.1.2	Protein Solitons .....	183
7.1.3	Biological Applications of Protein Solitons .....	190
7.1.4	DNA Solitons and the Hijackers .....	196
7.1.5	The Coils of Chromatin .....	203
7.2	On Growth and Form .....	204
7.2.1	The Physics of Form .....	205
7.2.2	Biological Membranes .....	211
7.2.3	Leonardo’s Law .....	214
7.2.4	Turing Patterns .....	219
7.2.5	Buridan’s Ass, Instability and Emergence.....	222
7.2.6	Relational Biology .....	225
7.2.7	A Clash of Scientific Cultures? .....	226
7.3	Physical and Life Sciences .....	229
7.3.1	Mathematical Biology.....	229
7.3.2	Collective Phenomena.....	230
7.3.3	Population Dynamics .....	232
7.3.4	Immense Numbers .....	236
7.3.5	Homogeneous vs. Heterogeneous Sets .....	238
7.3.6	Biological Hierarchies .....	239

7.4	Neuroscience .....	240
7.4.1	Nerve Models .....	242
7.4.2	The Multiplex Neuron .....	252
7.4.3	The McCulloch–Pitts Model of the Brain .....	257
7.4.4	Hebb’s Cell Assembly .....	260
7.4.5	Cognitive Hierarchies .....	274
<b>8</b>	<b>Reductionism and Life</b> .....	277
8.1	Newton’s Legacy .....	277
8.1.1	The Reductive Program .....	278
8.1.2	Supervenience and Physicalism .....	279
8.1.3	Practical Considerations .....	280
8.2	Objections to Reductionism .....	280
8.2.1	Googols of Possibilities .....	281
8.2.2	Convolutd Causality .....	281
8.2.3	Nonlinear Causality .....	283
8.2.4	Time’s Arrow .....	284
8.2.5	Downward Causation .....	284
8.2.6	Open Systems .....	285
8.2.7	Closed Causal Loops and Open Networks .....	287
8.3	Theories of Life .....	290
8.3.1	Artificial Life vs. Autopoiesis .....	291
8.3.2	Relational Biology .....	292
8.3.3	Mechanisms .....	293
8.3.4	Complex Systems and Chaotic Emergence .....	296
8.3.5	What Is Life? .....	300
<b>9</b>	<b>Epilogue</b> .....	303
<b>A</b>	<b>Phase Space</b> .....	307
<b>B</b>	<b>Quantum Theory</b> .....	315
	<b>References</b> .....	321



<http://www.springer.com/978-3-540-34152-9>

The Nonlinear Universe

Chaos, Emergence, Life

Scott, A.C.

2007, XIV, 364 p. 86 illus., Hardcover

ISBN: 978-3-540-34152-9