Contents

1	Con	plexity	v and Emergence
	1.1	The Is	sue Considered
	1.2	A Bas	ic Viewpoint
		1.2.1	The Main Claim
		1.2.2	Hierarchies
		1.2.3	Emergence
	1.3	Key P	Points of the Argument
		1.3.1	Multiple Types of Causation.
		1.3.2	Hierarchy and Causation 10
		1.3.3	Types of Top-Down Causation 1
		1.3.4	The Nature of Variables 12
		1.3.5	The Causal Efficacy of Non-physical Entities
		1.3.6	Room at the Bottom
		1.3.7	Supervenience
	1.4	Is It R	Real? Testing the Proposal
		1.4.1	Causal Effects 1
		1.4.2	Experimental Tests 1
		1.4.3	Kinds of Data 1
		1.4.4	There Is No Other Option 2
	1.5	Signif	icant Implications
		1.5.1	Health Care
		1.5.2	Mental Health 2
		1.5.3	Education: Learning to Read 2
	1.6	An O	utline of the Book
		1.6.1	The Contents
		1.6.2	What Is New
		1.6.3	What Is Controversial
	1.7	The N	Recessity of the Conclusion
		1.7.1	The Conclusion
		1.7.2	The Necessity of the Conclusion 2
	Refe	erences	

xiii

2	Digi	tal Con	nputer Systems	35
	2.1	Comp	utational Basics.	35
	2.2	Modul	ar Hierarchical Structures	38
		2.2.1	Structures: Combination and Abstraction	39
		2.2.2	Decomposition and Modularity	40
		2.2.3	Encapsulation and Information-Hiding	41
		2.2.4	Naming, Combination, and Recursion	42
		2.2.5	Hierarchy: Class Structure and Object Structure	43
		2.2.6	Evolution	45
	2.3	Orthos	gonal Modular Hierarchical Structures	45
		2.3.1	The Two Kinds of Hierarchies	46
		2.3.2	The Implementation (Vertical) Hierarchies	46
		2.3.3	The Logical (Horizontal) Hierarchies	49
		2.3.4	The Relation Between the Two Hierarchies	50
		2.3.5	Causality in the Hierarchies	52
	2.4	Bottor	n-Up and Top-Down Causation	52
		2.4.1	The Combination of Bottom-Up and Top-Down	
			Action	53
		2.4.2	TD1: Deterministic Top-Down Processes	54
		2.4.3	TD2: Non-adaptive Feedback Control Systems	56
		2.4.4	TD3: Adaptive Selection	57
		2.4.5	TD4: Feedback Control with Adaptive Goals	59
		2.4.6	TD5: Adaptive Selection of Adaptive Goals	59
		2.4.7	Goals and Learning in Relation to These Kinds	
			of Causation	60
	2.5	The C	Core Feature: Equivalence Classes	63
		2.5.1	Multiple Realization	63
		2.5.2	The Link with Top-Down Causation	64
		2.5.3	The Ontological Nature of Computer Programs	65
	2.6	Resou	arces: Memory and Deleting	65
		2.6.1	The Unphysical Nature of Infinity	66
		2.6.2	Deletion and Garbage Collection	67
		2.6.3	The Memory Hierarchy	68
		2.6.4	Modular Hierarchical Structure and Scoping	
			of Variables	68
		2.6.5	Deletion, Adaptive Selection, and Irreversibility	69
	2.7	The (Dutcome: Causation in Digital Computers	70
		2.7.1	Computer Programs Are Non-physical, but Causally	
			Effective	70
		2.7.2	Computer Programs Embody Abstract Logic,	
			and Act Top-Down	72
		2.7.3	Room at the Bottom	74
		2.7.4	Predictable Outcome?	76
		2.7.5	Possibility Spaces and Their Causal Effects	77

		2.7.6	Top-Down Action from the Mind	81
		2.7.7	Genuine Emergence.	81
	Refe	rences		82
3	The	Basis o	of Complexity	85
-	3.1	The N	lature of Emergence.	85
		3.1.1	Emergence of Complexity Is Based on Structure	86
		3.1.2	Emergence Is Different in Different Contexts	87
		3.1.3	Emergence Results in a Structural/Functional	07
			Hierarchy	88
		3.1.4	Emergence Enables Logical Hierarchies,	
			Information Flows	91
		3.1.5	Emergence Has Different Timescales	93
		3.1.6	Emergence Is Based on Modularity	93
		3.1.7	Emergence Is Based on Interlevel Relations	95
	3.2	Bottor	n-Up Effects	96
		3.2.1	Coarse-Graining	96
		3.2.2	Physics	97
		3.2.3	Biology	97
		3.2.4	Mathematics of Emergence.	98
		3.2.5	Strong Reductionism	99
	3.3	Emerg	gence and Higher-Level Variables	100
		3.3.1	Emergence of Higher Level Structure and Behavior	100
		3.3.2	Coherent Higher Level Dynamics	102
		3.3.3	Emergent Higher Level Variables	105
		3.3.4	Intrinsically Higher Level Variables.	108
	3.4	Top-D	Down Effects	109
		3.4.1	Limits to Bottom-Up Emergence	109
		3.4.2	Top-Down Causation via Constraints	110
		3.4.3	Top-Down Action via Control Parameters	112
		3.4.4	Top-Down Effects in Logical Hierarchies	114
		3.4.5	Top-Down Effects in the Mind	115
		3.4.6	Top-Down Effects and Supervenience	116
		3.4.7	Top-Down Effects and Emergence.	117
	3.5	The K	Ley Concept: Equivalence Classes	119
		3.5.1	Equivalence Classes	119
		3.5.2	Equivalence Classes and Top-Down Causation	120
		3.5.3	Multiple Realisability and Supervenience	122
	3.6	Demo	nstrating Top-Down Causation	122
		3.6.1	Altering Context	123
		3.6.2	Identifying Equivalence Classes	123
		3.6.3	Identifying Dynamics.	124
		3.6.4	Computer Modelling	124
	3.7	Const	raints on Emergence	125
		3.7.1	Matter, Energy, and Entropy	125

		3.7.2	Constraints on Higher Level Possibilities	126
		3.7.3	Constraints on Higher Level Logic	126
	Refe	rences.		127
4	Kino	ls of Te	op-Down Causation	133
•	4.1	Detern	ninistic Top-Down Causation TD1	134
		4.1.1	The Nature of the Process	134
		4.1.2	Machines	137
		4.1.3	Physical Systems.	138
		4.1.4	Living Systems	140
		4.1.5	Logical Systems	142
		4.1.6	Mathematical Models: Boundary Conditions	
			and Constraints	144
		4.1.7	Randomness and Noise	149
	4.2	Non-A	Adaptive Feedback Control (TD2)	151
		4.2.1	The Nature of the Process	152
		4.2.2	Engineering Systems	157
		4.2.3	Organisations	158
		4.2.4	Biology	160
		4.2.5	Mathematical Models: Control Theory	162
		4.2.6	The Nature of Goals	163
	4.3	Adapt	ive Selection of Outcomes (TD3)	163
		4.3.1	The Nature of the Process	164
		4.3.2	Physics and Chemistry	169
		4.3.3	Life	169
		4.3.4	The Mind: Learning and Perception	172
		4.3.5	Mathematical Models: Adaptive Selection	174
		4.3.6	Multilevel Selection.	176
		4.3.7	The Nature of Selection Criteria	182
	4.4	Adapt	tive Selection of Goals (TD4)	183
		4.4.1	The Nature of the Process	184
		4.4.2	Evolution	185
		4.4.3	Microbiology	185
		4.4.4	Behaviour	185
		4.4.5	Engineering Systems	186
		4.4.6	Mathematical Models.	186
		4.4.7	The Nature of Causality	187
	4.5	Adapt	tive Selection of Selection Criteria (TD5)	187
		4.5.1	Ine Nature of the Process	188
		4.5.2	Evolutionary Biology and Animal Behavior	188
		4.3.3	Mathematical Madala	189
		4.3.4	Mathematical Models.	189
		4.3.3	The Hieroreby of Cooler Ethics and March	190
		4.3.0	Occurrence of Meta Deflection	191
		4.3.7	Occurrence of Meta-Kenection	193

	4.6	Complex Adaptive Systems	193
		4.6.1 The Process	194
		4.6.2 Evolutionary and Developmental Outcomes	194
		4.6.3 Adaptive Processes and Learning	195
	4.7	Intelligent Top-Down Causation	195
		4.7.1 The Nature of the Process	196
		4.7.2 Language	197
		4.7.3 Other Symbolic Systems	201
		4.7.4 The Power of Symbolic Thinking	203
		4.7.5 The Effectiveness of Abstract Variables	204
		4.7.6 The Mind, Intention, and Goals	205
	Refe	rences	210
5	Roo	m at the Bottom?	217
	5.1	Room at the Bottom: Over-Determination?	217
	5.2	Contextual Constraints	219
		5.2.1 Boundary Conditions	219
		5.2.2 Passing Higher Level Variables or Parameters	221
	5.3	Structure and Constraints	222
		5.3.1 Physical Systems.	222
		5.3.2 Artefacts	223
		5.3.3 Biology	223
		5.3.4 The Brain	224
		5.3.5 Organisations	224
	5.4	Changing the Nature of Constituent Entities	224
		5.4.1 Physics and Chemistry.	225
		5.4.2 Biology	226
		5.4.3 The Brain	226
		5.4.4 Society	227
		5.4.5 Logic	227
	5.5	Leading to Existence of the Elements	228
		5.5.1 Physics	228
		5.5.2 Biology	229
		5.5.3 Society	230
		5.5.4 Logical Hierarchies	230
	5.6	Deleting Lower Level Elements.	231
		5.6.1 Biology	231
		5.6.2 Computers	233
		5.6.3 The Mind	234
		5.6.4 Society	235
		5.6.5 Physics and Chemistry.	235
		5.6.6 Micro Indeterminism and Adaptive Selection	236
	5.7	Queries	237
		5.7.1 Criticism and Response	238
	Refe	rences	240

6	The	Found	ations: Physics and Top-Down Causation	243
U	61	The B	ottom Level: Quantum Dynamics	244
	0.1	611	The Basic Dynamics	244
		612	Alternative Possibilities	247
		613	The Outcome	248
		614	Particle–Wave Duality	248
	6.2	The E	mergence of Higher Level Behavior	249
	012	6.2.1	Examples of Emergence.	250
		6.2.2	Statistical Mechanics	253
		6.2.3	Condensed Matter Physics	255
		6.2.4	Chemistry and Biology	257
		6.2.5	Bottom-Up Effects: Cosmology	258
	6.3	Top-D	Down Causation	259
		6.3.1	Equivalence Classes	260
		6.3.2	Changing or Creating the Basic Elements	260
		6.3.3	Types of Top-Down Causation in Physics	260
	6.4	Deterr	ninistic Top-Down Effects in Physics (TD1)	261
		6.4.1	Contextual Variables	261
		6.4.2	Effect of Boundary Conditions	262
		6.4.3	Structural Conditions and Effective Potentials	263
		6.4.4	Binding Energies and Altered Properties	264
		6.4.5	Computational Mechanics	265
	6.5	Adapt	ive Selection in Physics and Chemistry (TD3)	265
		6.5.1	Adaptive Selection	265
		6.5.2	Maxwell's Demon.	266
		6.5.3	Separation and Purification Processes	267
	6.6	Top-D	Down Effects: Micro Physics	267
		6.6.1	Open Systems and Their Environment	267
		6.6.2	Decoherence	269
		6.6.3	Lattice Waves and Quasiparticles	269
		6.6.4	Topological Effects	271
		6.6.5	State Preparation	271
		6.6.6	Measurement	273
	6.7	Top-I	Down Effects: Cosmology	274
		6.7.1	Element Formation	275
		6.7.2	Structure Formation	276
		6.7.3	Olbers' Paradox	278
		6.7.4	Mach's Principle	280
		6.7.5	The Arrow of Time	280
	n -	6.7.6	Existence of Isolated Systems	284
	Ref	erences	• • • • • • • • • • • • • • • • • • • •	286

7	The	Mind a	and the Brain	291
	7.1	Introdu	uction	292
		7.1.1	Dynamical Systems Versus Plasticity and Learning	293
		7.1.2	Modular Hierarchical Structure, Neural Nets	294
		7.1.3	Rationality, Intuition, and Emotion in a Social Context	295
		7.1.4	Bottom-Up and Top-Down Effects Both Occur	295
		7.1.5	The Effectiveness of Thoughts: Symbolism	
			and Language	296
		7.1.6	The Key Role of Purpose and Meaning	296
		7.1.7	The Relationship with Platonic Spaces.	297
		7.1.8	Mental Powers and Free Will	297
	7.2	Basics	of the Brain	297
		7.2.1	Brain Anatomy	298
		7.2.2	Basic Brain Function	302
		7.2.3	Large Scale Function	310
		7.2.4	Environmental and Genetic Influences:	
			Brain Plasticity	314
		7.2.5	The Origin of Humanity: The Social Mind	
			and Language	320
	7.3	Top-D	Down Processes	324
		7.3.1	The Different Kinds	325
		7.3.2	Memory, Learning, and Deleting.	326
		7.3.3	Vision	328
		7.3.4	Language and Reading	331
		7.3.5	Goal-Directed Behaviour and Attention	334
		7.3.6	Health	336
		7.3.7	Social Neuroscience	340
		7.3.8	The Physical Substrate	344
	7.4	Purpo	se and Meaning as the Key Driving Forces.	347
		7.4.1	Goals and Purpose	347
		7.4.2	The Human Search for Meaning	348
		7.4.3	Purpose. Ethics, and Understanding.	349
		744	The Meaningful Social Context.	351
	75	Symbo	olism and Effectiveness of Thought	351
	110	751	Logical Functions	352
		7.5.2	Naming, Symbolism and Language	354
		753	Effectiveness of Thought	358
		7.5.4	Thoughts and Neural Networks.	360
		7.5.5	Causal Power of Social Constructions	361
		7.5.6	The Power of Emergent Levels	364
	76	The F	ffects of Platonic Entities	365
	7.0	761	Mathematical Relations	365
		762	Computational Algorithms	367
		763	Accessing Platonic Realms.	368
		,.0.5		

	7.7	The Co	omplex Whole	369
		7.7.1	A Synthesis	370
		7.7.2	Genuine Emergence.	372
		7.7.3	Crick's Fallacy	375
		7.7.4	Top-Down Action and the Free Will Debate	375
		7.7.5	Neuroscience and Humanity	382
	Refe	erences.		385
8	The	Broade	er View	395
	8.1	The N	ecessity of True Emergence	395
		8.1.1	Cosmological Unpredictability	396
		8.1.2	Evolutionary History	399
		8.1.3	Conclusion: Genuine Emergence Must Occur	399
		8.1.4	The Alternative: The Demiurge	400
	8.2	The So	ources of Emergence	401
		8.2.1	Self-Assembly: Emergence in the Natural World	402
		8.2.2	Natural Selection: Emergence in the Biological	
			World	402
		8.2.3	Design and Construction: Emergence	
			in the Man-Made World.	406
		8.2.4	How Far Can Bottom-Up Emergence Succeed?	407
		8.2.5	Not by Physics Alone: The Missing Elements.	409
		8.2.6	The Interconnected Causes: Chance, Necessity,	
			and Purpose	410
	8.3	Types	of Causation	417
		8.3.1	Levels of Causation and Aristotle	417
		8.3.2	Multiple Causes and Contextual Factors	419
		8.3.3	Causal Effects of Platonic (Non-Emergent) Entities	421
	8.4	Aristo	tle and Types of Knowledge	422
	8.5	A Mo	re Holistic View	423
		8.5.1	Recognising Emergence and Top-Down Causation	423
		8.5.2	Other Causal Influences Than Physics	426
		8.5.3	The Main Thesis	427
		8.5.4	The Counter View: Scientific Reductionism	427
	8.6	Implic	cations: Learning to Read and Write	430
		8.6.1	The Broad Context: Underlying Views of Literacy	430
		8.6.2	The Brain, Prediction, and Reading	436
		8.6.3	Reading as Transacting with Texts	438
		8.6.4	Part to Whole: Skills-Based Approaches to Literacy	440
		8.6.5	The Contextual Approach to Learning	444
		8.6.6	Holistic Approaches to Literacy	444
		8.6.7	Educational Implications	447

Contents

8.7	Conclu	usion .						•		•			•											•			•	449
	8.7.1	The '	Thes	es	of	thi	is i	Bo	ool	ĸ																	•	450
	8.7.2	То В	e Do	one						•			•							•		••		•		•		450
	8.7.3	When	e Is	Tr	uth	1?																		•				453
Refe	rences			•••	۰.	•		•		•		•	•	 •	•	• •	•	• •	•	•	•		•	•	••	•	•	456
Author	Index				•					•	• •	•	•	 ٠	•			•		•	•	• •	•			•		465
Index .			•••		• •	••		•				•	•	 •				•		•			•	•		•	•	467
Titles in	This !	Series.									•			 •			•								•			479