Contents

1	Introd	uction	1
	Brigitte	Falkenburg and Margaret Morrison	
	1.1	Reduction	3
	1.2	Emergence	5
	1.3	Parts and Wholes	7

•

Part I Reduction

On tl	he Succes	ss and Limitations of Reductionism in Physics	13
Hildegard Meyer-Ortmanns			
2.1	Introdu	uction	13
2.2	On the	e Success of Reductionism	15
	2.2.1	Symmetries and Other Guiding Principles	15
	2.2.2	Bridging the Scales from Micro to Macro	20
	2.2.3	When a Single Step Is Sufficient: Pattern Formation	
		in Mass and Pigment Densities	24
	2.2.4	From Ordinary Differential Equations to the	
		Formalism of Quantum Field Theory:	
		On Increasing Complexity in the Description	
		of Dynamic Strains of Bacteria	27
	2.2.5	Large-Scale Computer Simulations:	
		A Virus in Terms of Its Atomic Constituents	31
2.3	Limita	tions of Reductionism	33
	2.3.1	A Fictive Dialogue For and Against Extreme	
		Reductionism	33
	2.3.2	DNA from the Standpoint of Physics	
		and Computer Science	35
2.4	Outloc	ok: A Step Towards a Universal Theory of Complex	
		ns	36
Refer	ences		37



3			on Between the Second Law of Thermodynamics and Quantum Mechanics	41
	Barba	ra Drosse	el	
	3.1	Introdu	uction	41
	3.2		listaken Idea of Infinite Precision	43
	3.3		Classical Mechanics to Statistical Mechanics	45
		3.3.1	The Standard Argument	45
		3.3.2	The Problems with the Standard Argument	46
		3.3.3	An Alternative View	47
		3.3.4	Other Routes from Classical Mechanics to the	
			Second Law of Thermodynamics	48
	3.4	From (Quantum Mechanics to Statistical Mechanics	49
		3.4.1	The Eigenstate Thermalization Hypothesis	49
		3.4.2	Interaction with the Environment	
			Through a Potential	50
		3.4.3	Coupling to an Environment with Many Degrees	
			of Freedom	51
		3.4.4	Quantum Mechanics as a Statistical Theory	
			that Includes Statistical Mechanics	52
	3.5	Conclu	isions	53
	Refere	ences		53
4	Wher	e Is the	Quantum Mechanical Systems: System and Where Is the Reservoir?	55
		im Anke		
	4.1		uction	55
	4.2		ation and Noise in Classical Systems	56
	4.3		ative Quantum Systems	57
	4.4		ic Heat for a Brownian Particle	60
	4.5		Reversed: A Reservoir Dominates Coherent	(1
	16		nics.	61
	4.6		ence of Classicality in the Deep Quantum Regime	63
	4.7 D.f		ary and Conclusion	66
	Refer	ences		67
5			Via Micro-reduction: On the Role of Scale	
	-		r Quantitative Modelling	69
		la Hillert		
	5.1		uction	69
	5.2	•	nation and Reduction	71
		5.2.1	Types of Reduction	72
		5.2.2	Quantitative Predictions and Generalized	
			State Variables	- 73

5.3	Predicting Complex Systems	74
	5.3.1 Scale Separation in a Nutshell	75
	5.3.2 Lasers	76
	5.3.3 Fluid Dynamic Turbulence	78
5.4	Scale Separation, Methodological Unification,	
	and Micro-Reduction	80
	5.4.1 Fundamental Laws: Field Theories	
	and Scale Separation	81
	5.4.2 Critical Phenomena	82
5.5	Perturbative Methods and Local Scale Separation	83
5.6	Reduction, Emergence and Unification	84
Refere	ences	86

Part II Emergence

Wh	y Is More Different?	
Mai	garet Morrison	
6.1	Introduction	
6.2	Autonomy and the Micro/Macro Relation: The Problem	
6.3	Emergence and Reduction	
6.4	Phase Transitions, Universality and the Need	
	for Emergence	
6.5	Renormalization Group Methods: Between Physics	
	and Mathematics	
6.6	Conclusions	
Ref	erences	
Aut	onomy and Scales	
Rob	ert Batterman	
7.1	Introduction	
7.2		
	Autonomy	
	Autonomy	
	7.2.1 Empirical Evidence	
7.3	7.2.1 Empirical Evidence	· · ·
7.3	 7.2.1 Empirical Evidence	
7.3	7.2.1Empirical Evidence7.2.2The Philosophical LandscapeHomogenization: A Means for Upscaling	· · · ·
7.3	 7.2.1 Empirical Evidence	· · · ·
7.3 7.4	 7.2.1 Empirical Evidence	· · · · · · · · · · · ·
7.4	 7.2.1 Empirical Evidence	· · · · · · · · · · · ·

More	is DifferentSometimes: Ising Models, Emergence,
and U	Indecidability
Paul V	W. Humphreys
8.1	Anderson's Claims
8.2	Undecidability Results
8.3	Results for Infinite Ising Lattices.
8.4	Philosophical Consequences
8.5	The Axiomatic Method and Reduction
8.6	Finite Results
8.7	Conclusions
Refere	ences
	er Weak, Nor Strong? Emergence and Functional
Redu	ction
Sorin	Bangu
9.1	Introduction
9.2	Types of Emergence and F-Reduction
9.3	Strong or Weak?
9.4	Conclusion
Refere	ences

Part III Parts and Wholes

10	Stabil	ity, Emergence and Part-Whole Reduction	169	
	Andreas Hüttemann, Reimer Kühn and Orestis Terzidis			
	10.1	Introduction	169	
	10.2	Evidence from Simulation: Large Numbers and Stability	173	
	10.3	Limit Theorems and Description on Large Scales	177	
	10.4	Interacting Systems and the Renormalization Group	180	
	10.5	The Thermodynamic Limit of Infinite System Size	184	
	10.6	Supervenience, Universality and Part-Whole-Explanation	188	
	10.7	Post Facto Justification of Modelling	193	
	A.1	Renormalization and Cumulant Generating Functions	194	
	A.2	Linear Stability Analysis	196	
	Refere	ences	199	
11	Betwe	een Rigor and Reality: Many-Body Models in Condensed		
	Matter Physics			
	Axel	Gelfert		
	11.1	Introduction	201	
	11.2	Many-Body Models as Mathematical Models	202	
	11.3	A Brief History of Many-Body Models	205	

	11.4	Constructing Quantum Hamiltonians		209
	11.5	Many-Body Models as Mediators and Contributors		214
		11.5.1 Rigorous Results and Relations		216
		11.5.2 Cross-Model Support.		217
		11.5.3 Model-Based Understanding		218
	11.6	Between Rigor and Reality: Appraising Many-Body	/	
		Models		220
	Refere	ences		225
12	How I	Do Quasi-Particles Exist?		227
	Brigitt	te Falkenburg		
	12.1	Scientific Realism		228
	12.2	Particle Concepts		230
	12.3	Quasi-Particles		235
		12.3.1 The Theory		235
		12.3.2 The Concept		238
		12.3.3 Comparison with Physical Particles		240
		12.3.4 Comparison with Virtual Particles		242
		12.3.5 Comparison with Matter Constituents		243
	12.4	Back to Scientific Realism		244
		12.4.1 Are Holes Fake Entities?		245
		12.4.2 What About Quasi-Particles in General? .		246
	12.5	How Do Quasi-Particles Exist?		248
	Refere	ences		249
13	A Me	chanistic Reading of Quantum Laser Theory		251
		ard Kuhlmann		
	13.1	Introduction		251
	13.2	What Is a Mechanism?		252
	13.3	Quantum Laser Theory Read Mechanistically		253
		13.3.1 The Explanandum		253
		13.3.2 Specifying the Internal Dynamics		253
		13.3.3 Finding the System Dynamics		258
		13.3.4 Why Quantum Laser Theory is a Mechani		
		Theory		260
	13.4	Potential Obstacles for a Mechanistic Reading		262
		13.4.1 Is "Enslavement" a Non-mechanistic Conc		262
		13.4.2 Why Parts of a Mechanism don't need to	-	
		Spatial Parts		264
		13.4.3 Why Quantum Holism doesn't Undermine		
		Mechanistic Reduction.		266

	The Scope of Mechanistic Explanations	
	Conclusion	
Refere	nces	270
Name Inde	X	273
Titles in th	is Series	277