## CONTENTS

	Preface	ix
1.	The Virosphere	1
	1.1 Deep Microspace Field	1
	1.2 The Expanding Viral Universe	7
	1.3 Structural and Genetic Diversity	9
	1.4 Viral Planet	15
2.	Alive or Dead?	19
	2.1 Computation and Life	19
	2.2 Viruses as Replicating Machines	22
	2.3 Viruses as Phases of Matter	25
	2.4 Evolving Genome Reduction	33
	2.5 The Space of Replicators	36
	2.6 Adaptation at High Mutation Rates	43
	2.7 Viral Quasispecies	45
	2.8 Critical Genome Size	53
3	Landscapes	55
	2.1 Climbing High	55
	2.2 Summer strike Count stition	62
	2.2 Symmetric Competition	60
	2.5 Epistasis in KIVA Viruses	08
	3.4 Experimental Virus Landscapes	/3
	3.5 The Survival of the Flattest Effect	11

## Contents

	3.6 Virus Robustness	82
	3.6.1 Intrinsic Mechanisms of Mutational Robustness	85
	3.6.2 Extrinsic Mechanisms of Mutational Robustness	86
	3.7 Selection: Fitness versus Robustness	87
4.	Virus Dynamics and Arms Races	91
	4.1 Virus-Host Interactions	91
	4.2 HIV Multiscale Dynamics	95
	4.3 Population Dynamics of HIV Infection	98
	4.4 Spatial Dynamics of HIV-1	105
	4.5 Antigenic Diversity Thresholds and AIDS	108
	4.6 Viral Symbiosis	116
5.	Epidemics	120
	5.1 Outbreak	120
	5.2 SIS Model	125
	5.3 SIS Model in Space and Graphs	130
	5.4 AIDS: Modeling HIV-1 Transmission	137
	5.5 Halting Viruses in Scale-Free Networks	141
6.	Emergent Viruses	149
	6.1 Ecological Disturbance: Hanta- and Arenaviruses as	
	Case Studies	152
	6.2 The Genetics of Adaptation to Novel Host	154
	6.2.1 Becoming Specialists	156
	6.2.2 Becoming Generalists	158
	6.2.3 The Causes of Specialization	161
	6.3 Epidemics of Emergence	162
7.	Origins	168
	7.1 Are Viruses Inevitable?	168
	7.2 Evidence from Digital Evolution	170
	7.3 Where Do Viruses Come From?	176
	7.3.1 Regressive Hypothesis	176
	7.3.2 Cellular Origin Hypothesis	177
	7.3.3 Protobiont Hypothesis	178
	7.4 Viruses and the Origin of Cells	185
	7.5 Viruses as Sources of Evolutionary Novelties	187
	7.6 But What Is a Virus Then?	188

	Contents	VII
8.	Computer Viruses and Beyond	190
	8.1 Viruses as Programs	190
	8.2 Emergence of Computer Viruses	191
	8.3 Cancer, Languages, and Minds	197
	References	203
	Index	219