

Contents

<i>Preface</i>	<i>page xi</i>
1 Introduction to the Cell	1
1.1 Architecture of the Eukaryotic Cell	1
1.2 The Organization of Genetic Material (DNA, Chromosomes, Genomes)	3
1.3 DNA Replication, Repair and Recombination	7
1.4 Transcription and Translation Machineries	10
1.5 Membrane Structure and Intracellular Trafficking	10
1.6 Cell Communication and miRNAs	14
1.7 Cell Division	18
1.8 Cell Death and Senescence	20
2 The Biology of Cancer	23
2.1 Cancer Origin and Evolution	23
2.2 Oncogenes and Oncosuppressors	26
2.3 The Role of P53 in Tumors	29
2.4 Big Data in Cancer	30
2.5 Cancer Stem Cells	32
2.6 Feeding the Tumor: Angiogenesis	33
2.7 Metastasis	34
2.8 Diagnostic Methods	36
3 A Modeling Toolbox for Cancer Growth	38
3.1 Branching Processes	38
3.2 Mutation Models of Cancer	45
3.3 Simulations of Gene Regulatory Networks	49
3.4 Individual Cell-Based Model	53
	vii

viii	<i>Contents</i>	
	3.5 Cellular Automata, Phase Fields and Other Coarse-Grained Models	55
4	Vascular Hydrodynamics and Tumor Angiogenesis	58
	4.1 Biological Aspects of Angiogenesis	58
	4.2 Vasculogenic Mimicry in Cancer	61
	4.3 Physical Aspects of Vascular Flow in Tumors	63
	4.4 Computational Models of Vascular Remodeling	65
5	Cancer Stem Cells and the Population Dynamics of Tumors	68
	5.1 Experimental Identification of Cancer Stem Cells	68
	5.2 Population Dynamics of Cancer Stem Cells	71
	5.3 Phenotypic Switching	75
	5.4 Cell Sorting and Imperfect Markers	79
6	Biomechanics of Cancer	81
	6.1 Elasticity	81
	6.2 Mechanics of Cancer Cells	83
	6.3 Tumor Growth Against Tissue-Induced Stresses	85
	6.4 Effect of Osmotic Pressure on Cancer Cells	87
	6.5 Mechanical Stresses and Cancer Progression	89
7	Cancer Cell Migration	92
	7.1 Individual Cell Motion	92
	7.2 Chemotaxis	95
	7.3 Cell Adhesion Molecules	98
	7.4 Traction Forces During Cancer Cell Migration	102
	7.5 Collective Cell Migration	105
	7.6 Physics of Cancer Metastasis	108
8	Chromosome and Chromatin Dynamics in Cancer	112
	8.1 Chromosomal Instability	112
	8.2 Theoretical and Computational Models of Chromosome Segregation	116
	8.3 Nuclear Alterations in Cancer	120
9	Control of Tumor Growth by the Immune System	123
	9.1 The Immune System	123
	9.2 Immunogenicity of Cancer Cells	125
	9.3 Cytokines and the Regulation of the Immune System	127
	9.4 Inflammation in Tumors	128
	9.5 Models for the Interaction Between Immunity and Tumors	130

	<i>Contents</i>	ix
10	Pharmacological Approaches: Old and New	132
10.1	The Traditional Approaches and Nanomedicine	132
10.2	Nutrition and Cancer	136
11	Outlook on the Physics of Cancer: A New Interdisciplinary Area	138
	<i>References</i>	141
	<i>Index</i>	171