1. Organs and Tissues for Human Movement	1
1.1 Neuroanatomical Basis for Control of Movement	2
1.1.1 The Central Nervous System	4
1.1.2 The Functional Systems of the Brain	12
1.1.3 The Morphology and Physiology of the Neuron	14
1.1.4 The Membrane Theory of Excitation and Contraction	16
1.2 Sensory Systems for Control of Movement	18
1.2.1 Hierarchical and Parallel Organization of Somatic Sensors	18
1.2.2 Frequency and Population Codes	21
1.2.3 Dermatomes	23
1.2.4 Cutaneous Mechanoreceptors	24
1.2.5 Muscle Receptors	26
1.3 Skeletal Muscles - Natural Actuators for Movement	28
1.3.1 Structure of Skeletal Muscle	29
1.3.2 Nerve Supply of Muscles	31
1.3.3 Microscopic Structure of a Myofibril 1.3.4 Neuromuscular Junction	31
1.3.5 The Nature of Contraction	33 34
1.3.6 Sliding Filament Theory of Muscular Contraction	35
1.3.7 Muscle Function	43
1.3.8 Tendons and Ligaments	45
1.4 Skeleto-Muscular Structure of Extremities	46
1.4.1 The Leg	46
1.4.2 The Upper Limb – Arm and Hand	57
2. Mechanisms for Natural Control of Movement	69
2.1 Organization and Mechanisms for Control of Movement	69
2.1.1 Hierarchical Organization of the Motor Systems	71
2.1.2 Parallel Organization of Motor Control Channels	74
2.1.3 Afferent Fibers and Motor Neurons	75
2.1.4 Interneurons and Propriospinal Neurons	76
2.1.5 Neuronal Pathways	77
2.2 Mechanisms for Control of Posture	78
2.2.1 Biomechanical Principles of Standing	80
2.2.2 Postural Adjustments for Focal Movement	83
2.2.3 Sensors for Control of Posture	84
2.2.4 Central Neural Mechanisms for Control of Posture	86

3.

2.3 Mechanisms for Control of Walking	87
2.3.1 The Development of Walking	88
2.3.2 Bipedal Walking	89
2.3.3 Role of Various Neural Mechanisms in Walking	91
2.3.4 Central Pattern Generator: A Mechanism for the Control of Walking	92
2.3.5 The Role of Peripheral Input in Generation of Normal Walking	
Patterns	95
2.3.6 Effects of Sensory Feedback	95
2.3.7 Motor Programs for Walking	96
2.3.8 Motor Program in Humans with Paraplegia	97
2.3.9 Biomechanics of Bipedal Walking	98
2.4 Control of Goal-directed Movement	99
2.4.1 The Development of Reaching and Grasping	100
2.4.2 Mechanisms for Control of Reaching and Grasping	
2.4.2 Motor Planning	100
2.4.4 Visual Guidance in Goal-directed Movement	101
2.4.5 Precision of Positioning of the Hand	105
2.4.6 The Planning Space and Frames of Reference	106
2.4.7 Redundancy and Synergies	107
2.4.7 Redundancy and Synergies 2.4.8 Redundancy and Motor Equivalence	109
2.4.9 The Equilibrium Point Hypothesis	111
2.4.9 The Equinorium Form Hypothesis 2.4.10 The Muscle Patterns Underlying Movement	111
2.4.10 The Muscle Fatterns Underlying Movement 2.4.11 Optimization Theory	114
2.4.12 Motor Execution	115
2.4.13 Reaching Movement	118
2.4.14 Grasping	119
2.4.15 Coordination of Reaching and Grasping	120
2.4.13 Coolemation of Reacting and Grasping	123
Pathology of Sensory-Motor Systems and Assessment of Disability	125
3.1 Pathology of Sensory-Motor Systems	105
3.1.1 Cerebro-Vascular Infarction (Stroke)	125
3.1.2 Diseases of Transmitter Metabolism	125
3.1.3 Spinal Cord Injuries	129
3.1.4 Injury of the Neuron	130
3.1.5 Diseases of the Motor Unit	135
3.1.6 Neurogenic and Myophatic Diseases	138
3.1.7 Peripheral Neuropathies	138
3.1.8 Myopathies	139
3.1.9 Muscle Atrophy	140
3.1.10 Fatigue in Paralyzed Muscles	141
3.1.11 Spasticity	143
3.1.12 The Amputation	144
3.2 Assessment Methods of Sensory-Motor Disorders	145
3.2.1 Standards for Classifying the Sensory-Motor Disability	146
3.2.2 The Functional Independence Measure (FIM)	146
3.2.3 The Quadriplegia Index of Function (QIF)	149
3.2.4 Muscle Assessment	149
	1 51)

Table of Contents	Χi
3.3 Movement Analysis	52
	52
	56
	56
0.0.4.77	58
3.3.5 Capturing Muscle Activity – EMG	59
3.3.6 Measurable Characteristics of Walking	60
Restoring Movement: State of the Art	71
	71
	74
	77
4.1.3 Surgery to Provide Muscle for Movement - Tendon Transfer	80
4.2 Neurorehabilitation	85
	89
	94
	98
•••	99
4.3 Neuroprostheses 20	05
	06
	12
	50
	59
	68
	77
4.4.4.00	81
4.4.4.501	90
4.40 0 0 10 4 1	90
4.40 m	91
A A A TTI TO 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	00
4.4.5.D	
A.F. A. J. C.	
4.5.1 m	02
450 4 25 - 1 + 1	02
450 A 11 1 0 10 A 10 A 10 A 10 A	04
4 5 4 5 4 5 4 5 5 5 5 5 5 5 5 5 5 5 5 5	06
4.5.4 Passive Arm-hand Prosthesis 30 4.5.5 Body Powered Prosthesis 30	
4.5.6 Electrically Powered Prosthesis	
4.5.7 Hybrid Prosthesis	
4.5.8 Artificial Extremities – Summary	

xii

5. External Control of Movement	317
510	027
5.1 Overview of Control Systems for Movement	318
5.1.1 Modeling of the Musculoskeletal System	323
5.1.2 Modeling of the Musculotendonal Systems	327
5.1.3 Identification of Model Parameters	330
5.1.4 Control Methods for Movement of a Single Joint	335
5.2 Hybrid Hierarchical Control Systems	350
5.2.1 Nonanalytical Methods for Coordination of Movement	353
5.2.2 Rule-Based Control Systems	354
5.2.3 Methods and Tools to Define Rules for RBC	355
5.2.4 Machine Learning for Determining of the Rules for RBC	360
5.3 Control Methods to Restore Standing	364
5.4 Controlling Neuroprostheses for Walking	371
5.4.1 Analytical Methods to Control Walking	371
5.4.2 Nonanalytical Techniques to Determine Walking Synergies	374
5.4.3 Hierarchical Hybrid Control of Walking	387
5.5 Controlling Neuroprostheses for Grasping and Reaching	391
5.5.1 Control Methods to Restore Grasping	391
5.5.2 Control Methods to Restore Elbow and Wrist Movement	400
6. Epilogue	409
References	413
Abbreviations	
Annicalations	473
Index	475