
Contents

Acknowledgments	ix
Introduction	xi
Chapter 1. Information Processing	1
1.1. Background	1
1.1.1. Encoding	2
1.1.2. Memorization	4
1.2. Information processing machines	5
1.2.1. The Turing machine	5
1.2.2. von Neumann architecture	7
1.2.3. CMOS technology	9
1.2.4. Evolution in microprocessor performance	14
1.3. Information and energy	16
1.3.1. Power and energy dissipated in CMOS gates and circuits	17
1.4. Technologies of the future	26
1.4.1. Evolution of the “binary coding/von Neumann/CMOS” system	27
1.4.2. Revolutionary approaches	31
1.5. Microprocessors and the brain	40
1.5.1. Physical parameters	40
1.5.2. Information processing	43
1.5.3. Memorization of information	45
1.6. Conclusion	46

Chapter 2. Information Processing in the Living	47
2.1. The brain at a glance	48
2.1.1. Brain functions	48
2.1.2. Brain anatomy	48
2.2. Cortex	50
2.2.1. Structure	50
2.2.2. Hierarchical organization of the cortex	52
2.2.3. Cortical columns	54
2.2.4. Intra- and intercolumnar connections	55
2.3. An emblematic example: the visual cortex	57
2.3.1. Eye and retina	58
2.3.2. Optic nerve	60
2.3.3. Cortex V1	60
2.3.4. Higher level visual areas V2, V3, V4, V5 and IT	62
2.3.5. Conclusion	63
2.4. Conclusion	64
Chapter 3. Neurons and Synapses	67
3.1. Background	67
3.1.1. Neuron	68
3.1.2. Synapses	69
3.2. Cell membrane	72
3.2.1. Membrane structure	72
3.2.2. Intra- and extracellular media	74
3.2.3. Transmembrane proteins	75
3.3. Membrane at equilibrium	78
3.3.1. Resting potential, V_r	82
3.4. The membrane in dynamic state	85
3.4.1. The Hodgkin–Huxley model	89
3.4.2. Beyond the Hodgkin–Huxley model	100
3.4.3. Simplified HH models	101
3.4.4. Application of membrane models	111
3.5. Synapses	122
3.5.1. Biological characteristics	122
3.5.2. Synaptic plasticity	125
3.6. Conclusion	127

Chapter 4. Artificial Neural Networks	129
4.1. Software neural networks	130
4.1.1. Neuron and synapse models.	130
4.1.2. Artificial Neural Networks	133
4.1.3. Learning	140
4.1.4. Conclusion	147
4.2. Hardware neural networks	148
4.2.1. Comparison of the physics of biological systems and semiconductors	149
4.2.2. Circuits simulating the neuron	154
4.2.3. Circuits simulating the synapse	189
4.2.4. Circuits for learning	198
4.2.5. Examples of hardware neural networks	201
4.3. Conclusion	210
References	211
Index	219