

Contents

1	Excitable Membranes and Neural Conduction	1
1.1	Membrane Potentials	1
1.2	The Hodgkin-Huxley Theory	4
1.2.1	Modeling Conductance Change with Differential Equations	5
1.2.2	The Potassium Channel	7
1.2.3	The Sodium Channel	9
1.2.4	Combining the Conductances in Space Clamp	11
1.3	An Analytical Approximation: The FitzHugh-Nagumo Equations	13
1.4	Passive Conduction	15
1.5	Propagating Action Potentials	19
1.6	Summary and Outlook	19
1.7	Suggested Reading	20
2	Receptive Fields and the Specificity of Neuronal Firing	23
2.1	Spatial Summation	23
2.1.1	Correlation and Linear Spatial Summation	23
2.1.2	Lateral Inhibition: Convolution	28
2.1.3	Correlation and Convolution	31
2.1.4	Spatio-Temporal Summation	33
2.1.5	Peri-Stimulus Time Histogram (PSTH) and Tuning Curves	34
2.2	Functional Descriptions of Receptive Fields	35
2.2.1	Isotropic Profiles: Gaussians	35
2.2.2	Orientation: Gabor Functions	37
2.2.3	Spatio-Temporal Gabor Functions	39
2.2.4	Why Gaussians?	40
2.3	Non-linearities in Receptive Fields	40
2.3.1	Linearity Defined: The Superposition Principle	40
2.3.2	Static Non-linearity	42

2.3.3	Non-linearity as Interaction: Volterra Kernels	44
2.3.4	Energy-Type Non-linearity	45
2.3.5	Summary: Receptive Fields in the Primary Visual Pathway	47
2.4	Motion Detection	49
2.4.1	Motion and Flicker	49
2.4.2	Coincidence Detector	50
2.4.3	Correlation Detector	51
2.4.4	Motion as Orientation in Space-Time	53
2.5	Suggested Reading	54
3	Fourier Analysis for Neuroscientists	57
3.1	Examples	58
3.1.1	Light Spectra	58
3.1.2	Acoustics	58
3.1.3	Vision	61
3.1.4	Magnetic Resonance Tomography	61
3.2	Why Are Sinusoids Special?	63
3.2.1	The Eigenfunctions of Convolution: Real Notation	63
3.2.2	Complex Numbers	66
3.2.3	The Eigenfunctions of Convolution: Complex Notation	67
3.2.4	Gaussian Convolution Kernels	68
3.3	Fourier Decomposition: Basic Theory	70
3.3.1	Periodic Functions	71
3.3.2	The Convolution Theorem; Low-Pass and High-Pass	72
3.3.3	Finding the Coefficients	75
3.4	Fourier Decomposition: Generalizations	77
3.4.1	Non-periodic Functions	77
3.4.2	Fourier-Transforms in Two and More Dimensions	78
3.5	Summary: Facts on Fourier Transforms	79
3.6	Suggested Reading	81
4	Artificial Neural Networks	83
4.1	Elements of Neural Networks	83
4.1.1	Activity and the States of a Neural Network	84
4.1.2	Activation Function and Synaptic Weights	85
4.1.3	The Dot Product	86
4.1.4	Matrix Operations	87
4.1.5	Weight Dynamics ("Learning Rules")	88
4.2	Classification	89
4.2.1	The Perceptron	89
4.2.2	Linear Classification	90
4.2.3	Limitations	92
4.2.4	Supervised Learning and Error Minimization	94
4.2.5	Support Vector Machines	99

- 4.3 Associative Memory 100
 - 4.3.1 Topology: the Feed-Forward Associator 101
 - 4.3.2 Example: A 2×3 Associator 102
 - 4.3.3 Associative Memory and Covariance Matrices 103
 - 4.3.4 General Least Square Solution 104
 - 4.3.5 Applications 105
- 4.4 Self-organization and Competitive Learning 106
 - 4.4.1 The Oja Learning Rule 107
 - 4.4.2 Self-organizing Feature Map (Kohonen Map) 109
- 4.5 Suggested Reading 111
- 5 Coding and Representation 113**
 - 5.1 Population Code 113
 - 5.1.1 Types of Neural Codes 113
 - 5.1.2 Information Content of Population Codes 114
 - 5.1.3 Reading a Population Code: The Center of Gravity Estimator 117
 - 5.1.4 Examples, and Further Properties 119
 - 5.1.5 Summary 123
 - 5.2 Retinotopic Mapping 123
 - 5.2.1 Areal Magnification 124
 - 5.2.2 Conformal Maps 126
 - 5.2.3 Log-Polar Mapping 127
 - 5.3 Suggested Reading 128
- References 131**
- Index 133**