# Contents

PREFACE	xi
ACKNOWLEDGMENTS	xiii
NOTATION	XV

### Chapter 1 Topological Properties

1.1.	The A	pproach to Neural Masses	1
	1.1.1.	Direct and Indirect Observations	1
	1.1.2.	The Use of Models in a Hierarchy	3
	1.1.3.	Macroscopic Forms of Cooperative Neural Activity	5
1.2.	Single	Neurons	10
	1.2.1.	The Structures of Neurons	10
	1.2.2.	The Operations of Neurons	11
	1.2.3.	The State Variables of Neurons	13
	1.2.4.	Specification of the Active States and Operations	16
	1.2.5.	Input-Output Relations of Single Neurons	19
	1.2.6.	Multiple Stable States of Neurons	22
	1.2.7.	Basic Topologies of Networks of Neurons	24
1.3.	Neura	1 Masses	25
	1.3.1.	A Topological Hierarchy of Interactive Sets	25
	1.3.2.	The State Variables of KO and KI Sets	34
	1.3.3.	The Operations of Neural Sets	37
	1.3.4.	Feedback Gain as a Parameter for Interaction	39
	1.3.5.	Multiple Stable States and the Levels of Interaction	42
	1.3.6.	The Relation of Multiple Stabilities to Neural Signals	46
	1.3.7.	The Conditions for Realizability	47
	1.3.8.	The Use of Differential Equations	49

### Chapter 2 Time-Dependent Properties

2.1.	Measurement of Neural Events		51
	2.1.1.	Representation of Events by Functions	51
	2.1.2.	Input-Output Functions	55
	2.1.3.	Linear Input-Output Functions	57
	2.1.4.	The Impulse and the Impulse Response	60
2.2.	Linear	Models for Neural Membrane	61
	2.2.1.	The Topology of the Membrane	61
	2.2.2.	Differential Equations	64
	2.2.3.	The Laplace Transform	67
	2.2.4.	Application of the Laplace Transform to the Membrane	70
2.3.	Linear	Models for Parts of Neurons	72
	2.3.1.	Convolution	72
	2.3.2.	The Convolution Theorem	76
	2.3.3.	Transfer Functions for Pulse Transmission	80
	2.3.4.	The Core Conductor Model	86
	2.3.5.	Synaptic Delay	91
2.4.	Linear	Models for Neurons	94
	2.4.1.	Formulation of the Topology	94
	2.4.2.	Input-Output Pairs and the Differential Equation	96
	2.4.3.	Interpretation of the Parameters	99
	2.4.4.	Linear Function for Wave to Pulse Conversion	101
2.5.	Linear	Models for Neural Masses	103
	2.5.1.	Use of Nonlinear Regression	103
	2.5.2.	The KO Neural Set	106
	2.5.3.	Oscillatory Responses from a KII Set	110

## Chapter 3 Amplitude-Dependent Properties

3.1.	Nonlinear Models for Neural Membranes		121
	3.1.1.	The Ionic Hypothesis	121
	3.1.2.	Metabolic Forces	125
	3.1.3.	The Concept of Equilibrium Potential	126
	3.1.4.	The Sodium Permeability Model	129
3.2.	Nonlinear Models for Neurons and Parts of Neurons		134
	3.2.1.	Action Potentials in Axons	134
	3.2.2.	Threshold Uncertainty in Axons	138
	3.2.3.	Postsynaptic Potentials in Dendrites	140
	3.2.4.	Amplitude-Dependent Input Output Relations	144
3.3.	Nonlinear Models for Neural Masses		146
	3.3.1.	Background Activity in the Wave Mode	146
	3.3.2.	Background Activity in the Pulse Mode	150
	3.3.3.	Relations of Waves and Pulses	154
	3.3.4.	Wave to Pulse Conversion in the KI Set	159
	3.3.5.	Pulse to Wave Conversion in the KI Set	163
	3.3.6.	The Forward Gain of the KI Set	165

## Chapter 4 Space-Dependent Properties

4.1.	Potential Fields of Single Neurons		172
	4.1.1.	Basis Functions for Measurement of Potential in Space	173
	4.1.2.	Basis Functions for Potential in Current Fields	177
	4.1.3.	Potential Functions for the Core Conductor	180
	4.1.4.	Potential Fields of Axons	185
	4.1.5.	Nodes and Branched Fibers	188
4.2.	Potential Fields of Neural Masses		193
	4.2.1.	Measurement of Observed Fields	193
	4.2.2.	Basis Functions for Potential Fields of Neural Masses	196
	4.2.3.	Compound Potential Fields: Modular Analysis	202
4.3.	Potential Fields in the Olfactory Bulb		211
	4.3.1.	Bulbar Geometry and Topology	212
	4.3.2.	Analysis of the Spatial Function of Potential	219
	4.3.3.	Time-Dependent Activity	228
4.4.	Poten	tial Fields in the Prepyriform Cortex	234
	4.4.1.	Cortical Geometry and Topology	234
	4.4.2.	Observed Fields of Cortical Potential	238
	4.4.3.	Relation of Potential Fields to Active States	245
4.5.	Diverg	gence and Convergence in Neural Masses	249
	4.5.1.	The Operation of Divergence	249
	4.5.2.	Evaluation of Spatial Distributions of Active States	253
	4.5.3.	Evaluation of Synaptic Divergence	260
	4.5.4.	Evaluation of Tractile Divergence	264

### Chapter 5 Interaction: Single Feedback Loops with Fixed Gain

5.1.	Gener	al Properties of Single Feedback Loops	270
	5.1.1.	Types of Neural Feedback	271
	5.1.2.	Derivation of the Lumped Piecewise Linear Approximation	273
	5.1.3.	Root Locus as a Function of Feedback Gain	278
	5.1.4.	Amplitude-Dependent Gain and Stability	284
5.2.	Reduc	tion from the KI Level	285
	5.2.1.	Topological Analysis of the Glomerular Layer	285
	5.2.2.	Differential Equations for the KI <sub>e</sub> Set	291
	5.2.3.	Self-Stabilization of the KI, Set	299
5.3.	Reduction from the KII Level		305
	5.3.1.	Topological Analysis of the Olfactory Bulb	305
	5.3.2.	Differential Equations for the Open Loop Cases	309
	5.3.3.	Differential Equations for the Closed Loop Cases	314
5.4,	Reduction from the KIII Level		321
	5.4.1.	Topological Analysis of the Prepyriform Cortex	321
	5.4.2.	Differential Equations for the Cortex	326
	5.4.3.	Transfer Function of the LOT Input Channel	330
	5.4.4.	Pulse-Wave Relations in Cortex and Bulb	334
	5.4.5.	Channels for Centrifugal Input	338

#### CONTENTS

## Chapter 6 Multiple Feedback Loops with Variable Gain

42
42
49
55
66
70
78
78
81
86
90
96

## Chapter 7 Signal Processing by Neural Mass Actions

Behavioral Correlates of Wave Activity in KII Sets		402
7.1.1.	The Operational Basis for Correlation	402
7.1.2.	Factor Analysis of AEPs	407
7.1.3.	Patterns of Change in AEPS with Attention	414
7.1.4.	A Proposed Cortical Mechanism of Attention	422
Transformations of Neural Signals by KII Sets		427
7.2.1.	Neural Coding in the Olfactory Bulb	429
7.2.2.	Bulbar Mechanisms for Phase Modulation	434
7.2.3.	Attention and the Cortical Expectation Function	440
7.2.4.	Possible Mechanisms of Cortical Output	446
Comments concerning Neocortical Mass Actions		448
7.3.1.	Rhythmic Potentials and Rhythmic Stimulation	449
7.3.2.	DC Polarization and Steady Potentials	452
7.3.3.	Unit Activity Correlated with Sensory and Motor Events	455
	7.1.1. 7.1.2. 7.1.3. 7.1.4. Transf 7.2.1. 7.2.2. 7.2.3. 7.2.4. Comm 7.3.1. 7.3.2.	<ul> <li>7.1.1. The Operational Basis for Correlation</li> <li>7.1.2. Factor Analysis of AEPs</li> <li>7.1.3. Patterns of Change in AEPS with Attention</li> <li>7.1.4. A Proposed Cortical Mechanism of Attention</li> <li>Transformations of Neural Signals by KII Sets</li> <li>7.2.1. Neural Coding in the Olfactory Bulb</li> <li>7.2.2. Bulbar Mechanisms for Phase Modulation</li> <li>7.2.3. Attention and the Cortical Expectation Function</li> <li>7.2.4. Possible Mechanisms of Cortical Output</li> <li>Comments concerning Neocortical Mass Actions</li> <li>7.3.1. Rhythmic Potentials and Rhythmic Stimulation</li> <li>7.3.2. DC Polarization and Steady Potentials</li> </ul>

## References

462

Author Index	473
Subject Index	477