

Contents

Part I Concepts of Brain Theory

1	Lettvin's Challenge	3
2	Issues Concerning the Nature of Neuronal Response	5
2.1	Impressions Gained from Histograms and Raster Displays	5
2.2	Cortical Firing Should Be Nearly Periodic – So Why Isn't It?	6
2.3	Sensitivity of Neurons to Synchronized Volleys of Spikes	8
2.4	Notes on Plastic Change at the Synaptic Level	9
3	"Events" in the Brain	11
3.1	The Brain Viewed as a Logic Network Without a "System Clock"	11
3.2	Looking for "Surprising Events" in the Neuronal Input Stream	12
3.3	<i>Poisson Surprise</i> as a Diagnostic Tool	13
3.4	Critique of Brain Models Relying on <i>Average Spike Rates</i>	14
3.5	The LTP Is Probably the <i>Marking</i> of Synapse Sets for Later Use	14
4	Cell Assemblies	17
4.1	Ignition	17
4.2	Synchronized "One-Spike" Ignitions	18
4.3	Ignitions and the Central Bins of Cross-Correlograms	19
4.4	Ignitions and Single-Unit Recording	20
4.5	Why Myelin Is Indispensable to Nervous Function?	20
5	Surprise, Statistical Inference, and Conceptual Notes	23
5.1	Spike Coincidence Interpreted in Terms of Surprise	24
5.2	<i>Local Knowledge</i> and Its Relation to Information	24
5.3	The Fundamental Law of Brain Theory	25

5.4	<i>Parsing the Network into Localities</i>	25
5.5	Brain Modeling Viewed as “Reverse Engineering”	26
6	A New Term: Ignitions Which “Reach” or “Don’t Reach” a Neuron	27
6.1	How Many Synapses Does It Take to Reach a Neuron?	28
6.2	Axons, Where They Arborize, Can Probably Contact Most Neurons	28
6.3	A Good Unit of Cortical Distance: The Width of a Column	30
6.4	Axonal Branching Near the Cell Body	31
6.5	Retinotopic Mapping	31
6.6	Axons Which Confine Their Branching to a Few Columns	32
7	Confirmation Loops, Powered by Self-Ignitions	35
7.1	The Principle of Overwhelming Odds	35
7.2	Prime Mover Networks at the “Sending End” of Surprising Signals	35
7.3	Confirmation Loops and the Classical “Reverberations”	37
8	Communicating “Relatedness” Through Time-Linked Ignitions	39
8.1	Time-Linked Ignitions Viewed as Sentences	40
8.2	Joining Sentences on Shared Nouns	40
9	Relational Firing: Broadcasting a Shape Through Time-Linked Ignitions	43
9.1	Labeled Lines: The Messenger Is the Message	43
9.2	Direction-Coded Cells	44
9.3	Relational Firing: Two Cell Groups Broadcasting a Relation	46
9.4	Visual Sentences Conveying that Two Sides Meet in One Point	47
9.5	“Kernel Cells,” Used in Joining Co-ignitions on Shared Points	48
9.6	Visual Sentences Communicating a Triangular Shape	50
9.7	“Contour Cells” and “Direction-Coded Cells”	52
9.8	Broadcasting More Complex Shapes	54
9.9	The Role of Retinotopy and Connectivity	57
9.10	Confirmation Loops and the Epochs on High Poisson Surprise	58
9.11	3D Extension of Polygon Graphics	59
9.12	Distributed Knowledge	59

Part II Contour Strings and the Contour Wave

10	Enter the Contour String	63
10.1	The Issue of Enabling Communication Between Parts of an Image	63

10.2	Cells Which Link Up to Pass Waves When Co-stimulated	64
10.3	Ignition on the Contour Moves Like a Wave (Contour Wave)	64
10.4	Seeing Viewed as Short-Term Learning	65
10.5	Only the Simple Cell Is Suitable for Conducting the Contour Waves	65
10.6	The Need for Drome-Selectivity in Simple Cells	65
10.7	The Problem of Converting “Facts” into “Events”	66
10.8	The Contour String as a “Prime Mover”	67
10.9	The Contour String as Representation of a Gestalt	68
11	Drift of the Retinal Image	71
11.1	<i>Tracking</i> the Nouns Used in Joining Sentences	71
11.2	The Word “Fixation” Is a Misnomer	72
11.3	A Period of Fixation Is a Period of Tracking	72
12	Theory of the Simple Cell	75
12.1	Simple Cells, When Detecting LGN Input, Must Link Up <i>Fast</i> . . .	75
12.2	<i>Warm-Up</i> of Simple Cells by the Approaching Contour Wave . . .	76
12.3	<i>Cross-Potentiation</i> : One Synapse Pool Changing the Effect of Another	76
12.4	The Graphical Notation of Neuron Sets and Synapse Sets	77
12.5	The Preparation of Simple Cells for Their Role in Contour Waves	79
13	Theory of the Complex Cell	85
13.1	<i>Tracking</i>	85
13.2	Tracking Based on Overlap: <i>Dynamically Marked</i> Synapses	86
13.3	<i>Dynamic Marking</i> Shown in Drawings as Just <i>Marking</i>	88
13.4	The Trick of Simple Cells Feeding into Complex Cells	88
13.5	Simple and Complex Cell Responses Are All <i>Contour</i> <i>Wave</i> Responses	90
13.6	How the Complex Cell Works	91
14	Corner Processing: Theory of the Hypercomplex Cell	93
14.1	Propagation of Contour Waves Toward and Away from Corners . .	93
14.2	Corner-Supporting Simple (CS Simple) Cells	94
14.3	Hypercomplex Cells	98
14.4	Comparing Hypercomplex and CS Simple Cells	99

Part III Nodes, Links, Bridgeheads

15	Nodes on Contour Strings	103
15.1	The Problem of Slow Propagation	103
15.2	The Stria of Gennari	103
15.3	Speed-Up by Means of <i>Nodes</i> Linked by Gennari Fibers	104
15.4	Nodes Viewed as Representing <i>Points</i>	105
15.5	A Note on the Fiber Requirement of Visual Integration	105

15.6	The Placement of Nodes on a Contour	106
15.7	A Link Between Nodes Has a <i>Bridgehead</i> on Each Node	107
16	Custom-Made Unstable Networks Made to Support Tracking	109
16.1	Self-Igniting Networks Which Continually Gain and Lose Cells	109
16.2	Active Linkage: Two Bridgeheads Repeatedly Co-igniting	110
16.3	Detecting When a Link Becomes Weak	111
16.4	The Linkage Between Tracking, Metric Relations, and Long-Term Storage	115
16.5	Tracking a Contour Whose Shape Changes	116
16.6	Restoring a Weakened Link	117
17	Why Is the Drifting Retinal Image Helpful in Perception?	121
17.1	The Growth of Nodes in the Course of Contour Drift	122
17.2	Kernel Cells in Multi-column Nodes	126
18	The Maintenance of Moving Nodes and Bridgeheads	129
18.1	Adding New Neurons to a Drifting Node	129
18.2	Spread of a Bridgehead Sideways, Along the Contour	133
 Part IV Firing Games and the Integration of Contours		
19	Making the First Links by Crawling Along a Contour String	141
19.1	Outline of the Continuity Detection and Contour Linkup	142
19.1.1	Nodes and Their Initial Ignitions	142
19.1.2	The Cells as Individuals Cannot See the Whole Picture	142
19.1.3	How a “Grand Design” Enables Cells to Convey More Than They Know	143
19.1.4	Localities Monitoring the Moving Wave Via Long Axons	143
19.1.5	The Smallest Cell Group Able to Trade Knowledge: The Node	144
19.1.6	Monitoring Single Contour Waves in Isolation: The “Tracer Wave”	145
19.1.7	Preventing Extra Waves from Being Traced: The “Second Enable”	146
19.1.8	Satisfying the Surprise Requirement of “Second Enable”: Warmup Runs	146

19.1.9	Tracer Waves Continuous with an “Arrival Volley” from the Next Node	147
19.1.10	How Can the Base Node Recognize the Arrival Volleys?	147
19.1.11	Saving the Detected Continuity in the Form of Hardware	148
19.1.12	Node A Knows that the Reaching Is Bidirectional; So Does Node B	149
19.1.13	Linkup and Active Link Operation	149
19.2	Operating Modes of Neurons	150
19.3	Firing Games: Goal-Directed Organization Without a Leader	151
19.4	Directional Specificity of Contour Cells: R-cells and L-cells	152
19.5	A Note on the Drawings Describing Contour Linkup	152
19.6	Synaptic Interactions During Tracer Runs and Linkup	156
19.7	Continuity Detection from the Standpoint of the Base Cells	161
19.8	“Understudy Processing” of Cells Before They Join a Node	164
19.9	Phases of a Linkup, with Each Phase “hammered in” by Repetitions	165
19.10	Suppressing Tracer Waves Beyond the First Node They Encounter	171
19.11	Recognition of Crosstalk Between Two Contours	172
20	Using Existing Links to Make New Links on the Same Contour	175
20.1	Outline of Using Two Links to Make a Third Link on the Same Contour	175
20.1.1	Relation “A on Same Contour as B” is Transitive; But There is a Catch	175
20.1.2	Linkup of Two Nodes Must Start from a Third, with Links to Both	176
20.1.3	Three-Node Ignitions	176
20.1.4	Making the Triple Ignitions Reach the Satellite Nodes	177
20.1.5	The Issue of Limiting the Search Volleys to a Range of Directions	177
20.1.6	How Do Nodes A and C Know that They Are Supposed to Link Up?	178
20.1.7	The Beginning of the Bridgeheads of an A–C Link	178
20.1.8	The Challenge of Making the Bridgeheads Ignitable	179
20.1.9	Gradual Growth of the New Bridgeheads	179
20.1.10	The Cessation of Omnidirectional Volleys	180
20.1.11	Setting Up Mutual Excitation Between Nodes A and C	181
20.1.12	The Next Step Is to Separate the A–B Link and B–C Link Again	181

20.1.13	How Do the Bridgeheads in B Know to Undo Their Linkage?	181
20.1.14	Restoring the A–B Link and B–C Link	182
20.1.15	Why Not Just Start a Free-for-All of Echolocation? . .	183
20.2	Extending a Long Link to the Next Node on a Contour	183
20.2.1	Node-Level Description of the Linkup Step	184
20.2.2	Description of the Linkup Step in More Detail	187
21	Completing a Triangle of Links	199
21.1	Closing a Triangle	199
21.2	How to Spot “Open” Triangles: The Three-Element Problem . . .	201
22	All-to-All Linkup on Smaller Shapes, Utilizing Chain Ignitions	207
22.1	Indiscriminate Linkup of All Nodes	207
	Closing Remarks	211
	References	213
	Index	219

<http://www.springer.com/978-0-387-88848-4>

Circuits in the Brain

A Model of Shape Processing in the Primary Visual
Cortex

Legéndy, C.

2009, XXVI, 226 p. 100 illus., Hardcover

ISBN: 978-0-387-88848-4