Closing Remarks

It has been my purpose throughout this book to make the things I presented appear self-evident. If somebody looks at my drawings and complains that their message is too obvious to be published, I will consider my efforts successful.

At the time of this writing I have, of course, no idea how much of what I write here will prove correct.

I am very confident that most of my methodology will survive: the idea of reaching, the idea of surprise, the principle of overwhelming odds, the logistic considerations dealing with local knowledge, and others. I am optimistic, in general, since my assumptions are not outlandish. After the dust settles, and after what I wrote here is re-worked to square with the facts, I assume the theoretical methods I have sketched out here will still be around.

It has cast a shadow over the development of neuroscience that the massively productive two-way interaction between theory and experiment, which is the engine driving the success of physics, chemistry, and molecular biology, is all but absent in brain research. But there is no good reason why this should be so; and if my book can improve the interaction, even a little bit, its goals will have been achieved.
References


213
References


Lashley, K. S. (1930) Basic neural mechanisms in behavior. Psychol. Rev. vol 37, pp 1–24
References


Index

A
Abeles, M., 24
Action potential, back-propagated, 9, 10
Adey, W. R., 20
Ahmed, B., 7
AND gate, 11
Arborize, axons, 28–30
Ariav, G., 6, 18
Availability, graphical estimation, 29
Average spike rates, critique of brain models, 14
Axonal branching, cell body, 31
Axons
  arborize, 28–30
  local branches of, 45, 48
  long horizontal, 3, 44–45, 51, 53, 103–106
  number available to a neuron, 29

B
Baillarger, J. G. F., 106
Bak, M., 30, 57
Baker, B. J., xx
Base cell standpoint, continuity detection from, 164–166
Belmonte, C., 43
Binding
  problem, 39, 41
  temporal, 39
Binzegger, T., 27, 103
Black box, 26
Blinkov, S. M., 105
Bliss, T. V. P., 10
Brain, connectivity, 27
Brain modeling, reverse engineering, 26
Brain theory
  alternative approaches to, 25
  average spike rates, 4, 14
  quantized time, 11–12
  fundamental law of, 25, 27
Braitenberg, V., xix, 18, 106
Branching to column, axons, 32–33
Bridgehead
  contour, 149, 176, 197, 207, 209
  directional, 108
  growth of, 121, 193–194
  of a link, 123, 196
  moving nodes maintenance of, see Moving nodes
  and node, link between, 107–108
  sideways growth of, 133–137
Brodmann, K., 108
Bullock, T. H., 7

C
Caianiello, E. R., 11
Cell assemblies, 17–21
  ignition, 17–20
  central bins of cross-correlograms and, 19–20
  single-unit recording, 20
  myelin, nervous functions, 20–21
  synchronized one-spike ignition, 18–19
Cell body, axonal branching, 31
Central bins of cross-correlograms, 19–20
Cessation of omnidirectional volleys, 191
Chain excitation, 64
Chain ignition, 64
Chino, Y. N., 116
Classical reverberations, confirmation loop, 37–38
Co-ignitions
  contour, 51–54, 141
  directional, 43, 47, 51–54, 175
  repeated, 46, 58, 111, 129, 141
  vertical, 127, 130
Collingridge, G. L., 10

219
Columns
CO blobs and, 31, 57, 105
orientation, 50, 134
Communicating relatedness, see Time-linked ignitions
Communication issue, between parts of image, 63
Complex cell theory, 85–92, 93–99
complex cell works, 91–92
contour wave responses
complex cell responses, 90
simple cell responses, 90
just marking drawing, dynamic marking show in, 88
simple cell feeding into complex cell, trick of, 88–90
tracking, 85–86
overlap based, dynamically marked synapse, 86–87
Complex shape broadcasting, 54–57
Computational methods section, 14
Concentrated arborization rule, 32
Conceptual notes, 23–26
See also Statistical inference
Confirmation loops
classical reverberations, 37–38
epochs on high Poisson surprise, 58–59
overwhelming odds principle, 35
powered by self-ignitions, 35–38
prime mover network
sending end, surprising signal, 35–37
random (irregular) timing, 37, 40
reverberations and, 37–38
Connections
in metaphorical sense, 39, 68
reciprocal connectivity, 45, 156
Connectivity, retinotopy role, 57–58
Continuity detection
base cells and, 161–165, 172
contour link, 142–150
tracer wave and, 148, 156–161
Contour cells, 51–55, 88, 148, 152
Contour linkup, drawing describing, 152–156
Contour string nodes, 103–108
Gestalt and, 68–69
nascent, 84
nodes and bridgehead, link between, 107–108
nodes on contour placement, 106–107
prime mover, 67–68
representing points
nodes view, 105
slow propagation, problem of, 103
speed-up
Gennari fibers, nodes linked by, 104
steady-state, 94, 96–97
stria of Gennari, 103–104
visual integration, fiber requirement, 105–106
Contour string, enter, 63–69
contour string, representation of Gestalt, 68–69
contour wave
ignition on, 64–65
simple cell suitable for conducting, 65
conversion
facts into events, problem of, 66–67
co-stimulated, cell link up to pass waves, 64
parts of image
communication issue between, 63
prime mover, contour string, 67–69
short-term learning, seeing viewed as, 65
cells, need for drome-selectivity in, 65–66
Contour wave
approach, warm up, 76
ignition on, 64–65
initiation of, 69
Contours crosstalk, recognition of, 172–174
Convergence rule, 33
Corner processing, hypercomplex cell theory, 93–99
contour waves propagation
away from corners, 93
CS simple cell, 94–99
hypercomplex cell, 98–99
Corner-supporting simple (CS simple) cell, 94–98
Correlation, 7, 14, 20–21, 25, 66
Cortex, 6–8, 20, 33, 57
Cortical, magnification, 30, 44, 57
Cortical distance, column width, 30–31
Cortical firing, neuronal response, 6–8
Co-stimulated, cell link up to pass waves, 64
Cragg, B. G., 27
Creutzfeldt, O. D., 6–7, 104
Critique of brain models, relying on average spike rates, 14
Cross correlogram, 19–20, 31, 54, 190
Cross-potentiation
complex cells and, 91–92
simple cells and, 3, 75–77, 81–82, 91, 94–98
surprise and, 75, 80
synapse pool changing effect, 76–78
Crosstalk, between contours, 146
Custom-made unstable networks, to support tracking, 109–119
active linkage
two bridgehead repeatedly co-igniting, 110–111
self ignition networks
gain and loss cells, 109–110
shape changes, tracking contour, 116–117
tracking, metric relation and long-term storage
linkage between, 116–117
weak link detecting, 111–115
weakened link restoring, 117–119
Cytochrome oxidase (CO) blobs, 31, 122

D
Degos, B., 13
Demyelination, 21
Dendrites, 6, 18, 29–30, 76, 84, 104, 116, 119
Dendritic spikes, 9–10, 16, 18, 28, 106
Denk, W., xx
Depolarization, 9
Destexhe, A., 7
3D extension, polygon graphics, 59
Diagnostic tool, Poisson surprise, 13–14
Direction-coded cells, 44–45, 51–54
Disconnexion syndromes, 27
Distributed knowledge, 59
Djurisic, M., xx
Domino wave, 64
Douglas, R. J., 84
Drifting retinal image, 71–74, 121–127
contour drift course, growth of nodes, 122–126
kernel cells, multi-column nodes, 126–127
Dynamically marked synapse, tracking, 86–88

E
Echolocation, 149, 150, 161, 183
Effective field, 45, 57, 118–119, 154, 178
Epochs on high Poisson surprise, 58–59
EPSP, see Excitatory postsynaptic potential
Events, brain, 11–16
critique of brain models
relying on average spike rates, 14
Poisson surprise
as a diagnostic tool, 13–14
surprising events
in the neuronal input stream, 12–13
synapse sets, LTP, 14–16
without system clock, logic network, 11–12
Event generator, 67
Events, fact conversion problems, 66–67
Excitatory postsynaptic potential (EPSP), 9, 15, 18, 28, 37, 69, 86–87

F
Fact, events conversion problems, 66–67
Fibers, per cubic millimeter, xix
Firing
bursts, 13, 58
games, 151–152, 199
Hebbian firing, 16
irregular, 7
First link making
base cell standpoint, continuity detection from, 161–164
continuity detection, contour link, 142–150
arrival volley, 147–148
bidirectional, 149
detected continuity, hardware form, 148–149
extra wave prevention, second enabled, 146
grand design, 143
initial ignition, nodes, 142
linkup, active link operation, 149–150
long axons, localities monitoring, 143–144
smallest cell group, able to trade knowledge, 144–145
tracer waves, single contour waves isolation, 145–146
warm up runs, second enable, 146–147
contour cells, directional specificity of R-cells, L-cells, 152
contour linkups, drawing describing, 152–156
by crawling, along contour string, 141–174
firing games
goal directed organization, without leader, 151–152
linkup phases
hammered in by repetitions, 165–171
operation nodes of neurons, 150–151
suppressing tracer waves beyond first node encounter, 171–172
synaptic interaction
during tracer runs and linkup, 156–161
two contours crosstalk, recognition of, 172–174
understudy processing cell, before join node, 164–165
Fixation
cats and, 72
misnomer, 72–73
Fixation (cont.)
period, tracking period, 72–73
tracking and, 72–73
Fundamental law of brain theory, 25

G
Gasparini, S., 10
Gedanken experiment, brain modeling, 26
Gennari, F., 103–104
Geschwind, N., 27
Gestalt representation, contour string, 68–69
Gilbert, C. D., 4, 45, 53, 108
Giuditta, A., 77
Glezer, I. I., 105
Grandmother cell, 3
Granule cells, 45
Gross, C. G., 3

H
Hanes, D. P., 13
Hay, E. D., 151
Hebb, D. O., xix, 17, 25, 37
Hebbian synapse modification, 66
Holt, C., 77
Holt, G. R., 7
Hypercomplex cell theory, corner processing, see Corner processing

I
Ignitable group
making bridgeheads ignitable, 192–193
neuron groups, 40, 63
Ignition
of cell assemblies, 17, 18, 19, 20, 24, 35
chain, 17, 64, 90, 103, 207–209
one-spike, 18–19, 38
repeated in confirmation loops, 35–38
time-linked, 39–41, 63
and sentences, 40
triple, 177, 183–186
vertical, 50, 127, 130–131, 137
Image, retinal
distortion of, 57, 118
drift of, 71–73, 145
Implied knowledge, 25
Information, 13, 24–25, 43
Input, to neurons, 19, 130
Integration of contours, 3, 72, 139–211

J
Johnston, D., 10
Joining
co-ignitions, 48–50
and the definite article, 41
and kernel cells, 48–50, 56
sentences, 40–41, 47–50, 58, 71, 107
on shared nouns, 40–41, 48, 58, 71

K
Kelly, J. P., 108
Kernel cell, 48–50, 88, 126–127
joining co-ignitions, 48–50
multi-column nodes, 126–127
Knowledge, local
gathered via long axons, 133
and information, 4, 24–25
at many localities, combined, 24–25
Koch, C., 7

L
Labeled lines, 43–44
and direction-coded cells, 44–46
messenger is the message, 43–44
and orientation-selective cells, 134
LaMantia, A., 105
Language, 39, 40, 41
Larkum, M. E., 6
Lashley, K. S., 37
Lateral geniculate nucleus (LGN), 66, 67, 75–77, 83, 109
input from, 66, 75, 109
L-cell, 152–156, 165, 167
directional specification of contour cell, 152
Learning, and seeing, 65
Legéndy, C. R., xix–xxi, 5, 7, 13–14, 17–18, 38, 58, 180
Lettvin, J. Y., 3–4
LGN, see Lateral geniculate nucleus
Link (and linkage) between nodes
active, 110–115, 149
becoming weak, 111–115, 119
contour link, 142–150, 152
cue for, 86, 180, 194
directional link, 56, 112, 175, 184
restoring when weakened, 117–119
triangle of, 176, 184, 199–206
closing, 184, 199–206
Livingstone, M. S., 31
Local knowledge, its relation to information, 24–25
Logistics, of local knowledge, 142, 211
Logothetis, N. K., 3
Long-term potentiation (LTP), 9, 10, 14–16, 28, 80, 86, 87, 116
Lorente de Nó, R., 37
Losonczy, A., xx, 10, 28, 106
Löwel, S., 103
LTP, *see* Long-term potentiation

**M**
Magee, J. C., xx, 10, 28, 106
Mainen, Z. F., 6
Marking
  - of synapse sets, 14–16, 86
    - dynamic, 86–88, 112, 117
Markram, H., xx, 15
Martinez-Conde, S., 72, 121
McCulloch, W. S., 11
Metric, and tracking, 115–116
Mode control mechanism, 151
Modes of operation, neurons, 164
Moving edge detectors, 3
Moving nodes, bridgehead maintenance of,
  - 129–137
    - bridgehead sideways spread, along contour,
      - 133–137
    - new neurons adding to drifting node,
      - 129–133
Müller, D., xx
Müller, J., 43
Multi-column nodes, kernel cell, 126–127
Myelin
  - myelinated fibers, 103, 106
  - nervous functions, 20–21

**N**
Net convexity detectors, 3
Net dimming detectors, 3
Network into localities, parsing, 25–26
Neuron(s)
  - axonal branching, cell body, 31
  - axons, arborize, 28–30
  - branching to column, axons, 32–33
  - cortical distance, column width, 30–31
  - ignitable groups of, 27, 32, 117,
    - 131, 179
  - ignitions, reach/don’t reach, 27–33
  - irregular firing, 7
  - operating modes of, 150–151
  - reaching neuron, synapses, 28
  - reliability of, 5, 6
  - retinotopic mapping, 31–32
  - sets, 77–78
    - notation using, 8, 77–78
Neuron groups, growth of
  - reconstitution during image drift, 24, 75
Neuron set, graphical notation of, 77–78
Neuronal response, issues concerning nature of, 5–10
  - cortical firing, 6–8
  - histograms, raster displays, 5–6
  - impressions gained from, 5–6
  - sensitivity of neurons
    - to synchronized volleys of spikes, 8–9
  - synaptic level, plastic change at, 9–10
Nevian, T., 6, 9
Newsome, W. T., 7
NMDA, *see* N-methyl D-aspartate
N-methyl D-aspartate (NMDA), 10
Noda, H., 20
Node(s)
  - base, 145, 147–148, 156–161
  - center, 124, 134, 135–137
  - and CO blobs, 31, 57, 105
  - fulcrum, 176, 177, 197–198, 206
  - growth of, 122–126, 133–134, 193
    - adding neurons during, 122–123, 126,
      - 133, 166
    - limiting the, 107, 133, 171
    - and reaching, 106, 121, 144, 149, 159,
      - 168, 194
  - maintenance of, 129–137
  - placement of, 106–107
  - and points, 48–50, 105
  - satellite nodes, 177, 183, 185, 194,
    - 200, 204
  - three-node ignitions, 183–184

**O**
One point, two side meet, 47–48
Open triangles, three-element problem,
  - 201–206
Operation nodes of neurons, 150–151
OR gate, 11, 88, 91
Orientation specificity, 53
Oshima, T., 7
Overwhelming odds principle, 35

**P**
Palm, G., xix, xxi, 13, 18, 27
Parallel processing, 40
Parsing, 25–26, 184
  - network into localities, 25–26
Peer input division, 95
Perkel, D. H., 7, 19
Phosphenes, 30, 57
Piper, M., 77
Pitts, W., 11
Plastic change, 9–10
Point skeleton, 52–53, 55–56
Points, and nodes, 48–50, 105
Poisson surprise scan, 13–14
Polygon graphics, 3D extension, 59
224

Pool
euron, 9, 12, 24, 40, 43–44, 50, 52, 76, 174
synapse, 9, 76–77, 97
Prime mover
contour string, 67–68
network, 35–37
self-igniting cell assembly, 37, 109–110
Proximity-coded cells, 49
Purves, D., 105

Q
Quadrangle, point skeleton of, 52

R
Rall, W., 6
Ramón y Cajal, S., 104
Rapoport, A., 17
Raster displays, histograms
impressions gained from, 5–6
Ratliff, F., 72, 121
R-cells, 152–156, 160, 167
directional specification of contour
cell, 152
Reaching
between columns, 57, 106
within columns, 57
between nodes, 107–108, 123, 178
bidirectional, 149, 160, 165, 196
number of synapses needed, 28
and rich branching of neurons, 27
Receptive field
classical, 4, 54
complex cell, 88
simple cell, 68, 79, 91, 98–99
subliminal, 76
Recording, 20, 75, 84, 123, 148
Recurrent collaterals, cell body, 31
Refractory period, 18–19, 52, 67, 111, 148, 196
Relational firing, 43–59
complex shape broadcasting, 54–57
confirmation loops
epochs on high Poisson surprise, 58–59
contour cell, 51–54
3D extension
of polygon graphics, 59
direction-coded cells, 44–45, 51–54
distributed knowledge, 59
kernel cell
horizontal ignition, 50
used in joining co-ignitions, shared
pints, 48–50
vertical ignition, 50
labeled lines, 43–44
retinotopy, connectivity role of, 57–58
shape broadcasting, 43–59
two cell groups broadcasting relation,
46–47
visual sentence
communication, triangular shape,
50–51
carrying, two sides meet in one point,
47–48
Relations, 39–41, 59, 80, 115–116, 143
Relative direction, 43–44, 46–47, 53, 179, 194,
199, 207
Remy, S., xx, 9–10, 28, 106
Retinal image, drift of, 71–73
fixation period, tracking period, 72–73
fixation word, 72
tracking, joining sentence, nouns used
in, 71
Retinotopic mapping, 31–32
connectivity role, 57–58
and reaching, 31
Reverse engineering, brain modeling, 26
Riggs, L. A., 72, 121
Rotation
sensitivity to, 55
three-dimensional, 55, 116

S
Salcman, M., xx–xxi, 7, 13–14, 38, 58
Same contours
using existing links, make new links on,
175–198
next node on contour, extend long link to,
183–198
using two links to third link, 175–198
three-node ignition, 183–184
Schmidt, E. M., 30, 57
Schmidt, K. E., 103
Schüz, A., 27, 106
Scient object, 25, 26
Scott, A., 18
Second enable, 146–148, 155–159, 161–162,
168, 173
Sejnowski, T. J., 6
Self-ignition
charge leakage into cells, 37
networks, 109–110
on a random schedule, 113, 166
self ignition power, see Confirmation loops
and tracking, 110, 111
Self-organization, 15
Sending end, surprising signal, 35–37
Index

225

Statistical engine, 151
Statistical inference, 23–26
  brain modeling, reverse engineering, 26
  fundamental law of brain theory, 25
  local knowledge
    its relation to information, 24–25
    parsing, network into localities, 25–26
    spike coincidence interpreted
      in terms of surprise, 24
STDP, see Spike-timing-dependent plasticity
Stepanyants, A., 29–30
Stettler, D. D., xx, 103–104
Stevens, C. F., 7
STP, see Short-term potentiation
Stria of Gennari, 103–104, 106–108, 144
Striate cortex, 103
Subliminal receptive field, 76
Summation interval, 18–19, 69
Suppressing tracer waves, 171–172
Surprise, 23–26
  and confirmation loops, 35
  and cross-potentiation, 76–77, 78, 84
  and meaningful events of firing, 66
  principle of overwhelming odds, 35, 211
  and statistical significance, 23, 38
  surprising events, neuronal input stream,
    12–13
  surprising multi-neuronal events, 14
  See also Statistical inference
Sustained contrast detectors, 3
Synapse
  colonies, 76
  modification, 65
  number per neuron, 28, 84
    and labeled lines, 43, 76, 154
  pools, 9, 76–77, 97
  reaching neuron, 28
  sets, 9, 14–16, 77–84
    dynamic marking of, 86
    graphical notation of, 77–78
    marking of, 14–16, 24, 27, 86–87
    notation using, 9, 77–78, 87, 157
  synapse sets, LTP, 14–16
  trigger, 77–80, 83–84, 94, 143
Synaptic interaction during tracer runs and
  linkup, 156–161
Synaptic level, plastic change at, 9–10
Synchronized one-spike ignition, 18–19
Synchronized volleys spikes, sensitivity of
  neurons, 8–9
Syntax, 39–40
System clock, logic network, 11–12, 17
Szentágothai, J., 104

Sentences
  view, time-linked ignitions, 40
  visual, 47–48, 50–51, 55, 71, 108
Seriés, P., 4, 45
Shadlen, M. N., 7
Shadow tracking, 91–92
Shannon, C. E., 13, 24
Shape
  broadcasting, time-linked ignitions, 43–59
  See also Relational firing
  perception, 3, 71
  polygonal, 47, 52, 54, 93
  triangular, 47, 48, 50–51
Shared nouns, joining sentences, 40–41
Shared points, joining co-ignitions, 48–50
Sheinberg, D. L., 3
Shkolnik-Yarros, E. G., 104, 108
Short-term learning, seeing viewed as, 65
Short-term potentiation (STP), 9, 28
Simple cell/Simple cell theory, 75–84
  contour wave, 65, 76, 79–84
  corner-supporting, 94–98, 107
  nascent operation, 94, 95, 96
  steady-state operation, 97
  cross-potentiation
    synapse pool changing effect, 76–78
    deducing LGN input, link up fast, 75
drome-selectivity need in, 66
neuron set, synapse set
  graphical notation of, 77–78
  simple cell preparation role
    in contour wave, 79–84
  warm up of, 76, 79, 91–92, 93–94,
    129, 178
  contour wave approach, 76
Single-unit recording, ignition, 20
Slow propagation, problem of, 103
Smaller shapes all-to-all linkup
  nodes, indiscriminate linkup of, 207–209
  utilizing chain ignitions, 207–209
Softky, W. R., 7
Song, S., 15
Speed-up, nodes linked by Gennari
  fibers, 104
Sperry R. W., 116
Spike coincidence interpretation, surprise, 24
Spike rate, average, 4, 14
Spike-timing-dependent plasticity (STDP), 15
Spike train, 7, 9, 12–14, 46, 58–59, 83,
  123–125, 184
Spruston, N., xx, 9–10, 28, 106
Starr, P. A., 13
Index

T
Temporal binding, 39
Temporal focusing effect, 18
Three-element problem, open triangle, 201–206
Three-node ignition, 176–177
Threshold, 9, 18–19, 28, 36, 69, 152
Time-linked ignitions
   communicating relatedness through, 39–41
   joining sentences, shared nouns, 40–41
   sentences view, 40
   See also Relational firing
Tomasek, J., 151
Tracer init volley, 150
Tracer wave
   arrival volley, 147–149, 160, 163
   initialization (tracer init), 146, 157, 159,
      163, 167
   second enable, 146–148, 155–157,
      161–162, 167, 168
   surprise requirement, 146–147
Tracking
   and complex cells, 89
   complex cell theory, 85–86, See also
      Complex cell theory
   and dynamic marking, 206
   fixation period, 72–73
   joining sentence nouns used in, 71
   of nouns, 71, 129
   and self-ignitions, 110–111
   shadow, 91–92
Transitive property, same-contour relation, 199
Triangle
   broadcasting a triangular shape, 51
   of links, 176, 199–206
   closing a triangle, 199–201
   open triangles, three-element problem,
      201–206
   spotting an open triangle, 201–206
Triangular shape, visual sentence communication, 50–51
Trigger synapses, 80
Triple (three-node) ignitions
   cue for discontinuing, 194, 196
Ts’o, D. Y., 4, 19, 21, 54, 108, 190
Two cell groups broadcasting relation, 46–47
Two side meet, one point, 47–48
U
Understudy processing cell, before join node,
   164–165
V
V1 (visual area 1), 32, 57, 103, 106, 179
V2 (visual area 2), 32, 50–51, 57, 106,
   108, 179
Valverde, F., 104, 108
Viana, F., 43
Vic-D’Azyr, F., 103
Visible lines, 52–53
Visual integration, fiber requirement, 105–106
Visual sentence communication, 50–51
Visual sentence conveyance, 47–48
Volleys
   arrival volley, 147–148, 160, 171
   echolocation, 149–150, 161, 163, 171, 183
   omnidirectional, 156, 177–178, 180–181,
      183, 186, 188, 191, 195, 200,
      201, 208
   and surprise, 28, 77, 87, 96
   tracer initialization (tracer init), 146, 155,
      157, 162, 163, 167, 167
von Bonin, G., 103
von der Malsburg, C., xix, 24, 39
von Ehrenfels, C., 69
von Neumann, J., 11
W
Warm up, contour wave approach, 76
Wave transmitting state, 80–82, 97
Weak link detecting, 111–115
Wertheimer, M., 69
Westheimer, G., 31
Wickelgren, W. A., xix, 18
Z
Zador, A.M., 7
Zhaoping Li, 4