

# Subject Index

- A-not-B task, 314–318, 392, 404
    - exploration, 315–317
  - Abstraction, 224, 385
  - Accessibility, 381
  - Accommodation, 66–69, 112
    - channel, 36
  - act, 46, 50, 55, 459
  - act\_avg, 285, 459
  - act\_dif, 459
  - act\_eq, 46, 50, 53, 459
  - act\_fun, 51, 53, 460
  - act\_gain, 46, 460
  - act\_m, 156, 157, 459
  - act\_p, 156, 157, 191, 459
  - Action potential, *see* Spike
  - Actions, 195–197, 307, 405
  - Activation, 24
    - based processing, 380–384, 392–395
      - see also* Active memory, Frontal cortex
    - equilibrium, 56
    - expected level (alpha), 43
    - function, 24, 40–42, 45–48
      - derivative, 160, 163, 164
      - exploration, 49–54
    - graded, 15
    - in learning, 125
    - in memory, *see* Active memory
    - linear, 54, 152, 154
    - phases, 156–157, 162–163, 167–170, 177, 198–199, 310
    - point neuron, 24, 38, 154
    - rate coded, 46–48
    - residual, 262, 263, 267, 298, 299
    - sigmoid, logistic, 40, 42, 47, 48, 134, 154, 155
    - spreading, 216, 278, 300, 312
    - variable, *see* act
  - Activation based receptive field, 247–250
  - Active memory, 206, 210, 212, 214–217, 222, 223, 276, 277, 299–314, 320, 403
    - control, gating, 188–189, 277, 306–313, 382, 385, 392, 395, 406
    - exploration, 301–305, 310–312
    - noise, 302–303
    - representations, 382–383, 395
    - resetting, 311
    - updating, 303–313
      - see also* Activation-based processing, Frontal cortex, Sequence learning
  - Actor, *see* Temporal differences learning (TD)
  - Adaptive critic (AC), *see* Temporal differences learning (TD)
  - Aggregation, of statistics, 432, 442, 449
  - Agnosia, 233, 265
  - Alexia, *see* Dyslexia
  - Algorithm, 115
    - backpropagation, *see* Backpropagation
  - BCM, 144–145
  - Boltzmann machine, 106, 166
  - CHL, 165–166, 168
  - clustering, 143
  - competitive learning, 143
  - CPCA, *see* Conditional PCA
  - DBM, 165–166, 168
  - delta rule, *see* Delta rule
  - generative models, 145
  - GeneRec, *see* GeneRec
  - GRAIN, 10
  - Hebbian, *see* Hebbian learning
  - Hopfield network, 106
  - IAC, 106
  - ICA, 145
  - Infomax, 144
  - Kohonen, 143
  - kWTA, *see* k-Winners-take-all
  - level of analysis, 4
  - MDL, 144
  - mean field learning, 166
  - Oja, 124–125, 128
  - PCA, *see* Principal components analysis
  - recirculation, 162, 163
  - RL, *see* Reinforcement learning
  - SRN, *see* Sequence learning
  - TD, *see* Temporal differences learning
  - Winner-take-all (WTA), 105, 143, 176
- Alpha,  $\alpha$  (expected activity level), 43, 133–135
  - alpha\_k, 43
  - Alternative uses task, 405
  - Ambiguous stimuli, 17, 92, 109, 111, 158, 189, 192, 279, 297, 368, 369, 373
  - Amnesia, 289–290
  - AMPA, 31

- Amplification, 85, 89–92, 210  
 exploration, 89–92
- Amygdala, 212, 416
- Annealing schedule, 109
- Answer key, 20
- Anti-saccade task, 404
- Aphasia, 326–327
- Apply button, 50, 430
- Artificial intelligence, 4
- Artificial neural networks (ANNs), 40
- Associative  
 learning, 11  
 LTP/D, 115–118, 129–130,  
 168–170, 175
- Attention, 17, 211, 227–228, 257–272,  
 407  
 exploration, 261–272  
 object-based, 227, 260, 267–268,  
 272  
 spatial, 221, 227, 234, 257–272  
 thalamic, 212, 230, 269
- Attractor, 86, 92–93, 108, 111, 210, 333  
 basin, 86, 300, 303  
 effects on generalization, 178, 180  
 in active memory, 299  
 in learning, 170  
 in priming, 352
- Automatic processing, 214, 217–218,  
 381, 385–387, 408–409
- Axon, 27, 29
- Bálint's syndrome, 260  
 exploration, 265–266, 271
- Backpropagation, 9, 147, 158–162, 184,  
 192  
 biological implausibility, 9, 162,  
 164  
 derivation, 160–161  
 learning rule, 159  
 temporal, 196  
*see also* Task learning,  
 Error-driven learning,  
 Backpropagation, GeneRec
- Basal ganglia, 72, 193–195, 213–214,  
 307, 310, 382, 385  
 Parkinson's disease, 213, 385, 393
- Basin of attractor, 86, 300, 303
- Basis functions, 16
- Basket neuron, 72
- Batch run, 140
- Bayes formula, 61
- Bayesian analysis, 10, 58–65
- BCM algorithm, 144–145
- Belief (probability), 59
- $\beta$ , *see* bias . wt
- Bias  
 in learning, 118–121, 134,  
 175–178, 180–182, 184, 192  
 input, 42, 44  
 input in kWTA, 101  
 weights, 42, 44, 80–81  
 learning, 152–155, 159, 163  
 variable, *see* bias . wt
- Bias-variance dilemma, 120
- bias . wt, 44, 157, 459
- Bidirectional connectivity, 17, 72,  
 85–93, 145, 177, 210, 288,  
 329  
 and parallel processing, 331  
 attractors, 352  
 effects on generalization, 178, 180  
 in active memory, 215, 299,  
 303–306, 308, 310, 314, 315,  
 317  
 in attention, 211, 268  
 in error-driven learning, 163,  
 166–167  
 in pattern completion, 290  
*see also* Lateral connectivity
- Binarization, 81
- Binding  
 hippocampal, 276, 289, 297,  
 408–409  
 problem, 220–222, 242–243, 255,  
 269
- Binding problem, 403
- Biology  
 basis of cognition, 3, 6, 9, 177, 379  
 conditioning, 193–195  
 cortex, 72–75  
 detailed models, 5, 9–10  
 frontal cortex, 305–306, 384–385  
 hippocampus, 287–289  
 implausibility of backpropagation,  
 9, 162, 164  
 language, 325–327  
 learning, 115–118, 129–130,  
 168–170, 175  
 level of analysis, 6  
 neurons, *see* Neuron  
 visual system, 228–234
- Blending in one-to-many mappings,  
 190, 191, 279, 280, 298
- Blobs, 231–232
- Boltzmann machine, 106, 166  
 deterministic (DBM), 165–166,  
 168
- Bootstrapping, 16, 18, 84, 89–93, 210  
 exploration, 89–92
- Bottom-up  
 approach, 5–6  
 processing, 17, 75–85, 162
- Brain damage, 12  
 agnosia, 233  
 aphasia, 326–327  
 basal ganglia, 385  
 comparing patient and normal  
 data, 264–265  
 dyslexia, *see* Dyslexia  
 frontal cortex, 189, 194, 305, 314,  
 320, 375, 381, 391, 393–395,  
 399, 401, 403–408  
 generalized effects of, 264–265  
 hippocampus, 278, 289–290, 297  
 inferotemporal cortex, 233  
 parietal, 233–234, 258, 260,  
 264–266  
 Parkinson's disease, 213, 385, 393  
 schizophrenia, 306, 387, 391  
 semantic deficits, 358–359
- Broca's area, 326–327
- Button (PDP++), 429  
 Apply, 50, 430  
 Cancel, 52, 430  
 Clear, 51  
 Init, 51  
 NewInit, 58, 150  
 Ok, 430  
 ReInit, 58  
 Revert, 50, 430  
 Run, 50, 58  
 Step, 56, 58
- Button, synaptic, 29
- Cable properties, 27
- Calcium, 31, 32, 35, 36, 45  
 in learning, 116

- Cancel button, 52, 430
- Canonical representations, 209, 223, 241–242, 317
- Catastrophic interference, 219, 276, 283–285
- Categories, 15, 76, 405
- Categorization, dynamic, 380–381, 392–403, 407
- Cell assembly, 8
- Center surround receptive field, 229–230
- Central processing unit (CPU), 24
- Cerebellum, 213, 214, 416
- Chain rule, 152, 158
- Chandelier neuron, 72
- Channels, 27
  - accommodation, 36
  - current equation, 37
  - excitatory, 35, 37, 39
  - inhibitory, 36, 37, 39
  - leak, 36, 37, 39
  - NMDA, 36
  - voltage-gated, 28, 35, 36
- Charge, 32
- Chloride, 32, 35, 36, 45
- Cingulate cortex, 212, 384, 406, 420
- Clamping inputs, 56, 86
- Cleanup, 333
- Clear button, 51
- Cluster plot, 77–79, 81–82, 84–85, 185, 192, 334, 362–363, 373–375
- Clustering algorithms, 143
- cnt\_sum\_se, 179
- Coarse coding, 16, 82, 231
- Cognitive
  - architecture, 205, 214–219, 408–409
  - level of analysis, 6
  - neuroscience, 1
  - psychology, 4, 8
  - science, 4
- Combinatorial representations, 139, 178, 342
- Competition, 11, 17–18, 94–95, 139, 177, 352, 357, 404
  - in attention, 17, 268
  - in learning, 137, 143, 175–176, 180, 184, 192*see also* Inhibition, k-Winners-take-all (kWTA)
  - Competitive learning, 105, 143
- Complete serial compound (CSC), 199, 200, 202, 309
- Completion, pattern, 85, 87–89, 93, 210, 290, 292, 296, 297, 319, 333
- Complexity, 4, 12, 13, 417–418, 422–423
- Computational
  - cognitive neuroscience, 1, 8–10
  - level of analysis, 4
  - modeling
    - challenges, 13–14, 413–421
    - contributions, 3–4, 12–13, 421–424
  - compute\_i, 464
- Computer metaphor, 4, 8, 15, 18, 24–25, 209, 217–218, 223, 324
  - see also* Production systems, Symbolic models
- Concentration gradient, 34
- Conditional PCA (CPCA), 116, 125–137, 143–145, 147–150, 155, 168, 171, 176–178, 181
  - biology, 129–130, 175
  - derivation, 128–129
  - exploration, 130–132
  - learning rule, 127, 128
  - vs. PCA, 128, 131*see also* Model learning, Hebbian learning, Principal components analysis (PCA)
  - Conditional probability, 60, 129
    - as correlation, 128, 133
  - Conditioning, 193–195
    - exploration, 199–202
    - second order, 195, 201*see also* Reinforcement learning, Temporal differences learning (TD)
    - Conductance, 33
    - Cones, 228
    - Conflict, 406
    - Conjunctive representations, 220–221, 223, 276, 291–292, 297, 342–343, 345, 347
    - Connection, 431, 438, 456
    - Connectionism, 9
    - Connectivity
      - bidirectional, *see* Bidirectional connectivity
      - feedforward, 75–85
      - lateral, *see* Lateral connectivity
      - unidirectional, 75–85
      - wrap-around, 236
    - Consciousness, 14–15, 18, 218–219, 381, 418, 419
    - Consolidation of memories, 289–290
    - Consonants, 328–329
    - ConSpec, 431, 439, 440, 457
    - Constraint satisfaction, 16, 72, 106–112, 145, 151, 210, 268, 367, 375–376
      - exploration, 110–112
    - Content-specific
      - processing, 209–210
      - representations, 25, 209–210, 219–224, 324, 325, 380
    - Context, 187, 284, 307
      - for sequences, *see* Sequence learning
      - internal, 210
      - sensitivity, 24
    - Continua, 16
      - in time, 186–187
    - Continuous performance tasks (CPT), 303, 304, 312
    - Contrast enhancement
      - retinal, 228
      - weights, 132–137, 139, 141, 150
    - Contrastive Hebbian learning (CHL), 165–166, 168
      - see also* GeneRec
    - Control
      - of active memory, 188–189, 277, 306–313, 382, 385, 392, 395, 406
      - of processing, 206, 214, 217–218, 381–382, 385–387, 403, 405–406, 408–409
    - Control panel, 49, 429, 430, 452–453
      - process, 58, 432
    - Controlled processing, 206, 214, 217–218, 381–382, 385–387, 403, 405–406, 408–409
      - see also* Frontal cortex, Active memory control
    - Convolution, 47
    - Cooperation, 95

- Correlations, 121–124, 138, 234–235, 238, 240  
matrix, 123
- Cortex, 20, 71–75, 416  
areas, 72, 74  
cingulate, 212, 384, 406, 420  
frontal, *see* Frontal cortex  
functional layers, 72–75  
in memory, 276–287, 298–303  
inferotemporal, 232, 233, 241, 245, 305  
lobes, 211–212, 228  
neuron  
tuning curves, 82  
types, 72  
occipital, 212, 214, 228, 230, 326, 327  
parietal, *see* Parietal cortex  
posterior, 205, 206, 214–217, 222, 276, 277, 381, 383, 405  
prefrontal, *see* Frontal cortex  
six-layered structure, 72–75  
specializations, 211–212, 214–217  
temporal, 212, 214, 228, 326, 327  
unity of, 72, 276, 277
- Cosine distance measure, 337
- Credit assignment, 151  
temporal, 193
- Cross entropy error (CE), 154–155, 160, 161, 196
- CSS (script language), 429, 443–447, 450–453
- Cued recall, 88, 290, 292, 319
- Cumulative research, 14, 419
- Current, 32, 34, 37
- Cycles, 46, 50, 56
- da, 56, 459, 465
- Dead units, 140
- Decision making, 379  
*see also* Higher-level cognition
- Declarative representations, 218–219, 276, 381
- Dedicated  
processing, 209–210  
representations, 25, 209–210, 219–224, 324, 325, 380
- Deep dyslexia, 331–341
- Deep networks, 181–186  
exploration, 183–186
- Degradation, graceful, 16
- Delayed response task, 305
- delta,  $\delta$ , 159–165, 196–198, 309
- Delta rule, 147, 150–158  
derivation, 152  
generalized, *see* Backpropagation  
learning rule, 151  
vs. temporal differences learning, 199  
*see also* Task learning,  
Error-driven learning,  
Backpropagation, GeneRec
- Dendrites, 26, 31–32  
spine, 29  
tree, 42, 45  
voltage-gated channels, 45
- Depolarization, 35
- Depression, synaptic, 115–118, 129–130, 168–170, 175
- Derivative, 38, 151–152, 160  
chain rule, 152, 158  
implicit, 163, 164
- Descriptive theories, 11, 417
- Detector, 23–27, 54–58, 69, 207  
as hypothesis testing, 58–65  
exploration, 54–58  
function vs. content, 24  
multiple roles, 84  
threshold, 26
- Deterministic Boltzmann machine (DBM), 165–166, 168  
*see also* GeneRec
- Deterministic processing, 47, 53, 166
- Development, 18, 120, 314–315, 317, 382
- Difference of Gaussians, 229
- Diffusion, 27, 33–34
- Digit recognition, 54–58, 76–85
- Discounting of future rewards, 195
- Discrete representations, 14, 383
- Disengage deficit, 260, 264–266, 268, 317
- Distance matrix, 77
- Distinctions, emphasizing and deemphasizing, 73, 75–79, 81–82, 207, 227–228, 241–256
- Distributed representations, 9, 11, 82–85, 90–92, 143, 177, 214, 216, 219–220, 223, 224, 227, 325, 366–367, 375  
combinatorial, 139, 178, 342  
exploration, 84–85, 90–92  
large scale, 208–209  
lexicon, 323–325, 329  
processing and memory, 206  
semantics, 358–360, 362, 364, 365  
*see also* Sparse distributed representations
- div\_gp\_n, 43, 458
- DNA, 18
- Dopamine, 117, 193–195, 214, 306–310, 387, 396
- Dot product distance measure, 337
- Dreams, 381
- Driving potential, 34
- dt\_net, 44, 461
- dt\_vm, 37, 45, 391, 461
- dur, 46, 460
- dwt, 123, 456
- Dynamic categorization, 380–381, 392–403, 407  
exploration, 397–402
- Dynamic principles, 206, 210–211
- Dynamic range, 132
- Dyslexia, 324, 326, 331–341  
deep, 331–341  
exploration, 335–341  
phonological, 331–333, 340  
surface, 331–333, 335–336, 338–339
- e\_rev, 45, 50, 52, 461
- Edge detectors, 230–232, 234–235, 238–240, 245
- Edit dialogs, 50, 430
- Effective weight value, 134
- Eigenvector, 124
- Electricity, 32–33
- Electrophysiology, 27, 32–40  
recording, 305, 384, 403
- Emergent phenomena, 3–4, 14, 40, 211, 218–219, 257, 325, 382, 384, 419  
*see also* Reconstructionism
- Encoding, memory, 290
- End stopping, 245

- Energy function, 106–107
- Entropy, 108, 154
- Environment, 55, 428, 431–432, 440–442, 450, 451
  - ScriptEnv, 191
- Environment, regularities, structure, 118, 324, 330–331, 341–342, 349–358, 420–421
- Environmental dependency syndrome, 405
- EnviroView, 55, 428, 431
- Epilepsy, 89, 99
- Episodic memory, 212, 276, 289, 297
- Epoch, 131, 139, 428
- EpochProcess, 428, 432, 442, 447, 449, 465
- Epsilon ( $\epsilon$ ), *see* lrate
- EPSP, 31
- eq\_gain, 46, 460
- Equilibrium
  - activations, 56
  - membrane potential, 38–40, 65
  - potential, 34
  - weight, 124, 129
- err, 176, 457
- Error
  - cross entropy (CE), 154–155, 160, 161, 196
  - delta,  $\delta$ , 159–165, 196–198, 309
  - measure, 149, 154, 179, 191, 196
  - minimizing, 151–152
  - signals, 8, 147–148, 162–163, 165, 167–168, 406, 420
    - see also* Phases of error-driven learning
  - summed squared (SSE), 149–151, 160, 196
- Error-driven learning, 116, 147–172, 176–178, 297
  - limitations, 157, 173–175, 182, 184
  - vs. Hebbian, 173–175
    - see also* Task learning, Delta rule, Backpropagation, GeneRec
- Euclidean distance, 77
- Event, 55, 428, 431
- Event related potentials (ERP), 168
- EventSpec, 428, 432
- Evolution, 17, 94–95, 119, 120, 166, 326
- Exceptions, 324, 330–331, 341–342, 349–358
  - regularities in, 331, 341
- Excitation, 31
  - and inhibition, separation, 32, 41
  - inputs, 31, 65
  - net input, 41–45
  - synaptic input channel, 35, 37, 39
- Excitatory neuron, 32, 41, 72
- Executive control, 206, 214, 217–218, 381–382, 385–387, 403, 405–406, 408–409
- Exiting from simulation, 54
- Expectation
  - in infant testing, 314–316
  - in learning, 156, 167–168
    - see also* Phases of error-driven learning
- Explanatory theories, 11, 417
- Explicit representations, 189, 218–219
- Explorations, 1, 20
  - installing, 427
    - see also* Projects
- ext, 86, 459
- External input, 86
- Extinction
  - in attention, 266
  - in conditioning, 193, 201
- Extracellular space, 35
- Familiarity, 282, 319
- Family trees task, 182–186
- Fatigue, neural, 66–69, 112
- Feature-based representations, *see* Distributed representations
- Feedback inhibition, 93–100
- Feedforward
  - connectivity, 75–85
  - inhibition, 93–100
- Feedforward connectivity, 72
- Fick’s first law, 34
- Finite state automaton (FSA), 189–193
- Flexibility, 380, 403–404
  - vs. specialization, 209, 219
- Fluency, 403, 405
- fm\_hid, 188
- fm\_prv, 188
- fMRI, 1, 208, 306, 312, 325, 384, 419
- Fovea, 228, 231
- Fractal, 7, 8, 208, 416
- Free energy, 108
- Free recall, 319
- Frequency-based probabilities, 60
- Frontal cortex, 14, 193–195, 205, 206, 212, 214–218, 222, 223, 277, 300, 305–314, 319, 320, 325, 381–392, 408–409
  - biology, 305–306, 384–385
  - context representations, 189, 307
  - damage, 189, 194, 305, 314, 320, 375, 381, 391, 393–395, 399, 401, 403–408
  - exploration, 310–312, 315–317, 388–391, 397–402
  - in language, 326, 327
  - in memory, *see* Active memory
  - in sequences, 189
  - representations, 382–383, 395
    - see also* Sequence learning
- g\_bar, 45, 50–53, 461
- GABA, 31, 72
- Gain
  - activation, 46, 48, 92, 387
  - weight, 134–135
- Ganglion retinal neurons, 229
- Gating, 188–189, 277, 306–313, 382, 385, 392, 395, 406
- Gaze, 314–316
- Generalization, 83, 178–181, 224, 243, 255–256, 324, 340, 342, 347–349, 375, 420–421
  - and simplicity, 120
  - exploration, 179–181
  - of invariance mapping, 254
  - statistic, 180
- Generalized delta rule, *see* Backpropagation
- Generative models, 145
- Generativity, 224
- GeneRec, 10, 148, 162–171, 176–178
  - biology, 166–170, 175
  - derivation, 163–165
  - exploration, 170–171
  - learning rule, 163
  - phases, 156–157, 162–163, 167–170, 177, 198–199, 310
  - relation CHL, DBM, 165–166

- see also* Task learning,  
 Error-driven learning,  
 Backpropagation,  
 Recirculation  
 Genetic constraints, 18, 119, 177, 314,  
 326  
 Geons, 256  
 Global maxima/minima, 108  
 Glutamate, 31, 35, 72  
     metabotropic receptors, 117  
 Goals, 380–383, 403, 405–407  
 Goodness, 108  
 Graceful degradation, 16, 66  
 Gradedness, 15–16, 66, 317  
     in learning, 18  
 Gradient descent, 151–152  
     *see also* Error-driven learning,  
     Task learning, Delta rule,  
     Backpropagation, GeneRec  
 GRAIN model, 10  
 Grammar, 186, 366  
     finite state, Reber, 189–193  
     *see also* Syntax  
 Grandmother cell, 82  
 GraphLog, 50, 56, 429, 433, 443  
     clearing, 51  
     number viewing, 50  
 GridLog, 80, 82, 86, 91, 316, 429,  
 433, 448  
  
 Hard clamping, 88  
 Harmony, 107–112  
 hebb, 176, 179, 183, 286, 457  
 Hebbian learning, 8, 9, 11, 115–150,  
 157, 171, 176–178, 181, 184,  
 192, 290, 316, 352  
     exploration, 130–132  
     limitations, 149–150, 173–175,  
     184  
     normalization, 124–125, 128  
     vs. error-driven, 173–175  
     *see also* Model learning, Principal  
     components analysis (PCA),  
     Conditional PCA  
 Hemispatial neglect, 233–234, 260,  
 264–266  
     exploration, 264–266  
 Heterarchical representations, 125–127  
 Hidden  
     cortical area, 74  
     layer, 72–75  
         in learning, 158  
         *see also* Transformations  
     layers, multiple, 181–186  
 Hierarchical representations, 125–127,  
 206–210, 212, 227, 242–256,  
 343  
     exploration, 246–255  
     of goals, 382  
 Higher-level association areas, 208  
 Higher-level cognition, 313, 379–410,  
 421  
 Higher-order representations, 302–303  
 Hippocampus, 14, 205, 206, 212,  
 214–217, 219, 223, 276–277,  
 287–298, 318–320, 325  
     binding, 276, 289, 297, 408–409  
     biology, 287–289  
     damage, 278, 289–290, 297  
     exploration, 293–296  
     role in spatial memory, 276, 297  
 Homunculus, 12, 217, 240, 307, 317,  
 382  
 Hopfield networks, 106  
 Hypercolumn, 232, 236  
 Hypothesis testing, 58  
     in learning, 18  
     null hypothesis, 46  
 Hysteresis, 66–69, 198  
  
 I<sub>net</sub>, 37, 50, 459  
 Iconifying windows, 50  
 ID/ED task, 393–403  
     exploration, 397–402  
     *see also* Dynamic categorization,  
     Wisconsin card sorting task  
     (WCST)  
 Ill-posed problems, 118  
 Imagery, 85  
 Imaging, 1, 208, 306, 312, 325, 384, 419  
 Implementational level of analysis, 4  
 Implicit  
     expectations, 167–168  
     learning, 189–190  
     representations, 218–219  
 Independent components analysis  
     (ICA), 145  
 Indeterminacy, 13, 418  
  
 Inference, 216, 300–301  
 Inferotemporal cortex, 232, 233, 241,  
 245, 305  
     damage, 233  
 Inflectional morphology, 324, 350  
     *see also* Past tense  
 Information maximization, 144  
 Inhibition, 17, 31, 72, 93–106, 317,  
 403–404  
     and excitation, separation, 32, 41,  
     71, 72  
     benefits of, 94–95  
     enabling modulatory effects, 271  
     exploration, 95–100  
     feedback, 93–100  
     feedforward, 93–100  
     function, 94, 100  
     in attention, 17, 268  
     in constraint satisfaction, 109  
     in perseveration, 314  
     inputs, 31, 65  
     of inhibition, 96  
     of return, 266–267  
     shunting, 36  
     synaptic input channel, 36, 37, 39  
     thermostat model, 93, 94  
     *see also* Competition,  
     k-Winners-take-all (kWTA)  
 Inhibitory neuron, 32, 41, 72, 93  
 Init button, 51  
 Inner product distance measure, 337  
 Input-output mapping, 147–148, 158  
 Inputs, 23, 26, 66  
     clamping, 56  
     cortical area, 74  
     excitatory, 31  
     inhibitory, 31  
     layer, 72–75  
     scaling, 44  
     weighting, 63  
 Insight problems, 158  
 Installing the software, 427  
 Integrate-and-fire model, 23, 26  
 Integration  
     in learning, 119, 206, 214–217,  
     283, 382  
     neural, 26  
     of inputs, 63

- Interactive activation and competition (IAC), 106
- Interactive approach, 5–6
- Interactivity, *see* Bidirectional connectivity
- Interblobs, 231
- Interference, 206, 246, 254, 255, 282–284, 344, 385, 390  
catastrophic, 219, 276, 283–285  
exploration, 284–286, 293–296  
in active memory, 216, 277, 299–301, 305  
in hippocampus, 277, 284, 287, 292, 296
- Interleaved learning, 119, 206, 214–217, 283, 382
- Interneurons, 32, 41, 72, 93
- Interpretation, 207
- Introspection, 14
- Intuition, 16
- Invariance, 207  
location, 228, 233, 343, 345–347  
mapping, generalization, 254  
rotational, 233  
size, 228, 233  
spatial, 228, 233, 241–256  
exploration, 246–255
- Inversion, of sensory input, 118
- Ionotropic receptors, 30
- Ions, 27, 32  
calcium, 32, 35, 36, 45  
chloride, 32, 35, 36, 45  
potassium, 32, 35, 36, 45  
sodium, 32, 35, 45
- IPSP, 31
- Isolated representations, 216, 300, 303, 304, 385, 397
- Joint probability, 60
- k, 285, 387, 464
- k-Winners-take-all (kWTA), 94, 100–106, 177, 236, 387  
average-based, 102, 139  
exploration, 103–105  
in learning, 137, 143–145, 166, 175–176, 180, 184  
nested, 244, 246  
*see also* Competition, Inhibition
- Knowledge, *see* Representations  
real world, 209
- Kohonen networks, 105, 143, 236
- Language, 212, 218–219, 323–377  
aphasia, 326–327  
Broca's area, 326–327  
direct pathway, 330–333, 335–341  
distributed representations, *see*  
Distributed representations:  
lexicon, semantics  
dyslexia, *see* Dyslexia  
exceptions, 324, 330–331, 341–342, 349–358  
in higher-level cognition, 383  
indirect pathway, 330–333, 335–341  
inflectional morphology, 324, 350  
lexicon, 323  
orthographic representations, 324, 329–350  
overregularization, 324, 350–358  
past tense, 324, 350–358  
phonological representations, 324, 327–358  
reading, *see* Reading  
regularities, 118, 324, 330–331, 341–342, 349–358, 420–421  
semantic representations, 324–327, 329–341, 349–358, 365, 367–368  
syntax, 325–327, 365–376  
Wernicke's area, 326–327  
word frequency, 330–331
- Latent semantic analysis, 358–360  
exploration, 361–365
- Lateral connectivity, 85, 87–89, 288  
in active memory, 299, 304–306, 308, 310, 314, 315, 317  
in pattern completion, 290  
*see also* Bidirectional connectivity
- Layer  
hidden, 72–75  
input, 72–75  
output, 72–75
- Layer, 431, 437–439, 463  
number of units, 438
- LayerSpec, 431, 439, 440, 464
- Leabra, 11, 19, 42  
summary, 177–178
- leabra++, 427–434, 455–465  
installing, 427
- Leak current, 52, 57–58, 65, 81, 82, 88–93, 96, 98, 100, 101, 104, 105  
channel, 36, 37, 39
- Learning, 18–19, 382  
activation dynamics, 125  
associative, Hebbian, *see* Hebbian learning  
bias weights, 152–155, 159, 163  
biology, 115–118, 129–130, 168–170, 175  
conditioning, *see* Conditioning  
curve, 149  
delayed, *see* Reinforcement learning  
error-driven, *see* Error-driven learning  
expectation, 156, 167–168  
*see also* Phases of error-driven learning  
hidden layers, 158  
implicit, 189–190  
integrative, interleaved, 119, 206, 214–217, 283, 382  
model, *see* Model learning  
overview, 115–116  
phases, 156–157, 162–163, 167–170, 177, 198–199, 310  
positive feedback, 137  
rate, 123, 128, 131, 141, 214–215, 276–277, 286, 287  
parameter,  $\epsilon$ , *see* `lrRate`  
reinforcement, *see* Reinforcement learning  
self-organizing, 115, 127, 137–142  
separating, 206, 214–217  
sequences, *see* Sequence learning  
statistics, 119  
task, *see* Task learning  
temporal, *see* Temporal differences learning  
trial-and-error, 18
- Least mean squares (LMS), *see* Delta rule
- Lesions, *see* Brain damage
- Levels of analysis, 4–6

- Lexicon, 323, 330  
 LGN, 212, 228, 230  
 Likelihood, 61  
 Limbic system, 194, 212  
 Line detector, 121–122, 130–132,  
 135–142, 179–181  
 Linear  
   activation function, 54, 152, 154  
   weight value, 134  
 List learning, 282  
   AB–AC, 282–287  
   exploration, 284–286, 293–296  
   length, strength effects, 319  
 lmix, 176, 457  
 Local maxima/minima, 108  
 Localist representations, 9, 82–84, 86,  
 87, 95, 104, 105, 143, 183,  
 334, 369, 373, 417, 419  
   exploration, 84–85  
 Logic, 15, 65, 380  
 Logistic, 40, 42, 47, 48, 134, 154, 155  
 Logs (PDP++), 429, 433–434  
 Long-term depression (LTD), 115–118,  
 129–130, 168–170, 175  
 Long-term potentiation (LTP), 115–118,  
 129–130, 168–170, 175  
 Loop counter, 432  
 lrate, 123, 128, 131, 141, 160, 179,  
 214, 286, 457  
 Luce choice ratio, 58  
 Magnocellular, 230  
 Mapping  
   input-output, 147–148, 158  
   one-to-many, 190, 191, 279, 280,  
   298  
 Markov sequence, 187  
 Marr's levels of analysis, 4  
 Mean field learning, 166  
 Membrane  
   cable properties, 27  
   neural, 27  
   potential, 26, 38, 41  
   potential, computing, 37  
 Memory, 275–321  
   active, *see* Active memory  
   amnesia, 289–290  
   consolidation, 289–290  
   cortical, 276–287, 298–303  
   declarative, 276  
   distributed, 206  
   dual-process models, 319  
   embedded, 206  
   encoding, retrieval, 290  
   episodic, 212, 276, 289, 297  
   frontal, *see* Frontal cortex  
   hippocampus, *see* Hippocampus  
   multiple systems, 275, 318  
   priming, *see* Priming  
   procedural, 276, 277  
   recognition, 318–319  
   semantic, 276, 277, 280, 289  
   spatial, 276, 297  
 Mental (internal) models, 118–119, 140,  
 145, 234  
 Menus (PDP++), 429, 437  
 Metabotropic receptors, 30, 117  
 mGlu, 31  
 Microtubules, 30  
 Midpoint method, 165  
 Minimizing error, 151–152  
   *see also* Error-driven learning,  
   Task learning, Delta rule,  
   Backpropagation, GeneRec  
 Minimizing windows, 50  
 Minimum description length (MDL),  
 144  
 Minus phase, 156–157, 162–163,  
 167–170, 177, 198–199, 310  
 Mixtures of experts, 176  
 Model learning, 115, 118–146,  
 176–178, 277  
   exploration, 130–132  
   other approaches, 142–145  
   vs. task learning, 173–175  
   *see also* Hebbian learning,  
   Principal components  
   analysis (PCA), Conditional  
   PCA  
 Modulatory inputs, 271  
 Monitoring, 403, 406  
 MonitorStat, 433  
 Motor control, 213–214, 384, 385, 404  
 Mouse buttons  
   left, 50, 429, 431, 433  
   middle, 57, 431, 433, 438  
   right, 433  
 Multiple constraint satisfaction, 16, 72,  
 106–112, 145, 151, 210, 268,  
 367, 375–376  
 Mutual support, 85, 88, 210  
 Mutually exclusive hypotheses, 59  
 Myelin, 29  
 Nativism, 18, 120  
 Negative feedback loop, 93  
 Neglect, 233–234, 260, 264–266  
 Neighborhood, 341  
 Neocortex, *see* Cortex  
 net, 44, 50, 57, 459  
 Net current, 37  
 Net input, 40, 41, 154  
   computing, 42–45  
   time averaging, 43  
 Net potential, 34  
 NetView, 49, 428, 431, 437, 438  
   moving within, 441  
 Network, 71  
   semantic, 109  
 Network, 428, 431, 437, 438  
 Neurobiology, *see* Biology  
 Neuroimaging, 1, 208, 306, 312, 325,  
 384, 419  
 Neuromodulators, 117, 193, 298, 306,  
 312, 416  
   dopamine, 117, 193–195, 214,  
   306–310, 387, 396  
 Neuron, 23–70  
   axon, 27  
   basket, 72  
   cell body, 27  
   chandelier, 72  
   channels, 27  
   cortical, 72  
   dedicated processing, 25  
   detector model, *see* Detector  
   excitatory, 32, 41, 72  
   exploration, 49–58  
   inhibitory, 32, 41, 72  
   inputs, 16, 26, 66  
   integration, 26  
   membrane, 27  
   nucleus, 27  
   output, 26, 42  
   point, 24, 38, 154  
   pyramidal, 24, 72



- receptors, 26, 28–32, 46, 116–117, 228
- self-regulation, 66–69
- specialization of, 25
- spiny stellate, 72
- weights, 26
- Neuron doctrine, 8
- Neurotransmitters (NT), 28, 30–31
  - dopamine, 117, 193–195, 214, 306–310, 387, 396
  - GABA, 31, 36
  - glutamate, 31, 35
- NewInIt button, 58, 150
- NMDA, 31
  - channel, 36
  - mediated LTP/D, 115–118, 129–130, 168–170, 175
- Nodes of Ranvier, 29
- Noise
  - and active memory, 302–303, 383
  - implications for processing, 66
  - in constraint satisfaction, 108–109, 112, 237
  - in learning curves, 170
  - spike timing, 47
- noise\_var, 53, 303, 462
- Noisy X-over-X-plus-1 (Noisy XX1)
  - function, 47–48, 50, 53, 54
- Non-accidental properties, 256
- Nonlinear
  - activation, 40, 48, 92
  - bidirectionality effects, 92, 182
  - discriminations, 158, 297
- Normalization
  - activation parameters, 45
  - Hebbian learning, 124, 128
  - net input, 43
- Noun phrase, 366
- Null hypothesis, 46, 64
- Object recognition, 212, 227–228, 232–233, 241–257, 324, 343, 349
  - exploration, 246–255
- Object-based attention, 227, 260, 267–268, 272
- Objective function
  - model learning, 127
  - reinforcement learning, 195
  - task learning, 151
- Objective probabilities, 59, 62
- Objects (PDP++), 428
- Occipital cortex, 212, 214, 228, 230, 326, 327
  - see also* V1, V2, V4
- Ocular dominance columns, 231–232
- Ohm's law, 33, 37
- Oja's Hebbian learning rule, 124–125, 128
- Ok button, 430
- One-to-many mapping, 190, 191, 279, 280, 298
- One-to-one connectivity, 90
- Optimality approaches, 5
- Orthographic representations, 324, 329–350
- Outcome, as target state, 156, 167–168
  - see also* Phases of error-driven learning
- Output
  - cortical area, 74
  - layer, 72–75
  - neural, 23, 26, 42
  - rate code, 42
  - target, 148, 156
- Overregularization, 324, 350–358
  - exploration, 353–357
- Paired associates learning, 282
- Paired-pulse facilitation, 31
- Parallel distributed processing (PDP), 9, 15, 24
- Parallel search, 109
- Parameter
  - act\_fun, 51, 53, 460
  - act\_gain, 46, 460
  - alpha\_k, 43
  - compute\_i, 464
  - div\_gp\_n, 43, 458
  - dt\_net, 44, 461
  - dt\_vm, 37, 45, 391, 461
  - dur, 46, 460
  - e\_rev, 45, 50, 52, 461
  - eq\_gain, 46, 460
  - err, 176, 457
  - fm\_hid, 188
  - fm\_prv, 188
  - g\_bar, 45, 50–53, 461
  - hebb, 176, 179, 183, 286, 457
  - k, 285, 387, 464
  - lmix, 176, 457
  - lrate, 123, 128, 131, 141, 160, 179, 214, 286, 457
  - noise\_var, 53, 303, 462
  - normalized, 45
  - savg\_cor, 134, 136, 137, 141, 458
  - thr, 45, 46, 460
  - v\_bar, 45
  - v\_max, 46, 460
  - v\_rest, 45, 461
  - vs. variable, 428
  - wt\_gain, 134, 136, 137, 141, 150
  - wt\_off, 135–137, 141, 150
  - wt\_scale, 44, 286, 303, 304, 308, 457
  - wt\_sig, 134, 135, 457
- Parameter fitting, 13, 418
- Parietal cortex, 212, 214, 228, 233–234, 258, 260, 264–266, 326, 327
  - damage, 233–234, 258, 260, 264–266
  - exploration, 261–268
- Parkinson's disease, 213, 385, 393
- Parsimony, 12
  - in learning, 118–122, 144
- Parvocellular, 230
- Past tense, 324, 350–358
  - exploration, 353–357
- Pathways
  - specialized, 206–208, 211–212, 227–228, 323–324
- Patients, *see* Brain damage
- Pattern
  - associator, 148–150
  - completion, 85, 87–89, 93, 210, 290, 292, 296, 297, 319, 333
  - exploration, 88–89, 294–296
  - overlap, 83, 149, 216, 285, 286, 294, 301
  - separation, 276, 284, 286, 290–292, 296, 297
  - exploration, 294
- Pattern, 55, 428, 431
- PDP++, 427–434
  - installing, 427

- PDP++ Root, 49, 54, 58, 436, 444, 446
- PDPLog, 429, 433
- pdw, 456
- Perception, 212, 220–224, 227–273
- Perceptron, 8
- Perseveration, 314–317, 393–395, 401, 403–404, 407
- Phases of error-driven learning, 156–157, 162–163, 167–170, 177, 198–199, 310
- Phonological  
dyslexia, 331–333, 340  
loop, 383  
representations, 324, 327–358
- Photoreceptors, 228–229
- Phrase structure, 366
- Physical reductionism, 2–3
- Pixel, 7, 55, 77, 119, 121, 126, 138, 228, 234, 235, 237, 245, 254, 414
- Plus phase, 156–157, 162–163, 167–170, 177, 198–199, 310
- Point neuron, 24, 38, 154
- Positive feedback, 89–92  
in learning, 137
- Posner spatial cuing task, 17, 258
- Posterior (Bayesian), 61
- Posterior cortex, 205, 206, 214–217, 222, 276, 277, 381, 383, 405
- Postsynaptic, 28
- Potassium, 32, 35, 36, 45
- Potential, 32  
equilibrium, reversal, driving, 34  
membrane, 26, 41  
membrane equilibrium, 38–40, 65  
negative resting, 35  
net, 34
- Potential, synaptic, 115–118, 129–130, 168–170, 175
- Predictions, importance of, 12, 423
- Prefrontal cortex, *see* Frontal cortex
- Presynaptic, 28
- Priming, 276, 278–279, 298  
long-term, weight-based, 276–282  
exploration, 279–282  
short-term, activation-based, 276, 278, 298–299  
exploration, 298–299
- Principal components analysis (PCA), 116, 122–125  
demonstration, 124  
sequential (SPCA), 125–127  
*see also* Model learning, Hebbian learning, Conditional PCA
- Principles, 6, 10, 13, 19  
dynamic, 210–211  
level of analysis, 6  
structural, 206–210
- Prior (Bayesian), 61, 144
- Probabilities, 59, 129  
conditional, 60, 128, 129, 133  
frequency-based, 60  
joint, 60  
posterior, 61  
prior, 61
- Problem solving, 379  
*see also* Higher-level cognition
- Procedural  
memory, 276, 277  
representations, 218
- Process, 428, 432–433, 442, 443, 447, 465  
control panel, 58, 432, 443
- Processing  
activation-based, 380–384, 392–395  
content-specific, dedicated, 209–210  
controlled vs. automatic, 214, 217–218, 381, 385–387, 408–409  
*see also* Controlled processing  
deterministic, 47, 53, 166  
distributed, 206  
embedded, 206  
speed, 386  
stochastic, 47, 53, 166  
weight-based, 380–381, 392–395
- Production systems, 8, 25, 209, 217, 382–383, 407  
*see also* Computer metaphor, Symbolic models
- Project  
ab.proj.gz, 315–317  
ab\_ac\_interference.proj.gz, 284–286  
act\_maint.proj.gz, 301–305  
act\_priming.proj.gz, 298–299  
amp\_top\_down.proj.gz, 89–90  
amp\_top\_down\_dist.proj.gz, 90–92  
attn\_simple.proj.gz, 261–268  
bidir\_xform.proj.gz, 86–87  
cats\_and\_dogs.proj.gz, 110–111  
creating, 435–453  
detector.proj.gz, 54–58  
dyslex.proj.gz, 335–341  
ed\_id.proj.gz, 397–402  
family\_trees.proj.gz, 183–186  
fsa.proj.gz, 190–193  
generec.proj.gz, 170–171  
hebb\_correl.proj.gz, 121–122, 130–132, 135–137  
hip.proj.gz, 293–296  
inhib.proj.gz, 95–100, 103–104  
inhib\_digits.proj.gz, 104–105  
loc\_dist.proj.gz, 84–85  
model\_and\_task.proj.gz, 179–181  
necker\_cube.proj.gz, 111–112  
objrec.proj.gz, 246–255  
objrec\_multiobj.proj.gz, 269–272  
pat\_assoc.proj.gz, 148–150, 156–158  
pat\_complete.proj.gz, 88–89  
pfc\_maint\_updt.proj.gz, 310–312  
pt.proj.gz, 353–357  
rl\_cond.proj.gz, 199–202  
self\_org.proj.gz, 138–142  
self\_reg.proj.gz, 68–69  
sem.proj.gz, 361–365  
sg.proj.gz, 370–375  
ss.proj.gz, 344–349  
stroop.proj.gz, 388–391

- transform.proj.gz, 79–82
- unit.proj.gz, 49–54
- v1rf.proj.gz, 237–240
- wt\_priming.proj.gz, 279–282
- Projection, 42
  - of world onto senses, 118
- Projection, 431, 438, 439
- ProjectionSpec, 431, 439
- Prototypes, 15, 16
- Punishments, *see* Conditioning, Reinforcement learning
- Pyramidal neuron, 24, 72
- Quitting from simulation, 54
- Rate code, 42, 46–48, 53
- Rational analysis, 5
- Re-representation, *see* Transformations
- Re-write rules, 366
- Reaction time, 258, 261, 278, 282, 388, 389
- Reading, 324, 326, 329–350
  - direct route, 349
  - division of labor, 331–332, 339, 341
  - dyslexia, *see* Dyslexia
  - exploration, 335–341, 344–349
  - indirect route, 349
  - latencies, 349
  - nonwords, 324, 331–332, 340–342, 347–349
- Recall
  - cued, 290, 292, 319
  - free, 319
- Receiving weights, 55
- Receptive field, 229–230, 237–239, 245, 247, 253, 361, 439
  - activation based, 247–250
  - and attention, 268
  - probe, 251–252
  - spatially localized, 245, 256
  - V1, 126–127
- Receptors, 26, 28–32, 46, 116–117, 228
- Recirculation, 10, 162–164
  - see also* GeneRec
- Recognition memory, 318–319
- Reconstructionism, 3–4, 14, 419
- Recurrence, *see* Bidirectional connectivity
- Recursion, 223–224
  - equations, 39, 196
- Reductionism, 2–3, 14, 418–419
- Refractory period, 29
- Regularities, 118, 324, 330–331, 341–342, 349–358, 420–421
- Regularization, 118–121, 134, 175–178, 180–182, 184, 192
- Reinforcement learning, 186, 187, 193–202, 307, 312, 313
  - exploration, 199–202
  - see also* Temporal differences learning (TD), Conditioning
- ReInit button, 58
- Release failures, 31
- REM sleep, 381
- Renormalization, 132–137, 141
- Representations, 25, 69, 76
  - accessibility, 381
  - active memory, 382–383, 395
  - canonical, 209, 223, 241–242, 317
  - categorical, 15, 76, 405
  - coarse-coded, 16, 82, 231
  - combinatorial, 139, 178, 342
  - comparing, 222
  - conjunctive, 220–221, 223, 276, 291–292, 297, 342–343, 345, 347
  - content-specific, dedicated, 25, 209–210, 219–224, 324, 325, 380
  - context, *see* Context
  - declarative, 218–219, 276, 381
  - discrete, 14, 383
  - distributed, *see* Distributed representations
  - explicit, 189, 218–219
  - feature-based, *see* Distributed representations
  - frontal, 382–383, 395
  - goals, 380–383, 403, 405–407
  - heterarchical, 125–127
  - hierarchical, 125–127, 206–210, 212, 227, 242–256, 343
  - hierarchical relationships, 222–223
  - higher-order, 302–303
  - implicit, 218–219
  - isolated, 216, 300, 303, 304, 385, 397
  - localist, 9, 82–84, 86, 87, 95, 104, 105, 143, 183, 334, 369, 373, 417, 419
  - object, 212, 227–228, 232–233, 241–257, 324, 343, 349
  - orthographic, 324, 329–350
  - phonological, 324, 327–358
  - procedural, 218
  - redundant, 222
  - semantic, 324–327, 329–341, 349–358, 365, 367–368
  - topographic, *see* Topographic representations
  - visual, 212, 227–272
- Rescorla-Wagner rule, 151, 199
- Resistance, 33
- Resonance, 16, 85, 88
- Resting potential, 35
- Retina, 228–229
  - contrast enhancement, 228
- Retinotopic organization, 230, 231
- Retrieval, memory, 290, 292, 319
- Reuptake, 30
- Reversal potential, 34
- Revert button, 50, 430
- Rewards, *see* Conditioning, Reinforcement learning
  - absorbing, 198, 311
- Rods, 228
- Rules, 118, 324, 330–331, 341–342, 349–358, 420–421
- Run button, 50, 58
- Saturation
  - activation, 40, 48, 92
  - weight changes, 130, 134, 155–156, 165
- savg\_cor, 134, 136, 137, 141, 458
- Scaling, 6–8, 42, 236, 416–417
  - input, 44
- Schizophrenia, 306, 387, 391
- ScriptEnv, 191, 450
- Scripts (PDP++), 429, 434, 436–437, 443–447, 450–453
  - language, 429, 443–447, 450–453
- Selection, 17, 94–95
  - see also* Competition, Inhibition

- Selection (PDP++), 438  
 Selectivity, 81, 132, 134, 137, 139, 207  
 Self-organizing learning, 115, 127,  
     137–142  
     exploration, 138–142  
 Self-regulation, neural, 66–69  
 Semantic  
     deficits, 358–359  
     memory, 276, 277, 280, 289  
     network, 109  
     representations, 324–327,  
         329–341, 349–358, 365,  
         367–368  
     exploration, 361–365  
     from word co-occurrence,  
         358–365  
 Sending weights, 86  
 Separation, pattern, 276, 284, 286,  
     290–292, 296, 297  
 Sequence learning, 186–193, 307  
     biological basis, 189  
     context updating, 188–189  
     exploration, 189–193, 370–375  
     network configuration, 453–454  
     *see also* Active memory  
 Sequences  
     Markov, 187  
 Sequential principal components  
     analysis (SPCA), 125–127  
 Serial processing, 14  
 Set point behavior, 93, 99–100  
 SettleProcess, 442, 465  
 Settling, 56, 86, 162  
 Shift-click, 57, 431, 433, 438  
 Shunting inhibition, 36  
 Sigmoid, 40, 42, 47, 48, 134, 154, 155  
     derivative, 155, 160  
 Similarity structure, 75–79, 81–82  
 Simple cells, 230  
 Simple recurrent network (SRN), *see*  
     Sequence learning  
 Simplification, 4, 13, 414–417  
 Simulated annealing, 109  
 Simulations, 20  
     installing, 427  
     quitting, 54  
     *see also* Projects  
 Sleep, 230, 381  
 SOAR, 11  
 Sodium, 32, 35, 45  
 Sodium-potassium pump, 35, 36  
 Soft clamping, 88, 110  
 Soft weight bounding, 130, 134,  
     155–156, 165  
 Software, installing, 427  
 Sparse distributed representations, 95,  
     143, 216, 234, 276, 284, 286,  
     290–292  
 Spatial  
     attention, 221, 227, 234, 257–272  
     cuing task, 17, 258  
     frequency, 231  
     invariance, 228, 233, 241–256  
     memory, 276, 297  
     processing, 212, 227, 232–234  
 Spec, 428  
 Specialization  
     areas, 72, 74–75, 177, 211–212,  
         214–217, 227–228, 286, 304  
     neurons, 25  
     pathways, 206–208, 211–212,  
         227–228, 323–324  
     vs. flexibility, 209, 219  
 Speed of processing, 386  
 Spike, 28, 29, 38, 42, 53  
     computing, 45–46  
     timing, randomness, 47, 53  
 Spines, dendritic, 29, 45  
 Spiny stellate neuron, 72  
 Spreading activation, 216, 278, 300, 312  
 Squared error, 149–151, 160, 196  
 Statistical models, 10  
 Statistics  
     aggregation, 442, 449  
     closest event, 280, 281, 448  
     cnt\_sum\_se, 179  
     learning, 119  
     max da, 465  
     PDP++, 429, 432, 443, 448–449,  
         451–452  
     sum\_se, 149  
     Unique pattern (unq\_pats), 140,  
         180  
     Wrong on, 270  
 Stem completion, 278–282, 298  
 Step button, 56, 58  
 Stepping grain, 156  
 Stochastic processing, 47, 53, 166  
     *see also* Noise  
 Strategic processing, 206, 214, 217–218,  
     381–382, 385–387, 403,  
     405–406, 408–409  
     *see also* Higher-level cognition  
 Stress, 108  
 Stroop task, 382, 383, 385–392, 395,  
     404  
     exploration, 388–391  
 Structural principles, 206–210  
 Structure, 118, 324, 330–331, 341–342,  
     349–358, 420–421  
     levels, 6  
 Subcortical areas, 72–75, 193–195,  
     212–214, 230, 306–307, 385  
     *see also* Basal ganglia, Thalamus  
 Subjective probabilities, 59, 62  
 Subroutines, 223–224  
 Substantia Nigra (SN), 193–195  
 sum\_se, 149  
 Summed squared error (SSE), 149–151,  
     160, 196  
     error count, 179  
 Supervisory attentional system (SAS),  
     407  
 Surface dyslexia, 331–333, 335–336,  
     338–339  
 Symbolic models, 8, 209, 219, 223,  
     241–242, 324, 330, 366,  
     379–380, 382–383  
     *see also* Computer metaphor,  
         Production systems  
 Symmetric weights, 86, 107, 165–167  
 Synapse, 26, 29–31  
     efficacy, 26, 27, 31  
     excitatory input, 35  
     inhibitory input, 36  
     modification, 115–118, 129–130,  
         168–170, 175  
 Syntax, 325–327, 365–376  
     exploration, 370–375  
 targ, 157, 459  
 Target output, 148, 156  
 Task learning, 116, 147–172, 176–178,  
     277  
     vs. model learning, 173–175  
     *see also* Error-driven learning,  
         Delta rule, Backpropagation,

- GeneRec
- Task variation, 317
- Teaching signals, 156, 167–168
- Template matching, 82
- Temporal, *see* Time
- Temporal cortex, 212, 214, 228, 326, 327
- Temporal differences learning (TD), 193–202
  - derivation, 196
  - exploration, 199–202
  - in active memory control, 308–313, 395–397, 406
  - phase-based, 198–199
  - vs. delta rule, 199
  - see also* Reinforcement learning, Conditioning
- Text comprehension, 408
- TextLog, 429, 433
- Thalamus, 72, 212, 228, 230, 269, 307
- Theories, descriptive vs. explanatory, 11, 417
- $\Theta$ , *see* thr
- thr, 45, 46, 460
- Threshold
  - detector, 26
  - error, 149
  - high, 291
  - parameter, *see* thr
  - soft, 48
  - spike, 28, 38, 42, 46, 53
- Tick (time step), 192, 200
- Time
  - averaging, 43
  - constant
    - dt\_vm, 37
    - dt\_net, 44
  - continuous, 186–187
  - learning over delays, *see* Reinforcement learning
  - summation, 43
- Tip-of-the-tongue, 16
- Top-down
  - approach, 4–6
  - processing, 17, 85–93, 162, 385, 392
- Topographic representations, 143, 240
  - V1, 231–232, 236–237
  - exploration, 237–240
- Tower of Hanoi/London task, 405, 406
- Tradeoffs, 206, 209, 213–217, 219, 286, 292, 300, 304, 343
- Training set, 151
- TrainProcess, 428, 432, 449
- Trajectories
  - continuous, 186–187
- Transformations, 72, 73, 185, 207–209, 227–228, 241–256
  - bidirectional, 85–87
  - exploration, 79–87, 246–255
  - learning, 158
  - sequences, 253
  - unidirectional, 75–85
- Trial, 428
- Trial-and-error learning, 18, 309, 313, 382, 395–397
- TrialProcess, 428, 432, 442, 447–449, 465
- Tripartite functional organization, 205, 214–217
- Tuning curves of cortical neurons, 82
- Turing test, 14
- U-shaped curve, 350–358
  - exploration, 353–357
- Unidirectional connectivity, 75–85
- Unified theories of cognition, 11, 12
- Unit, 23–70
  - as population of neurons, 7, 42, 46, 48
  - dead, loser, 140
  - exploration, 49–58
  - weights, 26
- Unit, 428, 431, 459, 460
  - number in a layer, 438
- UnitSpec, 52, 428, 431, 439, 460, 462
- V1, 126–127, 212, 230–232, 234–241
  - exploration, 237–240
  - pinwheel, 232, 239
  - singularity, 232, 239
  - topography, 231–232, 236–237
- V2, 212, 233
- V4, 212, 233
- v\_bar, 45
- v\_m, 37, 50, 459
- v\_m.r, 46, 460
- v\_rest, 45, 461
- Value function, 195–196
- Variable
  - act, 46, 50, 55, 459
  - act\_avg, 285, 459
  - act\_dif, 459
  - act\_eq, 46, 50, 53, 459
  - act\_m, 156, 157, 459
  - act\_p, 156, 157, 191, 459
  - $\beta$ , *see* bias.wt
  - bias.wt, 44, 157, 459
  - da, 56, 459, 465
  - dwt, 123, 456
  - ext, 86, 459
  - I\_net, 37, 50, 459
  - net, 44, 50, 57, 459
  - pdw, 456
  - targ, 157, 459
  - v\_m, 37, 50, 459
  - vs. parameter, 428
  - wt, 43, 55, 135, 456
- Variable binding, 209
- Variance
  - as information, 144
  - vs. bias, 120
- Ventral tegmental area (VTA), 193–195, 214, 306–307
- Verb phrase, 366
- Vesicles, 30
- View window, 428
- Visual
  - cortex, *see* V1, V2, V4, Occipital cortex
  - pathways, 15, 228–234
  - representations, 212, 227–272
  - search, 271
- Voltage-gated channels, 28, 35, 36, 39, 45, 117
  - in dendrites, 45
- Vowels, 328
- Weighted average, 39
- Weights, 26, 27, 31, 63
  - based memory, 210, 276–298, 314
  - based processing, 380–381, 392–395
  - contrast enhancement, 132–137, 139, 141, 150
  - decay, 165, 175
  - equilibrium, 124, 129

- gain, 134–135
- in memory, 210, 276–298, 314
- learning, *see* Learning
- linking/sharing, 244
- receiving, 55
- renormalization, 132–137, 141
- sending, 86
- soft bounding, 130, 134, 155–156, 165
- symmetric, 86, 107, 165–167
- updating, 123
- variable, *see* wt
- Wernicke's area, 326–327
- What vs. where, 15, 227, 232–234, 315, 403
- Wickelfeatures, 342, 343
- Windows
  - Control panel, 49, 429, 430, 452–453
  - edit dialogs, 50, 430
  - EnviroView, 428, 431
  - GraphLog, 429, 433
  - GridLog, 429, 433
  - iconifying, minimizing, 50
  - NetView, 49, 428, 431
  - PDP++ Root, 49, 54, 58, 436, 444, 446
  - Project, 436, 442
  - TextLog, 429, 433
- Winner-take-all (WTA), 105, 143, 176
  - see also* k-Winners-take-all (kWTA)
- Wisconsin card sorting task (WCST), 392–393, 404, 407
  - see also* Dynamic categorization, ID/ED task
- Word superiority effect, 17, 89, 90, 106
- Working memory, *see* Active memory
- Wrap-around connectivity, 236
- wt, 43, 55, 135, 456
- wt\_gain, 134, 136, 137, 141, 150
- wt\_off, 135–137, 141, 150
- wt\_scale, 44, 286, 303, 304, 308, 457
- wt\_sig, 134, 135, 457
- X-over-X-plus-1 (XX1) function, 46
- XOR task, 158