

Index

a

action potentials 153–156, 217, 260–265, 263, 265
 – duration (APD) 258
 – alternans 258, 262–264, 266, 267
 adaptive
 – behavior 3, 11
 – data analysis 245
 – systems 1, 149, 150
 adjacency matrix 181, 247, 252
 alpha rhythm 161, 164
 Alzheimer’s disease 150, 187, 190
 amorphous computing 113
 – Turing activator–inhibitor system 140
 amplitude equation 267
 analytic signal 219, 225, 226, 249
 APD. *See* action potentials, duration (APD)
 applied mathematics 2, 4, 7, 10
 arrhythmias. *See* cardiac arr.
 asynchronous state 234, 240, 241
 autocatalysis 114, 120, 122, 124
 axon 8, 155, 156–159, 250
 – corticocortical 159
 – myelinated 156, 164
 – propagation speed 174

b

band-limited 11, 72, 238–241
 Bayesian ensemble approach 107
 Bernstein inequality 80
 Beurling–Landau densities 66
 bifurcation 118–120, 135, 137, 138, 260, 262, 265, 267
 biological circuits 86, 96, 123–130, 141
 – biological networking strategy 125
 – delays 128, 129
 – GRN, templated networks 125

– nonlinearities in genetic regulation 127, 128
 – regulation and feedback loops 125–127
 – titration effects 129
 – biological networks modeled by chemistry 123, 124
 – biological reaction circuit 124, 125
 – biosystems 124
 – higher level motifs and modularity of biochemical networks 129, 130
 biological networks 123, 124, 128, 129, 140
 – models of 141
 birdsong data 289–290
 bistable molecular switches 86
 bivariate single neuron distance 293
 blood-oxygen level-dependent functional magnetic resonance imaging (BOLD fMRI) 13, 224, 233, 234, 241
 – blood-oxygen-level-dependent response (BOLD) 13, 212, 233, 234, 238, 239
 – dynamics 238, 239
 – measurements 233
 – model 239
 – signal 238, 239, 240
 brain 1, 149, 150
 – basic anatomy 154
 – brainstem 154
 – cerebellum 154
 – cerebral cortex 160, 210
 – complexity 149, 151, 156, 162, 174
 – corticocortical connections 159, 160
 – graph theory 160
 – corticocortical fibers 149, 156–163, 205
 – EEG record and spectrum 154

- electrical transmission 156
- electrophysiology 160–166
- functional connectivity (FC) patterns 13, 180, 191, 224, 234
- imaging at multiple spatial and temporal scales 151–153
- macrocolumn 157, 158, 160, 166, 170
- mammalian 150
- multiple scales of dynamics in consciousness 153, 154
- synchronization of synaptic activity 153
- using binocular rivalry 153
- multiscale network (*See* multiscale network organization)
- multiscale recordings 208, 209
- neocortex 156–158
- nested hierarchy of 158, 159
- synaptic and action potential current sources 154
- theories providing
 - quantitative physiological framework for 151, 152
- brain dynamics 12, 13, 154–156, 234–236
- comparison with experimental data 239, 240
- at rest, structure shapes dynamics 233–241
- Brownian motion, Langevin treatment of 108

- c**
- Ca alternans 251, 260–262
- Ca cycling dynamics 260–265
- Ca-induced Ca release (CICR) 258
- calcium release unit 251
- calcium spark 257–262
- calcium wave 257–260
- cardiac arrhythmias 257, 271
- Ca signaling hierarchy 259, 260
- Casimir operator 67, 77
- causal involvement testing
 - in cognition, and behavior 228, 229
- chaos synchronization 269, 270
- in cardiac tissue 270
- chaotic EAD dynamics 265
- CICR. *See* Ca-induced Ca release (CICR)
- circadian rhythm 295
- circular causality 149, 150, 151, 159, 164, 165
- closed systems 114, 116, 117, 162, 180
- clustering 182, 183, 188, 222, 223, 278, 289
- coarse-graining 136
- complexity 1, 8, 12, 23, 87, 113, 116, 122, 124, 129, 135, 137, 141, 149, 150, 151, 156, 162, 174, 182, 185, 205, 219, 246
- complex reaction networks
 - deterministic predictive models 105–107
- compressed sensing 11
- computing *See* amorphous, DNA
- concordant alternans 266
- conduction velocity 234, 238
- finite 238
- infinite 236
- restitution 267
- consciousness 3, 150–152
- assumed to emerge from dynamic interactions 12
- global neuronal workspace model 3
- neural correlates 174
- constrained simulated annealing (CSA) 54
- correlation matrices 239, 240
- cortical macrocolumn 158
- cortical minicolumn 158
- criticality 194, 258, 260, 264
- cross-frequency coupling (CFC) 217, 224–226
- cross-level interactions, physiological correlates 210–212
- cross-scale coupling 212, 213
- cross-scale interactions
 - brain web 206, 207
- cubature formula 77

- d**
- data analysis/processing 2, 5, 9, 11, 65, 70, 81, 218, 219, 245, 253
- degree distribution 189, 194
- Delaunay triangulation weighted 41
- diffusion maps 10, 253
- Dirac functions 70
- Dirac measure 33, 71, 72, 73, 76, 80
- Dirichlet boundary conditions 73
- discrete Dirichlet data 54
- discrete Dirichlet energy 40, 43
- discrete Dirichlet-to-Neumann map 49, 54
- discrete geometric homogenization 31, 32, 37, 39
- DNA computing 140
- domain discretization 24
- dual frame 69, 79
- dynamical systems 193, 206

- e**
- eigenmaps 251
- electrical impedance tomography (EIT) 23, 49–52
- electroencephalogram (EEG) 149, 188, 205, 233

- activity 277
- signal 218
- electronic frequency analyzers 218
- electrophysiology
 - cognitive 223
 - large-scale model of EEG standing waves 162–164
 - local vs. global brain models 161, 162
 - and spatial scale 161, 162
 - mechanical analog 164–166
 - multiscale theory 160
 - characteristic EEG and physiological timescales 160, 161
 - single-neuron, temporal link between 209
- entrainment receptive fields (ERFs) 14, 245, 254
- adaptive 254
- entropy-based measure 278, 286, 291
- epilepsy 159, 173, 208, 295
 - networks 208
- Euclidean spaces 10, 66, 70, 75, 81, 185, 246, 247, 249, 252
- Euler-Lagrange equations 168–171
- excitation dynamics, on tissue and organ scales 266–270

- f**
- feedback 7, 85, 86, 89, 90, 93, 95, 105, 110, 119–129, 134, 150, 159, 207, 258
- fibrillation 255, 265, 267
- finite conduction velocity 234, 236, 238
- Fisher's z -transform 225
- Fokker–Planck equation 234
- Fourier transform 9, 75, 169, 246
 - sliding-window 219
 - frames 69, 70, 73, 76–77
 - frequencies
 - intrinsic 249
 - multiple 212, 213
 - natural oscillation 165, 166
 - resonant 161, 162, 165
 - frontal theta-alpha coupling 227
 - functional brain network 12, 188, 189, 191
 - functional magnetic resonance imaging (fMRI) 3, 10, 13, 65, 152, 173, 180, 187–190, 212, 224, 233, 241, 295

 - g**
 - gamma-frequency fluctuations 210
 - genelet circuits 85
 - geometric homogenization 37–39
 - geometric multiscale analysis 9

 - Gershgorin disks 39
 - Gillespie algorithm 109
 - GNU Linear Programming Kit 55
 - graph theory 11, 160, 247
 - Laplacian *See* Laplacian, combinatorial
 - Green formula 69

 - h**
 - harmonic coordinates 22, 23, 26, 28, 31, 51–53, 55, 56, 59
 - Heaviside function 238
 - Hebbian principle 191
 - heterogeneous connectivity, implications for mathematical modeling 182
 - heterogeneous data 1
 - hierarchical modularity
 - dendrogram displaying, modular and submodular structure 184
 - of human brain functional network 188
 - network hierarchy 183
 - high-frequency oscillations 210–212
 - Hilbert frames 66, 69, 70
 - Hilbert space 67, 69, 70, 79
 - Hilbert transform 219, 225, 249, 250
 - Hodge decomposition 30
 - homogenization 8
 - as nonlinear operator 24
 - by linear interpolation 33–37
 - by volume averaging 32
 - inverse 8, 19, 21, 32, 45–47
 - human brain. *See* brain

 - i**
 - ICPS. *See* interchannel phase synchronization (ICPS)
 - identity matrix 28, 43, 238
 - independent component analysis 233, 238
 - information processing 5, 9, 13, 14, 113, 123, 185, 193, 208, 217, 219, 228, 245, 246
 - inhibitory postsynaptic potentials (IPSPs) 156, 159, 172
 - interchannel phase synchronization (ICPS) 223, 224
 - intracellular Ca alternans 260–262
 - intracranial 152, 153, 159, 208–210, 228, 233, 239–241
 - invasive electrodes, for multiscale recordings of the human brain 208
 - inverse conductivity problem 23
 - in vitro* reconstruction of artificial networks 141
 - in vitro* transcriptional oscillator 86
 - IPSPs. *See* inhibitory postsynaptic potentials (IPSPs)

- ISI-distance 282–285, 294
 - vs. SPIKE-distance 285, 286, 288
 - vs. van Rossum metric 277, 278, 282, 287, 289, 294
- k**
 - kernel function 280
- kinetic model 6, 109, 114, 117, 120, 128, 135–140
- l**
 - Lagrangian splines 79
 - Laplace-Beltrami (LB) operator 67, 68, 70, 247
 - Laplacian, combinatorial 247, 249, 253
 - linear model approach 225
 - linear noise approximation (LNA) 108
 - local field potentials (LFPs) 153, 205, 208, 209, 233, 277, 295
 - localized frames 73
 - on compact manifolds 73–76
 - L-type calcium (Ca) channels (LCCs) 257
 - stochastic openings 262
- m**
 - magnetoencephalography (MEG) 13, 152, 153, 159, 172, 187, 233, 241, 295
 - manifolds 66, 67, 70, 75, 77, 101
 - compact homogeneous manifolds 67, 68
 - discretization 70
 - homogeneous 66, 78
 - interpolation on 79
 - Riemannian *See* Riemannian
 - sampling of functions on 66
 - Shannon sampling of band-limited functions on 72
 - MATLAB code 181
 - Michaelis–Menten kinetics 6, 95, 127, 136
 - microelectrodes 159, 208, 209
 - modes 13, 54, 105, 123, 135, 165, 233–240, 253, 267, 268
 - modularity 86, 180, 183–185, 188–194
 - molecular circuits, scaling up 86, 96, 110
 - molecular clocks 89, 90
 - experimental implementation and data 95
 - oscillatory regime, analysis 91–94
 - two-node molecular oscillator 90, 91
 - molecular “load” process 86
 - molecular processes, synchronization of 96, 97
 - insulation 102, 103
 - molecular programming 7, 113–115
 - Morris–Lecar model 248
 - MRA. *See* multi-resolution, analysis (MRA)
 - multifrequency oscillations 210, 211
 - multilevel interactions 212
 - multiresolution 9, 14, 66, 70
 - analysis (MRA) 2, 4, 9, 10, 65, 70, 245–247, 249, 252–254
 - multiscale analysis 1, 2, 4–6, 8–11, 247, 249, 254
 - multiscale architecture 180, 187, 192, 194
 - multiscale network organization 179–195
 - functional multiscale organization 187–191
 - hierarchical modularity 193, 194
 - power-law scaling 194
 - structural 181–187
 - structure and function 191–193
 - multiscale nonlinear dynamics
 - in cardiac electrophysiology 257–271
 - EAD-mediated nonlinear dynamics 264, 265
 - excitation dynamics on tissue and organ scales 266–270
 - fast pacing-induced complex APD dynamics 262–264
 - intracellular Ca alternans 260–262
 - spatially discordant APD alternans 266, 267
 - spiral and scroll wave dynamics 267–269
 - subcellular scale
 - criticality in transition from Ca sparks to Ca waves 258–260
 - multiscale recordings 209, 246
 - multiscale theory, in electrophysiology 160, 161
 - characteristic EEG and physiological timescales 160, 161
 - voltage-gated membrane 161
 - large-scale model of EEG standing waves 162–164
 - local *vs.* global brain models and spatial scale 161, 162
 - mechanical cortical analog 165
 - string–springs analog 166
 - n**
 - nearest-neighbor coupling 259
 - neocortex 156–158, 165–168, 172
 - nested hierarchical systems 149
 - networks 1–3, 6, 7, 10–14, 51, 52, 57, 83–86, 88, 93, 103, 104, 108, 112, 121–125, 160, 162, 179–181, 188, 190, 209, 210, 215, 222, 225, 232, 239, 250, 277, 295. *See also* biological networks
 - neuromodulators 155, 158, 159, 171

neuronal oscillations 12, 206, 212, 213
 – computational function 245–254
 – cross-level interactions, physiological correlates 210–212
 – cross-scale interactions, brain web 206, 207
 – human brain, multiscale recordings 208, 209
 – level entanglement, and cross-scale coupling 212, 213
 – phase–amplitude coupling 213
 – scale up and scale down brain dynamics 205–213
 neuronal synchronization 14, 245, 254
 neurotransmitters 155, 166
 noise-induced chaos phenomenon 265
 nonlocal interactions 149
 nonparametric permutation testing 222
 normalized cuts algorithm 253
 numerical
 – methods 47, 52, 55
 – tests 44, 52, 53

o

open systems 115–119
 operators 66
 – bi-invariant 67
 – bijective operator mapping 36
 – Casimir 67, 77
 – elliptic 9, 21
 – Laplace–Beltrami 67, 68, 70, 247
 – linear interpolation 22, 33, 35, 36, 38
 – noninjective 28
 – nonlinear 24, 32, 36
 – nonsymmetric 21
 oscillators/oscillations 4, 6–8, 12, 13, 85, 86, 89–91, 94–97, 99–106, 108–110, 113, 118, 122–124, 127, 129–133, 135, 137–140, 205, 206, 209–213, 217–219, 221–224, 227, 229, 233–238, 240, 241, 249, 250, 253, 254, 258, 260
 – chemical oscillator designed, with PEN toolbox 139
 – fluctuations 211
 – influence of reduced reaction volume 109
 – in-phase oscillators 217
 – *in vitro* transcriptional 86
 – modifications in oscillator equations 97
 – perturbation 100–104, 106
 – phase–amplitude modulations 213
 – rhythms 224
 – space location plots 250
 – transcriptional 85–110
 – and tweezers coupled through insulating genelet 106

– two-node molecular 90, 96, 103
 out-of-equilibrium chemical systems 114
 – building nonequilibrium systems 116
 – closed systems 116, 117
 – energetic requirements 116
 – partially open systems 118
 – pseudo-open systems 117, 118
 – design principles 119
 – dynamism 119–121
 – modularity 122, 123
 – instabilities, and dynamic stability 118, 119

p

PAC. *See* phase-amplitude coupling (PAC)
 Paley–Wiener space 71
 Parseval frames, on homogeneous manifolds 69, 70, 76–79
 period-doubling bifurcation 260, 262
 Perron–Frobenius theorem 237
 phase–amplitude coupling (PAC) 210, 212, 213, 224
 – calculation algorithms 227
 phase clustering (PC) 223
 phase modulations
 – nonlinear dynamics, and behavior 221–224
 Plancherel–Polya inequalities 65, 72
 positron emission tomography (PET) 152
 power law distribution 260
 probability distribution 238
 – conditional 169, 170
 programmable *in vitro* dynamics 130–139
 – DNA–RNA sequence amplification 131
 – enzymatic systems 130
 – genelet system 131
 – nonenzymatic networks 134, 135
 – numerical modeling 135
 – LSA and bifurcation analysis for design 137, 138
 Purkinje fiber system 257

q

Q-adapted 40, 41–44
Q-optimal mesh 44–47
 quasiperiodic behavior 267

r

random fluctuations 265
 – microscopic 264
 Rentian scaling 185, 186, 187
 resting state networks (RSNs) 13, 233, 234, 240, 241
 restitution curve 262–264, 267, 268

- Riemannian manifold 11, 65, 66, 70, 72, 247
 - of bounded geometry 71
 - Riesz basis 80
 - Rossum metric 277, 278, 280, 282, 287, 289, 293–295
 - ryanodine receptors (RyRs) 257
- s**
- sampling theorem *See* Shannon
 - scale
 - spatial 1, 4, 7, 8, 11, 12, 150, 151, 154, 158, 159, 161, 164, 168, 179, 180, 195, 205, 206, 212, 217, 246, 253, 295
 - time 2–4, 6, 8, 87, 92, 97–102, 104, 118, 127, 140, 152, 160–162, 180, 190, 191, 205, 249
 - scaling 6, 86, 87, 96, 168, 180–182, 186, 187, 189–191, 194, 206, 211–213, 236, 288
 - Rentian *See* Rentian
 - schizophrenia 158, 166, 183, 187
 - Schwartz function 75
 - Shannon sampling
 - of band-limited functions on manifolds 66, 72, 73
 - theorem 65
 - short term memory 3, 166–168, 253
 - sleep 152, 209–212, 217
 - sliding-window Fourier transforms 219
 - small-world behavior 149
 - Sobolev space 67, 68, 72, 79
 - sparse
 - approximation 11
 - coding 11
 - representation 11
 - spatially concordant APD alternans 266
 - spatially discordant APD alternans 258, 266, 267
 - spatial-temporal mapping 208
 - spatial topography 208
 - spectral theorem 73, 74
 - spike-time-dependent plasticity 217
 - spike train synchrony measurement
 - dissimilarity measurement
 - within population 290–292
 - between populations 292, 293
 - distances on birdsong data 289, 290
 - entropy-based measure 286
 - ISI-distance 284
 - vs. SPIKE-distance 287
 - vs. van Rossum metric 287, 288
 - from single neurons to populations 277–296
 - SPIKE-distance 285, 286, 290, 291, 294, 295
 - vs. Victor–Purpura metric 288
 - van Rossum metric. *See* van Rossum metric
 - population extension 292
 - Victor–Purpura metric. *See* Victor–Purpura metric
 - population extension 292, 293
 - spiral/scroll wave dynamics 267–269
 - splines variational interpolating 11, 66, 79–81
 - statistical mechanics 108, 151, 164, 167–173
 - stochastic effects 107–110
 - chemical master equation 108
 - structural connectivity (SC) 233
 - structural resolution parameter 183
 - subcellular scale, transition from Ca sparks to Ca waves 258–260
 - sudden cardiac death 257
 - synchrony/synchronization 3, 9, 10, 13, 14, 96, 153, 162, 189, 205–207, 210, 211, 217, 218, 223, 224, 249, 277, 285, 286, 290, 291, 294, 295
 - plateaus 251
 - pyramid 245
 - synergetics 149, 165
 - synthetic biochemical circuits 254
 - synthetic biological circuits 86
 - synthetic biology 3, 11, 85, 107, 254
 - synthetic transcriptional modules 86, 87
 - elementary activation 87
 - elementary transcriptional networks 88
 - experimental implementation 88, 89
 - genelet-based circuits 89
 - features 89
 - inhibition pathways 87
 - lac operon 86
 - simple loops 87
 - stripped-down analog, transcriptional gene 87
 - switches, autoregulation 88
 - systems biology 1–4, 10, 11, 14, 85, 106, 107, 109, 271
 - systems neuroscience 1–4, 7, 10, 11, 14
- t**
- tachycardia 257, 269
 - thalamocortical fibers 157, 159
 - thalamocortical networks 161, 162, 206
 - time-frequency analysis 10, 218, 219, 221, 222, 238
 - transcranial alternating current stimulation (TACS) 229
 - advantage 229
 - transcranial magnetic stimulation (TMS) 229

transcriptional oscillators. *See* oscillators
two-node transcriptional oscillator 86, 91, 95,
96, 103

v

van Rossum metric 280–282, 287, 293
– population extension 292–293
variational approach, to isotropic
meshing 45
variational splines on manifolds 79–81
Victor–Purpura metrics 277, 279–280,
288, 290, 292, 294
– population extension 292, 293
visual cortex 153, 213, 227, 228,
246, 248

w

wake–sleep cycle 212
wavelets 9–11, 65, 66, 69, 70, 81, 219, 238,
246, 247, 249, 254, 267, 269
waves
– brain 152, 162, 164
– calcium 257–260
– scroll 267–269
– slow cortical 212
– spiral 258, 267–269
– standing 151, 162–164, 174
– traveling 8, 162
Weyl’s asymptotic formula 70, 72, 73
white matter 156–160, 162–164, 166, 182,
187, 191, 234, 235–237, 239

