

Index

- actin filaments 477, 499, 501, 505
adaptor protein 477, 486, 502
adhesion, cell-cell 426, 435–36,
 438
adipose tissue, subcutaneous 45,
 50, 53
AFM, *see* atomic force microscopy
algebraic reconstruction technique
 (ART) 312–14, 322
anisotropic lipid bilayers 189–90,
 192, 198, 201
ART, *see* algebraic reconstruction
 technique
artificial membranes 231, 234,
 244–45, 252–53, 273
atomic force microscopy (AFM)
 166–67, 173
- basal
 cells 421, 450
 layer of epidermis 63, 468, 471
 layers 65, 68, 70, 72, 80–81, 83,
 191, 473–74
 membrane 45, 47, 435–40, 448,
 450
basale 68, 73–74, 77, 80, 470
basement membranes 462, 474
bidirectional reflectance
 distribution function
 (BRDF) 5, 15–16, 37
bidirectional scattering-surface
 distribution function
 (BSSDF) 5
bidirectional transmittance
 distribution function
 (BTDF) 5
- biological
 cells 357, 364, 366–67, 369,
 371, 373
 model complexity 453–54
 models 421–22, 426, 451, 453
 tissues 26, 55, 96, 122, 297, 302,
 364, 366, 375, 378, 386–87
- biomechanical models 426, 452,
 454
- cell-center-based 434–35
- biomedical optics 26, 29–30, 55
- bioModels database 424, 441–42
- biopartitioning micellar
 chromatography (BMC) 254
blood 14–15, 26–27, 33, 35–36,
 41, 45–46, 193, 195, 359–61,
 376, 379, 401, 403, 405–6,
 409
 concentration 38
 flow 396
 oxygenation 41, 408
 vessels 46, 55, 246, 251, 359,
 375, 380, 397, 403
- bloodless tissue 45–47
- BMC, *see* biopartitioning micellar
 chromatography
- BRDF, *see* bidirectional reflectance
 distribution function
- BSSDF, *see* bidirectional scattering-
 surface distribution function
- BTDF, *see* bidirectional
 transmittance distribution
 function
- CBM, *see* cell behavioral models
- cell

- behavioral models (CBM) 424, 426–29, 431–34, 443
 box-shaped 370, 372
 cork 221
 corneocyte 221
 cycle model 441–42
 differentiation models 443, 447, 452
 division 68, 430–31, 441–42, 444–45, 447–48, 452
 ellipsoidal 437
 elliptical 437
 layers 163–64, 168, 171, 190, 197, 234, 339, 448, 454
 mast 41, 193–94
 membrane 67, 192, 354, 360, 363, 367, 370, 373, 378
 periphery 474, 477–79, 499, 505
 proliferating 436, 442
 red blood 373, 396
 shapes 169, 354, 363, 367, 369–70, 372–73, 380, 386–87
 suspensions 353, 355, 362–67, 387
 types 358, 367, 370–71, 429
 cellular
 layers 168, 171, 175
 modeling 423, 452
 cellular-scale models 168, 170–72
 CEMOVIS *see* cryo-electron microscopy of vitreous skin section
 ceramides 295–96, 298–99, 302–3
 cholesterol 246–47, 253, 255–56, 292–93, 295–97, 300, 302–3, 359
 collagen 15, 42, 44–45, 100, 105, 113, 134–36, 139, 141, 143, 149, 193, 251, 360
 fiber stiffness 141–42, 144
 fiber undulation 133, 148–49
 fibers 10, 15, 37, 97–98, 100, 110–11, 133, 135–49, 152, 360
 computational
 fiber-matrix dermis models 138–39, 141, 143, 145, 147, 149
 modeling 25, 96
 models 26, 117–18, 120, 122, 133
 Compute Unified Device
 Architecture (CUDA) 26, 28, 412
 constitutive parameters 99–100, 106, 109–11, 122
 continuum mechanics 95, 100–1
 continuum tissue model 453
 corneocyte 97–98, 161–62, 167–72, 174–78, 188–90, 197, 202–3, 205, 217–22, 226, 228–30, 234–35, 246–47, 358–59, 471–72
 isolated 166, 176
 keratin filament network 292, 301, 321
 membranes 163–64
 permeable 199–200
 phase diffusivities 202–3
 phases 189, 197, 204
 corneodesmosomes 161–65, 167–68, 170–75, 177–78, 246, 471–72
 mechanical properties of 172, 178
 non-peripheral 163–64, 171
 corticotropin releasing hormone (CRH) 66, 68
 CRH, *see* corticotropin releasing hormone
 cryo-electron microscopy 291–93, 301
 cryo-electron microscopy of vitreous skin section

- (CEMOVIS) 291, 293–94, 296
- CUDA, *see* Compute Unified Device Architecture
- data monitoring components (DMCs) 433–34
- de-epidermized dermis (DED) 250–51
- DED, *see* de-epidermized dermis
- deeper vessel plexus (DVP) 358–60, 376, 378, 380
- dendrites 68, 72, 74, 76, 80–81, 84, 479, 504
- dermal layers 10, 12, 48, 135, 381
- dermal–epidermal junction 462
- dermatology 120
- dermis 44–45, 47, 97–98, 120, 133–38, 142, 146–48, 150–53, 191–96, 246, 250–51, 358–61, 374–76, 379–80, 462–64
- papillary 10, 14–15, 27, 36, 38, 135, 152, 195, 358–59, 376, 380
- desmoplakin 468, 470–71
- desmosomes 468, 470–71
- diabetes 414
- dielectric
- multiscale model 364, 386
 - parameters 361, 363, 369, 373, 381–82, 386
 - properties 355, 361, 363, 366, 368–69, 379–82, 387
- spectroscopy 354–55, 367, 372
- spectrum 362–63
- DMCs, *see* data monitoring components
- dodekahedra 223–25
- dry skin 290, 385
- untreated 384–85
- DVP, *see* deeper vessel plexus
- dyneins 477, 479, 500–1, 503–4
- E-cadherin 470, 473, 483–84
- eclipse modeling framework (EMF) 425
- EET, *see* extending epidermal tongue
- EGFR, *see* epidermal growth factor receptor
- eight-chain non-Gaussian network models 133, 144
- elastic models of skin, nonlinear 103, 105, 107, 109, 111
- elasticity
- non-linear 138–39, 143
 - tensors 100, 102–3
- elastin 135, 142–43, 360
- fibers 42, 134, 137, 140, 142, 148–49, 193
- electron
- microscopy 168, 290, 315–17, 319, 325, 477
 - microscopy simulation 291, 295–96, 298–301
 - tomography 290, 302, 306–7, 309, 311, 313
- EMF, *see* eclipse modeling framework
- endosomes 476–77, 490
- epidermal
- barrier 333, 441, 444, 450
 - barrier formation 422, 424, 440
 - cells 44
 - growth factor receptor (EGFR) 471
- homeostasis 70, 421–22, 424, 434–35, 437, 439, 441, 443, 445, 447, 449, 453, 462–64, 466, 469, 472, 480–81, 489, 497
- hyperplasia 467, 469
- layers 72–75, 77

- melanin 475
- melanocytes, human 482–83
- models 249–51
- stratification 462, 469, 491
- tissue kinetics 447, 450–51
- epidermis 64, 70–71, 73–74, 189, 374, 421–22, 434, 439, 453, 473, 484, 490
 - aged 247
 - living 27, 35–36, 38, 97–98, 120, 359
 - viable 191
 - tissues 17
- EPISIM 421–22, 424–26, 428, 430, 432, 434, 436, 438, 440, 442, 444, 446, 448, 450–54
 - modeller 424–29, 433, 441, 452
 - simulator 425–26, 430, 433–35, 447, 452
- epithelial cells 483
- epithelium, multilayered 454
- ESM, *see* extending shield mechanism
 - eumelanin 10, 13, 15, 26, 35–36, 38, 66, 69, 474–75
 - extending epidermal tongue (EET) 454
 - extending shield mechanism (ESM) 454–55
 - extracellular lipid matrix 218, 228, 294–95, 298–300, 321
- facial skin 117, 136
- FEM, *see* finite element method
- FFAs, *see* free fatty acids
- fiber-matrix models 103, 133–34, 136, 138, 140, 142, 144, 146, 148, 150, 152
- fibroblasts 67, 250–51, 358–59, 429, 462, 467, 473, 481, 484
- finger 39–41, 463
- fingernail 39–41
- finite element method (FEM) 95–96, 354, 370
- Flynn database 257–63, 267–68, 270
- forearm 39–41, 120
- Franz cells 236, 244, 248, 262, 264, 269
- free fatty acids (FFAs) 246–47, 292, 295, 297, 302–3, 359, 472
- G-protein coupled receptors (GPCRs) 485, 487, 489, 497
- Gaussian process 273
- glycerol 43–44, 177–78
- GME, *see* graphical model editor
- GML, *see* graphical modeling language
- Goldberg tetrakaidekahedra 222–23
- GPCRs, *see* G-protein coupled receptors
- GPU, *see* graphics-processing unit
- granulosum cells 429, 439, 441, 444, 448
- graphical model editor (GME) 424–25, 429–30, 432
- modeling language (GML) 430
- multiscale modeling of epidermal homeostasis 421–22, 424, 426, 428, 430, 432, 434, 436, 438, 440, 442, 444, 446, 448, 450
- graphics-processing unit (GPU) 26–32, 412
- hair follicles 135, 188, 248, 251, 360, 463–64, 473, 481
- hematocrit 26–27, 33, 36

- hemidesmosomes 467–68, 470–71, 473
- hepatocyte growth factor (HGF) 468, 473, 481, 483
- HGF, *see* hepatocyte growth factor
- homeostasis 447–48, 451, 466–67, 491–92
- HSS, *see* skin substitutes
- humidity 104, 339, 341–42, 349
- hydration 162, 176, 303, 334, 339–40, 343, 345–46, 349
- full 198–99, 204–6
- gradient 339, 345–47
- partial 198–99, 204–6
- hydrophilic
- compounds 200, 203, 251, 265, 289
 - solutes 188, 199, 201–2, 207, 248
- hypodermis 97, 120, 246, 358, 360–61, 374, 376, 379, 463
- IAM, *see* immobilized artificial membrane
- immersion optical clearing (IOC) 26, 41–43, 47–48, 51, 55
- immobilized artificial membrane (IAM) 254
- integrins 467, 471, 474, 478
- intercellular
- lipids 168–69, 172, 174–75, 178, 197, 246
 - pressure 435–36, 438
 - spaces 162, 166, 169, 171, 174–78, 189–90, 198, 218
- intradermal injection, model of 50, 53
- IOC, *see* immersion optical clearing
- keratin-filled cells 289, 321
- keratinocyte 64, 66–68, 71–72, 79, 82–83, 218, 249–51, 429, 434, 439, 453–54, 462–63, 467–69, 473–74, 478–84
- basal 462, 467–68, 471, 473
- cell behavioral model 439
- differentiation 218, 246, 440, 447, 468, 470
- movement 68, 70, 83
- skin-derived 67
- stratified 462, 466
- keratins 190–91, 219, 254, 294, 359, 468, 470–71, 484
- kinesins 477, 500, 503–4
- laminins 467, 469
- Langerhans cells 464, 483
- laser Doppler flowmetry (LDF) 395–97, 406, 414
- layer-specific properties 188–89, 191, 193, 195
- LDF, *see* laser Doppler flowmetry
- life sciences 313, 315–18, 322–23
- lipid 166, 169–70, 173, 177–78, 197, 199–200, 202–3, 206, 218, 230, 248, 265, 290–92, 358–59, 441
- bilayers 164, 201, 206, 217–18, 235, 247–48, 264
- gradient 447, 449–50
- matrix 197, 218–19, 226, 228–29, 247, 290, 292, 294, 301, 303–4, 315, 322, 348
- phase 170, 199–202, 378
- lipophilicity 262, 266, 273, 276
- LROs, *see* lysosome-related organelles
- lysosome-related organelles (LROs) 474, 477

- MAPK, *see* mitogen-activated protein kinase
- MCC, *see* model connector component
- MCF, *see* membrane-coated fiber
- melanin 45, 47, 63–65, 67–68, 70–75, 77, 79–83, 473–77, 479, 481
- content 25, 38, 41, 55, 65, 72–73, 78, 82, 482
- degradation 65, 72
- distribution of 64, 70, 73
- synthesis 474–76, 482
- melanocyte 63–72, 76, 79–80, 84, 462–63, 466, 468, 473–84, 500, 503, 505
- dendricity 479, 482
- density 83
- stimulating hormone (MSHs) 66, 480
- melanogenesis 64–71, 75–76, 476, 479–80, 482, 484
- melanoma 64, 69
- cells 66
- melanosome 14–15, 17, 63, 67–68, 70, 76, 84, 474–80, 497–99, 501, 503–5
- biogenesis 474–76, 497–99, 501, 503, 505
- biogenesis and motility 497, 499, 501, 503
- distribution of 19, 70, 479
- motility 497–98, 503, 505
- stage II 476, 498
- transport 70, 477, 503–4
- membrane-coated fiber (MCF) 252
- microcirculation 395–96, 414
- microscopic transport models 187–88, 192, 196–97
- microtubules 70, 477, 479, 499–501, 503
- MIFs, *see* molecular interaction fields
- mitogen-activated protein kinase (MAPK) 471, 482, 485
- model-based analysis approach 395, 397
- model connector component (MCC) 426–27, 433, 452
- modeling approach, multiagent-based tissue 453
- modeling approaches for skin biomechanics 98–99
- models
- corneocyte 221
 - extended ceramide bilayer 298
 - human-based keratinocyte 250
 - isotropic Arruda-Boyce 106, 145
 - linear 275–76
 - mechanical 168–69, 171
 - mechanistic 245, 265
 - mitosis 445–46
 - predictive skin permeability 274
- molecular
- interaction fields (MIFs) 271–72
 - models 293, 301
 - organization 289–94, 296–98, 300–4, 306, 308, 310, 312, 314, 316, 318, 320, 322, 324, 326
 - motility 413, 483, 497, 499, 501, 503
- MSHs, *see* melanocyte-stimulating hormone
- Mullins effect 117, 138, 142
- multilayered skin models 17
- multiscale cell cycle model 441–42
- nerve growth factor (NGF) 468, 481
- NGF, *see* nerve growth factor
- object-oriented programming (OOP) 26, 28, 30
- OCA, *see* optical clearing agent
- OOP, *see* object-oriented programming

- optical clearing agent (OCA) 42–44, 50, 53, 55
- organelles 357–58, 363, 370, 374, 474, 477, 499, 501, 503
- lysosome-related 474, 477
- orthotropy 106, 138–39
- parameters, solvatochromic 268
- PCA, *see* principal component analysis
- PCR, *see* principal component regression
- PDF, *see* probability density function
- perfusion 192, 386, 408, 411–12
- permeability 192, 200–1, 203, 249–51, 256–58, 265–67, 270, 272–73, 396
- permittivity 364, 375, 380, 382
- phantom generator 300, 317–18, 320, 325
- phenomenological models 98–99, 134
- pheomelanin 10, 13, 15, 26, 35–36, 38, 69, 474–75
- photon migration 51
- photons 49, 51, 53–54, 397, 399, 403–5
- PKA, *see* protein kinase A
- PKC, *see* protein kinase C
- plasma membrane 477, 479, 484, 486–87, 501
- principal component analysis (PCA) 272
- principal component regression (PCR) 272
- probability density function (PDF) 133, 400–2
- protein kinase 480–81
- protein kinase A (PKA) 69, 481–83
- protein kinase C (PKC) 480, 482, 489, 503
- proteins 67, 69, 177, 190, 271, 359, 362, 374, 471, 475, 477, 482–83, 486–88, 497–99, 503
- transmembrane 173, 218
- proteoglycans 97–98, 100, 135, 193
- QLV, *see* quasi-linear viscoelasticity
- quasi-linear viscoelasticity (QLV) 112–13, 147
- rat epidermal keratinocytes (REK) 250
- RBCs, *see* red blood cells
- receptor tyrosine kinase (RTK) 471, 485–88
- reconstruction 301–2, 306–7, 309, 311–14, 316, 322–24, 366, 387
- methods 310–12, 314–15
- problems 307–8, 310, 312, 322, 325
- red blood cells (RBCs) 55, 373, 395–401, 403, 409–12, 415
- regularization parameter 314, 323
- REK, *see* rat epidermal keratinocytes
- relative humidity 162–63, 165, 176, 335–36, 338–40, 342, 344
- representative volume element (RVE) 169
- reticular dermis 10, 14–15, 27, 36, 48–49, 135, 195, 358–59, 376
- RTK, *see* receptor tyrosine kinase
- RVE, *see* representative volume element
- SBME, *see* SBML model editor
- SBML model editor (SBME) 424–25, 429, 432

- SC, *see stratum corneum*
 scaffold proteins 472, 480, 486–87
 scanning electron microscopy (SEM) 164, 172–73
SEM, see scanning electron microscopy
 single layer neural network 274
 skin 195, 244–45, 250, 353, 357, 383, 385
 absorption 244, 252, 271
 aging 117
 anisotropic mechanics of 104–5
 appearance 19, 98, 119
 appendages 188, 463
 biomechanics 95–96, 121, 162
 cancer 354
 cells 64, 217–8
 complexity 360
 computational models of 99, 121–22
 constitutive models of 97, 112
 fractional ablation 42–43
 fragility 468, 471
 growth 117–18
 hydrated 198
 inelastic models of 116–17
 irritations 354
 mathematical models of 122
 mechanical properties of 97, 152
 normal 50, 53, 55, 83, 483
 scattering properties of 37
 substitutes (HSS) 67
 three-layer model of 120
 viscoelastic properties of 112
 skin barrier 42, 185, 217–18, 220, 222, 224, 226, 228, 230, 232, 234, 236, 238, 244–47, 256, 259
 skin color 10, 12, 14, 16, 18, 25, 26, 32, 40, 83, 476
 calculator 27, 29, 31
 modeling 25, 32
 simulation 33, 35, 37
 skin components 301, 306
 skin damage 43, 114
 skin diffusion models 197
 skin diseases 162, 290–91, 306, 464
 skin layers 11–12, 34–37, 44–47, 49–51, 53–55, 165, 236–37, 361, 376, 378–79, 386
 epithelial 47, 219
 functional 250
 outermost 218
 parameters of 36, 45
 pigmented 47
 upper 51–52, 54–55, 480
 uppermost 354, 383
 skin lipids 252, 290–93, 301–3
 organization 291, 293, 297, 306
 skin mechanics 97, 116
 skin microrelief 119–20
 skin modelling 231
 skin models 27, 45, 48, 106, 111, 249–50, 354, 358, 374–76, 383, 385–87, 409
 human 32–33, 374
 skin morphology 358–59
 skin optics 27
 skin penetration 244–45, 249, 256–57, 259, 261, 263, 265–67, 269, 271, 273–75
 skin permeability 187–88, 190, 192, 194, 196, 198, 200, 202–4, 206, 254–56, 258, 266–7, 270–71, 273–74, 276
 coefficients 254, 262, 268
 mathematical models of 187–88, 190, 192, 194, 196, 198, 200, 202, 204, 206
 measurements 252, 257
 prediction 245, 248–49, 251, 253, 255, 275–76
 studies 248–49, 266
 skin permeation 243–45, 256, 266
 skin pigmentation 63–64, 66, 68, 70, 72, 74, 76, 78, 80, 82–84, 472–73, 475, 479, 497
 skin reflectance 25–6, 39, 51–52

- skin reflectance spectra 25, 38, 55–6
 skin samples 43, 48, 143–44, 163, 248, 291, 297
 skin structure 248, 355
 skin surface 11, 16, 42, 46, 49, 68, 72, 119, 152, 359–60, 367, 465
 skin surface folds 10–11, 15–16
 skin tattoo 41, 43, 45, 47, 49, 51, 53
 simulation of 41, 43, 45, 47, 49, 51, 53
 skin thickness 260, 276
 skin tissue chromophores 35
 skin tissues 35–36, 267, 356, 358, 378, 381, 398
 layered 361
 skin types 73, 475, 480
 skin wrinkles 119–21
 skin wrinkling 120
 soft tissues 107, 113, 115–17, 137–38, 142–43, 147, 149, 152
 biological 100, 106, 108, 112, 117
 specificity analysis 375, 380–81
 spectral density function 366
 spinosum cells 443–45, 448
 stem cells 439, 445, 447–48
 steroids 254, 260, 263–64, 268, 270, 275, 465
stratum basale 68, 97, 219
stratum corneum (SC) 42–43, 76–77, 161–63, 165–68, 174–78, 187–89, 199–206, 217–21, 236–38, 246–47, 333–34, 336–40, 342–49, 358–59, 374–76
 geometry model 220–21, 223, 225
 human 161–62, 164, 166, 168, 170, 172, 174, 176, 178
 microscopic transport models 196–97, 199, 201, 203
 numerical model 167, 169, 171, 173, 175, 177
stratum granulosum 68, 77, 80–81, 219, 441, 450, 480
stratum spinosum 68, 77, 80–81, 219, 439
 sucrose 199–203, 205–6, 248, 264
 systems biology 461, 466, 489–90, 492–93
 principles 489, 491, 493, 495
 tanning 19, 63–65, 71, 73, 75, 77, 79, 81
 mathematics of 71, 73, 75, 77, 79, 81
 response 64, 66–67, 70–71, 75, 482
 tattoo 26–27, 41, 43, 49–51, 53–55
 pigments 41–42, 44
 TEM, *see* transmission electron microscopy
 testosterone 199–201, 204–6, 251
 tetrakaidekahedra 218, 220–29
 model 226–27, 229
 TEWL, *see* transepidermal water loss
 tissue modeling 357, 364, 368, 374
 tissue models 368, 374, 379, 397
 bio-optical 397
 cell-based 423
 multicellular 423
 multilayer 358
 reliable macroscopic 374
 tissue simulation 426, 429–31, 433–35, 446, 451
 controller 433–34
 multiagent-based 424, 426, 433
 multicellular 423, 426, 428, 454
 snapshots (TSSs) 433–34
 tissues 42–45, 98–100, 142, 149, 151, 163, 191–94, 200, 354–55, 362–64, 368–69, 386–88, 396–97, 421–22, 450

- cutaneous 15
- laser-illuminated 395–96
- viable 224, 333–34, 336–39, 349
- transcription factors 67, 69, 485
- transdermal drug delivery 244–45, 290–91, 303
- transepidermal water loss (TEWL) 333–34, 337, 339, 343–50
- transmission electron microscopy (TEM) 300, 307, 320
- TSSs, *see* tissue simulation snapshots
- ultraviolet radiation 463–64
- UML, *see* Unified Modeling Language
- Unified Modeling Language (UML) 425
- upper vessel plexus (UVP) 358–59, 376, 378, 380
- UVP, *see* upper vessel plexus
- vesicles 476–77, 500
- viscoelastic models 113
- viscoelastic models of skin, nonlinear 112–13, 115
- viscoelasticity 95, 112, 116, 137–39, 143, 146–47
- wrinkles 96, 119–20