

## Index

### a

- abiotic elicitors 307
  - acetoclastic methanogens 548, 549
  - acetogenesis 534, 548
  - acetone–butanol–ethanol fermentation 545
  - acid/alkali pretreated biomass 551
  - acoustic settlers 444–445
  - acrylic polymer-based hydrogels 117
  - activated sludge process 476–481
  - active composting phase 523
  - adenosine triphosphate (ATP) 548
  - aerated static pile 528
  - aerobic and anaerobic processes 495
  - agricultural waste treatment 542
  - Agrobacterium rhizogenes* 264
  - Agrobacterium tumefaciens* CCNWGS0286 339
  - air-well sparging mini-fermentor system 177
  - alternate sugars and amino acids 425–426
  - alternating tangential flow (ATF) 438–440
  - alumina 140
  - aluminum etching agent 606
  - Amaranthus retroflexus* 343
  - amine transaminases (ATA) 33
  - amino acids 390–392
    - and alternate sugars 425–426
    - ω-aminocarboxylic acids 35–37
  - 6-aminopenicillanic acid (6-APA) production 20–21
  - amorphous calcium silicate hydrates (A-CSHs) 603
  - AMT-BIOCLAIM™ 581
  - anaerobic baffled reactors (ABR) 490–491
  - anaerobic digestion (AD) 494 *see also*
    - methane fermentation
    - continuous/batch systems 537–538
    - digestate use and quality 538
    - factors 534
    - mesophil/thermophil systems 537
    - microorganisms and phases 533–534
    - single-or two-stage systems 537
    - status 538
    - technologies 534–535
    - wet/dry digestion 535–537
  - anaerobic fixed bed reactors (AFBR) 551
  - anaerobic fluidized bed reactors 491–492
  - anaerobic membrane reactors 492–494
  - anaerobic sludge digestion 601
  - anaerobiosis 601
  - analytical and diagnostic enzymes 29–31
  - anchorage dependent cells 404
  - animal cell culture 5
  - animal manure management 605
  - antibiotics 399
  - antibody-dependent cell-mediated cytotoxicity (ADCC) 270
  - antioxidants 5, 398
  - aqueous polyvinyl alcohol (PVA) 118
  - aqueous–organic two phase systems (ATPSs) 306–307
  - AraGEM 308
  - arbuscular mycorrhizal fungi (AMF) 340–341
  - AT-rich elements (ARE) 363
  - atmospheric nitrogen (N) 336
  - Atorvastatin 33, 62, 91–92
  - avidin/biotin system 125, 126
- ### b
- baby hamster kidney (BHK) 359, 417
  - Bacillus subtilis* strain SJ-101 334
  - Baeyer–Villiger monooxygenases (BVMO) 36
  - balanced salt solutions (BSS) 383
  - balloon type bubble bioreactors (BTBBs) 295
  - basal medium 386, 387, 395, 410

- bio-based P recycling
  - aqueous solution 602–604
  - biological P removal 600–601
  - polyP-rich sludge 601–602
- bio-waste 525
  - biological treatment 522–538
  - mechanical–biological treatment 538–541
- bioaccumulation 579
- bioaugmentation-assisted phytoextraction 6
- biobetter drugs 274
- biobetters 270
- biocatalysis
  - atorvastatin 33, 62, 91–92
  - biocatalyst immobilization 87–88
  - biocatalyst yield 85–86
  - mixing 95
  - optically pure chiral amines 95
  - process concept 81, 82
  - product concentration 86
  - product value 81, 82
  - productivity 85
  - protein and genetic engineering 87
  - reaction engineering 88–89
  - reaction yield 84–85
  - sitagliptin 92–94
  - structured approach 83
- biocatalyst engineering
  - biocatalyst immobilization 87–88
  - protein and genetic engineering 87
  - reaction engineering 88–89
- biocatalyst immobilization 87–88
- biocatalyst yield 85–86
- biochemical engineering 1
- biodegradability index (BI) 496, 508, 510
- biodegradable waste 525
- biodegradative bacteria 330–333
- biodiesel fuels 545, 560
- biodrying 540
- biogas
  - bioduel production 562–563
  - genetic engineering tools 563–564
  - global carbon recycling 562
  - global warming 561
  - renewable and sustainable resource 561
  - upgradation 561–562
- bioleaching 581–583
- BioLector 176
- biological aerated filters (BAF) 485–487
- biological engineering/bioengineering 1
- biological oxygen demand (BOD) 472–473
- biologically synthesized polyP 598–599
- biomass production rate 219
- biomass sensor and flow cytometry 198
- biomining 581
- bioprecipitation/biomineralization 574, 575, 585–586
- bioprocess control *see* microbial process control
- bioprocess optimization 417
- bioprocess parameters
  - aeration 295–296
  - agitation 295
  - medium composition and optimization 294
  - temperature and pH 294–295
- bioreactors
  - biological catalysts 170
  - biomass sensor and flow cytometry 198
  - chromatography based methods 452
  - computational fluid dynamics 171
  - disposable 447
  - electrochemical methods 453
  - electronic tongues and noses 198
  - enzymatic assays 450
  - EU experts' recommendations on sensors 198
  - fed batch *see* fed batch bioreactor operations
  - flow injection analysis 199–200
  - hydrodynamic conditions 170
  - *in situ* sensors 196–197
  - ion mobility spectrometry 200
  - microbial cultivation 169
  - microscopy-based methods 452–453
  - near infrared spectroscopy 199
  - oxygen supply 170
  - oxygen transfer performance 170
  - oxygen uptake rate 171
  - parallel *see* parallel bioreactor systems
  - perfusion *see* perfusion mode of bioreactor operation
  - primary modes 417–419
  - process analytical technology 200–203
  - quality by design 170
  - single-use disposable bioreactor systems *see* single-use disposable bioreactor systems
  - soft sensors 198–199
  - spectroscopy based methods 452
- biosensors 3
- biosolids 604–605
- biosolubilization 606
- biosorbents 579
- biosorption 579
- Biostat CultiBag<sup>®</sup> 194
- biotechnology 1
- biotin 393
- biotin-4-fluorescein 125
- biotin-labeled enzymes 125

- biotowers 481  
 biovolatilization 577–578, 586–587  
 bolus mode of feeding 429  
 bovine serum albumin (BSA) 406  
 box-and container composting 530  
 brewing strain 215  
 “brikollare”-composting process 530–531  
 bubble column systems 188–189  
 bulk ions and trace elements 395–396  
 2,3-butanediol 558
- C**
- caffeic acid phenethyl ester (CAPE) 149–150  
 13C-based metabolic flux analysis  
 – examples 225–227  
 – principles 223, 224  
 carbon nanotubes (CNTs) 140  
 carrot cells 289–290  
 catalytic macromolecular components 388  
 cauliflower mosaic virus (CaMV) 355  
 promoter 309  
 cavitation 496–499  
 cell adhesion molecules 404–405  
 cell growth environment 384–386  
 cell immobilization 306  
 cell suspension cultures 263  
 CELL-trainer<sup>®</sup> 195  
 CellCelector<sup>™</sup> 373  
 centrifuges 441–442  
 channel and tunnel composting 529–530  
 cheese making 13  
 chemical oxygen demand (COD) 473  
 chemically defined medium 386–387  
 chemically defined synthetic medium, F12 383  
 chemically reduced graphene oxide (CRGO) 154  
 Chinese Hamster EF-1alpha (CHEF1) gene 361  
 Chinese hamster ovary (CHO) cell lines 361, 417  
 – CHO-K1 cell lines 363  
 chip-type reactors 100  
 choline oxidase (ChOx) 147  
 chromatography based methods 452  
 cis-acting DNA elements 367–369  
 Class I solvents 303  
 Class II solvents 303  
 Class III solvents 304  
 CLEA-based enzyme microreactor (CEM) 146  
 click chemistry 152–153  
 clone stability 376  
 ClonePix system 373  
 clustering analysis 215, 216  
 CO<sub>2</sub> evolution rate (CER) 239  
 Cobalamin (B12) 393  
 coenzymes 17, 155  
 compost use and quality 531–532  
 comprehensive phenotypic analysis  
 – high-throughput culture system 228  
 – microarray analysis method 230  
 – *Saccharomyces cerevisiae* 227  
 – specific growth rate 228  
 – yeast cells 228–230  
 continuous bioprocessing 253  
 continuous culture system 244–246  
 continuous feed 429  
 continuous/batch systems 537–538  
 continuously stirred tank reactor (CSTR) 549, 550  
 controlled-environment greenhouses 262  
 controlled shear filtration (CSF) 440  
 conventional methane fermentation process 549–551  
*Corynebacterium glutamicum* 219–221, 225, 226, 246  
 CRISPR/Cas9 genome editing system 434  
 cross-flow filtration 438  
 crosslinked enzyme aggregate (CLEA) 146  
 cryogel 118  
 crystalline calcium silicate hydrates (CSHs) 603  
 Cu-resistant strain *Sinorhizobium meliloti* CCNWSX0020 338  
 Cube shaped Nucleo Bioreactors 448  
 CultiBag 183  
 curing phase 523–524  
 cyanobacteria 231  
 cyclodextrins 406
- d**
- decoy protein 271  
 dehydrated waste activated sludge (DWAS) 554  
 dextrin production 14, 15  
 α,ω-dicarboxylic acids 35  
 diffused aeration 479  
 digestate use and quality 538  
 dihydrofolate reductase (DHFR) 363  
 direct immobilization to channel wall 142  
 direct toxicity assessment (DTA) 472  
 disposable bioreactors 301–303, 447  
 dissolved oxygen (DO) concentration 242  
 distillery wastewater 507–509  
 DNA hybridization system 126  
 DNA microarray 214

**e**

Eagle's Minimal Essential Medium (MEM) 383

ectomycorrhizia (EM) 341

ectomycorrhizal fungi (EMF) 341–342

eicosapentaenoic acid (EPA) 38

electro-chemical methods 453

Elelyso 273–275

ELELYSO<sup>®</sup> 289, 305, 310–312

elicitation 307–308

embedded monolith 127, 139

encapsulation with semipermeable membrane cover 529

endotoxin free water 389

ENERGIA 18

enhanced biological phosphorus removal (EBPR) 600–601

environmental bioengineering 6

environmental protection agency (EPA) 473

environmentally responsive hydrogels 151

enzymatic assays 450

enzymatic cascade reactions 35–37

enzymatic microreactors 100

enzyme immobilization

- adsorption 101–108
- affinity labeling 119–126
- azide chemistry 152–153
- covalent linking 127–149
- entrapment 110–117
- graphene-based nanomaterial 153–154
- hydrogen bonds 151
- microfluidics 149–150
- organisms 149
- ProSAR 155
- proteins modified with
  - solid-support-binding modules 154
- thermoresponsive hydrogels 151–152

enzyme polymerization 146–149

enzyme technology 2

- recombinant technology *see* recombinant technology
- early period up to 1890 13–16
- enzymatic cascade reactions 35–37
- immobilized *see* immobilized enzymes
- metabolic engineering 37–39
- metagenome/protein databases 32–34
- period from 1890 to 1940 16–19
- protein engineering 34–35

enzyme-adsorbed AuNPs 109

enzyme-immobilized reactors 100

*Escherichia coli* cultures 243

essential fatty acids 407

ethanol stress tolerant strain 217–218

ethanolamine 408

1-ethyl-3-(3-dimethyl  
aminopropyl)carbodiimide (EDC) 143

ethylene 335–336

ethylene diamine tetraacetic acid (EDTA) 343

euchromatin 368

Eupergit<sup>®</sup> oxirane acrylic beads 140

European Federation of Biotechnology (EFB) 251

European Section of Biochemical Engineering Science (ESBES) 251

expanded granule sludge blanket (EGSB) Reactor 492, 493, 550

extended aeration 478

extended bed composting systems 528

extended Kalman filters (EKFs) 240–242

extracellular polymeric substances (EPS) 487

**f**

fast acetic acid manufacture 14, 15

fatty acids and lipids 393–395

fed batch bioreactor operations

- alternate sugars and amino acids 425–426
- challenges 430, 434
- culture working volume 423
- design of feed composition 419–421
- dual control 425
- glucose 423–424
- glutamine 424–425
- mode and frequency of feeding 429–433
- nutrient consumption rate 426–427
- oxygen uptake rate 428–429
- pH 427–428
- predicted growth rate 427

fed-batch culture 242–244

Fenton chemistry 500–501

flow injection analysis (FIA) 199–200

fluorescent assisted cell sorting (FACS) 372, 373

flux balance analysis (FBA) 219–221

folded-sheet mesoporous materials (FSM) 109

**g**

Gamborg's B5 medium 268

$\beta$ -galactosidase 117

gene amplification 369–370

gene deletion mutants 216

Gene Ontology Annotation 218

genes conferring ethanol stress tolerance, identification of 215–217

genetic engineering 27

genome scale model (GSM)

- biomass production rate 219

- design of metabolic modification 221–223
  - reconstruction 219–222
  - glucose 419, 423
  - β-glucosidase 140
  - Glut1 transporter 390
  - Glut5 390, 426
  - glutamine 391–392, 420–426
  - glutamine synthetase (GS) 363, 370
  - γ-glycidioxypropyltrimethoxysilane (GPTEs) 143
  - glycoprotein production 178
  - gold nanoparticles (AuNPs) 109
  - graphene oxide (GO) 153, 154
  - graphene-based nanomaterial 153–154
  - gravity settlers 435, 437
  - greenhouse conditions 333
  - greenovation Biotech GmbH 264–265
  - growth associated components 388
  - GST-tag/glutathione system 125
- h**
- hemagglutinin-neuraminidase glycoprotein 274
  - heterochromatin 368
  - heterologous protein production 289, 309, 310
  - heterotrophic microbes 582
  - hierarchical clustering (HC) method 215
  - high molecular weight and complex supplements
    - cell adhesion molecules 404–405
    - insulin 402
    - lipid supplements 406–407
    - protein hydrolysates 405–406
    - serum 400–402
    - serum albumin and other carrier proteins 403–404
    - transferrin 402–403
  - high-throughput bioreactors (HTBRs) 182
  - His-tag/Ni-NTA system 119
  - hollow fibers 438
  - homo-fermentative lactic acid bacteria 246
  - host cell 359–360
  - human CD30-specific antibody 265
  - human cytotoxic T-lymphocyte antigen 4-immunoglobulin (hCTLA4Ig) 310
  - hydrocyclones 443
  - hydrodynamic cavitation reactor 499, 507
  - hydrogen production
    - anaerobic bacteria 556–558
    - bioreactor 559–561
    - feasible substrates 558–559
    - methane fermentation 555–556
  - hydrogenotrophic methanogens 548
  - hydrolysis 547
  - ω-hydroxycarboxylic acids 35, 36
  - hyperaccumulating plants 329
  - hyperaccumulators 329
- i**
- immobilized biocatalysts 25
  - immobilized enzymes
    - application 24–27
    - fundamental research 19–20
    - penicillin amidase 20–23
    - sugar isomerization 23–24
  - immobilized lipase 118
  - in situ* product removal (ISPR) 89, 306–307
  - in situ* sensors 196–197
  - indole acetic acid (IAA) 333–335
  - inducible promoters 361
  - industrial enzymes 26, 31–32
  - industrial P recycling 606–607
  - Infliximab 441
  - influenza hemagglutinin protein 269
  - insect cell baculovirus expression vector system (IC-BEVS) 5
  - insulin 402
  - insulin-like growth factors (IGF) 401, 402
  - insulin–transferrin–selenium (ITS) 407
  - Integrated Fixed Film Activated Sludge System 486–487
  - inverse metabolic engineering 214
  - ion exchange 602
  - ion mobility spectrometry (IMS) 200
  - isomaltose 17
- j**
- Jatropha curcas* 342
  - jet aeration 479–480
- k**
- Kozak sequence 362
  - Kluyvera ascorbata* SUD165 339
  - Kluyveromyces marxianus* 246–249
- l**
- laccase 151–152
  - lactic acid fermentation 245, 246
  - Lactococcus lactis* 246
  - layer-by-layer (LBL) assembly technology 110
  - L-3,4-dihydroxyphenylalanine (L-DOPA) 148
  - light-dependent expression platforms 264–265
  - lipids 545
    - supplements 406–407

- long chain fatty acids (LCFAs) 548
- low-temperature cofired ceramics (LTCC) technology 140–141
- m**
- mammalian cell culture 286, 400, 429
- matts 528
- mechanical biological treatment (MBT) 539–540
- mechanical damage protective agents 398–399
- mechanical-biological stabilization (MBS) 540
- Medicago truncatula* plants 334, 339
- medium for industrial production
  - biopharmaceutical processes 410
  - chemically defined media 407
  - essential fatty acids 407
  - ethanolamine 408
  - insulin–transferrin–selenium 407
  - medium design 408
  - osmolarity condition 409
  - quality by design 409
  - selenium 408
  - serum-free media formulation 407
  - specific media formulations 408
  - transferrin 407–408
- membrane bioreactors 484–486
- mercaptoethylpyridine 273
- mesophil/thermophil systems 537
- metabolic engineering 37–39, 220, 231, 308
- metagenome/protein databases 32–34
- metal-binding peptides 580
- metal-resistant rhizobia 338
- methane fermentation
  - advantage 545–546
  - basic knowledge 546–549
  - conventional 549–551
  - high ammonia 552–555
  - high salinity 551–553
- Methanosaeta* 549
- Methanosarcina* 549
- method of transfection 365
- methotrexate (MTX) 369
- micro-/mini-bioreactors (MBRs) 169, 171–172
- micro/nanoparticles and nanotubes 139–140
- microarray analysis method 230
- microbial metal removal/recovery
  - application 589
  - bioleaching 581–583
  - bioprecipitation/biomineralization 575–577
  - biosorption 578–581
  - biovolatilization 577–578
  - environmental conservation and solutions 587–589
  - strategies for other elements 589
- microbial oxidation 576
- microbial phosphate precipitation 577
- microbial process control
  - continuous culture 237, 244–246
  - control system design 237
  - control technologies 252–253
  - extended Kalman filters 240–242
  - fed-batch culture 242
  - filtering 239
  - mixed cultures 246–250
  - online estimation 239
  - online measurements 238–239
  - production costs 237
  - sensors technologies and analytical methods 251–252
  - software sensors 239
  - supervision and fault detection 249–250
  - tight and effective control systems 238
  - yield and productivity 237
- microbial process engineering
  - bioreactor development 2–3
  - measurement and monitoring 3–4
  - SSF 4–5
- microbioreactors 251
- microfluidic microbioreactor systems 184–188
- microfluidic paper-based analytical device ( $\mu$ PAD) 109, 110
- microfluidics 149–150
- microorganisms 523
- microscopy based methods 452–453
- microtiter plate systems 172–178
- microtube-type reactors 100
- Minamata tragedy 573
- mini bioreactors 448
- miniaturized bioreactor systems 3
- mixed liquor suspended solids (MLSS) 476
- mixed liquor volatile suspended solids (MLVSS) 476
- mixed microbial cultures 246–250
- modified prepared activated sludge (MPAS) 510
- moisture and oxygen/aeration 524
- molecular farming
  - biobetter drugs 274
  - cell suspension cultures 263
  - light-dependent expression platforms 264–265
  - pharmaceutical proteins 273

- quality and consistency of recombinant proteins 269–271
- quantity of recombinant proteins 267–269
- recombinant glucocerebrosidase 274
- regulatory and industry barriers 271–273
- tissue cultures 264
- whole plants and cell/tissue cultures 261–262
- whole plants vs. *in vitro* culture platforms 265–267
- monoliths and particles 109
- mouse myeloproliferative virus (MPSV) 361
- multi-omics analysis and data integration 230–231
- multi-walled carbon nanotubes (MWNTs) 140
- municipal and industrial wastewaters
  - activated sludge process 476–481
  - aerobic and anaerobic processes 495
  - anaerobic baffled reactors 490–491
  - anaerobic digestion 494
  - anaerobic fluidized bed reactors 491–492
  - anaerobic membrane reactors 492–494
  - biological aerated filters 485–487
  - biological oxidation 509–511
  - biological treatment 471–475
  - cavitation 496–499
  - combined processes 505–507
  - distillery wastewater 507–509
  - expanded granule sludge blanket reactor 492, 493
  - Fenton chemistry 500–501
  - integrated fixed film activated sludge system 486
  - mathematical modeling 475–476
  - membrane bioreactors 484–486
  - ozonation 501–503
  - PACT systems 484, 485
  - photocatalysis 503–505
  - regulations 473
  - rotating biological contactors 483
  - submerged biological contactors 484
  - trickling filters 481–483
  - types 471
  - UASB reactors 489–490
  - ultrasound 487–488
- municipal solid waste (MSW)
  - compost use and quality 531–532
  - composting process 522–525
  - composting technologies 525–531
  - continuous/batch systems 537–538
  - digestate use and quality 538
  - mechanical biological treatment 538–539
  - mechanical-biological stabilization 540
  - mechanical-physical stabilization 541
  - mesophil/thermophil systems 537
  - process of anaerobic digestion 532–534
  - single-or two-stage systems 537
  - status of anaerobic digestion 538
  - status of composting 532
  - status of MBT 541
  - waste disposal 521
  - wet/dry digestion 535–537
- Murashige and Skoog (MS) medium 268
- mycorrhizae 340–342
- n**
  - N-acetylneuraminic acid (NANA) 359
  - N-glycolylneuraminic acid (NGNA) 359
  - natural cellular environment 384–386
  - near infrared spectroscopy (NIRS) 199
  - nitrocellulose (NC) 109
  - nitrogen fixation 336–339
  - non-essential amino acids 392
  - non-immobilized (soluble) enzymes 24–25
  - non-nutritional medium components
    - alternative buffers 397–398
    - antibiotics 399
    - antioxidants 398
    - mechanical damage protective agents 398–399
    - phenol red 396
    - sodium bicarbonate buffer 396–397
  - non-silica-based matrices 117–119
  - Novozyme 435<sup>®</sup> 150
  - nucleic acid fermentation processes 606
  - nucleotides 126
  - nutrient consumption rate 426–427
- o**
  - omics-integrated approach
    - <sup>13</sup>C-based metabolic flux analysis 223–227
    - comprehensive phenotypic analysis 227–230
    - genome scale model 219–223
    - metabolic pathways 213
    - multi-omics analysis and data integration 230–231
    - transcriptome analysis 214–218
  - oncogene activated production system 360
  - OptKnock 221–222
  - organic waste 525
  - organic waste energy recovery
    - advanced methane fermentation processes 551–555
    - advantage of methane fermentation 545–546

- organic waste energy recovery (*contd.*)
  - basic knowledge of methane fermentation 546–549
  - biogas *see* biogas
  - conventional methane fermentation process 549–551
  - hydrogen production *see* hydrogen production
- oxidation ditches 479, 480
- oxidative pentose phosphate pathways 231
- oxoglutarate dehydrogenase complex (ODHC) 225
- oxygen uptake rate (OUR) 239, 428–429
- ozonation 501–503
  
- P**
- P recycling
  - animal manure 605
  - biosolids 604–605
  - biosolubilization 606
  - industrial recycling 606–607
- PacificGMP 195
- packed bed microreactor 150
- Paclitaxel 302–303
- parallel bioreactor systems
  - basic characteristics of high-throughput systems 171–172
  - bubble column systems 188–189
  - microfluidic microbioreactor systems 184–188
  - microtiter plate systems 172–178
  - parallel-use micro-/ mini-bioreactor system 189–193
  - stirred tank reactor systems 178–184
- parallel-use micro-/ mini-bioreactor system 189–193
- Paxillus involutus* 342
- penicillin amidase (PA) 20–23
- penicillin hydrolysis and derivatives 20–23
- percolation technology 535–536
- perfusion mode of bioreactor operation
  - acoustic settlers 444–445
  - advantages 435
  - alternating tangential flow 438–440
  - cell density based feeding 445
  - centrifuges 441–442
  - challenges 446
  - controlled shear filtration 440
  - cross-flow filtration 438
  - gravity settlers 435, 437
  - hollow fibers 438
  - hydrocyclones 443
  - metabolite based feeding 445–446
  - spin filters 441
  - tangential flow filtration 438
  - vortex flow filters 440–441
- phenol red 396
- phosphoenol-pyruvate carboxykinase (PEPck) 225
- phosphoenol-pyruvate carboxylase (PEPc) 225
- phosphorus recovery
  - agricultural efficiency 607
  - agriculture 598
  - algal toxin production 597
  - animal manure management 605
  - application of biosolids 604–605
  - aqueous solution 602–604
  - bacterial polyP accumulation 599–600
  - biological P removal 600–601
  - biosolubilization 606
  - biotechnology 607
  - cheap supply 607
  - chemical precipitation 598
  - food security 597
  - P<sub>1</sub> acquisition in bacteria 598–599
  - P-solubilizing microorganisms 607
  - polyP-rich sludge 601–602
  - sustainable use 598
- photocatalysis 503–505
- photosynthetic microalgae 265
- phytodegradation 329
- phytoextraction 329
- Phyton Biotech® 288, 302–303
- phytoremediation
  - biodegradative bacteria 330–333
  - definition 329–330
  - examples 342–343
  - metals and organics 328
  - mycorrhizae 340–342
  - plant growth-promoting bacteria 333–340
  - stable isotope probing 343
  - traditional cleanup procedures 328–329
- phytostabilization 329
- phytotransformation 329
- phytovolatilization 329
- Pichia pastoris* cultures 252
- PiggyBac transposon 369
- plant cell and tissue culture platforms
  - cell suspension cultures 263
  - light-dependent expression platforms 264–265
  - tissue cultures 264
- plant cell culture 5
- Plant Cell Fermentation (PCF™) 302–303
- plant cell suspension culture
  - aeration 295–296
  - aggregation 292–293



- agitation 295
  - cell growth and morphology 291–292
  - cell immobilization 306
  - choice of culture system 288–290
  - culture development and maintenance 286–288
  - disposable bioreactors 301–303
  - elicitation 307–308
  - gas requirements 292
  - medium composition and optimization 294
  - medium rheology 293
  - metabolic engineering 308
  - operational modes 296–297
  - Paclitaxel 314–315
  - Phytion Biotech<sup>®</sup> 288, 314–315
  - Plant Cell Fermentation (PCF<sup>TM</sup>) 314–315
  - pneumatic bioreactors 300–301
  - products 283–285
  - Protalix and ProCellEx<sup>TM</sup> Platform 310–313
  - recombinant protein extraction and purification 304–305
  - recombinant-protein-specific strategies 309–310
  - shear sensitivity 293–294
  - shikonin 295
  - specialized metabolite extraction and purification 303–304
  - specialized metabolites 306–307
  - stirred-tank reactors 297, 299–300
  - temperature and pH 294–295
  - plant glycans 269–270
  - plant growth-promoting bacteria (PGPB)
    - ethylene 335–336
    - indole acetic acid 333–335
    - nitrogen fixation 336–339
    - siderophores 339–340
  - plant-derived pharmaceutical protein 270
  - plasmid cloning in *E. coli* 364
  - plasmid conformation 366
  - plastic roller bottles 447
  - plug flow technology 536, 537
  - Pluronic F68 398
  - pneumatic bioreactors 288–289
  - poly(*N*-isopropylacrylamide) hydrogel 151, 152
  - poly-adenylation signal 362–363
  - polyethylene glycol (PEG) 111
  - polyethyleneimine (PEI)-coated
    - silica–monolithic grass microchip 109
  - polyketone polymer 151
  - polyP kinase (PPK) 599
  - polyP-rich sludge 601–602
  - polyvinylidene fluoride (PVDF) 109
  - powdered activated carbon treatment (PACT)
    - systems 484, 485
  - process analytical technology (PAT)
    - biochemical process engineering 200
    - biopharmaceutical manufacturing 201
    - fermentation and downstream processing technologies 200
    - implementations 202–203
    - product quality 201
    - tools 201–202
  - Protalix and ProCellEx<sup>TM</sup> Platform 310–313
  - protein and genetic engineering 87
  - protein engineering 34–35
  - protein hydrolysates 405–406
  - protein production
    - adaptation 374
    - cis-acting DNA elements 367–369
    - clone stability 376
    - gene amplification 369–370
    - host cell 359
    - intron 362
    - method of transfection 365
    - plasmid cloning in *E. coli* 364
    - plasmid conformation 366
    - poly-adenylation signal 362–363
    - process and product attributes 374–375
    - promoter/enhancer 360–362
    - scale-down model 375–376
    - screening platform 373–374
    - secretion leader sequence 364
    - selection marker 363–364
    - single cell cloning 370–371
    - site specific integration 367
  - protein secretion pathway 434
  - proteins modified with solid-support-binding module 154
  - proteolytic enzymes 19
  - Pseudomonas aeruginosa* 339
  - Pseudomonas brassicacearum* strain Zy-2-1 335
  - Pseudomonas denitrificans* 243
  - Pseudomonas putida* GR12-2 334
  - Pseudomonas putida* KNP9 339, 340
  - Pseudomonas* strains 330
  - pyridoxal-5'-phosphate (PLP) dependent enzymes 33
  - pyruvate carboxylase (Pc) 225
- r**
- reaction engineering
    - product removal 89, 90
    - reactant supply 89
    - two-phase systems 90–91

- recombinant glucocerebrosidase 274–275
  - recombinant proteins 263
    - extraction and purification 304–305
    - specific strategies 309–310
  - recombinant technology
    - analytical and diagnostic enzymes 29–31
    - genetic engineering 27–29
    - industrial enzymes 26, 31–32
  - recombinase-mediated cassette exchange (RMCE) 367
  - recycling of precious metals 588
  - RegulonDB 218
  - remote plasma enhanced chemical vapor deposition (RPECVD) system 117
  - restriction enzymes 27, 28, 30, 366
  - return activated sludge (RAS) 477
  - reusable bioreactors 272
  - revolutionary molecular biology method 30
  - rhizobial bacterium *Mesorhizobium* sp. 342
  - rhizobial strains 337, 338
  - rhizodegradation 329
  - rhizofiltration 329
  - rice  $\alpha$ -amylase 3D (RAmy3D) promoter 297, 309
  - Robinia pseudoacacia* 339
  - rotary drum composting 531
  - rotating biological contactors (RBCs) 483
- s**
- Saccharomyces cerevisiae* 227
  - scaffold/matrix attachment regions (S/MAR) 368
  - SEAP 435
  - secretion leader sequence 364
  - selenium 408
  - selenium recovery
    - bioprecipitation 585–586
    - biovolatilization 586–587
    - *P. stutzeri* NT-I 583–585
  - self-assembled monolayers (SAMs) 141
  - semi-solid medium system 373
  - sequencing batch reactors (SBR) 478–479
  - serum 400–402
  - serum albumin and carrier proteins 403–404
  - serum-free media formulation 407
  - shikonin 283, 289, 295, 306, 307
  - siderophores 339–340
  - silica-based matrices 111, 117
  - silica-based nanospring mats 142
  - silica-containing monoliths 127
  - silo composting 531
  - single cell cloning 370–373
  - single-or two-stage systems 537
  - single-use disposable bioreactor systems 169, 193
    - features 194
    - in practical use 195–196
    - sensors and monitoring 194–195
  - single-walled carbon nanotubes (SWNTs) 140
  - Sinorhizobium meliloti* strain 336, 338
  - Sinorhizobium meliloti* strain RD64 334
  - sitagliptin 92–94
  - sludge incineration 602
  - sludge volume index (SVI) 478
  - small scale bioreactors 169
  - small unilamellar vesicles (SUVs) 125
  - sodium bicarbonate buffer 396–397
  - sodium carboxymethyl cellulose 398
  - soft sensors 198–199, 251
  - solid state fermentation (SSF) 4–5
  - solid–liquid two-phase systems 307
  - solvent extraction 602
  - somaclonal variation 268
  - spectroscopy based methods 452
  - spin filters 441, 446
  - Sporolactobacillus inulinus* ATCC15538 246
  - stabilizing and antirepressor (STAR) elements 368
  - stable isotope probing (SIP) 343
  - stably transformed hairy root cultures 264
  - stainless steel fermentors 169, 193
  - Staudinger ligation 152
  - Stickland reaction 548
  - stirred-tank reactors (STRs) 178–184, 297, 299–300
  - streptavidin-coated microbeads 125
  - streptavidin-linked enzymes 125, 126
  - Streptomyces acidiscabies* E13 340
  - Streptomyces tendae* F4 339
  - stress ethylene 335
  - submerged biological contactors (SBCs) 484
  - sugars 390
  - surface aeration 480
  - switchgrass 5
  - symbiotic N fixing bacteria 336
  - synthetic polymer membranes and papers 109
- t**
- tangential flow filtration 438
  - Taxol<sup>®</sup> 283, 314
  - Teflon<sup>®</sup> 100
  - 1,1,3,3-tetramethyldisiloxane (TMDSO) monomer 117
  - Thelephora terrestris* 341

thermochemically treated sludge ash 602  
 thermoresponsive hydrogels 151–152  
 thiamine pyrophosphate 393  
 threonine production 230  
 tissue cultures 264  
 tobacco plants 289, 310  
 total dissolved solids (TDS) 478  
 total organic carbon demand (TOC) 472  
 traditional cell culture medium 386  
 transcriptome analysis  
 – DNA microarray 214  
 – ethanol stress tolerant strain 217–218  
 – identification of genes conferring ethanol stress tolerance 215–217  
 – inverse metabolic engineering 214  
 – omics analysis 214  
 – RNA-seq 214  
 transferrin 401–403, 407–408  
 3.6 kb transgene expression enhancing sequence 368  
 trickling filters 481–483  
*Trigonella foenum-graecum* plants 341  
 trypsin-entrapped tetraethoxysilane (TEOS) polymer 111  
 tryptophan biosynthesis genes 216  
 tube spin bioreactors 449

**u**

ubiquitous chromatin opening elements (UCOE) 368  
 ultrasonic horns 497, 498, 510  
 unconsumed components 388  
 universal nutrient consumption rate 422  
 upflow anaerobic sludge blanket (UASB) 489–490, 550, 556  
 Urban Wastewater Treatment Directive 473  
 Ure2 protein 149

**v**

vector engineering 434  
 vitamins 392–393  
 volatile suspended solids (VSS) 475, 476  
 vortex flow filters (VFFs) 440–441

**w**

waste activated sludge (WAS) 477  
 waste disposal 521, 581, 606 *see also* municipal solid waste (MSW)  
 wastewater treatment plants (WWTPs) 600, 601, 603  
 Water Framework Directive 473  
 water in media preparation 388–389  
 water quality 388, 389  
 water-soluble vitamins 393  
 wave bioreactors 301, 302, 447, 448  
 wet/dry digestion 535–537  
 whole effluent toxicity (WET) test 472  
 whole plants and cell/tissue cultures 261–262  
 whole plants vs. *in vitro* culture platforms 265–267  
 whole transcriptome shotgun sequencing (RNA-seq) 214  
 windrow composting 527–530

**z**

zwitterions 397  
 zymase 18

