Index

Page numbers in italics refer to entries in tables or figures.

“3-R” strategy (reduce, reuse, recycle)  88

a
ACEO process  118, 119
acetone  30
acetone butanol ethanol (ABE) fermentation  29
acrylic acid  121, 122, 139
adipic acid  132
advanced biofuels, see second-generation biofuels; third-generation biofuels
agricultural land, see land use
algae-based fuels  35–43, 60
– advantages  36
– companies involved in  40
– in hydrogen production  44–46, 47, 48
– production  36
– see also microalgae
Algae Biofuels Challenge  38
Algenol  40
Amyris  29
Animal and Plant Health Inspection Service (APHIS)  167–169, 174, 182
“antenna complexes”  45, 46
aquaculture  42
Arizona Public Service Co  91
aromatics  67, 69, 83
arsenic  74, 75, 77
artemisinin  127, 129, 130
artificial cells  145, 149, 184
asphyxiation  50
atrazine  74
Aurora Biofuels  40
Australia Group guidelines  171, 179–181, 191
Austria, regulations  196–198

b
Bacillus anthracis  183
Bacillus cereus  183
Bacillus thuringiensis  166
bacteria
– biosensors  73, 74, 75
– extremophiles  146
– nitrogenases and hydrogenases  45, 47
– in water treatment  77, 78
– see also individual bacteria
base case  38, 39
Belgium, regulations  182
benthic unattended generator (BUG)  58
bio-based non-degradable bioplastics  109
bio-derived polyethylene  109, 111
bio-photovoltaic cells  54, 55, 58, 59
biobutanol  29, 30, 60
– economic potential  32
– from lodgepole pine  135
– social aspects  33, 34
biocatalysts  117, 118, 125–127, 131
biocides  125
BioCleanCoal, Australia  91
biodegradability  85
– biomaterials  106
– biopolymers  108, 110, 111, 114, 115
– cellulosomes  134
biodiesel  9, 10, 28, 29, 60
– from algae  35
– economic potential  32
– environmental impact  32, 33
– global production  18
– greenhouse gas emissions  22
– production  33
– social aspects  34
BioDME project  31

bioethanol 9, 10
- from biomass 16
- economic potential 20, 21
- environmental impact 22–24
- global production 18
- global trade 18, 20
- production 19, 20, 59
- social and ethical aspects 24–27
bioethics 206, 207
biofuels 7, 8
- from biomass 8, 135, 136
- Chinese research 212
- companies 24, 227, 228
- conversion process 15
- economic potential 8, 11, 12
- environmental impact 12, 13–17
- EU forecasts 10
- European consumption 27
- generations of 9, 10
- life cycle 12, 22
- from protocols 148
- recommendations for 59–61
- social and ethical aspects 17–19
- see also algae-based fuels; bioethanol;
  hydrogen production; microbial fuel cells
  (MFCs); non-ethanol fuels
Biofuels Directive (EU) 136
biogas 9, 34
biohydrogen 60, 61
- production 4, 44, 49
biological diversity 176, 177
biological oxygen demand (BOD) 78
Biological Weapons Convention 178, 179, 181
biomass
- biofuels from 8, 135, 136
- biomaterials from 105
- from carbon recapture 89, 90
- environmental pressure, relief of 14
- hydrogen production 44, 49
- microalgae 38, 39
- production and conversion to ethanol 16
- solid 34
- see also cellulose; lignocellulose
biomaterials 103–107
- building-blocks 104, 105
- recommendations for 138, 139
- see also biopolymers; bulk chemicals;
  cellulosomes; fine chemicals
biomembranes 79–82
biomineralization 69
bioplastics, see biopolymers
biopolymers 107–116
- biodegradability 108, 110, 111, 114, 115
- capacity 112
- formulation challenges 110
- major applications 108
biopropanol 29, 32
bioremediation 67–70
- Chinese research 212, 216
- companies 229, 230
- recommendations for 98, 99
- see also biosensors; carbon dioxide
  recapturing; soil decontamination; solid
  waste treatment; water treatment
biosafety 107, 139, 151, 153
- Cartagena Protocol 177, 178, 182, 190
- Chinese regulations 215–217
- and synthetic biology 209, 210
biosafety levels (BSL) 161, 162
biosecurity 70, 124
- China 217, 218
- EU 191–193
- Switzerland 203, 204
biosensors 55, 70–77, 98
- applications 71, 73
- bacterial 73, 74, 75
- Chinese research 212
- enzymes as 71, 75
- global trade 73
- RNA 71, 72, 74
- types 71–73
Biosensors for Effective Environmental
Protection and Commercialization 75
biotechnology, see synthetic biology
bioterrorism 79, 125, 173
black biotechnology 3
blue biotechnology 3
bottom-up approaches 95, 98, 145, 188
Brazil, biofuel production 13, 23, 24
BREW study 122, 123
brown biotechnology 3
brownfields 82, 84
building-block chemicals 104, 105
built environment 103, 104, 147, 148
bulk chemicals 116–125
- commercial scale 139
- fermentation 119, 120–122
- large-scale production 120
- sustainability 116, 117, 124
- technological changes 118
butanediol 119

cap and trade scheme 93, 94
carbon capture and recycling (CCR) 98,
  146, 147
carbon dioxide emissions
- algal fuels and 41
- reducing 89, 131
carbon dioxide recapturing 89–98
  – current projects using algae 91, 92
  – drawbacks to market 94
  – government subsidies 92, 97
  – purification and compression 89
  – storage sites 89
  – sustainability 90, 92, 95, 96
carbon dioxide sequestration 48, 90, 92
carbon economy 93, 96, 97
carbon neutral hydrocarbons 23
carbon trading 93, 94, 97
carbonic acid 146
Cartagena Protocol on Biosafety 177, 178, 182, 190
catalysts 116
  – biocatalysts 117, 118, 125–127, 131
  – cellulose 108, 133, 135, 137
  – see also lignocellulose
cellulosomes 133–138
  – applications 134
  – biodegradability 134
  – intellectual property rights 137
cephalexin 132
cellular oxygen demand 78
chemical synthetic biology, see xenobiology
chemical weapons 179
chemicals, see bulk chemicals; fine chemicals
Chicago Climate Exchange 94
China 210–220
  – biosecurity and dual-use 217, 218
  – government bodies 214
  – R&D projects 212, 213
  – regulations, adapting and improving 218, 219
chiral compounds 125, 126, 129, 130
Chlamydomonas reinhardtii 45
chlorinated hydrocarbons 83
chlorophyll 45
clean development mechanism 94
Clostridium acetobutylicum 29
Clostridium thermocellum 134, 135
cogasification 44
cohesins 134
Columbia Energy Partners, USA 91
commercial distribution 165
commercial purposes 164, 165
community general export authorizations (CGEAs) 191, 192
composting 86, 88, 108, 115
ConocoPhillips, USA 92
consumer countries 26, 27
Convention on Biological Diversity 176, 177
conventional biofuels, see first-generation biofuels
cost, see economic potential; price
Counter-Terrorism Strategy 193
cyanobacterial hydrogenases 45, 47
cyanobacterial nitrogenases 45, 47
d
Defence Advanced Research Projects Agency 39
Deinococcus 128
Department of Commerce Regulations 170–172
Department of Health and Human Services (HHS) 173–175
desalination, see water desalination
"designer" biofuels 10
dimethylether 31
DNA
  – biosensors 71
  – synthetic DNA 163, 175, 176
  – see also recombinant DNA
DNA synthesis 151–153, 187, 188
  – Chinese research 213
  – export authorizations 192
  – German regulations 200
dockerins 134
domestic waste, EU 86
double-stranded DNA 175, 176
dredge sludge 69
dual-use biologicals
  – Australia Group 179
  – China regulations 217, 218
  – EU regulations 191, 192
  – German regulations 199, 200
  – Swiss regulations 203, 204
  – US regulations 170, 171
e
E-On Hansa 92
eco-efficiency analysis 132, 133
economic potential
  – algae-based fuels 37–41
  – bioethanol 20, 21
  – biofuels 8, 11, 12
  – biomaterials 104, 106
  – biopolymers 111, 112
  – bioremediation 68, 69
  – biosensors 73
  – bulk chemicals 119–122
  – carbon dioxide recapturing 92, 93
  – cellulosomes 135, 136
  – fine chemicals 128–131
  – hydrogen production 46–49
  – MFCs 56
– non-ethanol fuels 32
– protocells 147
– soil decontamination 83, 84
– solid waste treatment 87
– water desalination 80
– water treatment 78
– xenobiology 150, 151
electricity, from MFCs 53, 55, 56–58
electron transfer, MFCs 55, 56
energy densities 28
energy yield 38
enforcement
– APHIS regulations 168
– Commerce Department Regulations 172
– EPA regulations 166, 167
– NIH guidelines 163, 164
– Select Agent Rules 174, 175
EniTecnologie, Italy 91
environmental biotechnology 3, 4
environmental impact
– algae-based fuels 41
– bioethanol 22–24
– biofuels 12, 13–17
– biomaterials 106
– biopolymers 112–114
– bioremediation 69, 70
– biosensors 74–76
– bulk chemicals 122, 123
– carbon dioxide recapturing 95, 96
– cellulosomes 136, 137
– fine chemicals 131–133
– hydrogen production 49–51
– MFCs 56–59
– non-ethanol fuels 32, 33
– protocells 147, 148
– soil decontamination 84, 85
– solid waste treatment 87
– water desalination 81
– water treatment 78
– xenobiology 151–153
“environmental” pharmaceuticals 145, 147
environmental pollutants 70–77
Environmental Protection Agency (EPA) 164–167, 182
enzymes
– biosensors 71, 75
– catalysts 117, 118, 126, 127, 131
– EPA exemptions 166
– see also cellulosomes
*Escherichia coli* 29, 30, 74
ethics
– algae-based fuels 42, 43
– bioethanol 24–27
– bioethics 206, 207
– biofuels 17–19
– biomaterials 107
– biopolymers 114–116
– bioremediation 70
– biosensors 76, 77
– bulk chemicals 123–125
– carbon dioxide recapturing 96–98
– cellulosomes 137, 138
– fine chemicals 133
– hydrogen production 51, 52
– MFCs 59
– non-ethanol fuels 33–35
– protocells 148, 149
– soil decontamination 85
– solid waste treatment 87–89
– water desalination 81, 82
– water treatment 79
– xenobiology 153, 154
ethylene 122, 139
Europe, *see* European Community; European Union; *individual countries*
European Community
– biofuel regulations 7, 16
– Framework Programme 6 (FP6) 190
– safety-related advisory bodies 193, 194
European Group on Ethics 206
European Trading Scheme 93
European Union
– alternative fuel introduction 10
– bioethanol production 21
– Biofuels Directive 136
– Counter-Terrorism Strategy 193
– domestic waste 86
– eco-industry 68
– existing regulations 190–195
– list of controlled items 193
– national regulations 195, 196
– regulations
  – – adapting and improving 205–209
  – – outlook 209, 210
– regulations vs. US 181, 182
– soil decontamination 82, 83, 84
– *see also* *individual countries*
exemptions
– EPA regulations 165, 166
– NIH guidelines 162, 163
Experimental Use Permit 166
Export Administration Regulations 170, 171
export authorizations 191–193
Export Control Classification Numbers 170, 171
extremophiles 146
fatty acids 29
fatty alcohols 29
Federal Food, Drug, and Cosmetics Act 170
Federal Insecticide, Fungicide, and Rodenticide Act 166
Federal Regulations and Guidelines 158–176
fermentation 20, 29
– biopolymers 110
– bulk chemicals 119, 120–122
– fine chemicals 126, 127, 131, 132
– hydrogen production 44, 49
– sewage 78
fine chemicals 4, 125–133
– fermentation 126, 127, 131, 132
– price 129, 130
first-generation biofuels 9, 10
Fisher–Tropsch process 31
fluorescein isothiocyanate 75
food
– biofuels and 18
– price of 25, 26
Food and Drug Administration (FDA) 169, 170
fossil fuels
– bioethanol, GHG emissions 23
– bioplastics from 109
– bulk chemicals from 120, 121
– global dependency on 7
– greenhouse gas emissions 22
Framework Programme 6 (FP6) 190
fuel cells 49
– see also microbial fuel cells (MFCs)
fuels
– energy densities 28
– from solid waste 86
– see also biofuels; fossil fuels
gasoline
– costs, vs hydrogen 46, 48, 49
– safety data 50
genetic circuits 187, 188, 212
– see also genetically modified (GM) organisms
genetically modified (GM) organisms 87, 88, 95, 109
– Australia Group guidelines 180
– Cartagena Protocol 177, 178, 190
– regulations 184, 208
– – Austrian 196, 197, 198
– – China 214, 215
– – EU 190, 191
– – German 199, 200
– – UK 201, 202
– – US 169, 181
– safety 151
genotypic information 165
Germany, regulations 198–201, 208, 209
global authorizations 192
Global Bioenergies 31
global trade
– biodiesel 18
– bioethanol 18, 20
– biofuels 11, 12
– biosensors 73
– fossil fuels 7
global warming 93
glycerine 31, 32
GMOs, see genetically modified (GM) organisms
government subsidies
– bioethanol 21
– carbon dioxide capturing 92, 97
green biotechnology 2
– green algal hydrogenases 45, 47
– green chemistry 107, 116, 117, 129
– – eco-efficiency analysis 132, 133
– – principles 113, 114
– Green Chemistry Resource Exchange 131
– GreenFuel Technology, USA 92
greenhouse effect 18, 26
greenhouse gases 13
– bioethanol 23
– bioethanol/biodiesel/fossil fuels 22
– bioplastics and 113
– bulk chemicals 122, 123
– carbon trading 93
– see also carbon dioxide emissions;
methane; nitrous oxide
– groundwater decontamination, see soil decontamination

halorhodopsin 80
harmful algal bloom 74
Health and Safety Executive (HSE) 207, 208
heavy metals 83
hepatitis virus 151
high-performance structural bioplastics 112, 138
HIV 151
hybrid biosensors 73
Index

hydrogen economy 46, 61
  – challenges to 47, 48
hydrogen production 43–52
  – algae-based fuels 44–46, 47, 48
  – biohydrogen 4, 44, 49, 60, 61
  – EU forecasts 10
  – fermentation 44, 49
  – price 46, 47, 48, 49
  – processes 44
  – safety 49, 50
hydrogenases 45, 47
3-hydroxypropionic acid 121, 122

i
immunobiosensors 71
incineration 86
individual licenses 192
industrial biotechnology 3
inequalities in access 97, 107, 125, 149
  – see also justice of distribution
infectious agents 162, 173, 216
Institutional Biosafety Committee (IBC)
  – approval 159, 160
intellectual property rights, cellulosomes 137
internal rate of return 39
International Conventions and Agreements
  176–180, 182
isobutene 31
isopropanol 30

j
jet fuel 39
joint implementation 94
justice of distribution 19
  – algae-based fuels 43
  – biosensors 77
  – cellulosomes 138
  – hydrogen production 52
  – MFCs 59
  – non-ethanol fuels 34, 35
  – solid waste treatment 88, 89
  – see also inequalities in access

k
Kolaghat Thermal Power Plant, India 91
Kyoto Protocol 93, 94
l
laccases 131
land use
  – biofuels 13, 14–16
  – biopolymers 113
  – bulk chemicals 122
landfill 86, 87, 88
large-scale production
  – algae-based 60
  – bioethanol 24
  – biofuels 17
  – bulk chemicals 120
leakage, hydrogen 49, 51
legislation, see regulations
life cycle assessments (LCA) 22, 106, 122, 123
lignin 137
lignocellulose 136, 137
  – bioethanol from 19, 20
  – degradation 134
  – see also cellulose
Linc Energy, Australia 91
lipids 35
liquefied petroleum gas 31
liquid hydrocarbon fuels 14
  – see also non-ethanol fuels

m
MBD Energy, Australia 91
medical market
  – biomaterials 104, 106, 108
  – EU regulations 194
  – see also pharmaceutical ingredients
mercaptan 50
mercury 75
methane 58, 87
methanol 31, 32
MFCs, see microbial fuel cells (MFCs)
microalgae 35, 36
  – carbon capture 90–92
  – energy yield 38
  – harmful algal bloom 74
  – hydrogen production 44–46, 47, 48
  – productivity 35, 36, 37
  – see also algae-based fuels
microbial agents, risk groups 161, 162
Microbial Commercial Activity Notice (MCAN) 164–166
microbial fuel cells (MFCs) 52–59, 61
  – applications 53, 55
  – classification 55, 56
  – electricity from 53, 55, 56–58
  – publications 54
  – types 53, 55
  – wastewater management 56, 57
microorganisms
  – EPA regulations 164–166
  – see also bacteria
mineral oil 83
minerals 67, 69, 77
minimal genomes 187, 188, 212
modularity 149, 150
Mycoplasma mycoides 149, 184

n
Nagoya–Kuala Lumpur Protocol 178
nano bio info cogno (NBIC) convergent 103
national general export authorizations (NGEAs) 191, 192
National Institutes of Health (NIH)
– director approval 159, 160
– recombinant DNA guidelines 158–164, 182, 183
natural gas
– EU forecasts 10
– safety data 50
– steam reforming 43, 44, 47
nitrogenases 45, 47
nitrous oxide 33, 69
“No Compromise® fuels” 29
non-ethanol fuels 27–35
– see also biobutanol; biodiesel
non-renewable energy use (NREU) 122
notification process, APHIS 167, 168
NRG Energy USA 92
nucleic acids
– biosensors 71, 72
– xeno 151, 153, 189
– see also DNA

o
oil prices 120, 121
oilgae, see algae-based fuels
organophosphate pesticides 75
organophosphorus hydrolase 75
orthogonality 150, 188

p
packaging industry 108, 111, 115, 116
paints 148
– smart 146, 147
palm oil production 13
permit process, APHIS 168
pesticides 75, 125, 126
– EPA regulations 166
PetroAlgae 41
pH changes 75
pharmaceutical ingredients 125, 126–130, 132
– see also medical market
phenols 75, 83
phenotypic information 165
photo-electrochemical production, hydrogen 44, 47
photobioreactors 36, 37
photoproduction, hydrogen 45, 46, 47
photosynthesis
– bio-photovoltaic production 54
– hydrogen production 44–46, 47
photovoltaic cells 54, 55, 58, 59
pig manure 69
plant oils 9
pollutants/pollution
– environmental 70–77
– water pollution 67, 77
poly-3-hydroxybutyrate 109
polyamide 11, 109
polycyclic aromatic hydrocarbons 83
polyethylene 109, 111
polyhydroxyalkanoate 109
polylactic acid 108–110
polyol 139
polyvinyl chloride 122, 139
post-translational biosensors 72, 73
power densities 52
precaution 5
pressure swing adsorption purification 48
price
– algal hydrogen systems 48
– bioethanol 25
– bioplastics 112
– desalination 81
– fine chemicals 129, 130
– food 25, 26
– hydrogen per kilogram 47
– hydrogen vs gasoline 46, 48, 49
– oil 120, 121
producer countries 26, 27
production cost plus profits 120, 121
productivity, algal strains 35, 36, 37
projected case 39
1,3-propanediol 118, 120, 121, 139
protocells 95, 98, 145–149
– biofuels from 148
– Chinese research 213
– interactive and social behavior 146
– R&D 187, 188
– recommendations for 154
– sustainability 148
public awareness/concern 52
– biopolymers 114, 115
– bioremediation 70
– carbon capture 96
– pollutants 76
– water desalination 81
PureBond 103
rainforest conversion 13
recombinant DNA 128, 153, 158
– FDA regulations 169, 170
– NIH guidelines 158–164, 182, 183
– Select Agent Rules 173
Recombinant DNA Advisory Committee (RAC) review 159, 160
recycled materials 68
recycling 86, 115, 116
– “3-R” strategy 88
– carbon capture and 98, 146, 147
red biotechnology 2
regulations
– adapting and improving 205–209
– Austria 196–198
– biofuels in the EC 7, 16
– China 210–219
– Germany 198–201, 208, 209
– impact on biofuel production 16, 17
– Switzerland 203–205, 208
– synthetic biology 5, 157–220
– United Kingdom 201, 202, 207, 208
– US vs EU current coverage 181, 182
– see also under European Union; National Institutes of Health; United States
research and development (R&D) 73, 94, 187, 188, 189
– in China 212, 213
rhizodeposition 58
rice paddies 58
risk 5
– EU regulations 194, 206–208
– see also biosafety; safety
risk groups, NIH 160, 161, 162
RNA biosensors 71, 72, 74
RWE, Germany 91
safety
– EC advisory bodies 193, 194
– GMOs 151
– hydrogen 49, 50
– xenobiology 152
– see also biosafety; risk
Sapphire Energy 40
Sapporo Breweries 49
Scientific Committee on Consumer Safety (SCCS) 193
Scientific Committee on Emerging and Newly Identified Health Risks (SCENIH) 193, 194, 207
Scientific Committee on Health and Environmental Risks (SCHER) 193, 194
Scientific Committee on Problems of the Environment (SCOPE) 13
Seambiotic, Israel 91
second-generation biofuels 10
Select Agent Rules 172–175, 183
separate hydrolysis and fermentation (SHF) 20
sewage treatment 78
simultaneous saccharification and fermentation (SSE) 20
small-scale production, biofuels 17, 24
social aspects
– algae-based fuels 42, 43
– bioethanol 24–27
– biofuels 17–19
– biomaterials 107
– biopolymers 114–116
– bioremediation 70
– biosensors 76, 77
– bulk chemicals 123, 125
– carbon dioxide recapturing 96–98
– celluloses 137, 138
– fine chemicals 133
– hydrogen production 51, 52
– MFCs 59
– non-ethanol fuels 33–35
– protocols 148, 149
– soil decontamination 85
– solid waste treatment 87–89
– water desalination 81, 82
– water treatment 79
– xenobiology 153, 154
soil decontamination 82–85
– European Union 82, 83, 84
– thermal soil treatment 84
solar energy conversion 53, 54
Solarvest BioEnergy 40
Solazyme 40
solid biofuels 9, 10
solid biomass 34
solid waste treatment 68, 85–89, 98, 99
– and biopolymers 111, 112, 114–116
– domestic waste 86
– fuels from 86
– sustainability 87
– technologies involved 87
Southeast Asia, palm oil production 13
speciality chemicals 125
standard biological parts 187, 188
steam reforming 43, 44, 47
steel works 86
succinic acid 121, 139
sugar-based building-blocks 104, 105, 120, 121
supermarkets 111, 115
supermethanol project 31, 32
sustainability
  – algal-based fuels 39
  – biofuels 12, 17
  – biopolymers 108, 115
  – brownfield regeneration 82
  – bulk chemicals 116, 117, 124
  – carbon dioxide capturing 90, 92, 95, 96
  – protocols 148
  – solid waste management 87
Switzerland, regulations 203–205, 208
SYNBIOSAFE 209
Synechococcus elongatus 29
syngas 34, 136
synthetic biology
  – activities included in 186
  – biosafety and 209, 210
  – current activities 2
  – definition 2, 186
  – R&D examples 187
  – vs genetic engineering 189
  – see also biofuels; biomaterials;
    bioremediation; regulations
synthetic biology applications
  – color-coded 2, 3
  – selecting and assessing 3–5
Synthetic Biology Policy Coordination
  Group, Royal Society 202, 207
synthetic DNA 163, 175, 176
Synthetic Genomics 40
synthetic organisms 70, 76, 77, 79, 184

taxonomic designation 165
thermal soil treatment 84
thermaplastic starch 108
thermochemical production, hydrogen 44, 47
third-generation biofuels 10
Toxic Substances Control Act (TSCA) 164, 166
toxicity 50
  – biobutanol 29, 60
  – bioremediation 70
  – detection 76
  – see also biosafety
Toyota Highlander Hybrid 46
transcriptional biosensors 72
transesterification 33
translational biosensors 72
transport fuels 8, 11
  – algae-based 41
  – biobutanol 29
  – bioethanol 23
  – costs, hydrogen vs gasoline 46, 48, 49
  – European consumption 27
transportation, bioethanol 21
Trident Exploration, Canada 91
TSCA Experimental Release Application
  (TERA) 164–166

u
United Kingdom, regulations 201, 202,
  207, 208
United States
  – Animal and Plant Health Inspection
    Service 167–169, 174, 182
  – biofuel economic indicators 11
  – biofuel production 7, 8
  – Department of Commerce Regulations
    170–172
  – Energy Independence and Security Act
    2007 11, 22
  – Environmental Protection Agency
    164–167, 182
  – Food and Drug Administration 169, 170
  – NIH Guidelines on recombinant DNA
    molecules 158–164, 182, 183
  – regulations, future prospects 183–185
  – regulations vs EU 181, 182
  – screening guidance double-stranded DNA
    175, 176
  – Select Agent Rules 172–175, 183
  – see also International Conventions and
    Agreements

v
viral select agents 183
viscosity 33
vitamins 125–128, 129, 130, 131, 133

w
Waste and Resources Action Programme
  116
waste management, see solid waste
  treatment
wastewater management 68, 69, 78
  – using MFCs 56, 57
water desalination 79–82
  – cost 81
  – molecular model 80
  – public concern 81
water pollution 67, 77
water supply 68
water treatment 77–79, 98, 99
  – bacteria in 77, 78
weather buoy 58
white biotechnology 3, 119
whole animals, biosafety levels 162
whole-cell biosensors 72–75
whole plants, biosafety levels 162
World Bank 93

x
xeno-nucleic acids (XNA) 151, 153, 189
xenobiology 149–154

– areas of research 150
– Chinese research 213
– R&D 187, 188, 189
– recommendations for 154
– safety 152
xenobiotics 67, 69

y
yellow biotechnology 3