

Index

(Numbers in **bold type** refer to the main references within a group)

- absorbance (extinction, optical density) 16
- absorption spectra
 betalains 215
 carotenoids 32–8
 chlorophylls 136–9
 flavins 196
 flavonoids 107–12
 haem and haemoglobin 145–6
 melanins 225, 227
 ommochromes 210–11
 phenazines 205–6
 purines and pterins 194–5
 quinones 77–9
 visual pigments 266–8
- accessory pigments
 photosynthesis 130, 158, 161, 284, 291, 301, 305, 306
 vision 257, 277–80
- Actinia equina* 28, 45, 66, 245
- actinioerythrin 28, 45, 66
- actinomycins 213
- action spectra 323, 324, 329, 330
- S-adenosylmethionine 53, 123, 172, 209
- adrenaline 237, 238, 252
- advertising colours (semasis) 20, 147, 244–5, 336
- Aequorea* 335, 336
- aeruginosin B 205
- aggregation–dispersion of pigment 246, 250, 251, 280, 328
- aklavinone 83
- albinos 237, 248, 277
- algae 40, 41, 52, 65, 67, 127, 130, 134, 139, 150, 155, 158, 159, 160, 161, 164, 172, 178, 182, 185, 283–5, 301, 304–6, 312–14, 317, 320, 323, 324
- alizarin 82, 95, 99
- alkannin 95, 99
- allomelanins 222, 227, 230, 233, 235
- allophycocyanin 159, 306–7
- alloxanthin 60, 61
- almond 124
- Amanita muscaria* 215
- δ -aminolaevulinic acid (ALA) 163–6, 177, 182, 183
 ALA dehydrase 166, 167, 182
 ALA synthetase 164–5, 178, 182, 183
 ALA transaminase 164
- amphibians 44, 155, 191, 192, 236, 245–7, 249, 263, 273, 274, 277, 328
- anaemia
 pernicious 154
 sickle cell 145
- angler fish 245, 334
- anhydrorhodovibrin 54
- animal integument, as general photo-receptor 328–30
- animal light organs 334
- Antedon* 330
- antheraxanthin 39, 286
- anthocyanidins 103–6, 109–12, 119–23
- anthocyanins 102, 106–15, 123–8, 213, 216, 253–4, 315
- anthracynones 83, 89, 100
- anthraquinones 74, 75, 77–8, 81–8, 92, 97, 99
- antibiotics, antiviral activity 83, 89, 98, 100, 209, 213
- Antirrhinum majus* 114
- aphanin 85
- aphids 75, 83, 85, 96, 97

356 *Index*

- aphins 75, 83, 85
Aphis fabae 83
Aplysia 162, 330
 aplysiocyanin 160, 162
 apo-carotenoids 27, 28, 68, 315
 aposemiasis 244–5
 apple 113, 125
 apricot 39
Arion ater 333
 Arthropoda 79, 146, 153, 189, 192, 196,
 209, 211, 228, 229, 259, 260, 280,
 328
 ascidians 139, 328
Aspergillus 112, 227, 233
 astacene 45
 astaxanthin 26, 27, 30, 31, 38, 41, 44,
 45, 66, 274, 279
Asterias rubens 45
 aurones 103, 105, 109, 112, 114, 118,
 119, 254
 auroxanthin 37, 38
 Autumn leaves 40, 114, 115, 315
- baboon 147
 Bacillariophyceae 301, 304
 background adaptation 249–51
 bacteria 26, 27, 41, 42, 46, 48, 52, 53,
 55, 58, 60, 61, 63, 64, 69, 79, 80,
 100, 130, 147, 164, 189, 200,
 204–9, 217, 219, 230, 323, 325–7,
 331, 332, 334, 337, 338,
 bacterial photosynthesis 284, 307–10,
 317
 bacteriochlorophyllide *a* 176, 177
 bacteriochlorophylls 131, 134, 135,
 138, 139, 176–8, 183, 185, 308,
 309, 315, 323
 bacteriophageophytin 309
 bacteriorhodopsin 325–7, 337, 338
 bacterioruberin 27, 28, 42, 55
 banana 224, 230
 barnacles 328
 bathorhodopsin (prelumirhodopsin) 269,
 270, 271
 bats 253
 Beer–Lambert laws 16
 bees 4, 114, 253, 277
 beetroot 213, 216
Beneckea 334
 benzoquinones 74–80, 85, 87, 91, 98,
 233
 berberine 217, 218
Beta vulgaris 213, 216
 betacyanins 213–16
 betalains 189, 213–17, 219, 220
 absorption spectra 215
 biosynthesis 216–17
 distribution 215–16
 functions and uses 217
 structures and properties 214–15
 betalamic acid 216, 217
 betanidin 214–17
 betanin 215, 216
 betaxanthins 213–17, 254
 Bignoniaceae 95
 bilberry 126
 bile 155, 157, 178, 180, 184
 bilins (bile pigments) 130, 132, 155–63,
 177–82, 184–6, 319, 321–3
 biosynthesis 177–82
 distribution 157–8
 functions 158
 structures and properties 155–7
 bilirubin 155, 156, 157, 178, 180, 181,
 184
 biliverdin 155–8, 178, 184
 biliviolins 184
 bioluminescence 333–6, 337, 338
 biopterin 193, 200, 202
 birds 7, 8, 23, 44, 66, 147, 153, 155,
 158, 226, 229, 236, 246, 248, 253,
 278, 279, 280
 eggs 44, 153, 158
 feathers 7, 44, 147, 153, 222, 224,
 226, 229, 230, 237, 246, 248, 249
 2, 3-bisphosphoglycerate (DPG) 143–5,
 182
 black grape 113, 126
 blackberry 113
Blakeslea trispora 41, 64
 blindness 273
 blood 140–7, 184
 green blood 148
 bloodworms 147
 blue tit 7
 blue wrasse 162
 Bohr effect 143–4
 bombardier beetle 98
 Boraginaceae 95
 Brachiopoda 146
Branchiostoma 330
Brevibacterium 206
 bruising 184, 185
 budgerigar 7
 butterflies 7, 8, 112, 191, 192, 213,
 253
- cacti 216
 camouflage (crypsis) 20, 112, 237, 244,
 245, 249, 336
 cancer 69, 72, 209, 224, 229, 237
Cantharellus cibarius 41

- canthaxanthin 34, 35, 37, 41, 44, 45, 60, 66, 68, 69
 capsanthin 40, 60, 62
Capsicum annuum 40, 65
Carassius auratus 44, 191, 277
 carbon monoxide poisoning 144
 carcinostatic activity 209
Carcinus maenas 244
 carminic acid 82, 83, 97, 99
 α -carotene 25, 26, 39, 40, 56, 57, 60
 β -carotene 24–6, 33–5, 39–42, 44, 56, 57, 60, 63–9, 184, 196, 263, 264, 273, 274, 290, 292, 306, 312, 315, 324, 325, 333
 β -carotene oxygenase, intestinal 263, 264
 β,γ -carotene 44
 γ -carotene 34, 41, 42, 56, 57
 γ,γ -carotene 33, 34
 δ -carotene 56, 57, 65
 ϵ -carotene 33, 34, 56, 57, 66, 279
 ξ -carotene 31, 32, 33, 51, 52, 65, 313
 carotenoids 13, 15, 23–73, 100, 191, 204, 246, 251, 254, 263, 268, 274, 278, 279, 280, 284, 286, 291, 292, 293, 301, 304, 306, 308, 309, 310, 312, 313, 314, 315, 316, 323, 324, 325, 328, 329, 330, 331, 332, 333, 338
 absorption spectra 32–8
 biosynthesis 29, 31, 46–66, 71, 313, 314
 commercial production by fermentation 41
 distribution 39–45
 functions 67, 71
 medical uses 68–9, 71, 72
 metabolism by animals 66–7, 263, 264
 properties, physical and chemical 31–8
 protection against photooxidation 64, 67, 292
 provitamins A 44, 71
 regulation, control of biosynthesis 63–6
 structures and nomenclature 23–30
 C_{30} carotenoids 28, 42, 48
 C_{45} , C_{50} carotenoids 27, 42, 55, 58, 59
 carotenoproteins 31, 38, 45, 71, 72
Carpobrotus acinaciformis 214
 carrot 24, 40, 44, 273
 cat 278
 catechins (flavan-3-ols) 103, 104, 107, 115, 119, 120, 122, 123
 catechol 74, 75, 76, 227, 228, 230, 233
 catechol melanins 227
 caterpillars 157, 158
 cattle 152, 265, 266, 273, 277, 281
 Centrospermae 215
 Cephalopoda 211, 229, 250, 251, 261, 274, 275, 334
 Chaetognatha 146
 chalkones 103, 105, 106, 109, 114, 116, 118, 119, 120, 254
 chameleon 250
Cheiranthus cheirii 254
 cherry 113
 chicken 147, 226, 279
 chimaphilin 92, 94
 chitin 45
Chlamydomonas 301, 313
Chlorella 172, 285, 301, 313
 chlorins 131, 133, 134, 139, 149, 172
 chlorobactene 43, 63
 Chlorobiaceae 43, 284, 307, 310
Chlorobium 134, 136, 138, 176, 177, 284, 307, 310
 chlorophylls 134–6, 138, 176, 177
 chlorocruorin (chlorohaemoglobin) 147–8
Chlorogloea fritschii 159, 313
 chlorophyll *a* 133, 134, 136, 137, 172, 174, 175, 177, 180, 289, 290, 291, 294, 295, 298, 299, 301, 304, 305, 306, 311
 different spectroscopic forms 291–2
 chlorophyll *a'* 136
 chlorophyll *a*_I dimer (P-700) 290, 292, 294, 295, 297, 298, 300, 304, 308
 chlorophyll *a*_{II} dimer (P-680) 290, 292, 295, 297, 298, 299, 300
 chlorophyll *b* 133, 134, 136, 137, 174, 175, 290, 291, 301
 chlorophyll *b'* 136
 chlorophyll *c* 134, 136, 137, 175, 177, 185, 301, 304
 chlorophyll *d* 134, 136, 137, 175, 177, 185, 301, 304
 chlorophyllase 174
 chlorophyllide 136, 139, 174, 176, 177, 180
 chlorophyll–proteins 290, 291, 294, 295, 304
 chlorophylls 15, 19, 48, 65, 114, 130, 131, 133–9, 157, 163–77, 178–83, 185, 186, 253, 284, 286, 288–95, 298, 299, 301, 304, 305, 306, 310–16, 319, 323, 327
 absorption spectra 136–9
 in animals 139
 biosynthesis 65, 163–76
 control 178–83
 properties 135–9
 structures and distribution 133–5
 Chlorophyta (Chlorophyceae) 41, 52, 65, 134, 301, 313

358 *Index*

- chloroplasts 26, 39, 40, 41, 46, 48, 60, 65, 66, 97, 113, 126, 127, 133, 134, 139, 170, 180, 182, 283–307, 310–18, 320, 323
 degeneration 315–16
 development and pigment synthesis 182, 310–14
 envelope 285, 286
 grana 39, 285, 287, 288, 290, 311
 stroma 285, 286, 287, 288, 306, 307, 311
 thylakoids 285, 287–90, 294, 300, 304, 306, 307, 310, 311, 312, 314
- chlorosis 182
 chlorosomes 307, 308
 chloroxanthin 54
 chorismic acid 90, 91, 207
 Chromatiaceae 43, 284, 307, 308, 310
Chromatium 284, 310
 chromatoblasts 248
 chromatophores (animal) 245–51, 255, 334
 chromatophores (bacterial) 307
Chromobacterium violaceum 217
 chromoplasts 46, 48, 52, 56, 254, 315
 chrysoaphin 83, 84
 Chrysophyta (Chrysophyceae) 134, 301, 304
 chrysopterin 192, 194, 202
 cinnamic acids 92, 103, 115, 116, 120, 123, 124
 circadian rhythms 328–30
 circular dichroism 14, 15, 19, 20, 22, 30, 266, 269, 275
 β -citraurin 28
 clams 329
 Coccidae 82, 85, 97
Coccinella septempunctata 44, 66, 245
 cochineal 82, 85, 99
Codium fragile 139
 Coelenterata 146, 153, 334
 coelenterazine 335
 Colorado beetle 44
 colour
 basic concepts 4–8
 blindness 276, 277
 changes (animals) 204, 229, 236, 239, 246, 247, 248–52, 254, 255, 327, 328
 discrimination (vision) 4–6, 23, 257, 268, 276–7, 279, 281
 and pattern 19, 243–56, 257
 in animals 244–5
 in plants 252–4
 polymorphism 244
 compound eyes 209, 259, 260, 261, 280
 cone cells 5, 6, 258, 259, 261, 262, 268, 273, 276, 277, 279
 copigmentation 114, 115, 127
 coproporphyrin 152, 153
 coproporphyrinogens I and III 167, 169, 170, 183
 corrins 154, 177, 182, 185
Corticium salicinum 69
 cortisolin 69
Corynebacterium poinsettiae 42
 'c.p.450' 42, 43, 58
 crinoids 82, 84, 97, 330
 Crustacea 30, 38, 45, 147, 191, 192, 244, 252, 274, 328, 329, 334, 335
 crustacyanin 38, 45
 crypsis 20, 112, 237, 244, 245, 249, 336
 Cryptophyta 158, 159
 β -cryptoxanthin 35, 36, 39
 cyanidin 106, 111, 113, 114
 Cyanobacteria (Cyanophyta) 41, 98, 134, 158, 159, 161, 185, 306, 313
Cypridina 335, 336
 cytochrome P₄₅₀ 149, 151, 152, 186
 cytochromes 17, 140, 148–9, 151, 152, 178, 185, 284, 297, 298, 299, 300, 310, 312
Cytophaga-Flexibacterium 69

Dactylopius coccus 99
 daffodil 39
Daldinia concentrica 227
 dandelion 39
 decaprenoxanthin 27, 28, 42, 58
 2-decarboxybetanidin 214
 delphinidin 106, 111, 113, 114, 115
Delphinium 106
 3-deoxyanthocyanidin 103, 104, 120
 dermal chromatophore unit 247, 250
Diadema 330
 diaponeurosporene 42, 43
 dibenzopyrazine 204, 205
 6,6'-dibromoindigo (Tyrian purple) 218, 219
 3,4-didehydroretinaldehyde 67, 263, 268, 274, 277
 3,4-didehydroretinol (vitamin A₂) 67, 273, 274
 difference spectra 17
Digitalis purpurea 253
 7,8-dihydroneopterin 200, 201, 202
 dihydroporphyrin (chlorin) 131, 133, 134, 139, 149, 172
 dihydroxanthommatin 209, 210, 211
 1,8-dihydroxynaphthalene 227, 228, 235

- dihydroxy-1,4-naphthaquinones 78, 79
 dimethylallyl pyrophosphate 47, 48
 6,7-dimethyl-8-ribityllumazine 203–4
 dinoflagellates 304, 323, 334, 336
 Dinophyceae 301
Diospyros 96
 Diptera 192
 disease resistance 124, 125
 diurnal rhythms, daylength 320–3, 327,
 328, 329, 330
 DOPA (dihydroxyphenylalanine) 216,
 217, 224, 230, 231, 233
 DOPACHrome 230, 231
 DOPA-melanin 224
 DOPAquinone 224, 226, 228, 230, 231,
 232, 234
 DPG (2,3-bisphosphoglycerate) 143,
 144, 145, 182
Drosera 96
Drosophila melanogaster 192, 211, 246,
 280
 drosoperin 192, 193, 194, 200, 202,
 280
 ducks 158
 dyes 74, 82, 99, 219
Dytiscus 112
- earthworm 153
 ebony 96
 echinenone 34, 35, 306
 Echinodermata 45, 78, 79, 80, 85, 97,
 98, 329, 330, 333
 eggs 44, 45, 67, 80, 153, 158, 185, 211
 electrochemical gradients 288, 300,
 325–7
 electron microscopy 261, 286, 287
 electron spin resonance (e.s.r.) 224
 electron transport
 photosynthetic 97, 149, 284, 288,
 289, 292, 295, 296–300, 302, 305,
 306, 308, 310, 312, 330
 respiratory 17, 52, 97, 148, 149, 151,
 296, 299, 314
 electronic absorption (u.v./visible) spectro-
 scopy 15, 16, 22, 32–8, 45, 107
Elysia viridis 139
 embryogenesis 248
 emodin 81, 82, 87, 88
 epidermal melanin unit 247, 248
 erythroaphin 83, 84
 erythromelanin 226
 erythrophores 193, 204, 246, 247, 250,
 251
 erythropterin 192, 194, 202
Eschscholtzia californica 39
 eschscholtzianin 39, 40, 60, 62
- etiolated seedlings 65, 180, 310, 311,
 312, 313, 314, 320
 etioplasts 310, 312, 313, 320
 conversion into chloroplasts 310–12
Euchloë cardamines 192
Euglena gracilis 40, 65, 312, 313, 314,
 323, 324
 ‘eye spot’ (stigma) 40, 323–4
 Euglenophyta (Euglenophyceae) 134,
 301
 eumelanins 222–30, 232, 235, 237, 277
Eupithecia oblongata 112
 excited states 9–15
 extended quinones 75, 83, 84, 85, 89, 98
 extinction 16
 extra-ocular and extra-retinal photo-
 receptors 327–30, 337, 338
 eyes 7, 23, 192, 196, 209, 210, 211, 213,
 229, 237, 238, 246, 257–82
 colour 7, 277, 280
 iris 7, 250
 light reflectors 193
 oil droplets 66, 278–80
 screening pigments 211, 213, 229,
 238, 258, 261, 277, 280
 eyeshine 278
- faeces 152, 155, 157, 169, 178, 183
 farnesol 134, 135, 149, 177
 farnesyl pyrophosphate 43, 47, 48
 ferns 320
 ferredoxin 297–300
 ferrihaem 141
 ferrimyoglobin 141
 ferrochelatase 170, 172
 firefly 334–5
 fish 7, 8, 23, 44, 66, 147, 162, 184, 191,
 192, 229, 236, 245, 246, 247, 249,
 263, 273, 274, 277, 328, 329, 334,
 335, 336
 flamingo 44, 66
 flash kinetic spectroscopy 22
 flash photolysis 321
 flavans (2-phenylbenzopyran) 102, 103,
 107, 108, 115, 119, 120, 122, 123
 flavan-3,4-diols (proanthocyanidins) 103,
 104, 107, 108, 115, 119, 120, 122,
 123
 flavan-3-ols (catechins) 103, 104, 107,
 115, 119, 120, 122, 123
 flavanones 103, 104, 108, 115, 116, 118,
 119, 120, 122
 flavanonols 103, 104, 119, 120, 121
 flavins and flavoproteins 124, 151, 189–
 204, 219, 220, 284, 298, 299, 324,
 334, 335, 337

360 *Index*

- flavins and flavoproteins – *continued*
 absorption spectra 196
 biosynthesis 197–204
 control 204
 nucleotides (FAD, FMN) 195, 334
 properties 196
 structures and distribution 195–6
Flavobacterium 42
 flavones 102, 103, 104, 106, 108, 109,
 112, 114, 115, 119, 120, 123, 125,
 254
 flavonin 112, 113
 flavonoids 91, 102–29, 216, 253, 254
 absorption spectra 107–12
 biosynthesis 90, 115–25
 control 123–5
 contribution to plant colours 113–15
 distribution 112–13
 food colorants 126–7, 128
 functions 125–6
 glycosides 103, 106, 107
 metabolism by animals 125
 metabolism by microbes 125
 properties 107–12
 structures and nomenclature 102–6
 flavonols 103, 104, 106, 108, 109, 112,
 114, 115, 119, 120, 123, 125, 254
 flexirubins 69, 70
 flowers 19, 39, 80, 84, 98, 102, 106, 111,
 112, 113, 114, 115, 123, 127, 229,
 243, 252–5, 320–2
 fluorescence 13–15, 107, 195, 196, 278,
 291, 334–6
 fly agaric 215
 folic acid 193, 200
 food colorants 68, 71, 82, 85, 99, 126,
 127, 128, 216, 219
 fovea 258, 276, 278
 foxglove 253
 free porphyrins in animals 152–3, 183–4,
 186, 333
 fringelite 84
 frogs 192, 246, 248, 277
 fruits 19, 23, 27, 28, 39, 40, 44, 46, 48,
 52, 56, 65, 80, 102, 112, 113, 114,
 124, 125, 126, 224, 230, 235, 243,
 252–5, 315, 316
 ripening 65, 315–16
 fucoxanthin 41, 304, 305
 fungi 30, 41, 46, 48, 52, 63, 64, 67, 69,
 74, 79, 80, 81, 83, 85, 87, 89, 97,
 98, 112, 125, 126, 130, 147, 196,
 204, 206, 213, 215, 224, 227, 230,
 233, 235, 323, 324, 325
Fusarium javanicum 87
Fusarium martii 98
Galago 196, 278
 gallophaeomelanin 226
 galloxanthin 279
 gallstones 157
 genetic control of flower colour and
 pattern 254
 geranyl pyrophosphate 47, 48, 95
 geranylgeraniol 134, 135, 174, 175
 geranylgeranyl pyrophosphate 46, 47,
 48, 49, 64
 glaucobilin (mesobiliverdin) 157
 glow-worm 334
 goldfish 44, 191, 277
Gonepteryx rhamni 192
 grasses 301
 grasshoppers 157
 guanine 8, 190, 191, 197, 198, 199, 200,
 246, 249, 278
 guanophores (iridophores) 191, 247
 haem and haemoproteins 130, 131, 140–
 152, 155, 162–72, 177, 178–83,
 330, 333
 biosynthesis 162–72
 control 178–83
 catabolism 155, 177–81, 185
 enzymes (catalase, peroxidase) 140,
 152
 haemerythrin 148
 haemochromogen 146
 haemocyanin 148
 haemoglobin 19, 140–7, 148, 149, 155,
 182, 184, 185
 adult haemoglobin A 141, 145
 carboxyhaemoglobin 144–6
 contribution to animal colours 147
 distribution 146–7
 foetal haemoglobin F 141, 145
 function in oxygen transport 142–5,
 185
 genetic defects 145
 methaemoglobin 142, 145
 oxyhaemoglobin 141–6, 148, 182
 sickle cell haemoglobin S 145
 spectroscopic properties 145–6
 structures and properties 140–2
 haemolymph 146, 157
 haemovanadin 148
 hallachrome 82, 83
Halobacterium halobium 42, 55, 325–7,
 337, 338
Haplopappus gracilis 120
 Harderian gland 328
 harderoporphyrin 328, 329
Helix pomatia 112, 148
 henna 74, 99

- herbicides 52, 65, 314
 high-altitude adaptation 182
Holothuria forskali 196
 holothurians 329
Homarus vulgaris 30, 38, 45
 homogentisic acid 91, 92, 94
 hormonal control of pigmentation 204,
 245, 248, 251–2, 254, 328
 hoverfly 192, 245
 human diseases, melanin overproduction
 237
 see also gallstones, jaundice, porphyria,
 tumours
 human foetus 141, 145, 236
 humming birds 253
Hydrangea macrophylla 114
p-hydroxybenzoate 91, 92, 95
 hydroxybenzoquinones 76, 233
 β -hydroxy- β -methylglutaryl-CoA reductase
 46, 47
 hydroxynaphthaquinones 76–9
 hydroxyspheroidene 42, 43, 54
 Hymenoptera 192
 hypericin 84, 96, 98
Hypericum 84, 98
 hypsorhodopsin 269, 271
- indican (3-hydroxyindole glucoside) 219
 indicaxanthin 214, 215
 indigo 218, 219
Indigofera tinctoria 219
 indigoidine 218, 219
 indole-5,6-quinone 223, 224, 230–3
 infrared spectroscopy 15, 79
 initiation of flowering 320
 Insecta 7, 8, 19, 23, 44, 66, 75, 82, 83,
 85, 96, 97, 98, 99, 112, 114, 125,
 157, 158, 191, 192, 196, 211, 213,
 228, 229, 244, 245, 246, 253, 275,
 280, 329, 334, 335
 attractants and deterrents 114, 125,
 229
 integumental colours 20, 43, 44, 45, 147,
 153, 157, 158, 161, 185, 192, 204,
 211, 228, 229, 238, 243–56, 328–
 330, 333
 interference colours 7
 intersystem crossing 13, 15, 293, 332
 intestine 67, 155, 178, 180, 263, 264
 invertebrate eye 259–61
 invertebrates 21, 23, 28, 30, 31, 38, 44,
 45, 66, 74, 78, 79, 80, 112, 139,
 146, 147, 148, 152, 153, 157, 158,
 161, 162, 185, 191, 192, 196, 210,
 211, 213, 219, 224, 229, 236, 244,
 245, 247, 249, 250, 251, 252, 257,
 259, 260, 261, 268, 274, 275, 277,
 280, 328, 329, 330, 333, 334, 335,
 336
- iodinin 205, 206, 208, 209
 iridescent colours 7, 8
 iridophores 191, 247, 248, 250, 251
 iris *see under* eyes
Iris 115
Isatis tinctoria 219
 isoalloxazine 190, 195, 204
 isobetanidin 214
 isocryptoxanthin 35, 36
 isoflavones 103, 105, 108, 119, 120
 isoguanine 190, 191
 isopentenyl pyrophosphate 47, 48
 isoprenoid pathway 46–9, 86, 92–5, 97
 isorhodopsin 266
 isozeaxanthin 35, 36, 37, 60
- jaundice 157
 javanicin 87, 88
Juglans regia (walnut) 80, 98
 juglone 80, 81, 92, 93, 95, 98
- kaempferol 106, 112
 keratin 7, 333
 kermes 99
 kermesic acid 82, 83, 99
Kermococcus ilicis 99
 kynurenine 209–13
- laccic acid D 89
 ladybird beetle 44, 66, 245
 lampyrine 335
Latia 335, 336
 lawsone 80, 81, 92, 93, 95, 99
Lawsonia alba 80, 99
 leaves 26, 46, 60, 80, 99, 112, 113, 114,
 124, 125, 229, 312, 320, 321
 leghaemoglobin 147
 lemur 278
 Lepidoptera 7, 8, 112, 191, 192, 213,
 253
Leptinotarsa decemlineata 44
 leucopterin 192, 194, 202
 lichens 74, 81, 85, 89, 97
 light absorption by atoms and molecules
 8–15, 20
 light absorption spectroscopy 15, 16, 22,
 32–8, 45, 107
 light-emitting bacteria 334
 light-harvesting chlorophyll *a/b*-protein
 (LHCP) 289–93, 301, 311, 312
Limulus polyphemus 328
 linear dichroism 18, 20
 liver 152, 264, 273

362 *Index*

- Lobelia* 115
locust 44
luciferase 334–6
luciferins 334–6
lumirhodopsin 269, 271
lutein 26, 39, 60, 274, 279, 291
lycopene 23, 25, 29, 32, 33, 34, 36, 39, 51, 52, 53, 54, 56, 57, 63, 65, 316
lycopersene 48, 49
- macula lutea 258, 278
madder 74, 82, 99
magnesium protoporphyrin IX 161, 171, 172
- mammals 46, 67, 139, 140, 141, 147, 152, 153, 157, 178, 196, 206, 222, 226, 229, 236, 244, 246, 248, 258, 264, 265, 266, 273, 277, 278, 281
hair 8, 147, 222, 224, 229, 230, 237, 246, 248, 249
skin 147, 224, 229
- man 67, 69, 139, 141, 144, 147, 206, 222, 225, 226, 236, 248, 258, 276, 277, 281
freckles 226
hair 222, 224, 225, 226, 229
skin (negro) 236
- marticin 98
mass spectrometry 16, 79, 107
- melanins 8, 96, 191, 204, 222–39, 246, 247, 248, 249, 250, 251, 277, 278, 280, 328, 330, 333
absorption spectra 225, 227
biosynthesis 230–8
control 234–8
chemistry 222–8
distribution 229–30
functions 238
- melanoblasts 249
melanocytes, melanophores 229, 236, 237, 246–8, 249, 250, 255, 328
melanocyte-stimulating hormone (MSH) 237, 251, 252
melanomas 224, 229, 237
melanosomes (granules) 229, 236, 237, 246, 249, 250
melatonin 252
menadione 92, 93
menaquinone 74, 80, 81, 90, 92, 93, 97
metamorphosis 248, 327
metarhodopsins 269, 271, 274, 275
methyl magnesium protoporphyrin IX 171, 172, 173
7-methyljuglone 96
mevalonic acid 46, 47, 52, 61, 92–5, 97
microbial symbionts 66, 97, 155, 196, 334
- microvilli 260, 261
miscellaneous *N*-heterocyclic pigments 217–19, 220
miscellaneous photofunctions 319–39
mixed-function oxidases 60, 149, 151
moles and birthmarks 237
Mollisia 80, 87
mollisin 80, 81, 87
Mollusca 112, 139, 148, 153, 161, 211, 219, 224, 229, 250, 251, 261, 274, 275, 329, 334, 335, 336
shell pigments 153, 161
- Morinda root 99
morindone 99
mosses 320
mother of pearl 8
Murex 219
musca-aurin I 215
mushrooms and toadstools 41, 227, 230, 233
- Mycobacterium* 64, 100
myoglobin 140–3, 145, 148, 185
oxymyoglobin 141, 145
three-dimensional structure 140
myricetin 106, 112
myxoxanthophyll 41
- naphthaquinones 74–81, 85–90, 92–4, 97–9
naphthazarins 78, 81
Nereis diversicolor 157
neoxanthin 39, 60
neural crest 248
Neurospora crassa 64
neurosporene 32, 33, 51, 54, 57
Nocardia 206
non-carotenoid polyene pigments 69
noradrenaline 252
Nucella 219
nuclear magnetic resonance (n.m.r.) spectroscopy 15, 20, 30, 79, 107, 136
- oats 320
ocellus ('median eye') 327, 328
octopus 229, 250, 261, 275
okenone 43, 63
ommatidia 209, 259–61, 280
ommatins 209, 210
ommins 209–12
ommochromes 189, 209–13, 220, 229, 250, 251, 280
absorption spectra 210–11
biosynthesis 211–13
distribution 211
functions 213
structures and properties 209–11

- Onchorhynchus keta* 147
 Onychophora 146
 opsin 18, 67, 263–76, 281
 optical density 16
 optical rotatory dispersion 19, 30
 orange 28, 44, 254
 orang-utan 226
 orsellinic acid 87
 outer segments: retinal rod, cone cells 258–62
 oxychlororaphine 205, 206
 oxygen-transporting blood pigments 140–8, 185, 186
- P-680 290, 292, 295, 297–300
 P-700 290, 292, 294, 295, 297, 298, 300, 304, 308
- papillochromes 213
 Papilionidae 213
 ‘parietal eye’ 328
 parrot 7
 parsley 116, 118, 127
 pea 291, 292
 peach 124
 peach leaf curl fungus 125
 peacock 7
 pelargonidin 106, 111, 113
 peridinin 304, 305
Periplaneta 196
 phaeomelanins 222, 226, 227, 229, 230, 232, 233, 234, 235, 237, 246
 phaeophorbide 136, 139, 315, 316
 Phaeophyta 41, 134, 301, 304
 phaeophytin 136
Phaffia rhodozyma 30
 phenazines 189, 204–9, 220
 absorption spectra 205–6
 biological activity 209
 biosynthesis 206–9
 distribution 206
 structures and properties 204–6
 phenolic coupling 76, 95, 96, 115, 230–5
 phenoxazines 209–13
 phenylalanine-ammonia lyase (PAL) 116, 124
 phorbin 133
 phosphorescence 13–15
Photobacterium 334
 photodynamic damage 330–3
 photophosphorylation 283, 284, 300, 301, 302
 photopic vision 268
 photoprotection 64, 67, 292, 330–3, 337, 338
 in animals 333
 DNA photodamage and repair 331–2
- photopsin 6, 268, 273, 276
 photosensitivity 98, 330–3
 photosynthesis 4, 15, 16, 17, 19, 20, 22, 67, 71, 97, 130, 134, 155, 158, 185, 253, 283–318, 319, 320, 323
 accessory light-harvesting pigments 130, 158, 161, 284, 291, 301, 305, 306
 bacterial 284, 307–10, 317
 carbon fixation 301–4
 in Cyanobacteria 306–7
 dark reactions 283, 300–4
 light-harvesting antennae 289–95, 297, 308, 309, 312
 light-harvesting chlorophyll *a/b*-protein (LHCP) 289–93, 301, 311, 312
 reaction centres 288–300, 307–9, 311, 315
 photosynthetic bacteria 42, 43, 53, 58, 64, 134, 136, 138, 172, 175, 176, 177, 178, 283, 284, 307–10, 314–315, 332
 development of photosynthetic apparatus 314–15
 photosynthetic electron transport 97, 149, 284, 288, 289, 292, 295, 296–300, 302, 305, 306, 308, 310, 312, 330
 photosynthetic unit 288, 289, 308
 photosystems I and II 285, 288–301, 305–8, 310, 311
 phototaxis 323–4, 337
 phototropism 67, 324–5, 337
 phycobilins and phycobiliproteins 130, 158–62, 178–82, 185, 284, 305, 306, 307, 313, 314
 biosynthesis 178–82
 phycobilisomes 158, 159, 161, 178, 185, 305, 306, 307, 313
 phycoerythrin 158, 159, 161, 182, 307, 314
 phycocyanobilin 159, 160, 161
 phycoerythrin 158, 159, 182, 305, 307, 314
 phycoerythrobilin (phycobiliverdin, phycoviolin) 159–62
Phycomyces blakesleeanus 63, 227
 phycourobilin 160, 161
 phylloerythrin 139
 phylloquinone 74, 80, 81, 90, 92, 93
 phytoalexins 124
 phytochrome 65, 124, 130, 162–3, 178, 186, 311, 312, 319–23, 337
 distribution and localisation 320
 mechanism of action 321–3
 processes regulated 320

364 *Index*

- phytoene 29, 31, 32, 42, 46, 48, 49, 50, 51, 52, 53, 63, 64, 65, 66
 phytofluene 31, 32, 51, 52, 53
 phytol 48, 134, 136, 172, 174, 175, 177, 315
 Pieridae 192
Pieris brassicae 158, 192
Pieris rapae 192
 pigment aggregation and dispersion 246, 250, 251, 280, 328
 pigment-dispersing and -concentrating hormones 252
 pigment epithelium, choroid 224, 258, 259, 272, 273, 274, 277, 278
 pigment microenvironment 16, 18, 20, 135, 191
 pigment-protein interactions 18, 19, 20, 39, 304, 311
 pigments in vision 257-82
 accessory pigments 277-80
 colour vision 276-7, 281
 the eye 257-62
 visual cycles 268-75, 276, 281
 visual pigments 262-8
 pike 184
 pineal 252, 327, 328
 plant breeding 114, 123, 127
 plant cell, tissue cultures 116, 118, 120, 127, 128
 plant senescence 321
 plastocyanin 297, 298, 299, 300, 310, 312
 plastoglobuli 285, 286
 plastoquinone 74, 80, 85, 90, 97, 290, 297, 298, 299, 300, 310, 312
 polarised light discrimination 260
 pollination and seed dispersal 19, 20, 217, 243, 253-4, 255
 polyketide pathway 61, 69, 86-9, 96, 115, 116, 124
 polymorphonuclear leucocytes 332
 Polyzoa 146
 Porifera 44, 146
 porphirin 130, 131
 porphobilinogen 163, 166, 167, 177, 183
 porphobilinogen synthetase 166, 167, 182
 porphyria 68, 69, 183-4, 186, 333
 porphyrins 69, 130-53, 162-88, 294, 315, 328, 329, 330, 333
 biosynthesis 162-88
 porphyropsin 263, 268, 273, 274, 277, 329
 potato 224, 230
 prebathorhodopsin 269
 prephenic acid 90, 91
 prephytoene pyrophosphate 48, 49, 64
 primin 98
Primula obconica 98
Prochloron 139
 prodigiosin 130, 217, 218
 prolamellar bodies 310, 311
 prolycopene 29, 36, 65
 proplastids 310, 312, 313
 prothylakoids 310
 protoaphins 83, 84, 85, 96
 protochlorophyllide *a* (magnesium vinyl phaeoporphyrin *a*₈ methyl ester) 172-5, 177, 180, 311, 313
 holochrome protein 172, 173, 180, 311
 Protochordata 146, 153
 protoporphyrin (*IX*) 140, 152, 164, 170, 171, 172, 183, 328, 329
 protoporphyrinogen (*IX*) 163, 167, 169, 170, 171
 Protozoa 147, 153
Prunella modularis 158
Pseudomonas 206, 219
 pterinosomes 246
 pterins 189-204, 219, 220, 246, 251, 278, 280
 absorption spectra 194-5
 biosynthesis 197-204
 control 204
 properties 193-5
 structures and distribution 190-3
 purines 189-204, 219, 220, 246, 278
 pyocyanine 205, 206, 208, 209
 Pyrolaceae 92
ε-pyrromycinone 89
 Pyrrophyta 134
 quantitative analysis 15, 16
 quercetin 106, 112, 126
 quinol 74, 75, 76
 quinones 14, 74-101, 330, 332, 333
 biosynthesis 85-97, 100
 contribution to colour 85
 functions, biological effects 97-8
 industrial, medical uses 99-100
 occurrence and distribution 79-84
 structures and properties 74-9
 Raman spectroscopy 17, 22
Rana pipiens 248
 raspberry 113
 rat 258, 273, 281
 reaction centres, photosynthetic 288-300, 307-9, 311, 315
 red cabbage 113
 red pepper 40, 65
 red wine 113
 renieratene 44, 45

- Renilla* 335, 336
 reptiles 44, 191, 192, 236, 245, 247, 249, 278, 280, 328
 resonance Raman spectroscopy 15, 18, 20, 22, 266, 269
 reticulo-endothelial tissues 155, 176, 180, 184
 retina 5, 66, 196, 258–60, 263, 264, 268, 269, 273, 275, 276, 278, 279, 280, 327, 328
 retinaldehyde (retinal, retinene) 18, 67, 263–77, 281, 326–7, 329
 retinochrome 275
 retinol (vitamin A₁) 67, 68, 69, 71, 263, 264, 272–4
 retinol-binding protein 67, 263, 264
retro-carotenoids 27, 39, 40, 60, 62
 rhabdom 259–62
Rhizobium 147
Rhodomicrobium vannielii 53
 Rhodophyta 134, 158, 159, 160, 161, 185, 301, 305, 306, 313
 rhodopin 53, 54
Rhodopseudomonas 43, 53, 175, 178, 308, 309, 310, 314, 315
 rhodopsin 5, 262–78, 281, 326, 328, 329
 rhodoptilometrin 82, 83
 Rhodospirillaceae 42, 284, 307, 308, 309, 310, 314
Rhodospirillum rubrum 42, 53, 284, 308, 309, 310, 315
Rhodotorula 41
 rhodovibrin 54
 rhodoxanthin 27, 40
 rhubarb 100, 113
 riboflavin (vitamin B₂) 189, 190, 195, 196, 197–204, 220, 278, 299, 323, 324, 325, 329
 biosynthesis 197–204
 rod cells 5, 258–9, 261, 262, 265–8, 273, 277
 rodents 328
 roots 24, 40, 44, 74, 80, 82, 95, 99, 112, 147, 213, 216, 224, 230, 273, 321
 rose 113, 114
 Rotifera 146
Rubia tinctorum 82, 99
 Rubiaceae 95

Saccharomyces cerevisiae 204
 salamander 192
 salmon 44, 147
Sarcina 42
 sarcinaxanthin 42, 43, 58
Scenedesmus obliquus 65, 301, 313

 sclerotins 228, 229
 scotopic vision (night vision) 268
 scotopsins 5, 6, 268
 screening pigments
 eye 211, 213, 229, 238, 258, 261, 277, 280
 integument 333
 sea anemone 28, 45, 66, 245
 seeds, seed coats and pods 227, 229, 230, 235, 320–2
 germination 320–2
 semasis 20, 147, 244–5, 336
 senna 100
Sepia officinalis, ink 224
 sepiapterin 193, 202
 sepiomelanin 224, 225, 229, 232
Serratia 217
Sertularella 112
 sexual display 245
 sheep 206, 277
 shikimic acid pathway 61, 86, 90–4, 97, 115, 116, 124, 207–8
 shikonin 99
 singlet oxygen, ¹O₂ 293, 332
Sipuncula 146
 snakes 192
 solar radiation 3, 283, 316, 317
 solorinic acid 89
 spheroidene 53, 54, 55
 spheroidenone 53, 55
 spinach 288
 spinochromes (echinochrome) 78, 80, 81, 82, 85, 97, 98, 330
 spinulosin 87
 spirilloxanthin 42, 43, 53, 54, 308, 309
Spirogyra 285
 squid 229, 250, 261, 275
Staphylococcus 42
 stercobilin 156, 157, 178, 180, 181
 stercobilinogen 178, 181
 strawberry 113
Streptococcus 42
Streptomyces 83, 206, 213
 streptovaricin 100
 structural colours 6, 20, 21, 44, 190, 229, 244, 247, 278
 structural white 8, 190, 191
o-succinylbenzoate 92, 93, 95
 suntanning 236, 248, 333

 tapetum lucidum 196, 258, 278
 Tardigrada 146
 taxonomy 40, 41, 113, 127, 146
Taxus baccata (yew) arils 27, 40
 tea 115, 123
Tenebrio molitor 230
 3,4,3',4'-tetrahydrocyclopene 52, 53

366 *Index*

- tetrahydroporphin (bacteriochlorin) 131, 134, 139
 tetrapyrroles 130–88
 theaflavin 123, 124
 thylakoids 285, 287, 288, 289, 290, 294, 300, 304, 306, 307, 310, 311, 312, 314
 thymine 331
 dimerisation 331
 thyroxine 252
 tiger 244
 toad 147, 192, 246
 tomato 23, 39, 46, 48, 52, 56, 65, 254, 316
 torularhodin 42
 touraco bird 153
 trichosiderins 226, 227, 233, 234
 triplet states 13, 14, 15, 293, 332
 trisporic acid 64
 tumours, melanomas 224, 229, 237
 turkey 147, 279
 turtle 280
 Tyndall blue, scattering 6, 7, 8, 191, 229
 Tyrian purple 218, 219
 tyriverdin 218, 219
 tyrosinase (polyphenol oxidase) 230, 233, 235, 237, 246
 tyrosine 116, 216, 230, 231, 232

 ubiquinone 74, 80, 85, 90, 91, 92, 97, 309, 310
Ulva lactuca 40
 ‘unsymmetrical ξ -carotene’ 51, 53
 uric acid 190, 191
 urine 152, 157, 178, 183
 urobilin 155, 157, 178, 180, 181
 urobilinogen 155, 156, 157, 178, 181
 uroporphyrin 152, 153
 uroporphyrinogens 163, 167, 168, 169, 177, 183

 Verbenaceae 95
 vertebrate eye 258–9, 262
Vespula vulgaris 192, 244, 245
 violacein 217, 218
 violaxanthin 26, 27, 37, 38, 39, 60, 286, 304
 vision 20, 67, 257–82, 319
 accessory pigments 211, 213, 229, 238, 257, 258, 261, 277–80
 colour vision 4–6, 276–7, 281
 the eye 257–62
 neural response 271, 272, 276
 visual cycles 266, 268–75, 276, 281
 visual pigments 5, 6, 18, 21, 23, 67, 257–266, 268–77, 279, 281, 326, 327
 bleaching 268–71, 273, 276
 regeneration 258, 272–3, 276
 vitamin A 67, 68, 69, 71, 263, 264, 273–4
 deficiency 273
 vitamin B₁₂ (cobalamin) 154, 155, 157

Wallemia 69, 130
 wasp 192, 244, 245
 woad 219
 wood, bark 74, 80, 96, 112, 115
 worms 82, 139, 147, 148, 153, 157, 196, 211, 329, 334
 wounding, infection (plants) 124

 xanthine 190, 191
 xanthoaphin 83, 84, 96
 xanthoblasts 248
 xanthommatin 209–13, 280
 xanthomonadin I 69, 70
Xanthomonas 69
 xanthophores 193, 204, 246–51
 Xanthophyceae 301
 xanthophylls 23–73, 291, 292, 306, 312, 315
 xanthopterin 192, 194, 195, 202
 X-ray diffraction, crystallography 140, 226, 261, 325

 yeasts 30, 41, 196, 204
 yew 27, 40

Zea mays 65
 α -zeacarotene 56, 57
 β -zeacarotene 26, 56, 57
 zeaxanthin 26, 35, 39, 60, 61, 66, 279, 286
 zebra 244
 Z-scheme, photosynthetic electron transport 296, 297, 301, 306