

Index

- A*_{2A} adenosine receptor (*A*_{2A}AR), 66–68
Abelmoschus moschatus, 286
 Absolute, 286
Acacia praecox, 284
Aceria guerreronis, 9
 Acetophenone, 140
 Acetylcaryophyllene, 263
 Acetylcholine receptors, 68–69
 Acetylcholine receptor modulation,
 125
 ACIII inhibitors, 124
 ACIII protein, 123
Acorus gramineus, 217
Acronychia pedunculata, 284
 Activation, in piriform cortex, 150–151
 Adaptation, olfactory, 145, 146
 Additivity, at peri-threshold level,
 156
 Adenosine receptors, 66–68
 Adenylyl cyclase enzymes, 119
 Adipic acid, perfume ingredients from,
 340–341
 Adrenergic receptors, structural
 determination of, 63–64, 64–66
 Adrenoceptors, structural determination of,
 63–64, 64–66
Aedes aegypti, 6, 157
 Agarbois, in fragrance ingredient design,
 384
 Ageing. *See also* Older consumers
 olfaction and, 222–229
 olfactory acuity and, 209
 Ageing processes, as a cause of olfactory
 dysfunction, 226–227
 Age-related odour loss, gender and, 224
 Age-related olfactory impairment,
 223–224, 228
 central vs. peripheral, 223–224
 homogeneous vs. heterogeneous, 224
 Aggression-inducing pheromones, 14
 Agonist recognition, 82–83
 AgOr1 receptor, 9
Agrotis ipsilon, 14
 Alcohols
 cinnamyl, 279
 isomeric, 251–252
 linear monoterpene, 252
 phenethyl, 279
 rose, 314–315
 sesquiterpenoid, 267
 sulfanyl, 289, 290–291
 Aldehydes, aliphatic, 358
 Alder, Kurt, 422. *See also* Diels–Alder
 reactions
 Aldol condensation, 332
 Alignments, 56
 Aliphatic aldehydes, 358
 Aliphatic esters, 404, 405, 406
 Allelochemicals, 12, 21
 Allergens, in cosmetics, 363–364, 365,
 366
 Allomones, 21
 Allosteric modulation, of G-protein
 coupled receptors, 116–118
 α -pinene, fragrance ingredients from,
 319–320
Alpinia katsumodal, 284
 Alprenolol, 88

- Alzheimer's disease
 olfactory impairment and, 225
 olfactory tests and, 217
- Amber, anosmia to, 167
- Amber analogues, 275–276
- Ambergris, 274, 301
- Ambergris models, 407–408, 412
- Amblyomma americanum*, 13
- Ambreine degradation products, 274–276
- Ambrinols, 274, 275
- Amino acid codes, 55–56
- Amino acid residues, 74, 76, 87
- Amino acids
 molecular structures of, 57
 polar, 118
 shikimate derived, 278
- Amino acid sequences, 110
 receptive ranges and, 112–114
- Ammonium hydroxide, 332
- Amoore, John, 413
- Amoore's camphor model, 404
- Amoore shape theory, 409, 413–416
- Amphibian noses, 15
- Amigdala, 131
- Anabaena*, 72
- Anarsia lineatella*, 421
- Anchor residues, 20
- Ancient perfumery, 296, 298, 300
- Androstenol, human sweat malodours and, 291
- Androstenone, 16, 105–106, 396
 anosmia to, 168, 169
 human sweat malodours and, 291
- Androstenone anosmia, 194, 195
- Anethole, 281
- Anethum graviolens*, 256
- Animal testing, 367
- Anisaldehyde, 277, 279
- Anopheles gambiae*, 6, 9, 35, 36, 124, 131, 157
- Anorexia, olfactory acuity and, 216
- Anosmia, 163–169, 194, 195, 412–413
 to amber, 167
 to androstenone, 168, 169
 brain damage and, 164–165
 general, 164–165
 head injury and, 164
 to isovaleric acid, 168
 to musks, 166
 overcoming specific, 169
 specific, 164, 165–168
- Antagonism, 114–116
- Antheraea polyphemus*, 35
- Anthonomus grandis*, 13
- Anthonomus pomorum*, 21
- Anti-feedants, as plant defense, 21, 22
- Apis mellifera*, 35, 36
- Araucaria bidwilli*, 21
- Arens–van Dorp citral synthesis, 305
- Aristotle, 388
- β -Arrestin, 121
- Artemisia tridentata*, 22
- Associativity, of odour descriptors, 396–399
- Asymmetric catalysis, 421
- Atom efficiency (utilization), 303
- Atoms, 388
- Attractants, plant volatiles as, 21
- Autism, odour detection thresholds and, 216
- Autobiographical odour memory, 212–213
- Availability, of fragrance ingredients, 378–379
- Avian chemical communication, 15
- Axel, Richard, 2, 421–422
- Axons, 131–132
- Azadirachta indica*, 22
- Azadirachtin, 22
- Azidophenylalanine, 73
- Azulenes, 265
- Bacillus licheniformis*, 4
- Backhousia citriodora*, 259
- Bacteria, human sweat malodours and, 289–292
- Bacterial contamination, 9–10
- Bacterial degradation, malodours from, 288
- Bacterial rhodopsin, structural determination of, 63
- Ballesteros–Weinstein system, 58–60
- Barbier–Bouveault–Tiemann citral synthesis, 304
- Barton, Sir Derek, 421
- Base notes, 197, 198–199
- BASF route to citral, 306–307, 308
- BASF synthesis of menthol, 307–308, 308–309
- Bayer–Villiger oxidation, 336

- Beaux, Ernest, 299
- Behaviour, pheromone-induced, 12–13
- Bell-shaped curves, 97–98
- Benzaldehyde, 279, 339
- Benzene, 287
- Benzoic acid, 279, 280
- Bergaptene, 280–281
- Bergström, Sune, 422
- Bersuker, Vlad & Gorbachov theory, 412
- β_1 -adrenergic receptor, structural
determination of, 63–64
- β_2 -adrenergic receptor, 72, 74, 76
structural determination of, 64–66
- β -arrestin, 121
- β -oxidation, 282–283
- β -pinene, fragrance ingredients from,
320–322
- Biases, in data selection, 391–392
- Binary mixtures
glomerular patterns of, 157
of odorants, 153–157
- Binaural rivalry, 43
- Binding sites, multiple, 83–84
- Binding threshold hypothesis (BTH), 89
- Bioaccumulation, 368
- Biodegradability, 368
- Biosynthesis
co-enzymes in, 242
of terpenoids, 238, 244–245
- Biotechnology, enzyme catalysts in,
312–313
- Bipolar disorder, odour detection
thresholds and, 216
- Birch, Arthur, vii
- Bisabolol, 266–267
- Bitter taste, 7, 25
- Black, James, 422
- Blind assessment, 196
- Bloom, 205, 373
- BmOR56 receptor, 9
- Body odours, 288–289
- Body position, effect on odour perception,
42
- Boelens's jasmine model, 404, 405
- Bombyx mori*, 9, 13, 35, 36
- Borneols, 257–258
- Boronia megastigma*, 284
- Bovine rhodopsin, 56–58
structural determination of, 63
- Braak stages, 218
- Brain, signals processed by, 130–131
- Brain centres, 143
- Brain damage, anosmia and, 164–165
- Brain plasticity, 143–144
- Broadly tuned receptors, 110–112
- Buck, Linda, 2, 421–422
- Bulbar activation, 95–96
- Bulbar (bulb) maps, 139
use in determining receptor range, 91–96
- Bulnesia sarmienti*, 264
- Bulnesol, 264
- Butadiene, in musk synthesis, 349–350
- Caenorhabditis elegans*, 4, 33, 34
- Caffeine, memory impairment and, 227
- Calone, 197
- cAMP (cyclic adenosine monophosphate)
cascade, 119–121
- Camphene, fragrance ingredients from,
326–327
- Campholenic aldehyde, sandalwood
odorants from, 327–329
- Camphor, 260–261, 389–390
- Candida rugosa*, 309
- Carbocation chemistry, 420–421
- Carcinus maenas*, 12
- Carlson, Arvid, 422
- Carnosine, 217
- Carotenes, 268
- Carotenoid degradation products, 268–274
volatile, 274
- Carotenoids, 238, 241, 409
- Carothers technique, 313
- Carroll reaction, 305–306
- Carum carvi*, 256
- Carvol, 255
- Carvone, 94, 96, 255–256, 257
- Carvone-responding neurones, 96
- Carvone synthesis, 311, 312, 313
- Caryophyllene, 262–263
- Castor oil, fragrance ingredients from,
342–343
- Catalytic processes, importance of, 424.
See also Enzymes
- Causality, structure/activity/odour
correlation and, 393–395
- Cedarwood oils, 263–264, 265
- Cedryl methyl ether, 264

- Central nervous system (CNS), diseases of, 215
- Cetones, 272
- Chalfie, Martin, 422
- Chamaecyparis nootkatensis*, 267
- Chamomile, 266
- Channelopathy insensitivity to pain (CAIP), 136
- Channelrhodopsin, optogenetics and, 134
- Chaperone proteins, 98
- Chauvin, Yves, 421
- Chemical analysis, of odour, 188–191. *See also* GC analysis
- Chemical communication, vii, 11–23
 - avian, 15
 - dangers of, 20–21
 - micro-organism- and parasite-induced, 23
 - in plants, 21–23
 - reptilian, 15
- Chemical compounds
 - anosmia to, 166, 167
 - nature-identical, 299
- Chemical hazard prediction, computer modelling for, 367–368
- Chemically reactive precursors, 238
- Chemical modelling techniques, 390
- Chemical oxygen demand (COD), 188
- Chemical purity, 191, 192
- Chemicals, regulations related to safety of, 363–368
- Chemical senses, 25
 - as warnings, 9–11, 215
- Chemical signals, 8, 11
 - responses to, 12
 - used by insects, 14
- Chemical taxonomy, 244
- Chemistry. *See also* Discovery chemistry
 - of natural products, vii, 2
 - of terpenoids, vii
- Chemokine receptors, 68, 69
- Chemophobia, 364–365
- Chemosensory cells, solitary, 43
- Chemotaxis, 53
- Chemotaxonomy, 287
- Chromatographic model, of olfaction, 412
- Chromatographic theory, 409, 412
- Ciliopathies, 214
- Cineoles, 258
- Cinnamaldehydes, 279, 339
- Cinnamic acid, 277, 279, 280
- Cinnamyl acetate, 279
- Cinnamyl alcohol, 279
- Citral, 114, 189, 190, 258–259, 307
 - in terpenoid manufacturing routes, 316
- Citral analogues, 259, 260
- Citral synthesis, 303–307, 315
- Citronella, 252
- Citronellal, 94, 259, 260
 - in terpenoid manufacturing routes, 316
- Citronellene, fragrance ingredients from, 323–326
- Citronellol, 86, 252–253
 - fragrance ingredients from, 329–331
 - in fragrance ingredient design, 382
 - in terpenoid manufacturing routes, 316
- Citrus aurantium*, 284
- Citrus fruits, 287
- Citrus hystrix*, 259
- Citrus odorants, 141
- Citrus oils, 287
 - components of, 189, 190
- Civetticus civetta*, 286
- Cladograms, 112–113
- Claisen–Cope rearrangement, 306. *See also* Cope rearrangement
- Claisen rearrangement, 306, 307
- Clove bud oil, 262–263
- Clove oil, perfume ingredients from, 343–344
- CNG channel blockers, 124–125
- CNG channel blocking, 150
- CNG channels, 119
- Coccinella septempunctata*, 9
- Co-enzymes, 240–241
 - in biosynthesis, 242
- Co-factors, 240
- Cognitive effects, on habituation, 148–149
- Cognitive judgements, odour effect on, 211
- Cohobation waters, 300
- Comparative molecular field analysis (COMFA), 391
- Component suppression, 155
- Component synergy, 154
- Composite odours, 15
- Computer-aided molecular modelling, 405
- Computer modelling, for chemical hazard prediction, 367–368

- Concentration dependence, 197, 415
in determining structure–odour relationships, 398
- Concrète, 286, 287, 300
- Conditions, causing olfactory dysfunction, 225–226
- Conformation, of odorants, 392–393
- Conformational analysis, 421
- Conformational flexibility, 407
- Conserved amino acid sequences, 56
- Consumer products, performance in, 375–376
- Convalaria majalis*, in fragrance ingredient design, 383
- Cope rearrangement, 307. *See also* Claisen–Cope rearrangement
- Copy number variation (CNV), 159
- Corey, Elias, 421
- Coriandrum sativum*, 284
- Correlation, causality and, 393–395
- Corynebacterium* sp., 266
human sweat malodours and, 289–290
- Coryneform bacteria, human sweat malodours and, 289–290, 291, 292
- Cosmetics, allergens in, 363–364, 365, 366
- Cost, of fragrance ingredients, 378–379.
See also Testing costs
- Cotesia marginiventris*, 22
- Coumarin, 280–281
- Coumarin synthesis, 311, 312
- Coupling systems, 241, 243, 244–245, 246
- Cross-adaptation, 190
- Crude sulfate turpentine (CST), 318–319, 369, 425
- Cryptococcus laurentii*, 314
- Crystallography, 62–71
- Crystal structures, of G-protein coupled receptors, 79
- Cultural background, odour and, 212
- Cuminaldehyde, 402
- Curcubita pepo*, 23
- CXCR4 chemokine receptor, 68, 69
- Cyclocitral, 273, 274
- Cyclodamol, 323–325
- Cyclogeranic acid, 273–274
- Cyclopentadecanolide, 349, 350, 351
- Cyclopentanone derivatives, 340, 341
- Cymbopogon citratus*, 252, 258
- Cymbopogon flexuosus*, 252
- Cymbopogon jwarancusa*, 252
- Cymbopogon martini*, 252
- Cymbopogon nardus*, 252, 259
- Cymbopogon winterianus*, 252
- D3 dopamine receptor, 68
- Dalbergia parviflora*, 266
- Damascone production, 333–334
- Damascones, 268–269, 270, 272–273
in fragrance ingredient design, 382–383
- Danger signals, use of smell as, 10–11
- Danio rerio*, 33, 138, 146
- Darcin, 19
- Data selection, limitations of, 391–392
- Decanal, 189, 190, 284
- Decane derivatives, 284–285
- Decanols, 284
- Decanones, 284
- DEET (*N,N*-diethyl-*m*-toluamide), 83–84
- Defense, plant volatiles for, 21–22
- Degradation products
ambreine, 274–276
carotenoid, 268–274
iripallidal, 276, 277
terpenoid, 268–276
volatile carotenoid, 274
- 3,4-Dehydro-*exo*-brevicommin (DHB), 23
- Dementia, odour detection thresholds and, 216–217
- Democritus, 388, 411
- Dendrites, 131–132
- De-orphaned human olfactory receptors, 103
- De-orphanisation, 108–109
- 2-Deoxy-glucose (2DG) technique, 133, 138
- Depression, olfactory memory impairment and, 219
- Desensitisation, 146
- Detection probability, 202–203
- Deterpenated (folded) oils, 300
- Deuteration, 415
- Diabetes, olfaction and, 219
- Diabrotica virifega*, 22
- Dicyclopentadiene, perfume ingredients from, 341, 342
- Diels, Otto, 422
- Diels–Alder reactions, 341, 344
perfume ingredients via, 345–346

- Dihydrofloriffone[®], 273
 Dihydromyrcene, 323
 Dipentene, 249–250
 Dipolar assisted rotational resonance (DARR), 72
 Discovery chemistry, 379–380
 future challenges in, 425–426
 Discovery chemists, 377, 386, 399–400
 Disease-related olfactory loss, gender and, 224
 Disease-related smell loss, 225–226
 Diseases
 causing olfactory dysfunction, 225–226
 odorants as indicators of, 423–424
 Disease treatment, 227
 Dishabituation, 149
 Distillation
 in perfumery, 298–300
 of plant material, 286
 Disulfide bridges, 74, 80–81
 Diterpenes, 241
 (Z)-7-Dodecen-1-yl acetate, 17
 Dopamine, 136
 Dopamine receptors, 68
 Double-blind protocol, 196
 Double electron–electron resonance (DEER) spectroscopy, 73
Drosophila melanogaster, 9, 12, 14, 24, 33, 34, 35, 80, 84, 91, 135, 136, 400, 415
Drosophila sechellia, 6
 Drug exposure, in Parkinson's disease, 218–219
 Drugs, effects on sense of smell, 214
 DRY motif, 57–58
 Dye cloning, 93
 Dyson, Wright & Turin vibration theory, 409, 413–416

 Ectohormones, 13
 EL2 receptor, 117
 Electronic noses (e-noses), 205–206
 Electron topological theory, 409, 412
 Electro-olfactograms, 132–133
 Electrophysiological techniques, 147
Elephas maximus, 17
 Elion, Gertrude, 422
 Emotions, odour-associated, 212, 213
 Enantiomers, 144. *See also* Stereoisomers
 odour characters of, 416
 in shape versus vibration debate, 414–415, 416
 Encephalography (EEG) measurements, 169
 Enflourage, 286
 Environmental odours, response to, 221
 Environmental safety, in the fragrance industry, 368
 Enzymes, 240–241
 as catalysts, 312–313
 metabolic, 48
 Epicurus, 388, 411
 Epilepsy, odour identification ability and, 220
 Epithelial damage, 226
Eremocharis triradiata, 284
Erinaceus europaeus, 9
 ERY motif, 57–58
 Eschenmoser synthesis, 349–350
 Essential oils, 286, 299, 300, 301, 357
 Esterhazy bouquet, 298–299
 Ester odorants, 199
 Esters, aliphatic, 404, 405, 406
 Estragole, 281
 Ethers, monocyclic monoterpenoid, 250
 Ethyl safranate, 274
 Eucalyptus, 258
Eucalyptus citriodora, 254, 259
Eucalyptus dives, 255
Eucalyptus globulus, 258
Eucalyptus staigeriana, 259
Eugenia caryophyllata, 262–263
 Eugenols, 115, 281, 343, 344
 Eugenol-sensitive mouse receptor, 86, 98–101
 European Cosmetics Directive, 363–364
Evernia prunastri, 282
 Evoked olfactory potential (EOP), 169
 Evolution, of olfaction, 4–7
 Evolutionary pressure, 5–6
 Excitatory concentration, 97
 Extracellular surface (ECS), 74–75

 False assumptions, in SOR-based olfaction theories, 410–411
 Farnesol, 265–266
 Farnesyl pyrophosphate, 244–245
 Fatty acid precursors, 283

- Fatty acids, human sweat malodours and, 289–290
- Fatty esters, 283, 284
- Favorski–Babayan conditions, 306
- Fenchone, 261
- Fermentation, 313–314
- Ferulic acid derivatives, 281, 282
- Fischer, Emil, 412
- Fish-like olfactory receptors, 37, 53, 113
- Fish olfaction, mammalian olfaction vs., 37
- Fixed reference points, of the senses, 196
- Flavonoids, 277
- Flavour, 7
- Flavour and fragrance (F&F) companies, 296–297
- Flavour industry ingredients, 301
- Flexible key in a flexible lock, 61
- Florentine flask, 300
- Flower oils, 287
- Folded oils, 300
- Food, evaluating, 7–10
- Food preferences, determining, 210
- Food source identification, 9
- Foramina, for olfactory neurons, 135, 226
- Forced choice triangle test, 165
- Formyl peptide receptors (FPRs), 39, 40
- Foul odours, origination of, 238–239. *See also* Malodours
- Fourier transform infrared (FTIR) spectroscopy, 73
- Fragrance(s). *See also* Perfume entries
 medical applications of, 229
 mood-enhancing, 229
 quality of life and, 228
- Fragrance chemicals, principles of manufacturing, 303–314
- Fragrance chemistry
 future challenges in, 420, 423–426
 intellectual challenges in, 420–423
- Fragrance company systems, of odour classification, 199
- Fragrance discovery chemists, 400
- Fragrance industry, 1–2, 26. *See also* Perfume/perfumery industry
 change in, 359
 environmental safety in, 368
 market trends in, 369
 older consumers and, 228–229
 performance requirements in, 369
 resources in, 368–369
 safety in, 359–370
 scientific discovery in, 369–370
- Fragrance ingredient design, 357–387
 progress in, 382–386
 safety in, 376–377
- Fragrance ingredients. *See also* New/novel fragrance ingredients; Perfume ingredients
 allergens in, 363–364, 365, 366
 availability and cost of, 378–379
 from camphene, 326–327
 from citronellene, 323–326
 from citronellol, 329–331
 designing, 2
 manufacture of, 296–356
 from myrcene, 322–323
 natural, 299–302
 non-terpenoid-related, 337–350
 from α -pinene, 319–320
 from β -pinene, 320–322
 plant materials as, 299–302
 replacement of threatened, 377–378
 safety of, 363
 synthetic, 2, 302–314
 tonnage of, 297–298
 toxicity of, 359–360, 361–362
- Fragrance research, Nobel Prizes for, 420–422
- Fragrance science, meeting future challenges in, 426–427
- Frankincense, 357
- Friedel–Crafts addition, 337
- Fruit flies, olfaction among, 6. *See also* *Drosophila* entries
- Fruity olfactophores, 405–407
- Functional magnetic resonance imaging (fMRI), 134
- Functional receptors, loss of, 4–5
- GABA (γ -aminobutyric acid), 136
- GABAergic inhibition, 148
- Gallamine, 118
- Gas chromatography (GC), 189, 190. *See also* GC entries
- Gas chromatography/mass spectrometry (GC/MS), 189–190, 243, 244, 287
- Gaussian distributions, 202

- GC analysis, 191. *See also* Gas chromatography (GC)
- GC-olfactometry, 190, 191
- Gender. *See also* Sex entries; Sexes
age-related odour loss and, 224
role in olfaction, 212
- Gene coding, 113
- General anosmia, 164–165
- General law of perception, 25
- Genes. *See also* Olfactory receptor genes
coding for olfactory receptor proteins, 2,
4, 5–6
loss of olfactory receptor, 5–6
olfactory per species, 6–7
- Genetics, odour perception and, 223
- Genetic variation, in olfactory receptor
genes, 159
- Geranial, 258, 307
- Geraniol, 251–252, 329
in fragrance ingredient design, 382
from α -pinene, 319–320
in terpenoid manufacturing routes, 316
- Geranyl nitrile, 259
- Geranyl pyrophosphate, 244–245
- Gilman, Alfred, 422
- Givescote[®], 274
- Glomerular maps, 133, 138–139
- Glomerular patterns, of binary mixtures,
157
- Glomerulus (glomeruli), 135, 136, 138
- Glucose, secondary metabolites and, 240
- Glutamine conjugates, release of sweat
acids from, 290
- Glycerol, in musk synthesis, 348–349
- Goat acid, human sweat malodours and,
289
- Golding, Bernard, vii
- Gorilla gorilla gorilla*, 18
- Gossypium hirsutum*, 9
- GPCR classifications, 54–55. *See also*
G-protein coupled receptors (GPCRs)
- GPCR/ligand interaction, 79, 87–88
- GPCR modelling programs, 88–89
- GPCR numbering systems, 58–60
- GPCR proteins, 54
- GPCR signalling modulation, 78–79
- GPCR structure, techniques for
investigating, 73–74
- GPR40 receptor, 61
- G-protein activation, 81–83, 119, 120
- G-protein coupled receptors (GPCRs), viii,
2, 7, 25, 36–37, 52, 206, 373–374,
415. *See also* Prostate specific GPCR
(PSGR); 7-Transmembrane (TM)
GPCRs
allosteric modulation of, 116–118
antagonism and, 114
Nobel Prizes for work on, 421–422
structural determination of, 62–74
X-ray crystal structures of, 79
- G-proteins, 77–78
- Grapholita molesta*, 14
- Greengard, Paul, 422
- Grignard, Victor, 422
- Grubbs, Robert, 321
- Grüneberg (Grueneberg) ganglion, 40–41
- GTP/GDP cycle, 121. *See also* Guanosine
diphosphate (GDP); Guanosine
triphosphate (GTP)
- Guaiacwood oil, 264–265
- Guaiane sesquiterpenoids, 266
- Guaiazulene, 265
- Guaiol, 264
- Guanosine diphosphate (GDP), 78, 119,
120. *See also* GTP/GDP cycle
- Guanosine triphosphate (GTP), 78, 119,
120. *See also* GTP/GDP cycle
- Guillemin, Roger, 422
- Gum turpentine, 318
- H1 histamine receptor, 68
- Haarmann–Reimer route, 311, 312
- Habituation
cognitive effects on, 148–149
in humans, 148
olfactory, 145–146, 147–149
- Habituation memory, 147
- Halobaena caerulea*, 15
- Halobaena desolata*, 15
- Halorhodopsin, optogenetics and, 134
- Hansch analysis, 390, 391
- Hassel, Odd, 421
- Head injury, anosmia and, 164
- Head notes, 197–198, 199
- Headspace analysis, 190
- Health, olfaction and, 213–221
- Health and well-being issues, 423–424

- Healthy sense of smell, benefits of
 maintaining, 227–228
- Heart notes, 197, 198
- Heck, Richard, 422
- Hemiterpenoid alcohols, 248
- Hemiterpenoids, 245–247
- Herb components, 287
- Herodotus, 296
- Heterocyclic compounds, 139
- Heterologous cells, cloning receptors into,
 96–97
- Heterologous expression, in determining
 receptive range, 96–111
- Heterorhabditis megedis*, 22
- Hexadecanolide, 313, 314
- cis*-3-Hexenol, 283, 284
- Hibiscus abelmoschus*, 284
- Hippocampus, 131, 148
- Histamine receptors, 68
- Hitchings, George, 422
- Homofarnesic acid, 336, 337
- Homofarnesol, 336, 337
- Homology modelling, 75
- Homology models, ligand-steered, 90
- Homo neanderthalensis*, 8
- Homo sapiens*, 8
- Horde database, 159
- Hormones, odour and, 212
- Human H1 histamine receptor, 68
- Human nose, anatomy of, 41–44
- Human olfaction
 extrapolation to, 23–24
 insect olfaction *vs.*, 34–37
 mammalian olfaction *vs.*, 38–41
 studies of, 33–34
- Human olfactory receptors, 206
 de-orphaned, 103
- Human olfactory sensory neurons, 37
- Human opioid receptors, 69–70
- Humans
 habituation in, 148
 sniffing behaviour in, 46
- Human sense of smell, 7, 8, 18, 41,
 209–236
- Human sweat, 17–18
- Human sweat malodour, 289–292
- Human sweat volatiles, 289
- Hydrocarbons
 linear monoterpene, 249
 monocyclic, 139
 monocyclic monoterpene, 250
- Hydrodiffusion, 300
- Hydrophobicity, 203
- Hydroxycitronellal, 259–260
- Hyperosmia, 107–108
- Hyposmia
 ageing and, 223, 224
 malnutrition and, 226
 specific, 165
- I7 rat receptor, odorant activity with,
 93–94. *See also* mOR17 receptor
- Iberolacerta cyreni*, 15
- Illusions, olfactory, 215
- Impaired neurogenesis, 220
- Impaired olfactory function, schizophrenia
 and, 220–221
- Incorrect odour descriptions, 191
- Indole, 279
- Industrial synthetic routes, to terpenoids,
 314–337
- Infection, semiochemicals produced in
 response to, 24
- Infrared (IR) spectroscopy, 135
 in GPCR structural determination, 73
- Injury, semiochemicals produced in
 response to, 24
- Insect olfaction, 8
 human olfaction *vs.*, 34–37
- Insect olfactory receptors, 36–37
- Insect pheromones, 13–15
- Insects, chemical signals used by, 14
- In silico* screening, 407
- Interleukin-8, 73
- International Fragrance Research
 Association (IFRA), 363
- Intracellular surface (ICS), 77–78
- In vitro* testing, 367, 368
- Ion channels, taste and, 7, 25
- Ionone production, 331–333
- Ionones, 268–269, 269–272
 in terpene manufacturing routes, 316
- ψ -ionones, 331–332
- Iripallidal, 277
- Iripallidal degradation products, 276,
 277
- Iris pallida*, 276

- Irones, 276, 277
 Isobornyl acetate, 326
 Isomenthones, 255
 Isomeric alcohols, 251–252
 Isomeric menthanes, 253–254
 Isopentenyl pyrophosphate, 239, 244
 Isoprene rule, 421
 Isoprene unit coupling, 243
 Isoprene units, in sesquiterpenoids, 261
 Isoprenoids, 241
 Isoprenol, 245–247
 Isopulegol, 254
 Isosteres, in fragrance ingredient design, 383
 Isotopes, in shape versus vibration debate, 414–416
 Isotopic substitution, 415–416
 Isovaleric acid, anosmia to, 168
Ixodes hexagonus, 9

 Jacobsen's organ, 38, 39. *See also* Vomeronasal organ (VNO)
 James, William, 25
 Jasmine, 151
 Jasmine accords, 396–397
 Jasmine components, 200, 285
 Jasmine oil, 371
Jasminum officinale, 285
 Jasmonates, 340, 341
 Jasmonoids, 286
 Just noticeable difference (jnd), 130

 Kandel, Erik, 422
 Karanal, 370
 Karrer, Paul, 422
Kirk-Othmer Encyclopaedia, 309, 351
 Knowles, William, 421
 Kobilka, Brian, 2, 422
 Kuhn, Richard, 422

 Labdane family, 335
 Lateral olfactory tract, 140
 Lavender oil, 266
 Law of specific nerve energies, 27
 LD₅₀ dose, 359–360
 Learning, effect on smell perception, 128
 Lefkowitz, Robert, 2, 422
 Lewy bodies, 218
 Ligand-binding pocket (LBP), 60, 61, 63, 75–77, 82, 118. *See also* Venus fly-trap domain
 Ligand conformation, in determining structure/activity/odour correlation, 393, 394
 Ligand design, receptor models in, 90
 Ligand/GPCR interaction, 79, 87–88. *See also* G-protein coupled receptors (GPCRs)
 Ligand–receptor association, 98
 Ligand-steered homology models, 90
 Light, optogenetics and, 134–135
 Ligustral, 370
 Limbanol, 272
 Limonene, 94, 189, 190, 191, 248–249
 d-Limonene, 21
 Linalool, 251
 from α -pinene, 319
 in terpenoid manufacturing routes, 316
 Linalool synthesis, 317
 Linalyl acetate, 251
 Linear monoterpene alcohols, 252
 Linear monoterpene hydrocarbons, 249
 Linear terpene precursors, 245
 Lipid derivatives, 283, 284
 Lipid-derived volatiles, 287
 Lipids, 282–286
Litsea cubeba, 258, 259
Lobesia botrana, 8
 Lock-and-key model, of olfaction, 412–413
 Locusts, plant protection against, 22
 Longifolene, 263, 264
 Long-lasting adaptation (LLA), 146
Lonicera caprifolium, 285
 Lowest unoccupied molecular orbital (LUMO), 408
 LUSH odour binding protein, 35–36
 Lyon Clinical Olfactory Test (LCOT), 165

 M2 muscarinic acetylcholine receptor, 68
 M3 muscarinic acetylcholine receptor, 69
 M3 muscarinic acetylcholine receptor modulation, 125
Macaca nemestrina, 41
 Macrocylic musk chemicals, 347, 348
 Magic angle spinning (MAS), 72

- Major histocompatibility complex (MHC), 17, 20
- Major olfactory epithelium (MOE), 38, 39
- Major urinary proteins (MUPs), 6, 19–20
- Malnutrition, hyposmia and, 226
- Malodour counteraction, 376
- Malodours, 372. *See also* Foul odours
- counteracting, 210
 - human sweat, 289–292
 - in nature, 288–292
- Mammalian odours, complexity of, 18
- Mammalian olfaction
- fish olfaction vs., 37
 - human olfaction vs., 38–41
 - reptilian olfaction vs., 38
- Mammalian pheromones, 16–21
- Mammals
- olfaction among, 6–7
 - for olfactory studies, 33
- Manduca sexta*, 22, 33
- Mantidactylus multiplicatus*, 15–16
- Manufacturing, safety in, 359
- Marker compounds, 189, 215
- Marker proteins, olfactory, 40
- Market trends, in the fragrance industry, 369
- Martin, Archer, 422
- Mass spectrometry (MS), 189
- McGurk effect, 129
- Measurement techniques, results of, 194
- Medical applications, of fragrances, 229
- Medical conditions, olfaction and, 215–221
- Mediodorsal nucleus of the thalamus (MDNT), 143
- Melospittacus undulates*, 15
- Memory (memories)
- habituation, 147
 - odour and, 142, 212–213
- Memory impairment, caffeine and, 227
- Menstrual synchrony, 16
- Mentha arvensis*, 253, 309
- Mentha cardiaca*, 256
- p*-Menthadienes, 249–250
- Mentha gracilis*, 256
- p*-Menthanes, 253–254, 255, 257
- Mentha piperita*, 253, 309
- Mentha pulegium*, 255, 309
- Mentha spicata*, 256
- Mentha viridis*, 256
- Menthofuran, 256, 257
- Menthol, in terpenoid manufacturing routes, 316
- Menthol production, from mint plants, 309
- Menthols, 253
- Menthol synthesis, 307–311
- Menthones, 255
- MEP (2-*C*-methyl-*D*-erythritol 4-phosphate), 239
- MEP route, 239
- Messenger systems, second, 119–125
- Metabolic enzymes, 48
- Metabolites
- primary, 238
 - secondary, 238–239, 240
 - volatile, 17
- Metabotropic glutamate-like receptors, 54–55
- Metals, effect on sense of smell, 125
- Metarhodopsin II, 71
- Methyl chavicol, 281
- α -Methylcinnamaldehyde, 402
- Methylenecaffeic acid derivatives, 281, 282
- Methylheptenone, 315, 317
- Methylionones, 271, 272
- Methyl jasmonate, 22–23
- Methylthiomethanethiol (MTMT), 81
- Mevalonic acid (MVA), 239
- Meyer–Schuster rearrangement, 306
- Mice. *See also* Mouse urine; Murine entries; *Mus musculus*
- olfaction among, 6
 - for olfactory studies, 33
 - sniffing behaviour in, 45–46
- Mice SO, receptors in, 95
- Micro-organism-induced chemical communication, 23
- Migraine, olfactory hallucinations and, 220
- Millennium carvone process, 313
- Mint plants, menthol production from, 309
- Minty odorants, 141
- Mitral cells, 137
- Mixtures
- binary, 153–157
 - component selection of, 157
 - distinguishing components of, 151–153
 - of odorants, 149–157
- Molecular modelling, 85
- computer-aided, 405

- Molecular modelling approaches, 391
- Molecular structure. *See also* Structure entries
- correlating with odour, 160
 - odour and, 2
- Molecular structure-perception link, 144-145
- Monarda fistulosa*, 252
- Monocyclic hydrocarbons, 139
- Monocyclic monoterpenoid ethers, 250
- Monocyclic monoterpenoid hydrocarbons, 250
- Monoterpenes, 237-238
- Monoterpenoid alcohols, linear, 252
- Monoterpenoid ethers, monocyclic, 250
- Monoterpenoid hydrocarbons
- linear, 249
 - monocyclic, 250
- Monoterpenoids, 241, 247-261, 315
- Monoterpenoid skeletons, 247
- Mood-enhancing fragrances, 229
- mOR23 receptor, 113-114
- mOR256-17 receptor, 107
- mOREG eugenol-sensitive mouse receptor, 86, 98-101, 115, 116, 135-136
- mOREV olfactory receptor, 98-100
- mOR17 receptor, 94. *See also* 17 rat receptor; OR17 receptor
- Morinda citrifolia*, 6
- Moschus moschiferus*, 285
- Mosquitos, olfaction among, 6
- Mouse urine, volatile odorants in, 19-20
- Mozell's chromatographic theory, 409, 412
- mSR1 receptor agonists, 95
- M/T cells, 136, 137
- Muguet ingredients, in fragrance ingredient design, 383-384
- Müller's law, 27
- Müller's Law of Specific Nerve Energies, 130
- Multidisciplinary teams, 426-427
- Multiple binding sites, 83-84
- Multiple sclerosis (MS), olfactory detection thresholds and, 220
- μ -opioid receptor, 69-70
- Murine olfactory bulb, 139
- Murine olfactory receptors, 98-101, 107, 113
- Murine sex pheromones, 18-19
- Muscarinic acetylcholine receptors, 68-69
- Muscarinic receptors, 125
- Music, smell and, 211
- Musk ketone, in fragrance ingredient design, 385, 386
- Musk model, 407
- Musk odorants, 391, 392
- in fragrance ingredient design, 384-386
- Musks, 285-286
- anosmia to, 166
 - synthesis of, 346-350
 - synthetic, 386
- Mus musculus*, 34
- Mutagenesis, 77-78
- in amino acid residue identification, 76
- MVA route, 239
- Myoporum crassifolium*, 266
- Myrcene, 247-248
- fragrance ingredients from, 322-323
 - in terpenoid manufacturing routes, 316
- Myrocarpus frondosus*, 265
- Naphthalene, perfume ingredients from, 341-342
- Naphthofuran, 274-275, 335, 336
- Narcissus tazetta*, 284
- Nasal airflow, 45
- Nasal chemistry, structure-odour relationships and, 399-400
- Nasal irritants, 43
- Nasal metabolism, 48-50
- false assumptions about, 411
- Nasal mucosa, metabolic enzymes in, 48
- Nasutitermes exitiosus*, 8, 13
- "Natural" designation, safety and, 365-367
- Natural extracts, 2, 301, 302
- Natural fragrance ingredients, 299-302
- Natural ingredients, 301
- Natural malodours, 288-292
- Natural odorants, diversity of, 287
- Natural oils, as allergen replacements, 365
- Natural products chemistry, vii, 2
- Natural scents, 237-295
- Nature-identical chemicals, 299
- Nature-made volatile chemicals, 237-241
- Navigation, by smell, 10
- Near infrared (NIR) spectroscopy, 135
- Negishi, Ei-ichi, 422

- Neoselulus baraki*, 9
- Nepeta cataria*, 21
- Nepetalactone, 21
- Neral, 258, 307
- Nerodia fasciata*, 38
- Nerol, 251–252, 329
- Nerolidol, 266
- Nerve response, trigeminal, 43–44
- Neural activity, non-sensory, 131
- Neural structures/processes, of olfactory bulb, 136–138
- Neurodegenerative conditions, 226–227
- Neurogenesis, impaired, 220
- Neurones, carvone-responding, 96
- Neurons
- olfactory, 226
 - use in determining receptor range, 91–96
- Neuroprocessing, olfactory, 125–149
- Neuroscience techniques, 132
- Neurotensin receptors, 70–71
- Neurotransmitters, olfactory, 125–126
- New molecule synthesis, 389
- New/novel fragrance ingredients
- criteria for, 370–379
 - design of, 357–387
 - development of, 379–382
 - need for, 358–359
- New products, slow volume growth of, 425–426
- Nicotiana attenuata*, 22
- Nicotiana rustica*, 284
- Nipple search “pheromone,” 17
- Nobel Laureates, discoveries of, 420–422
- Non-sensory neural activity, 131
- Non-terpenoid-related fragrance ingredients, 337–350
- Nootkatene, 267
- Nootkatone, 267–268
- Norda carvone process, 311, 312
- Norepinephrine, 137
- Nose receptors, 43–44
- Noses
- amphibian, 15
 - anatomy of human, 41–44
 - electronic, 205–206
- Noyori, Ryoji, 421
- NTSR1 neurotensin receptor, 70–71
- Nuclear magnetic resonance (NMR) spectroscopy, 188–189
- in GPCR structural determination, 71–73
- Oakmoss, 282
- Ocimene, 248
- Odorant activity
- with I7 rat receptor, 93–94
 - modulation of, 123–125
- Odorant binary mixtures, 153–157
- Odorant concentration, structure–odour relationships and, 398
- Odorant conformation, in determining structure/activity/odour correlation, 392–393
- Odorant delivery, to receptors, 50–51
- Odorant design, future challenges in, 425–426
- Odorant detectors, developing, 205–206
- Odorant interactions, 190
- at the receptor, 114
- Odorant mixtures, 92–93, 149–157, 210
- Odorant/receptor couples, 109
- Odorant–receptor interaction, false assumptions about, 411
- Odorant recognition, 81–83, 99–100
- Odorants, 141
- derived from orsellinic acid, 282, 283
 - discrimination between, 138
 - diversity of natural, 287
 - ester, 199
 - insect, 35–36
 - reacting with receptors, 399
 - sandalwood, 91–92
 - on transparent films, 103
- Odorous plant extracts, human use of, 286–287
- Odorous shikimates, 277–282
- Odour. *See also* Malodours; Odours; Smell
- adverse reaction to, 221
 - basic requirements for, 237
 - body, 288–289
 - characterisation of, 373
 - chemical analysis of, 188–191
 - communication via, 11
 - correlating molecular structure with, 160
 - cultural background and, 212
 - effect on cognitive judgements, 211

- Odour (*Continued*)
 importance of, 372–373
 measurement and characterisation of, 191–202
 as a mental percept, 26–27
 as a molecular property, 410
 molecular structure and, 2
 primary, 167
 radiance, bloom, and trail of, 205
 subjectivity of, 192–194, 400–401
 Odour-binding proteins (OBPs), 6, 34–36, 44, 47–48, 206
 Odour character (quality), 194–195, 196–202
 classification of, 199–200
 concentration dependence of, 197, 415
 of enantiomers, 416
 test for, 380
 understanding, 297
 Odour classification, 1
 Odour coding, temporal effects in, 144
 Odour data, 192, 193, 194, 396
 Odour descriptions, incorrect, 191
 Odour descriptors, 202, 398
 associativity of, 396–399
 uses of, 414
 Odour detection, 4
 Odour detection probability, 202–203
 Odour detection thresholds (ODTs), 193–194, 202–203, 331, 373, 400–401
 autism and, 216
 bipolar disorder and, 216
 dementia and, 216–217
 Odour discrimination, schizophrenia and, 220–221
 Odour identification, multiple sclerosis and, 220
 Odour identification ability, epilepsy and, 220
 Odour intensity, 193, 203–204
 Odourless perfume ingredients, 371
 Odour markers, 19
 Odour measurement techniques, 194–196
 Odour memories, 142, 212–213
 Odour objects, 127, 141–142
 Odour percept, inputs to, 128–131
 Odour perception, 128–131. *See also* Smell perception
 body position effect on, 42
 genetics and, 223
 Odour perception variability, 193
 Odour properties, methods for determining, 193–194
 Odour purity, 191, 192
 Odour quality. *See* Odour character (quality)
 Odour response desensitisation, 146
 Odours. *See also* Odour
 composite, 15
 emotional effects of, 202
 origination of foul, 238–239
 recognizing signature, 17
 Odour space, 200–202
 Odour space maps, 201–202
 Odour space mathematical map, 202
 Odour subjectivity, 158–163
 Odour tenacity (persistence), 204–205
 Odour tests, 225
 Odour type linkages, 200–201
 Odour vocabulary, 191–192, 194
 Ohloff's triaxial rule model, 407–408
 Oils
 essential, 286, 299, 300, 301
 extraction of, 299–300
 Olah, George, 421
 Older consumers, fragrance industry and, 228–229. *See also* Ageing
 Olefin metathesis, 421
 in musk synthesis, 350, 351
 Olfaction. *See also* Sense of smell; Smell ageing and, 222–229
 chromatographic model of, 412
 comparison among species, 33–41
 in the context of senses, 24–25
 diabetes and, 219
 evolution of, 4–7
 health and, 213–221
 human, 23–24
 insect vs. human, 34–37
 lock-and-key model of, 412–413
 mammalian vs. fish, 37
 mammalian vs. human, 38–41
 mammalian vs. reptilian, 38
 measurement of, 196
 mechanism of, 32–187
 medical conditions and, 215–221
 nature of, 399–400

- ortho-nasal and retro-nasal, 5, 8
- personal perspective on, vii
- research in, 422–423
- role in food selection, 9
- sex and hormones and, 212
- studies of human, 33–34
- study of, vii
- Olfaction research, future challenges in, 423
- Olfaction theories, 408–411
 - based on structure/activity/odour correlation, 409–411
- Olfactive purity test, 204–205
- Olfactive stability, test for, 380–381
- Olfactometers, 195
- Olfactophore approach, 391
- Olfactophores, 405–407
- Olfactory acuity
 - ageing and, 209
 - anorexia and, 216
 - differences between the sexes, 17
- Olfactory adaptation, 145, 146
- Olfactory bulb (OB), 32, 34, 136–140
 - optogenetics and, 134–135
- Olfactory code, 109
- Olfactory cortex, 127, 140
 - habituation in, 147
 - primary, 32
- Olfactory detection thresholds, multiple sclerosis and, 220
- Olfactory dysfunction
 - ageing processes as a cause of, 226–227
 - diseases/conditions as a cause of, 225–226
 - multiple sclerosis and, 220
- Olfactory epithelium (OE), 5, 11, 38–39
 - human, 41–42
 - olfactory receptor distribution across, 51
- Olfactory fatigue, 145–149
- Olfactory function, schizophrenia and impaired, 220–221
- Olfactory genes, per species, 6–7
- Olfactory habituation, 145–146, 147–149
- Olfactory hallucinations/illusions, 215
 - migraine and, 220
 - schizophrenia and, 221
- Olfactory impairment(s), 214, 217
 - age-related, 222–223, 223–224, 228
 - Alzheimer's disease and, 225
 - Parkinson's disease and, 217–219, 225–226
- Olfactory loss, 214
 - gender and age-related, 224
 - in Parkinson's disease, 219
- Olfactory marker protein (OMP), 40, 113–114
 - optogenetics and, 134
- Olfactory memory impairment, depression and, 219
- Olfactory mucus, 46–47
- Olfactory nerve infection, Parkinson's disease and, 218
- Olfactory neurons, 226
- Olfactory neuroprocessing, 125–149
 - key pathways in, 127
 - techniques for studying, 131–136
- Olfactory neurotransmitters, 125–126
- Olfactory receptor (OR) distribution, across olfactory epithelium, 51
- Olfactory receptor expression patterns, 51
- Olfactory receptor function, 80
- Olfactory receptor genes, 52–53
 - Horde database of, 159
 - loss of, 5–6
 - SNP effects on, 159
- Olfactory receptor modelling, 85–90
- Olfactory receptor nomenclature, 55
- Olfactory receptor proteins, 1, 32
 - genes responsible for, 2, 4, 5–6
- Olfactory receptors (ORs), vii–viii, 52–118, 415
 - de-orphaned human, 103
 - false assumptions about, 411
 - fish-like, 53
 - human, 41–42, 206
 - insect, 36–37
 - in non-olfactory-epithelium organs, 53
 - receptive ranges of, 90–112
 - transport to, 44–51
 - tuning of, 411, 414–415
- Olfactory receptor structure/activation, 79–83
- Olfactory route, 26
- Olfactory science, applications of, 423–424
- Olfactory sensory neurons (OSNs), 11, 32, 39, 46, 52, 95, 124, 126, 135–136, 409
 - human, 37
 - optogenetics and, 134

- Olfactory signals, 33, 34, 142–143, 144
- Olfactory system, interaction with trigeminal system, 130
- Olfactory testing, 195
- Olfactory tests, Alzheimer's disease and, 217
- Olfactory tract, 126–127
- Olibanum, 357
- Opioid receptors, 69–70
- Opsin, 77
structural determination of, 62–63
- Optical imaging, 133
- Optogenetics, 27, 134–135
- OR1A1 receptor, 106
- OR1A2 receptor, 106
- OR1D2 receptor, 4, 101–103
- OR1G1 receptor, 103–105, 115
- OR2AG1 olfactory receptor agonists, 87
- OR2W1 receptor, 108–109
agonists and non-agonists of, 110
- OR7D4 receptor, 105
- OR37 receptor family, 143
- OR51E2 receptor, 107
- OR67d receptor, 91
- Orbitofrontal cortex (OFC), 32–33, 127, 129, 131, 142–143
habituation in, 148
- ORCO olfactory receptor protein, 36–37, 84, 117, 124
- Organic chemistry
in perfume industry, 299
synthetic, 357–358, 388
- Organic ingredients, 301
- Organoleptic purity, 191, 395–396
in shape versus vibration debate, 414
- Organoleptic specifications, 303
- OR17 receptor, 114, 115. *See also* I7 rat receptor; mOR17 receptor
- Ornithorhynchus anatinus*, 34
- ORS25 mouse receptor, 89
- Orsellinic acid, odorants derived from, 282, 283
- Ortho-nasal olfaction, 5, 8
- Orthonasal route, 41
- Osler, Sir William, 158
- Osmanthus fragrans*, 284, 285
- Oxidation, of sclareol, 313–314
- β -Oxidation, 282–283
- Paracelsus (Theophrastus Bombastus von Hohenheim), 359
- Parasite-induced chemical communication, 23
- Parkinson's disease (PD), olfactory impairment and, 217–219, 225–226
- Patchouli oil, 261, 262
- Patte and Laffort's σ and τ factors, 153–154, 155
- Pattern recognition, 149, 152–153
- Perceived intensity, suppression of, 155
- Perception
factors affecting, 160
general law of, 25
- Perception–molecular structure link, 144–145
- Performance requirements, in the fragrance industry, 369
- Perfume(s). *See also* Fragrance entries
analysis of, 189–190
in daily life, 210–213
in human life, 209
safety of, 360–363
traditional uses of, 210
- Perfume formulae, performance of, 374–375
- Perfume ingredients. *See also* Fragrance ingredients; Perfumery materials
from adipic acid, 340–341
from clove and sassafras oils, 343–344
from dicyclopentadiene, 341, 342
discovery of, 369–370
effects of, 376
from naphthalene, 341–342
odourless, 371
from phenol, 337–338
from toluene, 339–340
from vegetable oils, 342–343
via Diels–Alder reactions, 345–346
via Prins reactions, 344–345
- Perfume manufacturing, 296
- Perfume notes, 197–199
- Perfume/perfumery industry, 2, 209, 210.
See also Fragrance industry;
Perfumery
history of, 357–358
personal perspective on, vii
synthetic organic chemistry in, 299

- Perfumery
 ambergris in, 274
 ancient, 296, 298, 300
 damascones in, 272–273
 distillation in, 298–300
 ionones in, 268–272
 use of amber analogues in, 275–276
- Perfumery materials, performance of, 374–376
- Perireceptor chemistry, structure–odour relationships and, 398–399
- Peri-threshold level, additivity at, 156
- Persistence, 204
- Personality type, effect on smell perception, 215
- Peruvial, 266
- Pest predator attraction, by plants, 22
- Petrochemical feedstocks, terpenoids from, 315–317
- Phaeomeria speciosa*, 284
- Phantosmias, migraine and, 220
- Phellandrenes, 249
- Phenethyl alcohol, 279
- Phenol, perfume ingredients from, 337–338
- Phenylalanine, 277
- 2-Phenylethanol, routes to, 338–339
- Pheromone classes, 13
- Pheromone-induced behaviour, 12–13
- Pheromones, 11
 aggression-inducing, 14
 insect, 13–15, 35–36
 mammalian, 16–21
 murine sex, 18–19
 vertebrate, 15–16, 16–21
 volatiles as, 15
- Phosphoenolpyruvate, 239
- Phylogenetic trees (cladograms), 112–113
- Physeter catodon*, 274, 301
- Pinanol, in terpenoid manufacturing routes, 316
- α -Pinene, fragrance ingredients from, 319–320
- β -Pinene, fragrance ingredients from, 320–322
- Pinenes, 250
 in terpenoid manufacturing routes, 316
- Pine oil, 253, 254
- Pinus longifolia*, 263
- Piper cubeba*, 266
- Piperitone, 255
- Piperonal, 279
- Piriform cortex (PC), 32, 33, 140–142
 activation in, 150–151
 in creating odour objects, 142
 habituation in, 148
- Plant extracts, 2
 human use of odorous, 286–287
- Plant materials, as fragrance ingredients, 299–302
- Plants
 chemical communication between, 22–23
 chemical communication in, 21–23
 pest predator attraction by, 22
- Plant volatiles
 analyses of, 287
 as attractants, 21
 for defense, 21–22
- Pogostemon cablin*, 262
- Polak, Ernst, 400–401
- Polar amino acids, 118
- Polyanthes tuberosa*, 285
- Polycyclic musks, 347, 348
- Polyketides, 282–286
- Polymethylenes, 421
- Populus balsamifera*, 266
- Positron emission tomography (PET), 133
- Potassium hydroxide, 332
- Predators, eavesdropping on chemical communications by, 20–21. *See also* Pest predator attraction
- Prenyl pyrophosphate, 244
- Primary metabolites, 238
- “Primary” odours, 167, 413
- Primary olfactory cortex, 32
- Primary taste cortex, 142
- Principal components analysis (PCA), 390–391
- Prins reactions, 322, 344
 perfume ingredients via, 344–345
- Probability summation (PS), 129–130
- Process chemistry, future challenges in, 424–425
- Products, performance of, 375–376
- Product use, safety in, 359–368
- Pro-fragrances, 425, 426

- Prostate specific GPCR (PSGR), 53. *See also* G-protein coupled receptors (GPCRs)
- Protein Local Optimization Program (PLOP), 90
- Protein modelling, 85–86
- Proteins
- amino acids in, 55–56, 57
 - chaperone, 98
 - GPCR signalling modulation by, 78–79
 - major urinary, 6
 - malodorous degradation of, 288
 - odour-binding, 6, 34–36, 44, 47–48, 206
 - olfactory marker, 40
 - olfactory receptor, 1, 2, 4, 5–6, 32
 - pyrazine-binding, 47
 - receptor transporting, 98
- Proteorhodopsin, 72
- PrP^c prion protein, 137
- Psidium guajava*, 284
- Psychophysical function, 203
- Pulegone, 255
- Purity
- of chemicals and odours, 191, 192
 - organoleptic, 395–396, 414
- Purity tests, olfactive, 204–205
- Pyramidal cells, 140
- Pyrazine-binding proteins, 47
- Quality. *See* Odour character (quality)
- Quality control (QC), 188
- Quality control perfumer, 297
- Quality of life, fragrance and, 228
- Quantitative structure activity relationship (QSAR) modelling, 368
- Rabbit nipple search “pheromone,” 17
- Radiance, 205, 373
- Rana catesbeiana*, 48
- Rapeseed oil, fragrance ingredients from, 342–343
- Rats
- ability to distinguish odorants, 152
 - for olfactory studies, 33
- Receptive ranges
- heterologous expression in determining, 96–111
 - investigating, 109–110, 111
 - of olfactory receptors, 90–112
 - receptor amino acid sequences and, 112–114
- Receptor activity, allosteric modulation of, 116
- Receptor amino acid sequences, receptive ranges and, 112–114
- Receptor arrays, 167
- Receptor groups, 52
- Receptor–ligand association, 98
- Receptor models, in ligand design, 90
- Receptor/odorant couples, 109
- Receptor–odorant interaction, false assumptions about, 411
- Receptor proteins, olfactive, 1, 2, 4, 5–6, 32
- Receptor response pattern, 157
- Receptors. *See also* G-protein coupled receptors (GPCRs); Olfactory receptor entries; Trace amine activated/associated receptors (TAARs); Transient receptor potential channels (TRPs)
- AgOr1, 9
 - BmOR56, 9
 - broadly tuned, 110–112
 - cloning into heterologous cells, 96–97
 - loss of functional, 4–5
 - in mice SO, 95
 - odorant delivery to, 50–51
 - odorant interactions at, 114
 - odorant reactions with, 399
 - OR1D2, 4, 101–103
 - smell, 5
 - taste, 5, 7
 - vomerionasal, 18
- Receptor sequences, 58–60
- Receptor transporting proteins (RTPs), 98
- Regulations, chemicals and safety, 363–368
- Reimer–Tiemann reaction, 311
- Renewable feedstocks, 342
- Renewable materials, 425
- Repellents, as plant defense, 21
- Reporter system, 96, 98
- Reptilian chemical communication, 15
- Reptilian olfaction, mammalian olfaction vs., 38
- Research Institute for Fragrance Materials (RIFM), 363

- Resources, in the fragrance industry, 368–369
- Response patterns, of receptors, 157
- Retinal, optogenetics and, 134
- Retinoic acid, 227
- Retro-nasal olfaction, 5
importance of, 8
- Retronasal route, 41
- Retro-synthetic analysis, 421
- Rhodopsin, 71, 72, 77
bovine, 56–58
structural determination of, 62–63
- Rhodopsin-like GPCRs, 54–55. *See also* G-protein coupled receptors (GPCRs)
- Rhone-Poulenc process, 317
- Robinson, Robert, 421
- Rodbell, Martin, 422
- rOR5 receptor, 103, 104
- Rosa damascena*, 272, 382
- Rose accords, in fragrance ingredient design, 382–383
- Rose alcohols, 314–315
- Rose oil, 371
- Rose oxide, 252, 253
- Rose oxide synthesis, 331
- Rose water, 286
- Ruta graveolens*, 284
- Ruzicka, Leopold, 421
- Sabatier, Paul, 422
- Safety
in fragrance industry, 359–370
in fragrance ingredient design, 376–377
of fragrance ingredients, 363
“natural” designation and, 365–367
of perfumes, 360–363
- Safety, health, and environment (SHE)
issues, 425
- Safety regulations
for fragrance ingredients, 363–368
stringency in, 367
- Safranal, 273–274
- Safranic acid, 273–274
- Safranic acid derivatives, 268, 271
- Safrole, 281, 343, 344
- Saimiri sciureus*, 41
- Salicylic acid, 276, 279
- Salt taste, 7, 25
- Salvia sclarea*, 275, 313
- Samuelson, Bengt, 422
- Sandalwood, 389–390
- Sandalwood materials, synthetic, 326–327
- Sandalwood odorants, 91–92
from campholenic aldehyde, 327–329
- Sandalwood oil, 261, 262, 302
- Santalum album*, 262, 301, 327
- Sassafras oil, perfume ingredients from, 343–344
- Scatole, 279
- Scents. *See also* Fragrance entries; Odour entries; Perfume entries
of nature, 237–295
signature, 13
stress relief and, 213
- Schally, Andrew, 422
- Schiff's bases, 81, 342
- Schistocerca gregaria*, 22
- Schizophrenia
impaired olfactory function in, 148
impaired olfactory function and, 220–221
- Schrock, Richard, 421
- Scientific discovery, in the fragrance industry, 369–370
- Sclareol, 275, 276, 335, 336
oxidation of, 313–314
- Sclareolide, 335
- SCN9A gene, 164
- Sea snakes, olfaction among, 5–6
- Secondary metabolites, 238–239, 240
- Second messenger, 119, 123
- Second messenger cascade, 119
element modulation of, 123–125
- Second messenger system, 119–125
- Secretin-like receptors, 54–55
- Seizure prevention, odour and, 220
- Sell, Charles S., viii
- Semiochemicals, 11–12
produced by plants, 21, 23
produced in response to injury/infection, 24
- Sense of smell. *See also* Olfact- entries; Smell entries
benefits of maintaining healthy, 227–228
creative use of, 227
in daily life, 209–236
effect of metals on, 125
effects of drugs on, 214

- Sense of smell (*Continued*)
 human, 7, 8, 18, 41, 209–236
 importance of, 7, 8
 loss or distortion of, 214
- Sense of Smell Institute, 227
- Senses
 as carriers of external information,
 24–25
 chemical basis of, 25
 fixed reference points of, 196
 input from, 1
 interaction among, 211
 olfaction in context of, 24–25
- Sensory images, 27
- Sensory neurons
 human olfactory, 37
 olfactory, 32
- Sensory techniques, 203
- Septal organ, 40
- Sesquiterpenes, 241
- Sesquiterpenoid alcohols, 267
- Sesquiterpenoids, 199, 261–268
- Sesquiterpenoid skeletons, 248
- Sex, odour and, 212. *See also* Gender
- Sex attractants, 13, 14–15
- Sexes, differences in olfactory acuity
 between, 17
- Sex pheromones, murine, 18–19
- Sex-related olfactory loss, 224
- Shape/anosmia theory, 412–413
- Shape theory, 409, 413–416
- Shape versus vibration debate, 413–416
- Sharpless, Barry, 422
- Shepherd, Gordon, 8, 27, 41, 140, 209
- Shikimate derived amino acids, 278
- Shikimates, 276, 277, 280, 281
 odorous, 277–282
- Shikimic acid derivatives, 276–282
- Shikimic acid pathway, 277, 278
- Shimomura, Osamu, 422
- Short-term adaptation (STA), 146
- σ factor, 153–154, 155
- Signalling systems, 12–13
- Signal processing, by brain, 130–131
- Signal processing flow, 126–128
- Signal sets, 15
- Signal shutdown/reset, 121–123
- Signature odours, recognizing, 17
- Signature scents, 13
- Silage, 205
- Single-nucleotide polymorphisms (SNPs),
 159, 160
- Single-photon emission computed
 tomography (SPECT), 133
- Sitobion avenae*, 36
- Slossen experiment, 210–211
- Smell. *See also* Odour entries; Olfact-
 entries; Sense of smell
 chemical aspects of, 3
 in daily life, 210–213
 declining with age, 222–223
 distinguishing features of, 26
 effects on stress, 215
 as a mental phenomenon, 210–211
 music and, 211
 navigation by, 10
 role in health and illness, 209
 role of, 1
 taste and, 7–8
 as a warning signal, 215
- Smell disorders, 214
- Smell loss, 423–424
 disease-related, 225–226
 “Smell of old age,” 222
- Smell perception. *See also* Odour
 perception
 effect of learning on, 128
 personality type effect on, 215
- Smell receptors, 5. *See also* Olfactory
 receptor entries
- Smell tests, 219, 223
- Snake plot diagrams, 80
- Sniffing, 45–46
- Sodium hydroxide, 332
- Solid-state nuclear magnetic resonance
 (SSNMR), 72
- Solitary chemosensory cells (SCSs), 43
- Solubility effects, odorant delivery to
 receptors and, 50–51
- Solvents, 286, 287
- SOR-based odour/olfaction theories, 409,
 410, 411–416. *See also*
 Structure–odour relationships (SORs)
 false assumptions in, 410–411
- Sour taste, 7, 25
- Spearmint, 256
- Specific anosmia, 164, 165–168
 overcoming, 169

- Specific hyposmia, 165
 Specific nerve energies, law of, 27
 Spices, 287
Spodoptera exigua, 22
Spodoptera littoralis, 9
Staphylococcus epidermis, 266, 289
Staphylococcus haemolyticus, 290
 Starting materials, 425
 Stereochemistry, 416
 structure/activity/odour correlation and, 402–403
 Stereoisomers, 403. *See also* Enantiomers
 Steric congestion, 404, 406
 Steric isotope effect, 415
 Steroids, 241
 human sweat malodours and, 289, 291–292
 Stevens's power law, 203, 204
 Stevens's power law plot, 205
Stevia stenophylla, 266
 Stress, effects of smell on, 215
 Stress relief, scents and, 213
 Structure/activity/odour correlation
 causality and, 393–395
 limitations of, 391–395
 olfaction theories based on, 409–411
 problems in, 401–404
 stereochemistry and, 402–403
 successes in, 404–428
 techniques of, 389–391
 Structure/activity relationships (SARs), 389
 Structure–odour relationships (SORs), vii, 374, 380, 388–419. *See also*
 SOR-based odour/olfaction theories
 ambergris, 407–408
 causality and, 393–395
 inability to develop, 389
 obstacles to determining, 395–401
 odorant concentration and, 398
 odour subjectivity and, 400–401
 perireceptor chemistry and, 398–399
 statistical nature of, 416
 in structure/activity/odour correlation
 success, 404
 Subjectivity, of odour, 158–163, 400–401
 Sulfanyl alcohols, human sweat malodours and, 289, 290–291
 Sulfate esters, human sweat malodours and, 292
 Sulfate turpentine, 318–319
 Sulfurous odorants, 398
 Super-threshold intensity, 203, 205
 Suppression
 of components, 155
 of perceived intensity, 155
 Sutherland, Earl, 422
 Suzuki, Akira, 422
 Sweat, human, 17–18
 Sweat acids, 289–290
 release from glutamine conjugates, 290
 Sweat malodour, human, 289–292
 Sweet taste, 7, 25
 Symrise menthol process, 309, 310
 Synapses, 132
 Synergy, of components, 154–155
 Sygne, Richard, 422
 Synthetic chemists, 424–425
 Synthetic fragrance ingredients, 2, 301–314
 advantages of, 303
 Synthetic musks, in fragrance ingredient design, 386
 Synthetic organic chemistry, 357–358, 388
 in perfume industry, 299
 Synthetic routes, to terpenoids, 314–337
 Synthetic sandalwood materials, 326–327
 Synthetic sandalwood odorants, 327–329
 Synthetic technology, in protecting new ingredients, 381–382
Syringa vulgaris, 9
Tachygllossus aculeatus, 34
 Tail to tail coupling, 244–245, 246
 Takasago menthol process, 309–310, 310–311
 Taste(s), 26
 effect on odour perception, 128
 five types of, 7, 25
 in food evaluation, 7–9, 9–10
 measurement of, 196
 words related to, 211
 Taste cortex, primary, 142
 Taste receptors, 5, 7
 τ factor, 153–154, 155
 TecnoScent, vii
 Temporal effects, in odour coding, 144
 Teneurins, 135
 Terpenes, 241

- Terpenoid analysis, 243–244
- Terpenoid biosynthesis, 238, 244–245
- Terpenoid chemistry, vii
- Terpenoid degradation products, 268–276
- Terpenoid manufacturing routes, 316
- Terpenoid names, 243
- Terpenoid precursors, linear, 245
- Terpenoids, 2, 241–276, 302
- classification of, 243
 - industrial synthetic routes to, 314–337
 - from petrochemical feedstocks, 315–317
 - from turpentine, 316, 317–319
 - understanding of, 420
 - volatile, 241
- Terpenoid skeletons, 244
- Terpineols, 253
- in terpenoid manufacturing routes, 316
- Testing. *See* Olfactory testing
- Testing costs, 380–382
- Tetrahydrogeraniol, 329
- 3a,6,6,9a-Tetramethyldodecahydro-naphtho[2,1-b]furan, production of, 335–337
- Thalamus, mediodorsal nucleus of, 143
- Theaspiranes, 274
- Thiols, 81
- Threatened fragrance ingredients, replacement of, 377–378
- Threshold calculations, 203
- Thymol, 256–257
- Thymus vulgaris*, 256
- Timberol[®], 272
- Tinctures, 301
- Titus Lucretius Carus, 388
- TMT
- (3,4-dehydro-2,4,5-trimethylthiazoline; 2,5-dihydro-2,4,5-trimethylthiazoline), 10–11, 12, 139
- Toluene, perfume ingredients from, 339–340
- Tonkarose[®], 425, 426
- Total odour percept, inputs to, 128–131
- Touch, 26
- measurement of, 196
- Toxicity, of fragrance ingredients, 359–360, 361–362
- Toxicology, basic principle of, 359–360
- Toxoplasma gondii*, 23
- Trace amine activated/associated receptors (TAARs), 11, 37, 39, 110, 111, 206
- Trail, 205, 373
- Transient receptor potential channels (TRPs), 7, 43
- Transmembrane (TM) GPCRs, 74–75. *See also* G-protein coupled receptors (GPCRs)
- 7-Transmembrane (TM) GPCRs, 52, 53–74
- Transmembrane region, 75–77
- Treemoss, 282
- Triangle test, 165, 195
- Triaxial rule model, 407–408
- Trigeminal nerve response, 43–44
- Trigeminal system, interaction with olfactory system, 130
- Trigeminal threshold, 165
- Trigona hyalinata*, 9
- Trigona spinipes*, 9
- TRPM5 bitter taste receptor, 130
- Trypodendron lineatum*, 13
- Tsien, Roger, 422
- Tuber melanosporum*, 291
- Tuning, of olfactory receptors, 411, 414–415
- Turbinates, 41
- Turpentine(s), 250–251, 368–369
- terpenoids from, 316, 317–319
- Two-nose cycling, 42–43
- Umami taste, 6, 7, 25
- Undecanal, 115
- University of Pennsylvania smell identification test (UPSIT), 219, 222–223, 224
- University of Plymouth, 420
- Urinary proteins, major, 6
- Urine, volatile odorants in mouse, 19–20
- Urine signals, 20
- Vaccenyl acetate, 35, 36
- Valencene, 267
- Vane, John, 422
- Vanillosmopsis erythropappa*, 266
- Vapour pressure, 373
- Vegetable oils, perfume ingredients from, 342–343

- Venus fly trap domain, 117. *See also*
Ligand-binding pocket (LBP)
- Verbal cues, 131
- Vertebrate pheromones, 15–16, 16–21
- Vetivera zizanioides*, 262
- Vetiver oil, 261, 262
- Vibration theory, 409, 413–416
- Viruses, chemical signals used by, 23
- Visual cues, 131
- Vitamins, in terpenoid manufacturing routes, 316
- Vitamin synthesis, 317
- Vitispiranes, 274
- Vitis vinifera*, 8
- Volatile carotenoid degradation products, 274
- Volatile chemicals
nature-made, 237–241
of plants, 21
- Volatile metabolites, 17
- Volatile molecules, 150
- Volatile odorants, in mouse urine, 19–20
- Volatile organic compounds (VOCs), 237.
See also Lipid-derived volatiles; Plant volatiles
- Volatiles, 190
olfactory responses to, 9
as pheromones, 15
- Volatile terpenoids, 241
- Volatility parameters, 237
- Volicitin, 22
- Vomeronasal organ (VNO), 11, 18, 19, 20, 38, 39–40, 119. *See also* Jacobsen's organ
- Vomeronasal receptors (VNRs), 18, 20, 39–40
- von Baeyer, Adolf, 420
- Wallach, Otto, 420–421
- Waters of cohabitation, 300
- Well-being, olfaction and, 213–214
- Wittig–Horner reaction, 334
- Woodward, Robert, 422
- *Woody odorants, 141–142
- Xenopus laevis*, 33, 98
- Xenopus* oocytes, 96
- X-ray crystallography, in GPCR structural determination, 62–71
- X-ray crystal structures, 90
of G-protein coupled receptors, 79
- Zaglossus attenboroughi*, 34
- Zaglossus bartoni*, 34
- Zaglossus bruijnii*, 34
- Zea mays*, pest predator attraction by, 22
- Zebrafish. *See* *Danio rerio*
- Zinc glucuronate, 126
- Zizyphus jujuba*, 284