



## Index

### **a**

- ability and flunixin synthesis 276  
acetal-based quinoline, as directing group 175  
acid (mixed) anhydrides 107–109  
acid chlorides, and carboxylic acids 107–109  
 $(\pm)$ -acredinone A synthesis 278  
alkenylation reaction  
    allenylation reaction 59–61  
    carbene coupling 58–59  
    Heck reaction 52–58  
alkenyl bromide difunctionalization 254  
alkenyl Catellani reactions 241, 251, 253, 255, 257, 283, 284  
alkenyl triflates 12, 94, 111, 116, 253–258, 260, 284, 290  
alkoxycarbonylation 74, 79, 110–112  
alkylating reagent 4, 92, 134, 137, 160, 168–170, 259  
2-alkylation of indoles 279–283  
alkylation reaction  
    alkyl halides 91–92  
    aziridines 97–98  
    boron reagents coupling reaction 67  
    C–C bond cleavage reaction 71–72  
    C–H activation of inert alkyl groups 71  
    epoxides 97  
    ethers and TMSI 98–99  
    germanium reagents coupling reaction 67–69  
     $ipso$  ketone  $\alpha$ -arylation 69–71  
    1,4-Pd shift 72–73  
alkyl bromide 3, 20, 49, 92, 139, 160, 209, 218, 251, 279  
alkyl carbagermatrane 8, 9  
alkynylation reactions 61, 62  
allenylation reaction 59–61, 80  
amination  
    N-benzoyloxyamines 113–114  
    dialkylamino carbonates 114–116  
aminocarbonylation 110–112  
annulation 2*H*-azirines, 96  
arenes  
    meta-C–H alkylation 168–170  
    meta-C–H alkynylation 178  
    meta-C–H amination 176–178  
    meta-C–H arylation 170–176  
    meta-C–H chlorination 176  
    meta-C–H functionalization 167, 168  
aromatic ketones 277  
aromatic substrates 251–252  
alkenyl triflates and bromides 253–255  
 $\alpha$ -carbamoylation of alkenyl triflates 257–258  
carbonyl 1,2-transposition 255–257  
distal alkenyl C–H bond  
    functionalization 258–260  
H/N reagents and NBEs 256  
partially aromatic substrates 252–253  
arylation reactions  
    aryl diazonium salts 105–106  
    aryl halides 101–103  
    decarboxylation coupling reaction 67





arylation reactions (*contd.*)  
*ipso* C–H arylation 64–67  
Suzuki coupling 61–64  
aryl bromides 8, 26, 28, 92, 94, 99, 104,  
105, 119, 148–150, 172, 185, 189,  
209, 244, 246–251, 284, 286  
aryl halide  
*ortho* acylation 277–278  
*ortho* alkylation 16–17, 19–20,  
267–273  
*ortho* amination 16, 17, 275–277  
*ortho* arylation 16, 17, 273–275  
aryl iodides 243–244  
aryl bromides 246–251  
aryl sulfonates 244–246  
aryl-norbornyl-palladacycle (ANP) 1, 46,  
89, 129, 157, 225  
aryl palladium(II) 1, 2, 5, 7, 10, 157  
aryl triflate annulation 245  
(-)-Aspidophylline A 164, 280, 281  
aspidospermidine syntheses 280  
assoanine synthesis 274, 275  
aziridines 24, 28, 31, 97–99, 129, 131,  
134, 135, 137, 212, 228, 272, 273  
2*H*-azirines 23–24, 96, 97

**b**

benzo-fused heterocycles 131, 132, 136  
benzoic acid 11, 67  
benzoic anhydride 11, 76  
benzoxanorbornadienes 286  
*O*-benzoylhydroxylamines 12, 22  
(-)-berkelic acid 270, 271  
biaryls monophosphine oxides 149  
bis(2-diphenylphosphinophenyl)ether  
(DPEPhos) 119  
borono-Catellani reactions 188–190  
boron reagents, coupling reaction 67  
borylation reaction 76, 78, 275  
brominated alkylamines 8  
 $\alpha$ -bromoacetophenones 30, 211, 212  
bromoalkyl indole 18  
bromoalkyl-tethered cyclopentanone 8  
2-bromoarylaldehyde hydrazones 10  
bromoenoate indole 18

bromoethylamines 24  
bromomethyl-tethered cyclohexanone 8  
bromonaphthols 21, 22

**c**

C2 alkylation of NH-indoles 159–166  
C–C bond cleavage reaction 45, 71–72,  
80  
C–H activation of inert alkyl groups 71  
C–H functionalization, NH-containing  
heteroarenes 159–167  
C–N bond construction 76  
C–O bond construction 76–78  
C–S bonds construction 78–79  
C–Se bonds construction 78–79  
N-Cbz-bromoalkylamines 28, 30  
 $\alpha$ -carbamoylation 257–258  
carbazomycin A 274, 275  
carbene coupling reaction 58–59  
carbon-electrophile  
*ortho* acylation  
acid (mixed) anhydrides 107–109  
acid chlorides 107–109  
alkoxycarbonylation 110–112  
aminocarbonylation 110–112  
carboxylation using thioesters and  
selenides 109–110  
carboxylic acids 107–109  
*ortho* alkylation  
alkylation using epoxides 97  
alkyl halides 91  
annulation using 2*H*-azirines 96–97  
aziridines 97–98  
ethers and TMSI 98–99  
methyl sulfonates 92–96  
trimethylphosphate salt 92–96  
phenyltrimethylammonium salt  
92–96  
*ortho* arylation  
aryl diazonium salts 105–106  
aryl halides 101–103  
chelating effect 103–105  
homo *ortho* arylation 103  
*ortho* effect in Pd/NBE catalysis  
99–101



- carbonyl 1,2-transposition 114, 117, 255–257, 284
- carboxylation, using thioesters and selenides 109–110
- carboxylic acids 11, 55, 71, 107, 141, 170, 175–176
- catalytic arene-NBE annulation (CANAL) synthesis 287
- catalytic asymmetric transformations chiral amino acids 139–142
- chiral norbornenes desymmetrization 142–144
- enantioselective transformations 147–152
- kinetic resolution 144–147
- chiral phosphine ligands 138–139
- catalytic cycle competitive or side reactions 46–51
- role of *ipso* 46
- Catellani reaction 4-bromoquinoline 207
- catalytic asymmetric transformations chiral amino acids 139–142
- chiral norbornenes 142
- chiral phosphine ligands 138–139
- good arene substrates 237
- iodobenzothiophenes 201
- 3-iodochromone 211
- 3-iodo-9-methylcarbazole 206
- iodopyrazoles 204
- 3-iodopyridine 206
- 3-iodoquinoline 206
- (+)-linoxepin via 134
- mechanism and stereoselective step 130
- orthogonal reactivity 243, 244
- stereochemistry intermolecular chirality transfer 132–137
- intramolecular chirality transfer 131–132
- Catellani-type annulation reactions 234
- Catellani-type arylation 228
- Catellani-type reaction 27, 45, 97, 130, 136, 139, 142, 144, 146–149, 152, 157, 158, 167, 168, 188, 190, 203, 235, 237, 240, 244, 249, 251, 258, 260, 275
- chelating effect, *ortho* arylation 103–105
- chiral amino acids 8, 138–142
- chiral biaryls monophosphine oxides 149
- chiral norbornenes desymmetrization 142–144
- enantioselective transformations 147–142
- kinetic resolution 144–147
- $\alpha$ -chloroamides 28
- cinchona alkaloid cocatalyst 30
- Cochlearol B 284
- (+)-cochlearol B synthesis 284, 285
- concerted metalation deprotonation (CMD) 1, 51, 208, 240
- coupling reaction boron reagents 67
- germanium reagents 67–69
- cularine synthesis 273, 274
- cyanation reaction 74–76
- cyclobutadienoid (CBD) 286
- d**
- dactyllactone A synthesis 273, 274
- dalesconol A synthesis 269, 270
- dearomatization process 21
- decarbonylative *ipso* thiolation reaction 80
- decarboxylative intramolecular coupling reactions 67
- dehalogenation (hydrogenation) reaction 51
- density-functional theory (DFT) 48, 113
- (−)-deoxoapodine 164, 282, 283
- desymmetrization 139, 140, 142–145, 185
- dicyclohexylcarbodiimide (DCC) 108
- 2,3-dihydrobenzofuran (DHBf) 24, 25, 97, 134, 144, 179, 207
- dihydrobenzofurans 129, 135, 268
- 1,2-dimethoxyethane (DME) 131
- dimethoxyethane (DME) 51, 131

*N,N*-dimethylacetamide (DMA) 53  
 dimethyl ether (DME) 105  
*N,N*-dimethylformamide (DMF) 53, 284  
 dinuclear transmetalation 1, 227  
 2-(diphenylphosphanyl)pyridine  
 (2-PyPPh<sub>3</sub>) 66  
 distal alkenyl C–H alkylation 260  
 distal alkenyl C–H arylation 260  
 distal alkenyl C–H bond functionalization  
 258–260

**e**

electron-withdrawing group (EWG) 26,  
 58, 69, 99, 139, 148, 150, 171  
 electrophile and terminating reagent  
*ipso* amination 15  
*ipso* Heck termination 12–15  
*ortho* acylation 11–12  
*ortho* alkenylation 15  
*ortho* alkylation 3–8  
*ortho* amination 12–15  
*ortho* arylation 8–11  
 Pd(II)-initiated annulations 15–16  
 electrophilic aromatic substitution  
 reactions 74, 166, 225  
 enantioselective remote C–H  
 functionalization 184–188  
 enantioselective transformations 142,  
 147–152, 191  
 epoxides, cyclizations 24  
 (±)-eptazocine synthesis 268

**f**

fluorenols, synthesis of 10, 12  
 4-fluorobromobenzene 227  
 fluorosulfation-Catellani reaction 246  
 free carboxylic acid, as directing group  
 175–176  
 Friedel–Crafts reactions 74  
 (±)-fufenozide synthesis 268  
 functional groups (FGs) 5, 10, 16, 17, 45,  
 80, 139, 141, 144, 146, 150, 152,  
 160, 167, 172, 175, 176, 178, 179,  
 188, 214, 225, 275, 286

**g**

germanium reagents coupling reaction  
 67–69  
 (±)-goniomitine 164, 279, 280

**h**

haloheteroarenes reactions  
 with incorporation 202–205  
 without incorporation 200–202  
 Heck acceptor 3, 4  
 Heck reaction 16, 52, 73, 80, 97, 103,  
 107, 111, 206, 207, 258  
 helical alkenes  
 synthesis 133  
 via domino-Catellani reaction 134  
 heteroarenes, functionalization of  
 199–219  
 (hetero)arenes, *meta*-C–H arylation 179  
 N-heterocycles 9, 12, 28, 30, 31, 97, 114  
 (homo)allylic alcohols 4  
 homo-coupling *ortho* arylation reactions  
 103  
 hybrid cycloolefin ligand strategy  
 235–237

**i**

indole formation 16  
 intermolecular chirality transfer  
 131–137  
 intramolecular chirality transfer  
 131–132  
 intramolecular cyclization step 16  
 2-iodobiphenyls 28  
 3-iodochromone 30, 209, 211–215  
 [2 + 2 + 1] annulation 213  
 iodocoumarins 252, 253  
 3-iodotoluene 230, 231  
*ipso*-alkyne insertion 20, 21  
*ortho* alkylation 5–7  
*ortho* alkylation 7  
*ortho* amination 21–22  
*ipso* alkynylation reactions 61, 62, 217,  
 218, 272  
*ipso* amination 15, 76, 274

- ipso* arene functionalization  
 catalytic cycle 46  
 dehalogenation reaction 51  
 electrophile reagents and *ipso*  
     functionalization reagents 48–49  
 NBE extrusion process 49–51  
 NBE insertion 46–48  
*ipso* C–alkyl termination, *ortho*  
     alkylation 8  
*ipso* C–H arylation  
     heterocycles 66  
     *ortho* alkylation 4  
     *ortho* acylation 11–12  
     *ortho* arylation 6  
*ipso* C–N termination  
     *ortho* alkylation 8–9  
     *ortho* arylation 8, 11  
*ipso* C–O termination 9–11  
*ipso* carbene coupling reaction 59  
*ipso* dearomatization 7  
*ipso* enolate termination  
     *ortho* alkylation 8, 10  
     *ortho* arylation 10, 14  
*ipso* formal benzene insertion 20–21  
*ipso* functionalization reactions  
     alkenylation reaction  
         allenylation reaction 59–61  
         carbene coupling 58–59  
         Heck coupling 52–58  
     alkylation reaction  
         boron reagents coupling reaction 67  
         C–C bond cleavage reaction 71–72  
         C–H activation of inert alkyl  
             groups 71  
         germanium reagents, coupling  
             reaction 67–69  
         *ipso* ketone  $\alpha$ -arylation 69–71  
         1,4-Pd shift 72–73  
     arylation reactions  
         decarboxylation coupling reaction  
             67  
         *ipso* C–H arylation 64–67  
         Suzuki coupling 61–64  
     borylation reaction 76  
 C–N bond construction 76–78  
 C–O bond construction 76  
 C–S bonds construction 78–79  
 C–Se bonds construction 78–79  
 cyanation reaction 74–76  
 hydrogenation reaction 74  
*ipso* iodination 79–80  
 Sonogashira coupling 61  
*ipso* functionalization reagents 45, 46,  
     48–49, 58, 64  
*ipso* Heck termination 12–15  
     *ortho* acylation 11–12  
     *ortho* alkylation 3–8  
     *ortho* arylation 11  
*ipso* iodination 79–80  
*ipso* ketone  $\alpha$ -arylation 69–71
- k**  
 ( $\pm$ )-ketoprofen synthesis 277  
 kinetic resolution 131, 142, 144–147,  
     185, 188  
 (+)-kopsihainanine A 164, 280  
 (+)-kopsiyunnanine C3 synthesis 276
- l**  
 light-emitting diode (LED) 57  
 (+)-linoxepin 134, 267
- m**  
 meta-C–H alkynylation, arenes 178  
 meta-C–H amination, arenes 176–178  
 meta-C–H arylation, as directing group  
     acetal-based quinoline 175  
     amide 170–172  
     free carboxylic acid 175–176  
     pyridine derivative 173–175  
     sulfonamide 172–173  
     tertiary amide 172  
 meta-C–H chlorination, arenes 176  
 meta constraint 237–240  
     NBE examination 241  
     scope for addressing 242  
 meta-electrophiles 237, 239  
 methyl sulfonates 92–96  
 methyl vinyl ketone 30  
 Michael addition 28–30, 32, 97, 137, 270

michellamines B synthesis 273  
 mixed anhydride 11, 56, 107–110  
 mono-and difunctionalization  
   of heterarenes 181–183  
   *meta*-C–H arylation 179–181

**n**

natural products and drugs  
   2-alkylation of indoles 279–283  
   aryl halides  
     *ortho* acylation reactions 277–278  
     *ortho* alkylation reactions 267–273  
     *ortho* amination reactions 275–277  
     *ortho* arylation reactions 273–275  
     *ortho* functionalization 265–267  
   organic aromatic materials 284–290  
   *ortho* functionalization of vinyl  
     substrates 283–284  
   Pd/NBE cooperative catalysis 266  
   transformations types 267  
 NH-carbazoles, C1 alkylation of  
   164–166  
 NH-indoles  
   C2 alkylation of 159–167  
   C2 arylation of 166  
   C2 glycosylation of 164  
   C2 methylenephosphorylation of 163  
   C2 trifluoroethylation of 162  
 NH-pyrroles, C2 alkylation of 164–166  
 NH-tryptophan, C2 alkylation of 162  
 nitidine synthesis 275  
 nitrogen-electrophile, *ortho* amination  
   N-benzyloxyamines 113–114  
   dialkylamino carbonates 114–116  
 N-methylpyrrolidone (NMP) 53  
 norbornadiene (NBD) 3, 5, 27–28, 32,  
   105, 203, 284, 286  
 norbornyl moiety 30–31, 240

**o**

O-heterocycles 31  
 olefins, substrate scope 53  
 organic aromatic materials 284–290  
 organometallic reagents 8

*ortho* acylation 12  
   acid (mixed) anhydrides 107–109  
   acid chlorides 107–109  
   alkoxycarbonylation 110–112  
   aminocarbonylation 110–112  
   carboxylation using thioesters and  
     selenides 109–110  
   carboxylic acids 107–109  
   *ipso* C–H arylation 11–12  
   *ipso* Heck termination 11, 13  
   reactions 66, 107–109, 189, 277–278  
*ortho* alkenylation 15, 57, 97  
*ortho* alkylation 10  
   alkyl halides 91–92  
   annulation using 2*H*-azirines 96–97  
   aryl halide 16–17, 19–20  
   aziridines 97–98  
   epoxides 97  
   ethers and TMSI 98–99  
   *ipso* alkyne insertion 5–7  
   *ipso* C-alkyl termination 8  
   *ipso* C–H arylation 4–5  
   *ipso* C–N termination 8–9  
   *ipso* dearomatization 7  
   *ipso* enolate termination 8  
   *ipso* Heck termination 3–4  
   methyl sulfonates 92–96  
   phenyltrimethylammonium salt  
     92–96  
   post-catalytic intramolecular Michael  
     additions 28–30  
   trimethylphosphate 92–96  
*ortho* alkylation reactions 91, 267  
*ortho* amination 12–15, 275–277  
   aryl halide 16–17  
   N-benzyloxyamines 113–114  
   dialkylamino carbonates 114–116  
   *ipso* alkyne insertion 21–22  
*ortho* alkoxylation 117–119, 121  
*ortho* arylation  
   aryl diazonium salts 105–106  
   aryl halide 16–17, 101–103  
   chelating effect 103–105  
   homo *ortho* arylation 103  
   *ipso* alkyne insertion 20–21

- ipso* C–N termination 8–9  
*ipso* C–O termination 9–10  
*ipso* enolate termination 10  
*ipso* formal benzyne insertion 20–21  
*ipso* Heck terminating reagents 10  
*meta*-substituents 239  
*ortho* effect in Pd/NBE catalysis 99–101  
*ortho* C–H alkylation 52–55, 59, 61, 64, 69, 74, 79  
*ortho* C–H functionalization 45–48, 55, 57, 61, 64, 70, 72, 75, 77, 89–121, 157, 171, 228, 229, 239  
*ortho* constraint 227–230  
annulation, C7-modified NBE 234–235  
bridgehead-substituted NBEs 230–234  
hybrid cycloolefin ligand strategy 235–237  
*ortho* effect and 227–230  
mono *ortho* C–H functionalization 229  
*ortho* effect 99–102, 227–230  
*ortho*-methoxylation 120, 208  
*ortho* thiolation, aryl or alkyl sulfenamides 116–117  
thiosulfonates 116  
*ortho* trifluoroethylation 239  
oxygen-electrophile, *ortho* alkoxylation 117
- p**
- palladium-catalyzed cross coupling reaction 45, 61  
palladium/norbornene (Pd/NBE) cooperative catalysis catalytic cycle 45–51, 226 chemistry 11, 14, 45, 52, 64, 71, 72, 74, 76, 80, 260 electrophiles development 90 first catalytic 226 3-halo-2-methoxypyridines 209 natural product/drug synthesis 266 *ortho* effect in 99–101 three-component coupling reaction 265 palladium–norbornene (NBE) effect annulation reaction 235  $\alpha$ -carbamoylation 258 palladium–norbornene (NBE) insertion alkenylation 49 *ipso* functionalization 48–49 ( $\pm$ )-pallescensin A synthesis 284, 286 partially aromatic substrates 252–253 ( $\pm$ )-pauciflorol F synthesis 278 Pd(II)-initiated annulations 15–16 Pd-catalyzed cross-coupling reactions 199, 244 Pd/NBE reactions haloheteroarenes reactions with incorporation 202–205 haloheteroarenes reactions without incorporation 200–202 parent heteroarenes 213–219 six-membered haloheteroarenes with incorporation 211–213 six-membered haloheteroarenes without incorporation 206–211 1,4-Pd shift 72–73 phenanthren-9-ols, synthesis of 13 phenanthridinones 11, 111, 150 *cis,exo*-2-phenylnorbornylpalladium chloride (PNP) 52 phenyltrimethylammonium salt 92–96 planar chiral ferrocenes (PCFs) 187, 188 polycyclic conjugated hydrocarbons 286, 289 poly(*para*-phenylene ethynylene)s (PPEs) 288 poly-substituted arenes 129, 225, 265, 284, 290 postcatalytic intramolecular Michael additions 28–30 potassium salt 4, 135 pratosine synthesis 274, 275 ( $\pm$ )-pronuciferine synthesis 272 pseudo halides 244 psymberin synthesis 269 pyrroles, *ipso*-alkynylation reactions 217

**r**

- racemic epoxides 24, 97, 146  
 $(\pm)$ -ramelteon synthesis 269  
 retro-Diels–Alder (rDA) reaction 28, 203, 212, 213  
 $(+)$ -rhazinal synthesis 54, 275, 276  
 $(+)$ -rhazinilam synthesis 138, 275, 276

**s**

- six-membered haloheteroarenes  
 with incorporation 211–213  
 without incorporation 206–211  
 Sonogashira coupling 19, 46, 61, 92, 99, 288  
 spiroindolenines, synthesis of 7, 8  
 $(\pm)$ -stepharine synthesis 272  
 stereochemistry  
   intermolecular chirality transfer 132–137  
   intramolecular chirality transfer 131–132  
 $(+)$ -strictamine synthesis 164, 281, 282  
 structurally modified NBEs (smNBEs) 48, 101, 209, 214, 228, 241  
 sulfonamide 131, 169, 170, 172–173, 238  
 sulfur-electrophile, *ortho* thiolation  
   aryl or alkyl sulfenamides 116–117  
   aryl or alkyl thiosulfonates 116  
 Suzuki coupling reactions 65  
 Suzuki cross-coupling reaction 76  
 Suzuki–Miyaura coupling 45, 92, 103, 105, 107, 113, 114, 272, 273, 278

**t**

- template-enabled remote C–H functionalization 183–184

tetrabutylammonium bromide (TBAB)

162

tetrahydrobenzo[*b*] azepines (THBAs)

13, 15, 234, 237, 275

tetrahydrofuran (THF) 51, 282

tetrahydroisoquinolines synthesis 98, 137, 183, 184, 272

tetrahydropyranyl (THP) 280

tetrahydroquinolines 8, 10, 138, 239

thiolation, aryl or alkyl

  sulfenamides 116–117

  thiosulfonates 116

thiophenes, *ipso*-Heck reactions

216

transition metal-catalyzed reactions 8, 251

transition-metal-catalyzed asymmetric couplings 147

triarylphosphines 247

2-trifluranyl phosphate (TFP) 73

trimethylphosphate 92–96

trimethylsilyl iodide (TMSI) 98–99

triphenylenes 21

(–)-tryprostatin A 164, 282, 283

turnover-limiting step (TLS) 243

**v**

vinyl substrates *ortho* functionalization 283–284

**w**

water-soluble PPE synthesis 288, 290

**z**

Z-alkenes, directing group-enabled distal C–H functionalization 178–179







