

Science of Synthesis Knowledge Updates 2022/2










	Preface	V
	Abstracts	VII
	Table of Contents	XV
10.17	Benzo[b]phospholes R. A. Aitken 	1
10.18	Benzo[c]phospholes R. A. Aitken 	43
10.20	Phosphorus Analogues of Indolizines R. A. Aitken 	55
15.3.4	Quinolines (Update 2022) U. Sharma  , R. Kumar  , S. S. Gupta  , and D. Chandra 	63
46.5.7	Three-Component Coupling Reactions that Generate 1,3-Dienes S. E. Sloane, K. T. Behlow, M. D. Mills, and J. R. Clark 	389
46.14	Conjugated Diene Synthesis by Rearrangement of 1,3-Dienes to 1,3-Dienes M. D. Mills and J. R. Clark 	441
	Author Index	453
	Abbreviations	465

Table of Contents

Volume 10: Fused Five-Membered Heteroarenes with One Heteroatom

10.17	Benzo[b]phospholes R. A. Aitken ^{OB}	2022
<hr/>		
10.17	Benzo[b]phospholes	1
10.17.1	Synthesis by Ring-Closure Reactions	2
10.17.1.1	By Annulation to an Arene	2
10.17.1.1.1	By Formation of Two P—C Bonds	2
10.17.1.1.1.1	Method 1: Reaction of Lithiated Phenylalkyne Derivatives with Phosphorus Dihalides	2
10.17.1.1.1.2	Method 2: Migratory Arylzincation of Alkynes Followed by Reaction with Phosphorus Dihalides	3
10.17.1.1.1.3	Method 3: Reaction of a Zirconacycle with Phosphorus Dihalides	6
10.17.1.1.1.4	Method 4: Reaction of Phenylalkynes with Phosphorus Pentachloride ...	7
10.17.1.1.2	By Formation of One P—C Bond and One C—C Bond	8
10.17.1.1.2.1	Method 1: Reaction of Diarylphosphine Oxides with Alkynes	8
10.17.1.1.2.2	Method 2: Reaction of Diarylthiophosphinic Amides with Alkynes	10
10.17.1.1.2.3	Method 3: Reaction of Triarylphosphines with Alkynes	12
10.17.1.1.3	By Formation of One P—C Bond	13
10.17.1.1.3.1	Method 1: Base-Induced Cyclization of (2-Alkynylphenyl)phosphines or their Oxides	13
10.17.1.1.3.2	Method 2: Photochemical Cyclization of a (2-Alkynylphenyl)phosphine ·	14
10.17.1.1.3.3	Method 3: Thermal Cyclization of [2-(Phenylalkynyl)phenyl]chlorophosphines	16
10.17.1.1.3.4	Method 4: Metal-Induced Cyclization of (2-Alkynylphenyl)diphenylphosphines	19
10.17.1.1.3.4.1	Variation 1: Using Lithium	19
10.17.1.1.3.4.2	Variation 2: Using Palladium/Copper Catalysis	20
10.17.1.1.3.5	Method 5: Reaction of an Arylphosphinidene–Metal Complex with an Arene	20
10.17.1.1.3.6	Method 6: Rearrangement of a Ruthenium Phosphaalkyne Complex ...	21
10.17.1.1.4	By Formation of One C—C Bond	22
10.17.1.1.4.1	Method 1: Radical Cyclization of Diaryl(arylethynyl)phosphine Oxides ..	22
10.17.1.2	By Annulation to a Phosphole	24
10.17.1.2.1	Method 1: Sulfurization of a Phosphole [2 + 2] Dimer	24
10.17.1.2.2	Method 2: Thermolysis of a Phosphole Sulfide [4 + 2] Dimer	24

10.17.2	Synthesis by Ring Transformation	25
10.17.2.1	Method 1: Photochemical Rearrangement of a Phosphadiazole	25
10.17.3	Aromatization	26
10.17.3.1	Method 1: Dehydrobromination	26
10.17.3.1.1	Variation 1: Using Triethylamine	27
10.17.3.1.2	Variation 2: Using 1,8-Diazabicyclo[5.4.0]undec-7-ene	27
10.17.3.2	Method 2: Gas-Phase Dehydrochlorination over a Solid Base	28
10.17.3.3	Method 3: Deprotonation of a Cyclic Phosphonium Salt	29
10.17.4	Synthesis by Substituent Modification	31
10.17.4.1	Modification at Phosphorus	31
10.17.4.1.1	Method 1: Oxidation	31
10.17.4.1.2	Method 2: Formation of an Ylide	32
10.17.4.1.3	Method 3: Formation of Quaternary Phosphonium Salts	32
10.17.4.1.4	Method 4: Substitution of a Halogen	33
10.17.4.1.5	Method 5: Substitution of Aryl Groups	35
10.17.4.1.6	Method 6: Reduction of <i>P</i> -Oxides	36
10.17.4.2	Modification at Carbon	36
10.17.4.2.1	Method 1: Removal of Silyl Groups	36
10.17.4.2.2	Method 2: Halogenation	37
10.17.4.2.3	Method 3: C—C Bond Formation	38
10.17.4.3	Modification of Substituents	39
10.17.4.3.1	Method 1: Reaction of a 2,3-Dihydrobenzo[<i>b</i>]phosphol-3-one with Electrophiles	39
10.18	Benzo[<i>c</i>]phospholes 2022 R. A. Aitken	
10.18	Benzo[<i>c</i>]phospholes	43
10.18.1	Synthesis from 2,2'-Bis(arylalkynyl)biaryls with Formation of One C—C and Two P—C Bonds	43
10.18.1.1	Method 1: Synthesis of Benzo[<i>c</i>]phospholes via an Organotitanium Compound	44
10.18.1.2	Method 2: Synthesis of Benzo[<i>c</i>]phospholes via an Organozirconium Compound	46
10.18.2	Annulation to a Benzene Ring with Formation of Two P—C Bonds	47
10.18.2.1	Method 1: From Phthaloyl Chloride and Tris(trimethylsilyl)phosphine ...	47
10.18.2.2	Method 2: From a Bis(phosphonium salt)	48
10.18.3	Aromatization of 1,3-Dihydrobenzo[<i>c</i>]phospholes	50
10.18.3.1	Method 1: Formation of 1 <i>H</i> -Benzo[<i>c</i>]phospholes	50
10.18.3.2	Method 2: Formation of 2 <i>H</i> -Benzo[<i>c</i>]phospholes	51

10.20	Phosphorus Analogues of Indolizines R. A. Aitken ^{1b}	2022
10.20	Phosphorus Analogues of Indolizines	55
10.20.1	Method 1: Cycloaddition of Phospholes with Dimethyl Acetylenedicarboxylate	55
10.20.2	Method 2: Formation of the Six-Membered Ring by Alkene Metathesis ..	57

Volume 15: Six-Membered Hetarenes with One Nitrogen or Phosphorus Atom

15.3	Product Class 3: Quinolines	
15.3.4	Quinolines U. Sharma, R. Kumar, S. S. Gupta, and D. Chandra ^{1b} ^{1b} ^{1b} ^{1b}	2022
15.3.4	Quinolines	63
15.3.4.1	Synthesis of Quinolines	64
15.3.4.1.1	Synthesis of Quinolines Using N-Unsubstituted Anilines	65
15.3.4.1.1.1	Intramolecular Cyclization of Aniline Derivatives	65
15.3.4.1.1.1.1	Method 1: Copper- or Palladium-Catalyzed Cyclodehydration of 1-(2-Aminoaryl)alk-2-yn-1-ols	65
15.3.4.1.1.1.2	Method 2: Copper(II) Trifluoromethanesulfonate/ 2,2,6,6-Tetramethylpiperidin-1-oxyl Catalyzed Aerobic Oxidation of Amino Alcohols	66
15.3.4.1.1.1.3	Method 3: Potassium <i>tert</i> -Butoxide Mediated Oxidative Cycloisomerization of 2-Cinnamylanilines	66
15.3.4.1.1.1.4	Method 4: Sodium <i>tert</i> -Butoxide-Mediated Synthesis of 3,4'-Biquinolines from 2-Aminochalcones	67
15.3.4.1.1.1.5	Method 5: Continuous-Flow Photoisomerization/Cyclization of 2-Aminochalcones	68
15.3.4.1.1.1.6	Method 6: Tetrabutylammonium Iodide Catalyzed Cyclocondensation of 2-Aminochalcones	69
15.3.4.1.1.1.7	Method 7: Benzylamine-Mediated Cyclocondensation of 2-Aminochalcones	70
15.3.4.1.1.1.8	Method 8: Iodine-Mediated Mechanochemical Synthesis of Functionalized Quinolines	71
15.3.4.1.1.2	Synthesis of Quinolines Using Alcohols	72
15.3.4.1.1.2.1	Synthesis Using Primary Alcohols	72
15.3.4.1.1.2.1.1	Method 1: Gold-Doped Titanium(IV) Oxide Catalyzed Multicomponent Photosynthesis of 2-Methylquinolines	72

15.3.4.1.1.2.1.2	Method 2:	Synthesis of 2- and 3-Substituted Quinolines by Cyclocondensation of Anilines and 1,3-Diols	73
15.3.4.1.1.2.1.3	Method 3:	Quinoline Preparation from Glycerol via Modified Skraup Reaction	73
15.3.4.1.1.2.1.4	Method 4:	Dehydrogenative Cyclocondensation of 2-Aminobenzyl Alcohols and Aliphatic Alcohols	74
15.3.4.1.1.2.1.5	Method 5:	Cross-Dehydrogenative Coupling of Primary Bioavailable Alcohols and Imines	75
15.3.4.1.1.2.1.6	Method 6:	Oxidative Cyclization of Anilines and Cinnamyl Alcohols	77
15.3.4.1.1.2.1.7	Method 7:	Aerobic Oxidative Aromatization of Anilines and Aliphatic Alcohols	78
15.3.4.1.1.2.1.8	Method 8:	Oxidative Annulation–Aromatization of Anilines and Allyl Alcohol	80
15.3.4.1.1.2.2		Synthesis of Quinolines Using Secondary Alcohols	81
15.3.4.1.1.2.2.1	Method 1:	Heck Reaction of 2-Bromoanilines and Allylic Alcohols	81
15.3.4.1.1.2.2.2	Method 2:	Metal-Free Synthesis of Substituted Quinolines from Alcohols by Indirect Friedländer Annulation	82
15.3.4.1.1.2.2.3	Method 3:	Tandem Isomerization/Cyclization of Secondary Allylic Alcohols with 2-Aminobenzyl Alcohol	84
15.3.4.1.1.2.2.4	Method 4:	Dehydrogenation and Condensation of Secondary Aryl Alcohols with 2-Aminobenzyl Alcohols	85
15.3.4.1.1.2.2.5	Method 5:	<i>ortho</i> -Allylation of Anilines with Allyl Alcohols	86
15.3.4.1.1.2.2.6	Method 6:	Annulation of Anilines with Allyl Alcohols	87
15.3.4.1.1.2.2.7	Method 7:	Dehydrative C–H Coupling of Anilines and 1,3-Diols	89
15.3.4.1.1.2.2.8	Method 8:	Condensation of 2-Aminobenzyl Alcohols and Secondary Alcohols	90
15.3.4.1.1.2.2.9	Method 9:	Annulative Coupling of Imidamides and Cyclopropanols	92
15.3.4.1.1.2.2.10	Method 10:	Cross Coupling of 2-Aminobenzyl Alcohol and Secondary Alcohols	92
15.3.4.1.1.2.2.11	Method 11:	Acceptorless Dehydrogenative Coupling Reaction of 2-Aminobenzyl Alcohols and Secondary Alcohols	93
15.3.4.1.1.2.2.12	Method 12:	Dehydrogenative Condensation of Secondary Aryl Alcohols with 2-Aminobenzyl Alcohols	94
15.3.4.1.1.2.2.13	Method 13:	Acceptorless Dehydrogenative Coupling of Secondary Aryl Alcohols with 2-Aminobenzyl Alcohols	95
15.3.4.1.1.2.2.14	Method 14:	Double Dehydrogenative Coupling of 2-Aminobenzyl Alcohol with Secondary Aryl Alcohols	96
15.3.4.1.1.2.2.15	Method 15:	Acceptorless Dehydrogenative Condensation of Secondary Aryl Alcohols with 2-Aminobenzyl Alcohols	97
15.3.4.1.1.3		Reaction of Anilines with Carbonyl Compounds	98
15.3.4.1.1.3.1		Reaction of Anilines with Aldehydes	98
15.3.4.1.1.3.1.1	Method 1:	Synthesis of Substituted Quinolines via Inverse-Electron-Demand Aza-Diels–Alder Reaction	98

15.3.4.1.1.3.1.2	Method 2:	Three-Component Reaction of Anilines, Aldehydes, and Ethyl 3,3-Diethoxypropanoate	99
15.3.4.1.1.3.1.3	Method 3:	Three-Component Reaction of Anilines, Aryl Aldehydes, and Acetone	100
15.3.4.1.1.3.1.4	Method 4:	Reaction of Anilines and Aldehydes Induced by an Oxidant ..	101
15.3.4.1.1.3.1.5	Method 5:	Three-Component Reaction of Anilines, Aryl Aldehydes, and Malononitrile in Water	102
15.3.4.1.1.3.1.6	Method 6:	Radical Cation Induced Synthesis of 2,3-Disubstituted Quinolines from Anilines and Aliphatic Aldehydes	103
15.3.4.1.1.3.1.7	Method 7:	Aerobic Synthesis of Substituted Quinolines from Anilines and Arylacetaldehydes	105
15.3.4.1.1.3.1.8	Method 8:	Ionic Liquid Catalyzed Three-Component Reaction of Anilines, Aryl Aldehydes, and Aliphatic Aldehydes	107
15.3.4.1.1.3.1.9	Method 9:	Three-Component Povarov Reaction of 4-Substituted Anilines, Aldehydes, and Aryl Ethynyl Selenides	108
15.3.4.1.1.3.1.10	Method 10:	Annulation of Anilines with Ethyl Glyoxylate and (Chalcogenoethynyl)trimethylsilanes	109
15.3.4.1.1.3.1.11	Method 11:	Three-Component Cascade Reaction of Anilines, Aryl Aldehydes, and Hydroxyalkynes	110
15.3.4.1.1.3.1.12	Method 12:	Annulation of 2-Vinylanilines with Aldehydes	111
15.3.4.1.1.3.1.13	Method 13:	Three-Component Domino Reaction of Anilines, Aryl Aldehydes, and Nitroethane	112
15.3.4.1.1.3.1.14	Method 14:	Three-Component Cascade Cyclization of Anilines, Pyruvates, and Aryl Aldehydes	113
15.3.4.1.1.3.1.15	Method 15:	Three-Component Solvent-Free Annulation of 2-Oxoaldehydes, 1 <i>H</i> -Indene, and Anilines	114
15.3.4.1.1.3.1.16	Method 16:	Acetic Acid Assisted Synthesis of 2,3-Disubstituted Quinolines from Anilines and Aliphatic Aldehydes	115
15.3.4.1.1.3.1.17	Method 17:	Annulative Coupling of 2-Alkenylanilines with Aryl Aldehydes ..	116
15.3.4.1.1.3.1.18	Method 18:	Annulation of 1-Aryl-3-(2-aminophenyl)prop-2-yn-1-ones with Dimethylformamide	117
15.3.4.1.1.3.1.19	Method 19:	Three-Component Dehydrogenative Reaction of Lactates, Anilines, and Aryl Aldehydes	118
15.3.4.1.1.3.1.20	Method 20:	Condensation of 2-[2-(Trimethylsilyl)ethynyl]anilines with Aryl Aldehydes in Alcohols	118
15.3.4.1.1.3.1.21	Method 21:	Condensation of Aromatic Aldehydes, 1-Naphthylamine, and Malononitrile for the Synthesis of 2-Amino-4-arylbenzo[<i>h</i>]quinoline-3-carbonitriles	119
15.3.4.1.1.3.1.22	Method 22:	Synthesis of 3-Substituted Quinolines by Annulation of Anilines with Aldehydes	120
15.3.4.1.1.3.1.23	Method 23:	Iridium-Catalyzed Multicomponent Reaction	121
15.3.4.1.1.3.2		Reaction of Anilines with Ketones	122
15.3.4.1.1.3.2.1		Reaction of Ketones with 2-Aminophenyl Ketones	122
15.3.4.1.1.3.2.1.1	Method 1:	Yttrium(III) Trifluoromethanesulfonate Catalyzed Friedländer Annulation	122

15.3.4.1.1.3.2.1.2	Method 2:	Silica-Supported Perchloric Acid Catalyzed Friedländer Annulation	123
15.3.4.1.1.3.2.1.3	Method 3:	Molecular Iodine Catalyzed Friedländer Annulation	124
15.3.4.1.1.3.2.1.4	Method 4:	Ethylammonium Nitrate Mediated Friedländer Annulation ...	124
15.3.4.1.1.3.2.1.5	Method 5:	Zirconium(IV) Nitrate Catalyzed Friedländer Annulation	125
15.3.4.1.1.3.2.1.6	Method 6:	Oxalic Acid Catalyzed Friedländer Annulation	126
15.3.4.1.1.3.2.1.7	Method 7:	Potassium Hydrogen Sulfate Catalyzed Friedländer Annulation in Water	126
15.3.4.1.1.3.2.1.8	Method 8:	Iron(III) Chloride Catalyzed Solvent-Free Friedländer Annulation	127
15.3.4.1.1.3.2.1.9	Method 9:	Sulfamic Acid Catalyzed Solvent-Free Friedländer Annulation ·	128
15.3.4.1.1.3.2.1.10	Method 10:	Zinc(II) Trifluoromethanesulfonate Catalyzed Solvent-Free Friedländer Annulation	128
15.3.4.1.1.3.2.1.11	Method 11:	Phosphotungstic Acid Catalyzed Solvent-Free Friedländer Annulation	129
15.3.4.1.1.3.2.1.12	Method 12:	Silica Sulfuric Acid Catalyzed Friedländer Annulation	130
15.3.4.1.1.3.2.1.13	Method 13:	Bismuth(III) Chloride Assisted Solvent-Free Friedländer Annulation	131
15.3.4.1.1.3.2.1.14	Method 14:	Cerium(III) Chloride Heptahydrate Catalyzed Friedländer Annulation	132
15.3.4.1.1.3.2.1.15	Method 15:	Neodymium(III) Nitrate Hexahydrate Catalyzed Friedländer Annulation	132
15.3.4.1.1.3.2.1.16	Method 16:	4-Toluenesulfonic Acid Assisted Solvent-Free Friedländer Annulation	133
15.3.4.1.1.3.2.1.17	Method 17:	Ytterbium(III) Trifluoromethanesulfonate Catalyzed Friedländer Annulation	134
15.3.4.1.1.3.2.1.18	Method 18:	Friedländer Annulation Mediated by an Acidic Ionic Liquid ...	135
15.3.4.1.1.3.2.1.19	Method 19:	Cesium Phosphotungstate Salt Catalyzed Solvent-Free Friedländer Annulation	136
15.3.4.1.1.3.2.1.20	Method 20:	Copper(II) Oxide Nanoparticle Catalyzed Solvent-Free Friedländer Annulation	136
15.3.4.1.1.3.2.1.21	Method 21:	Triethylammonium Hydrogen Sulfate Mediated Solvent-Free Friedländer Annulation	137
15.3.4.1.1.3.2.1.22	Method 22:	Silica Nanoparticle Catalyzed Solvent-Free Friedländer Annulation	138
15.3.4.1.1.3.2.1.23	Method 23:	Sulfuric Acid Modified Polyethylene Glycol 6000 Promoted Solvent-Free Friedländer Annulation	139
15.3.4.1.1.3.2.1.24	Method 24:	Silica-Supported Phosphorus Pentoxide Catalyzed Solvent-Free Friedländer Annulation	141
15.3.4.1.1.3.2.1.25	Method 25:	Zinc(II) Oxide Nanoflake Catalyzed Solvent-Free Friedländer Annulation	142
15.3.4.1.1.3.2.1.26	Method 26:	Tartaric Acid/1,3-Dimethylurea Mediated Friedländer Annulation	142
15.3.4.1.1.3.2.1.27	Method 27:	Propylphosphonic Anhydride Promoted Friedländer Annulation	143

15.3.4.1.1.3.2.1.28	Method 28:	Zirconium(IV) Trifluoromethanesulfonate Catalyzed Solvent-Free Friedländer Annulation	144
15.3.4.1.1.3.2.1.29	Method 29:	Lithium Trifluoromethanesulfonate Catalyzed Solvent-Free Friedländer Annulation	145
15.3.4.1.1.3.2.1.30	Method 30:	Potassium Prolinate Catalyzed Friedländer Annulation for the Synthesis of 4-(Trifluoromethyl)quinolines	146
15.3.4.1.1.3.2.1.31	Method 31:	Chitosan Sulfonic Acid Catalyzed Friedländer Annulation	147
15.3.4.1.1.3.2.1.32	Method 32:	Nickel(II) Oxide Nanoparticle Catalyzed Friedländer Annulation	148
15.3.4.1.1.3.2.1.33	Method 33:	Titanium(IV) Oxide Nanoparticles Catalyzed Solvent-Free Friedländer Annulation	149
15.3.4.1.1.3.2.1.34	Method 34:	CuFe ₂ O ₄ Nanoparticle Catalyzed Friedländer Annulation in Water	150
15.3.4.1.1.3.2.1.35	Method 35:	Ionic Liquid Catalyzed Friedländer Annulation	151
15.3.4.1.1.3.2.1.36	Method 36:	Friedländer Annulation of 1-(2-Aminophenyl)pent-4-en-1-one in Acetic Acid	152
15.3.4.1.1.3.2.1.37	Method 37:	Brønsted Acid and Lewis Acid Catalyzed Friedländer Annulation	154
15.3.4.1.1.3.2.1.38	Method 38:	Atroposelective Friedländer Annulation	155
15.3.4.1.1.3.2.1.39	Method 39:	Nafion NR50 Catalyzed Friedländer Annulation	156
15.3.4.1.1.3.2.1.40	Method 40:	Zinc(II) Chloride Promoted Friedländer-Type Annulation	157
15.3.4.1.1.3.2.1.41	Method 41:	4-Toluenesulfonic Acid/Ionic Liquid Promoted Synthesis of Quinolines	159
15.3.4.1.1.3.2.2		Reaction of Ketones with 2-Aminobenzyl Alcohols	160
15.3.4.1.1.3.2.2.1	Method 1:	Palladium-Catalyzed Modified Friedländer Annulation	160
15.3.4.1.1.3.2.2.2	Method 2:	Ruthenium-Catalyzed Modified Friedländer Annulation	160
15.3.4.1.1.3.2.2.3	Method 3:	Transition-Metal-Free Indirect Friedländer Annulation	162
15.3.4.1.1.3.2.2.4	Method 4:	Copper(II) Chloride Catalyzed Modified Friedländer Annulation	163
15.3.4.1.1.3.2.2.5	Method 5:	Rhodium-Catalyzed Modified Friedländer Annulation	164
15.3.4.1.1.3.2.2.6	Method 6:	Iridium-Catalyzed Modified Solvent-Free Friedländer Annulation	165
15.3.4.1.1.3.2.2.7	Method 7:	Nickel-Catalyzed Dehydrogenative Coupling of 2-Aminobenzyl Alcohol with Aryl Methyl Ketones or Benzyl Cyanides	165
15.3.4.1.1.3.2.2.8	Method 8:	Nickel-Catalyzed Dehydrogenative Coupling	167
15.3.4.1.1.3.2.2.9	Method 9:	Iridium(I)-Catalyzed Borrowing Hydrogen Strategy	170
15.3.4.1.1.3.2.2.10	Method 10:	Metal-Ligand Cooperative Approach for Quinoline Synthesis	171
15.3.4.1.1.3.2.2.11	Method 11:	N-Heterocyclic Carbene-Copper Catalyzed Indirect Friedländer Annulation	172
15.3.4.1.1.3.2.2.12	Method 12:	Mesoporous Copper Organic Nanorod for Modified Friedländer Annulation	173

15.3.4.1.1.3.2.2.13	Method 13:	Praseodymium(III) Oxide Supported Ruthenium Nanolayers for Acceptorless Dehydrogenative Synthesis of 2-Substituted Quinolines	174
15.3.4.1.1.3.2.2.14	Method 14:	One-Pot Synthesis of Quinolines Using a Half-Sandwich Ruthenium Complex	175
15.3.4.1.1.3.2.2.15	Method 15:	Superbase-Mediated Indirect Friedländer Annulation	177
15.3.4.1.1.3.2.2.16	Method 16:	N-Heterocyclic Carbene Catalyzed Indirect Friedländer Annulation	177
15.3.4.1.1.3.2.2.17	Method 17:	Modified Friedländer Annulation Using Palladium–Silver Alloy Nanoparticles Supported on Carbon	178
15.3.4.1.1.3.2.3		Multicomponent Reactions Using Ketones	180
15.3.4.1.1.3.2.3.1	Method 1:	Iron-Catalyzed Quinoline-2,4-dicarboxylate Synthesis from Anilines, Ethyl Glyoxylate, and α -Oxo Esters	180
15.3.4.1.1.3.2.3.2	Method 2:	Hydrogen Iodide Promoted Three-Component Reaction of Methyl Ketones, Anilines, and Pyruvates	180
15.3.4.1.1.3.2.3.3	Method 3:	Molecular Iodine Promoted Three-Component Reaction of Anilines, Glyoxylates, and Methyl Pyruvate	181
15.3.4.1.1.3.2.3.4	Method 4:	Molecular Iodine Promoted Three-Component Reaction of Anilines, Aryl Methyl Ketones, and 1,4-Dithiane-2,5-diol	182
15.3.4.1.1.3.2.3.5	Method 5:	Molecular Iodine/Aniline Promoted Three-Component Synthesis of 2-Aroylquinolines	183
15.3.4.1.1.3.2.3.6	Method 6:	Copper-Catalyzed Oxidative Cyclization of Anilines, Aryl Methyl Ketones, and Dimethyl Sulfoxide	184
15.3.4.1.1.3.2.3.7	Method 7:	Iodine-Promoted Direct Synthesis of 2,3-Diaroylquinolines by Three-Component Reaction of Aryl Methyl Ketones, Enaminones, and Anilines	185
15.3.4.1.1.3.2.3.8	Method 8:	Palladium(II)-Catalyzed Three-Component Reaction of Ketones, 2-Aminobenzonitriles, and Arylboronic Acids	186
15.3.4.1.1.3.2.3.9	Method 9:	Copper-Catalyzed Regioselective Three-Component Reaction of Enaminones, Aldehydes, and Anilines	187
15.3.4.1.1.3.2.4		Reaction of Ketones with 2-Aminobenzaldehydes	188
15.3.4.1.1.3.2.4.1	Method 1:	Friedländer Synthesis of Complex Quinoline Scaffolds	188
15.3.4.1.1.3.2.4.2	Method 2:	Potassium <i>tert</i> -Butoxide Mediated Friedländer Annulation of <i>tert</i> -Butoxycarbonyl-Protected 2-Amino-4-(trifluoromethyl)benzaldehyde and Ketones	189
15.3.4.1.1.3.2.4.3	Method 3:	Bromodimethylsulfonium Bromide Catalyzed Solvent-Free Friedländer Annulation	191
15.3.4.1.1.3.2.4.4	Method 4:	Enzymatic Synthesis of Quinolines	191
15.3.4.1.1.3.2.4.5	Method 5:	Copper-Catalyzed Retro-Aldol Reaction of β -Hydroxy Ketones with 2-Aminobenzaldehydes	192
15.3.4.1.1.3.2.5		Reaction of Ketones with 2-Alkynylanilines	193
15.3.4.1.1.3.2.5.1	Method 1:	4-Toluenesulfonic Acid Promoted Annulation	193
15.3.4.1.1.3.2.5.2	Method 2:	Synthesis of 2,3-Disubstituted 4-Methylquinolines from 1,3-Dicarbonyl Compounds and 2-Ethynylanilines	194

15.3.4.1.1.3.2.5.3	Method 3:	Copper-Catalyzed Annulation of 2-Ethynylanilines with an <i>N,O</i> -Acetal or Ethyl Glyoxylate	195
15.3.4.1.1.3.2.6		Reaction of Ketones with 2-Alkenylanilines	197
15.3.4.1.1.3.2.6.1	Method 1:	Metal-Free Synthesis of 2-(Difluoromethyl)quinolines from 2-Alkenylanilines and Ethyl 4,4-Difluoro-3-oxobutanoate	197
15.3.4.1.1.3.2.6.2	Method 2:	Synthesis of Multisubstituted Quinolines from 2-Alkenylanilines and β -Oxo Esters	197
15.3.4.1.1.3.2.7		Reaction of Ketones with 2-Aminophenylboronic Acids	199
15.3.4.1.1.3.2.7.1	Method 1:	Rhodium-Catalyzed Synthesis of Quinolines	199
15.3.4.1.1.3.2.8		Reaction of Ketones with 2-(Aminomethyl)aniline	200
15.3.4.1.1.3.2.8.1	Method 1:	Synthesis of Quinolines via C—N Bond Formation	200
15.3.4.1.1.3.2.9		Reaction of Ketones with Anilines via C—H Activation	201
15.3.4.1.1.3.2.9.1	Method 1:	Cobalt(III)-Catalyzed C—H Activation	201
15.3.4.1.1.3.2.10		Reaction of Ketones with Anilines Using Potassium Persulfate	202
15.3.4.1.1.3.2.10.1	Method 1:	Potassium Persulfate Mediated Synthesis of 4-Arylquinolines	202
15.3.4.1.1.3.2.10.2	Method 2:	Potassium Persulfate Mediated Synthesis of 3-Aroylquinolines from Enaminones	203
15.3.4.1.1.3.2.11		Reaction of Ketones with 2-Iodoanilines	204
15.3.4.1.1.3.2.11.1	Method 1:	Synthesis of 2-Arylquinolines from 2-Iodoanilines	204
15.3.4.1.1.3.2.12		Reaction of Ketones and Anilines in the Presence of Silver	205
15.3.4.1.1.3.2.12.1	Method 1:	Silver-Catalyzed Oxidative Coupling of Anilines and α,β -Unsaturated Carbonyl Compounds	205
15.3.4.1.1.4		Reaction of Anilines with Alkynes	206
15.3.4.1.1.4.1		Reaction of Anilines with Terminal Alkynes	206
15.3.4.1.1.4.1.1	Method 1:	Scandium(III) Trifluoromethanesulfonate Catalyzed Multicomponent Reaction of Anilines, Benzaldehydes, and Ethyl Propynoate	206
15.3.4.1.1.4.1.2	Method 2:	Trifluoromethanesulfonic Acid Mediated Multicomponent Reaction of Ethynyl Ketene <i>S,S</i> -Acetals, Anilines, and Aldehydes	207
15.3.4.1.1.4.1.3	Method 3:	Montmorillonite K-10 Catalyzed Multicomponent Reaction of Anilines, Arylacetylenes, and Aldehydes	208
15.3.4.1.1.4.1.4	Method 4:	Iron-Catalyzed Multicomponent Reaction of Anilines, Arylacetylenes, and Aldehydes	209
15.3.4.1.1.4.1.5	Method 5:	Molecular Iodine Catalyzed Multicomponent Reaction of Anilines, Arylacetylenes, and Aldehydes	210
15.3.4.1.1.4.1.6	Method 6:	Silver-Catalyzed Reaction of 2-Aminoaryl Carbonyl Compounds with Terminal Alkynes	211
15.3.4.1.1.4.1.7	Method 7:	Copper-Catalyzed Three-Component Reaction of Benzaldehydes, Propargyl Glycosides, and Anilines	212
15.3.4.1.1.4.1.8	Method 8:	Indium(III) Chloride Catalyzed Regioselective Synthesis of Quinolines	213

15.3.4.1.1.4.1.9	Method 9:	Recyclable Iron(III) Trifluoromethanesulfonate Catalyzed Solvent-Free Three-Component Synthesis of Quinolines ····	215
15.3.4.1.1.4.1.10	Method 10:	Cobalt-Catalyzed Three-Component Reaction of Anilines, Aryl Aldehydes, and Phenylacetylene ·····	216
15.3.4.1.1.4.1.11	Method 11:	Silver-Catalyzed Synthesis of 4-(Trifluoromethyl)quinolines in Water ·····	216
15.3.4.1.1.4.1.12	Method 12:	Copper-Catalyzed Three-Component Reaction of Anilines, Aldehydes, and Terminal Alkynes ·····	217
15.3.4.1.1.4.1.13	Method 13:	Niobium(V) Chloride Catalyzed Three-Component Reaction of Anilines, Benzaldehyde, and Phenylacetylene ·····	218
15.3.4.1.1.4.1.14	Method 14:	Trifluoromethanesulfonic Acid Catalyzed Three-Component Reaction of Anilines, Benzaldehydes, and Terminal Alkynes ··	219
15.3.4.1.1.4.1.15	Method 15:	Iron(III) Chloride Catalyzed Three-Component Reaction of 4-(Pentafluorosulfanyl)aniline, Aldehydes, and Arylacetylenes	221
15.3.4.1.1.4.1.16	Method 16:	Cobalt(III)-Catalyzed C—H Activation/Cyclization of Anilines with Arylacetylenes ·····	221
15.3.4.1.1.4.1.17	Method 17:	Regioselective Synthesis of 3-Arylquinolines via Hetero-Diels–Alder Cycloaddition of Azadienes with Arylacetylenes ·····	223
15.3.4.1.1.4.1.18	Method 18:	Three-Component Synthesis of 4-Arylquinolines from Arylacetylenes, Anilines, and Dimethyl Sulfoxide ·····	224
15.3.4.1.1.4.1.19	Method 19:	Rhodium(III)-Catalyzed Alkynylation of Hydrazones ·····	225
15.3.4.1.1.4.1.20	Method 20:	Microwave-Assisted Metal-Free Rapid Synthesis of 4-Arylquinolines via Povarov-Type Multicomponent Reaction ·	226
15.3.4.1.1.4.2		Reaction of Anilines with Internal Alkynes ·····	227
15.3.4.1.1.4.2.1	Method 1:	Nickel-Catalyzed Cyclization of 2-Iodoanilines with Aroylalkynes ·····	227
15.3.4.1.1.4.2.2	Method 2:	Copper-Catalyzed Oxidative Cyclization of Enynes ·····	228
15.3.4.1.1.4.2.3	Method 3:	Silver-Catalyzed Cyclization of <i>N</i> -Arylimines and Internal Alkynes ·····	230
15.3.4.1.1.4.2.4	Method 4:	Copper(I)-Catalyzed Synthesis of 2-Perfluoroalkylated Quinolines ·····	231
15.3.4.1.1.4.2.5	Method 5:	Copper(II) Trifluoromethanesulfonate Catalyzed Annulation of 2-Aminophenyl Carbonyl Compounds with Acetylenecarboxylates ·····	232
15.3.4.1.1.4.2.6	Method 6:	Copper(II)-Catalyzed Three-Component Cascade Annulation of Diaryliodonium Salts, Nitriles, and Alkynes ·····	232
15.3.4.1.1.4.2.7	Method 7:	Palladium-Catalyzed Synthesis of Polysubstituted Quinolines from 2-Aminophenyl Ketones and Internal Acetylenes ·····	233
15.3.4.1.1.4.2.8	Method 8:	Recyclable Copper(II) Oxide Nanopowder Catalyzed Synthesis of Quinoline-2,3-dicarboxylates under Ligand-Free Conditions	234
15.3.4.1.1.4.2.9	Method 9:	Metal- and Protection-Free [4 + 2] Cycloaddition of Azadienes with Alkynes ·····	235
15.3.4.1.1.4.2.10	Method 10:	Palladium-Catalyzed Annulation of 2-Styrylanilines with Alkynes ·····	236

15.3.4.1.1.4.2.11	Method 11: Solvent-Free Synthesis of Quinolines Catalyzed by Propylphosphonium Tetrachloroindate Ionic Liquid Supported on Nanosilica	237
15.3.4.1.1.4.2.12	Method 12: Palladium-Catalyzed Tandem Annulation of 2-Vinylanilines with Alkynoates	238
15.3.4.1.1.4.2.13	Method 13: Copper(II)-Catalyzed Cascade Annulation	239
15.3.4.1.1.4.2.14	Method 14: Metal-Free 1,8-Diazabicyclo[5.4.0]undec-7-ene-Promoted Cascade Michael Addition	240
15.3.4.1.1.4.2.15	Method 15: Silver-Catalyzed Three-Component Cascade Annulation of Amines, Acetylenecarboxylates, and Terminal Alkynes	241
15.3.4.1.1.5	Reaction of Anilines with Alkenes	242
15.3.4.1.1.5.1	Method 1: Acetic Acid Mediated High-Throughput One-Pot Synthesis of 2-Methylquinolines	242
15.3.4.1.1.5.2	Method 2: Copper-Catalyzed Domino Synthesis of Quinolines from Baylis–Hillman Acetates	243
15.3.4.1.1.5.3	Method 3: C–N Coupling/Condensation of 2-Aminophenyl Carbonyl Compounds and Vinyl Iodides	244
15.3.4.1.1.5.4	Method 4: Three-Component Povarov Reaction for the Synthesis of 2-(2-Pyridyl)quinolines	245
15.3.4.1.1.5.5	Method 5: Palladium-Catalyzed Heck Reaction and Cyclization of Morita–Baylis–Hillman Adducts with 2-Iodoaniline	246
15.3.4.1.1.5.6	Method 6: Improved Skraup–Doebner–von Miller Reaction Utilizing Acrolein Diethyl Acetal	247
15.3.4.1.1.5.7	Method 7: Metal-Free Access to Quinolines via C–C Bond Cleavage of Styrenes	248
15.3.4.1.1.5.8	Method 8: Synthesis of Substituted Quinolines by Visible-Light Photoredox Catalysis	249
15.3.4.1.1.6	Aniline Dimerization	250
15.3.4.1.1.6.1	Method 1: Gold-Catalyzed Dimerization of 2-Ethynylanilines	250
15.3.4.1.1.6.2	Method 2: Indium(III) Bromide Promoted Dimerization of 2-Ethynylanilines	252
15.3.4.1.1.6.3	Method 3: Bismuth(III)-Catalyzed Tunable Dimerization of 2-Alk-1-ynylanilines	253
15.3.4.1.1.7	Reaction of Anilines with Boronic Acids	254
15.3.4.1.1.7.1	Method 1: Palladium-Catalyzed Regioselective Hydroarylation	254
15.3.4.1.1.7.2	Method 2: Rhodium-Catalyzed Regioselective Hydroarylation	255
15.3.4.1.1.7.3	Method 3: Palladium-Catalyzed Tandem Reaction of 3-(2-Aminophenyl)acrylonitriles with Arylboronic Acids	256
15.3.4.1.1.8	Reaction of Anilines with Epoxides	257
15.3.4.1.1.8.1	Method 1: Iron-Promoted Tandem Reaction of Anilines with Styrene Oxides	257
15.3.4.1.1.8.2	Method 2: Scandium(III) Trifluoromethanesulfonate Mediated One-Pot Synthesis of 2,3-Disubstituted Quinolines	258

15.3.4.1.1.9	Reaction of Anilines with Azides	259
15.3.4.1.1.9.1	Method 1: Synthesis of 3-(Sulfonylamino)quinolines by Ring Expansion	259
15.3.4.1.1.9.2	Method 2: Tetrabutylammonium Fluoride Catalyzed Tandem Synthesis of Triazolo[4,5- <i>c</i>]quinolines	260
15.3.4.1.1.10	Reaction of Anilines with Acids	260
15.3.4.1.1.10.1	Method 1: Divergent Synthesis of Functionalized Quinolines from Anilines and Two Distinct Amino Acids	260
15.3.4.1.1.10.2	Method 2: Metal-Free Synthesis of 2-Fluoroalkylated Quinolines Using Polyfluoroalkanoic Acids	261
15.3.4.1.1.11	Reaction of Anilines with Iodoarenes	262
15.3.4.1.1.11.1	Method 1: Palladium-Catalyzed Multicomponent Reaction of 2-Ethynylanilines, Aryl Iodides, Primary Amines, and Carbon Monoxide	262
15.3.4.1.1.12	Reaction of Anilines with Hydrazines	263
15.3.4.1.1.12.1	Method 1: Palladium-Catalyzed Cascade Reaction of 2-Aminocinnamionitriles with Arylhydrazines	263
15.3.4.1.1.13	Reaction of Anilines with Isonitriles	264
15.3.4.1.1.13.1	Method 1: Palladium-Catalyzed Aerobic Oxidative Cyclization of 2-Ethynylanilines with Isocyanides	264
15.3.4.1.2	Synthesis of Quinoline Using <i>N</i> -Substituted Anilines	265
15.3.4.1.2.1	Synthesis of Quinolines Using Secondary and Tertiary Anilines	265
15.3.4.1.2.1.1	Method 1: Iodine Monochloride Mediated Cyclization of Trifluoromethanesulfonyl-Protected <i>N</i> -Alk-2-ynylanilines	265
15.3.4.1.2.1.2	Method 2: Molecular Iodine Catalyzed Electrophilic Cyclization of <i>N</i> -Alk-2-ynylanilines	266
15.3.4.1.2.1.3	Method 3: Gold-Catalyzed Cyclization of Trifluoromethylated <i>N</i> -Propargylanilines	267
15.3.4.1.2.1.4	Method 4: Copper-Catalyzed Synthesis of Azaheterocycles	268
15.3.4.1.2.1.5	Method 5: Electrophile-Driven Regioselective Synthesis of Functionalized Quinolines	269
15.3.4.1.2.1.6	Method 6: Oxidative Povarov Reaction via C(sp ³)-H Oxidation of Secondary Anilines	270
15.3.4.1.2.1.7	Method 7: C(sp ³)-H Functionalization of Glycine Derivatives	271
15.3.4.1.2.1.8	Method 8: Iron-Catalyzed Oxidative Coupling of Secondary Anilines and Terminal Alkynes	273
15.3.4.1.2.1.9	Method 9: Annulation of Anilides with Alkynes or Silyl Enol Ethers	274
15.3.4.1.2.1.10	Method 10: Base-Mediated Synthesis of Quinolines	275
15.3.4.1.2.1.11	Method 11: Visible-Light-Induced Synthesis of Substituted Quinoline-Fused Lactones	275
15.3.4.1.2.1.12	Method 12: Visible-Light-Induced C(sp ³)-H Functionalization of <i>N</i> -Arylglycinates with Unactivated Alkenes	277
15.3.4.1.2.1.13	Method 13: Potassium Persulfate Mediated Cross-Dehydrogenative Coupling of <i>N</i> -Arylglycine Derivatives with Alkenes	278


15.3.4.1.2.1.14	Method 14: (η^5 -Pentamethylcyclopentadienyl)cobalt-Catalyzed Annulation of Anilides with Internal Alkynes	280
15.3.4.1.2.1.15	Method 15: Cobalt-Catalyzed Redox-Neutral Annulation of Anilides with Alkynes	281
15.3.4.1.2.1.16	Method 16: Visible-Light-Induced Cyclization of Aromatic Enamines	283
15.3.4.1.2.1.17	Method 17: Povarov Reaction of <i>N</i> -Arylalanine Esters	285
15.3.4.1.2.1.18	Method 18: Annulation of Anilides with Diarylacetylenes Promoted by Trifluoromethanesulfonic Anhydride/2,6-Dichloropyridine ...	287
15.3.4.1.2.1.19	Method 19: Brønsted Acid Catalyzed Metal- and Solvent-Free Quinoline Synthesis from <i>N</i> -Alkylanilines and Alkynes or Alkenes	288
15.3.4.1.2.1.20	Method 20: Photoredox-Catalyzed Cascade Addition/Cyclization of <i>N</i> -Propargylanilines	289
15.3.4.1.2.1.21	Method 21: Intramolecular Cyclocondensation of Enamino Ketones	290
15.3.4.1.2.1.22	Method 22: Visible-Light-Promoted Metal-Free Cascade Cycloaddition of <i>N</i> -Propargylanilines and Sodium Sulfates	291
15.3.4.1.2.1.23	Method 23: Molecular Iodine Mediated Cyclization of α -Arylamino Ketones with Terminal Alkynes in Water	293
15.3.4.1.2.1.24	Method 24: Iron(III) Chloride Mediated Cyclization of <i>N</i> -Aryl- <i>N</i> -(3-arylprop-2-ynyl)-4-toluenesulfonamides	294
15.3.4.1.2.1.25	Method 25: Intramolecular Palladium(0)-Catalyzed C—H Functionalization of <i>N</i> -Cyclopropylanilines	295
15.3.4.1.2.2	Synthesis of Quinolines Using Imines	297
15.3.4.1.2.2.1	Method 1: Povarov Reaction of Ethyl 2-(Arylimino)acetates and <i>N</i> -Vinylamides	297
15.3.4.1.2.2.2	Method 2: Condensation of Benzylideneanilines with Aldehydes Catalyzed by Hydrogen Chloride in Dimethyl Sulfoxide	298
15.3.4.1.2.2.3	Method 3: Molecular Iodine Mediated Synthesis of 2-Ferrocenylquinolines	298
15.3.4.1.2.2.4	Method 4: Annulation of <i>N</i> -Benzylideneanilines with Allylsilanes	299
15.3.4.1.2.2.5	Method 5: Annulation of <i>N</i> -Benzylideneanilines with Aldehydes	300
15.3.4.1.2.2.6	Method 6: Palladium-Catalyzed Synthesis of Quinolines via Sonogashira Coupling	301
15.3.4.1.2.2.7	Method 7: Metal-Free Cyclization of <i>N</i> -Benzylideneanilines and Enamides	302
15.3.4.1.2.2.8	Method 8: Annulation of <i>N</i> -Benzylideneanilines with Electron-Deficient Alkynes	303
15.3.4.1.2.2.9	Method 9: Formal [4 + 2] Annulation of <i>N</i> -Benzylideneanilines with Vinyl Azides	304
15.3.4.1.2.2.10	Method 10: Trifluoromethanesulfonic Anhydride Promoted Synthesis of Functionalized Quinolines from Ketoximes and Alkynes	305
15.3.4.1.2.2.11	Method 11: <i>N</i> -Heterocyclic Carbene Catalyzed Umpolung of Benzylideneanilines	307
15.3.4.1.2.2.12	Method 12: Copper-Catalyzed Tandem Cyclization for the Synthesis of Polyfunctionalized Quinolines	308
15.3.4.1.2.2.13	Method 13: Tandem Cyclization/Annulation of α -Acidic Isocyanides with <i>N</i> -Benzylidene-2-(3-Oxoalk-1-enyl) anilines	309

15.3.4.1.2.2.14	Method 14: Superacid-Promoted Cyclization of Vinylogous Imines	310
15.3.4.1.2.2.15	Method 15: Tandem Radical Annulation of Phenyl Isocyanides with Alkoxyamines	311
15.3.4.1.3	Synthesis of Quinolines Using Azides	312
15.3.4.1.3.1	Method 1: Iminophosphorane-Mediated Cyclization of Azides	312
15.3.4.1.3.2	Method 2: One-Pot Cascade Reaction for Annulation of 2-[(<i>E</i>)-2-Nitrovinyl]phenyl Azides	313
15.3.4.1.3.3	Method 3: Copper-Promoted Synthesis of Substituted Quinolines from Benzylic Azides and Internal Alkynes	314
15.3.4.1.3.4	Method 4: Synthesis of 2,4-Unsubstituted Ethyl Quinoline-3-carboxylates	315
15.3.4.1.3.5	Method 5: <i>N</i> -Bromosuccinimide-Mediated Radical Cyclization of 3-Arylallyl Azides	316
15.3.4.1.3.6	Method 6: Efficient Synthesis of Quinolines via Knoevenagel/Staudinger/Aza-Wittig Sequence	317
15.3.4.1.3.7	Method 7: Acid-Promoted Rearrangement of Benzylic Azides	318
15.3.4.1.3.8	Method 8: Lewis Acid Promoted Synthesis of 4-Alkoxyquinolines	320
15.3.4.1.3.9	Method 9: Copper-Catalyzed Solvent-Free Cyclization of 2-Azidobenzaldehydes and 1-Aryl-2-nitroethenes	321
15.3.4.1.3.10	Method 10: Trifluoromethylsulfanylation/Cyclization of 1-Aryl-3-(2-azidophenyl)prop-1-yne	322
15.3.4.1.3.11	Method 11: Silver-Catalyzed Carbocyclization of Arylethynyl 2-Azidophenyl Ketones	323
15.3.4.1.3.12	Method 12: Cascade Knoevenagel/Aza-Wittig Reactions for the Synthesis of Substituted Quinolines	324
15.3.4.1.3.13	Method 13: 4-Toluenesulfonic Acid Cascade Reaction of 1-Aryl-3-(2-azidophenyl)prop-2-yn-1-ols	326
15.3.4.1.3.14	Method 14: Triphenylphosphine-Mediated Three-Component Reaction of 2-Azidobenzaldehydes, α -Fluoro β -Oxo Esters, and Amines	327
15.3.4.1.4	Synthesis of Quinolines Using Isatins	327
15.3.4.1.4.1	Method 1: Pfitzinger Synthesis of Quinolines Using Sodium Hydride	327
15.3.4.1.4.2	Method 2: Pfitzinger Synthesis of Quinolines Using Potassium Hydroxide	328
15.3.4.1.4.3	Method 3: Microwave-Assisted Pfitzinger Synthesis of Quinolines Using Sodium Hydroxide	329
15.3.4.1.4.4	Method 4: Ultrasound-Promoted Synthesis of Quinolines Using Basic Ionic Liquids	330
15.3.4.1.4.5	Method 5: Multicomponent Reaction of Isatin, an Acetylenedicarboxylate, and a Chloro Oxo Ester	331
15.3.4.1.4.6	Method 6: Copper-Catalyzed Improved Pfitzinger Reaction under Acidic Conditions	332
15.3.4.1.4.7	Method 7: Efficient Synthesis of Perfluoroalkylated Quinolines via Metal-Free Cascade Michael Addition/Rearrangement/Cyclization	333
15.3.4.1.4.8	Method 8: Cascade Reaction of Isatins with 2-Nitroethene-1,1-diamines for the Synthesis of Quinoline-4-carboxamides	334

15.3.4.1.4.9	Method 9:	Pyridine-Catalyzed Synthesis of Quinoline-2,3,4-tricarboxylates	335
15.3.4.1.4.10	Method 10:	Bismuth(III) Trifluoromethanesulfonate Catalyzed Domino Cyclization of Isatins with Enaminones	336
15.3.4.1.4.11	Method 11:	Three-Component Synthesis of Quinoline-3,4-dicarboxylates from Isatins, β -Oxo Esters, and Alcohols	337
15.3.4.1.5		Synthesis of Quinolines Using Nitrobenzenes	338
15.3.4.1.5.1	Method 1:	Iron/Hydrogen Chloride Mediated Reduction of 2-Nitrobenzaldehyde for Friedländer Reaction	338
15.3.4.1.5.2	Method 2:	Palladium-on-Carbon Assisted Hydrogenolysis of 3-(2-Nitrophenyl)isoxazoles	339
15.3.4.1.5.3	Method 3:	Tin(II) Chloride Mediated Synthesis of Quinolines	340
15.3.4.1.5.4	Method 4:	Three-Component Reaction of Nitrobenzenes, Aryl Aldehydes, and Phenylacetylene in Water	341
15.3.4.1.5.5	Method 5:	Titania-Supported Iridium Subnanocluster Catalyzed Synthesis of Quinolines from Nitrobenzenes and Alcohols	342
15.3.4.1.5.6	Method 6:	Atom-Economic Quinoline Synthesis from Substituted 2-Nitrotoluenes	343
15.3.4.1.5.7	Method 7:	Reductive Cyclization 2-(2-Nitroaryl)-4-oxoalkanenitriles	344
15.3.4.1.5.8	Method 8:	Tin(II) Chloride Mediated Reductive Cyclization of 2-Nitrobenzaldehydes and Terminal Alkynes	345
15.3.4.1.5.9	Method 9:	Ruthenium-Catalyzed Hydrogen Transfer	346
15.3.4.1.5.10	Method 10:	Ruthenium(II)-Catalyzed Hydrogen Transfer/Annulation Cascade Process between Alcohols and 2-Nitrobenzaldehydes	347
15.3.4.1.5.11	Method 11:	Transition-Metal-Free Synthesis of Quinolines from 2-Nitrobenzyl Alcohol in Water	348
15.3.4.1.5.12	Method 12:	Molybdenum-Catalyzed Sustainable Friedländer Synthesis of Quinolines	349
15.3.4.1.5.13	Method 13:	Iron Powder Induced Condensation of 2-Nitrobenzaldehyde with Aryl β -Enamino Ketones	350
15.3.4.1.5.14	Method 14:	Microwave-Assisted Synthesis of 2-(Quinolin-3-yl)anilines via Indole Ring Opening	351
15.3.4.1.5.15	Method 15:	Cobalt-Catalyzed Reductive Annulation of 2-Nitrobenzaldehydes with Electron-Deficient Alkynes	353
15.3.4.1.6		Synthesis of Quinolines Using Anthranils	354
15.3.4.1.6.1	Method 1:	Annulation of Anthranils with Propargyl Silyl Ethers	354
15.3.4.1.6.2	Method 2:	Metal-Free Three-Component Reaction of Anthranils, Acetophenones, and Dimethyl Sulfoxide	355
15.3.4.1.6.3	Method 3:	Copper(II)/Silver(I)-Catalyzed Cascade Reaction of (Arylsulfonyl)hydrazones with Anthranils	356
15.3.4.1.6.4	Method 4:	Cobalt-Catalyzed Electrophilic Amination with Anthranils	357
15.3.4.1.6.5	Method 5:	Copper-Catalyzed Ring-Opening of Anthranils	358
15.3.4.1.6.6	Method 6:	Rhodium-Catalyzed C—H Amination/Annulation of Acrylic Acids and Anthranils	359

15.3.4.1.7	Synthesis of Quinolines Using Aldehydes/Ketones	360
15.3.4.1.7.1	Method 1: Condensation/Cyclization of Aryl Ketones with Urea	360
15.3.4.1.7.2	Method 2: Copper-Catalyzed One-Pot Cascade Reaction of 2-Bromobenzaldehydes with Aryl Methyl Ketones and Aqueous Ammonia	361
15.3.4.1.7.3	Method 3: Copper-Catalyzed Tandem Knoevenagel Condensation, Amination, and Cyclization	362
15.3.4.1.7.4	Method 4: Copper-Catalyzed Domino Reactions of Enaminones	365
15.3.4.1.8	Synthesis of Quinolines Using Aryl Isocyanides, Aryl Isothiocyanates, and Related Substrates	366
15.3.4.1.8.1	Method 1: Alkyl Trifluoromethanesulfonate Triggered Annulation of Aryl Isothiocyanates with Alkynes	366
15.3.4.1.8.2	Method 2: Light-Induced Iridium-Catalyzed Domino Radical Triple-Bond Insertion	367
15.3.4.1.8.3	Method 3: Synthesis of 2,4-Diiodoquinolines via Photochemical Cyclization of 2-Alkynylaryl Isocyanides	368
15.3.4.1.8.4	Method 4: [5 + 1] Annulation of 2-(2-Isocyanophenyl)vinyl Ketones with Nitroalkanes	368
15.3.4.1.8.5	Method 5: Manganese(III)-Mediated Regioselective 6- <i>endo-trig</i> Cyclization of 2-Vinylaryl Isocyanides and Arylboronic Acids	369
15.3.4.1.8.6	Method 6: One-Pot [2 + 2 + 2] Cascade Annulation with Diaryliodonium Salts, Benzonitriles, and Alkynes	370
15.3.4.1.8.7	Method 7: Copper-Catalyzed Cascade Annulation of Diaryliodonium Salts, Carbodiimides, and Alkynes	371
15.3.4.1.8.8	Method 8: Copper-Catalyzed Cascade Cyclization of Isothiocyanates, Alkynes, and Diaryliodonium Salts	372
15.3.4.1.9	Synthesis of Quinolines Using Pyridines	374
15.3.4.1.9.1	Method 1: Cyclization of Alkyl 2-[Acetoxy(2-chloropyridin-3-yl)methyl]acrylates with Nitroethane	374
15.3.4.1.9.2	Method 2: Rhodium(III)-Catalyzed Oxidative Annulation of Pyridines with Symmetrical Alkynes	374
15.3.4.1.9.3	Method 3: Domino Benzannulation of 2-Chloropyridin-3-yl Ynones with Nitromethane	375
15.3.4.1.10	Synthesis of Quinolines Using Diazo or Diazonium Compounds	376
15.3.4.1.10.1	Method 1: Copper-Promoted Tandem Reaction of Azobenzenes with Allyl Bromides	376
15.3.4.1.10.2	Method 2: Cascade Three-Component Annulation of Arenediazonium Salts with Nitriles and Alkynes	377
15.3.4.1.10.3	Method 3: Metal-Free Three-Component Annulation of Arenediazonium Salts with Nitriles and Styrenes in the Presence of 2,3-Dichloro-5,6-dicyanobenzo-1,4-quinone	378
15.3.4.1.11	Synthesis of Quinolines Using Indoles	379
15.3.4.1.11.1	Method 1: Rhodium(II)-Catalyzed Synthesis of Quinoline-3-carboxylates via Ring Expansion of Indoles	379
15.3.4.1.12	Synthesis of Quinolines Using Tetrazoles	380

15.3.4.1.12.1	Method 1: Annulation of 1-Aryltetrazoles with Internal Alkynes	380
Volume 46: 1,3-Dienes		
46.5	Synthesis by Metal-Mediated C–C Bond Forming Reactions of Alkynes, Diynes, and Enynes	
46.5.7	Three-Component Coupling Reactions that Generate 1,3-Dienes	New
	S. E. Sloane, K. T. Behlow, M. D. Mills, and J. R. Clark ^{1b}	
46.5.7	Three-Component Coupling Reactions that Generate 1,3-Dienes	389
46.5.7.1	Transition-Metal-Catalyzed Three-Component Coupling	389
46.5.7.1.1	Method 1: Nickel-Catalyzed Reactions	389
46.5.7.1.1.1	Variation 1: Synthesis of 1,3-Dien-5-ynes	389
46.5.7.1.1.2	Variation 2: Synthesis of 1,3-Dienes through Two Molecules of Acrylate and One Alkyne Molecule	391
46.5.7.1.1.3	Variation 3: Synthesis of 1,3-Dienes through Use of Alkynes, Enones, and Alkenylboronic Acids	393
46.5.7.1.1.4	Variation 4: Synthesis of Dienyl Alcohols	396
46.5.7.1.1.5	Variation 5: Synthesis of Polysubstituted Conjugated 1,3-Dienes	397
46.5.7.1.2	Method 2: Copper-Catalyzed Reactions	400
46.5.7.1.2.1	Variation 1: Synthesis of 1,4-Disubstituted (<i>E,E</i>)-1,3-Dienes	400
46.5.7.1.3	Method 3: Palladium-Catalyzed Reactions	402
46.5.7.1.3.1	Variation 1: Synthesis of Selectively Chlorinated 1,3-Dienes	402
46.5.7.1.3.2	Variation 2: Synthesis of 1,3-Dienes Using Vinyl Halides, Internal Alkynes, and Organoborane Reagents	404
46.5.7.1.3.3	Variation 3: Synthesis of 1,3-Dienes Using Allenes, Aryl Iodides, and Diazo Compounds	407
46.5.7.1.3.4	Variation 4: Dearomative Functionalization of Haloarenes	409
46.5.7.1.3.5	Variation 5: Synthesis of 1,3-Dienes Using Arylaldehydes, γ -Borylated Allylic Acetates, and Vinylstannanes	414
46.5.7.1.4	Method 4: Ruthenium-Catalyzed Reactions	415
46.5.7.1.4.1	Variation 1: Synthesis of 1,4-Bis(trimethylsilyl)buta-1,3-dienes	415
46.5.7.1.4.2	Variation 2: One-Pot Synthesis of Stereodefined, Hydrosilylated 1,3-Dienes	418
46.5.7.1.4.3	Variation 3: Synthesis of Polyketides Using a Ruthenium Catalyst	420
46.5.7.1.5	Method 5: Palladium-/Copper-Catalyzed Reactions	424
46.5.7.1.5.1	Variation 1: Synthesis of 1-Borylated 1,3-Dienes	424
46.5.7.1.6	Method 6: Chromium-Catalyzed Reactions	427
46.5.7.1.6.1	Variation 1: Synthesis of Cyclohexadienones	427
46.5.7.1.7	Method 7: Stoichiometric Use of Indium Metal	428

46.5.7.2	Organocatalytic Three-Component Coupling	429
46.5.7.2.1	Method 1: Metal-Free Reactions	429
46.5.7.2.1.1	Variation 1: Generation of 1,3-Dienes in Aqueous Media	429
46.5.7.2.1.2	Variation 2: Diene-Transmissive Diels–Alder Synthesis of 1,3-Dienes in Deuteriochloroform	431
46.5.7.2.1.3	Variation 3: Generation of 1,3-Dienes Catalyzed by Quinidine	433
46.5.7.3	Reactions Using Ionic Liquids	435
46.5.7.3.1	Method 1: Synthesis of Cyclohexa-1,3-dienes	435
46.5.7.3.2	Method 2: <i>ortho</i> -Benzenedisulfonimide/Triethylammonium Acetate To Promote Synthesis of 1,3-Dienes	437
46.14	Conjugated Diene Synthesis by Rearrangement of 1,3-Dienes to 1,3-Dienes New M. D. Mills and J. R. Clark 	
46.14	Conjugated Diene Synthesis by Rearrangement of 1,3-Dienes to 1,3-Dienes	441
46.14.1	Method 1: Ruthenium Hydride Catalyzed Isomerization of 1,3-Dienes to 1,3-Dienes	441
46.14.1.1	Variation 1: In Situ Formation of an Undefined Ruthenium Hydride	441
46.14.1.2	Variation 2: Isomerization of 1,3-Dienes to 1,3-Dienes Promoted by a Well-Defined Ruthenium Hydride Catalyst	443
46.14.1.3	Variation 3: Tandem Ene–Yne Metathesis and Isomerization of 1,3-Dienes	444
46.14.1.4	Variation 4: Ring-Closing Metathesis, Isomerization, and Cycloaddition ..	445
46.14.2	Method 2: Cobalt Hydride Catalyzed Isomerization of 1,3-Dienes to 1,3-Dienes	446
46.14.3	Method 3: Iodine-Catalyzed <i>E/Z</i> Isomerization of 1,3-Dienes	449
46.14.4	Method 4: Base-Catalyzed Isomerization of Dienyl Ethers	450
46.14.4.1	Variation 1: 1,5,7-Triazabicyclo[4.4.0]dec-5-ene-Catalyzed Isomerization of 1,3-Dienes	450
	Author Index	453
	Abbreviations	465