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A novel synthesis of substituted quinolines using ring-closing metathesis (RCM): its application to the synthesis of key intermediates for anti-malarial agents

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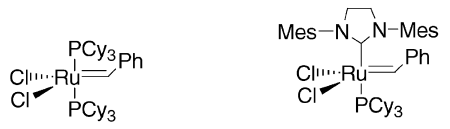
Abstract—A method for synthesizing substituted quinolines using ruthenium-catalyzed ring-closing metathesis as a key step has been developed. Substituted 1,2-dihydroquinolines, 4-silyloxy-1,2-dihydroquinoline and 4-methoxy-1,2-dihydroquinoline, were successfully synthesized in excellent yields via ene–ene metathesis and silyl or alkyl enol ether–ene metathesis, respectively. The synthetic intermediates of the antimalarial agents quinine, chloroquine, and PPMP–quinine hybrid were efficiently synthesized by this methodology.

Quinolines are a major class of alkaloids and play an important role in the fields of natural products and medicinal chemistry. Several methods for synthesizing quinoline have been known since the late 1800s.[1] However, despite their versatility, these conventional methods have several drawbacks. First, these reactions usually require high temperature and/or strongly acidic conditions, which lead to the decomposition of products and a tedious isolation procedure. Regioselectivity is another problem with the intramolecular electrophilic substitution of unsymmetrically substituted aniline derivatives. To overcome these problems, modern synthetic methods for quinoline using a transition metal-catalyst, such as ruthenium, palladium, rhodium, iron, copper, manganese or cobalt, have been investigated.[2]

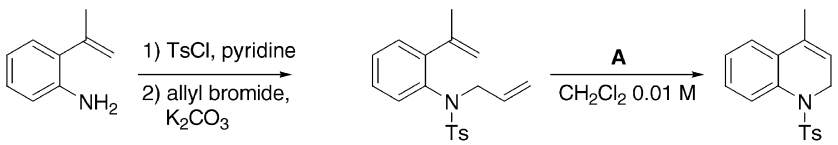


A B

Figure 1. Ruthenium carbene catalysts.

We have been studying the synthesis of some nitrogen-containing cyclic compounds by ring-closing metathesis (RCM) using ruthenium carbene catalysts **A**[3] and **B**[4] (Fig. 1).[5] We previously developed a novel method for synthesizing substituted 1,2-dihydroquinolines using ene–ene metathesis and silyl or alkyl enol ether–ene metathesis, which proceeds under mild conditions and gives an excellent yield.[6] This process leads to spontaneous air oxidation to quinoline after deprotection. In this article, we report the details of this reaction and its application to the synthesis of key intermediates for antimalarial agents, such as quinine, chloroquine, and PPMP–quinine hybrid.

We first investigated RCM conditions for α,ω-diene **1** derived from commercially available 2-isopropenylaniline (Scheme 1). When **1** was reacted with 30% Grubbs' catalyst **A** in CH_2Cl_2 (0.01 M, degassed by freezed–pump–thaw



1 2

Scheme 1. Synthesis of 1,2-dihydroquinoline **2** using RCM.

Keywords: Quinine; Chloroquine; Quinoline alkaloid; Anti-malaria; Ring-closing metathesis (RCM); Silylenol-ether.
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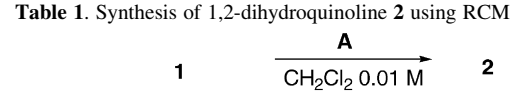
Table 1. Synthesis of 1,2-dihydroquinoline **2** using RCM

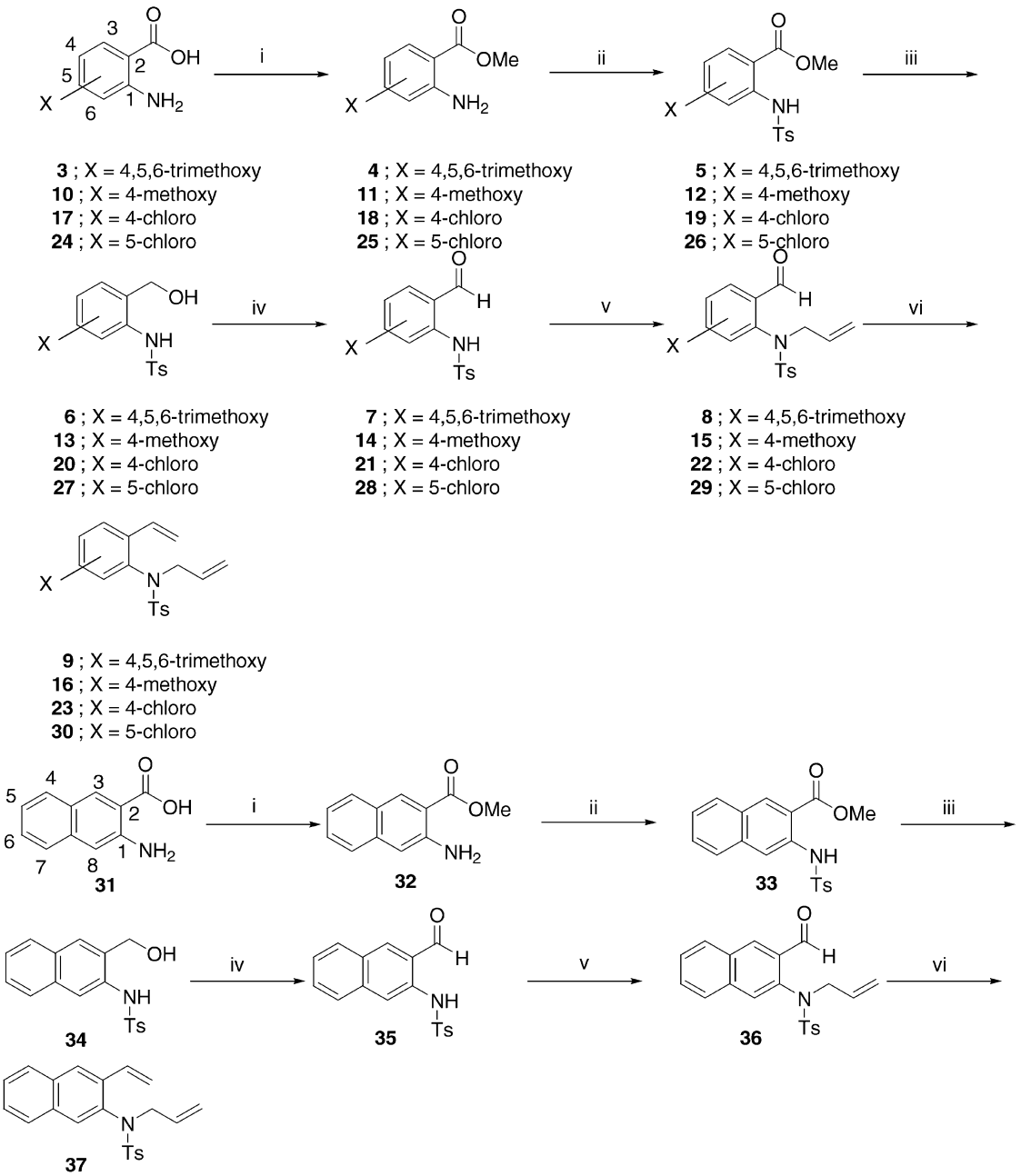


Run	Catalyst **A** (mol%)	Conditions		Yield (%)
1	30	Room temperature	3 h	94
2	5	Room temperature	3 h	72
3	5	Reflux	1 h	92

(FPT) cycle) at room temperature for 3 h, the corresponding 1,2-dihydroquinoline **2** was obtained in 94% yield (Table 1, run 1), whereas the use of 5 mol% of catalyst **A** reduced the yield to 72% (run 2). However, the reaction at reflux temperature gave **2** in 92% yield within 1 h (run 3).

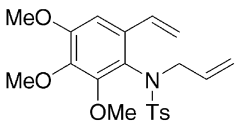
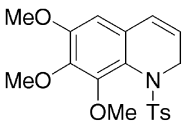
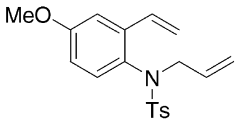
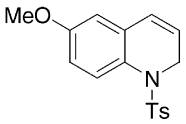
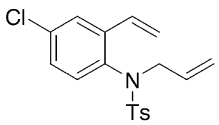
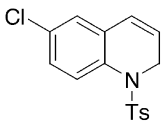
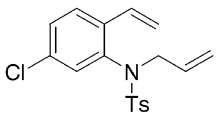
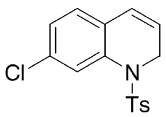
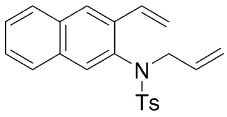
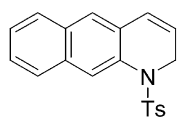
Under these optimized reaction conditions, we examined the scope and limitations of RCM for 1,2-dihydroquinoline synthesis. Various dienes were prepared from anthranilic acid derivatives (Scheme 2) and subjected to RCM reaction. The results are summarized in Table 2.

Initially, dienes (**9**, **16**, **23**, **30**, **37**) were subjected to the optimized RCM conditions described above. As a result, cyclized 1,2-dihydroquinolines (**38**–**42**) were isolated in good to excellent yields, regardless of the substitution pattern on the aromatic ring (–OMe, runs 1 and 2 or –Cl, runs 3–5). Benzoquinoline was obtained in 98% yield (run 6). According to recent reports, catalyst **B** is more reactive in a metathesis reaction.[4] Therefore, substrate **30** was re-examined with catalyst **B**, which confirmed its superior



Scheme 2. Preparation of α,ω-dienes. (i) $Me_2C(OMe)_2$, HCl; (ii) TsCl, pyridine; (iii) DIBAH; (iv) MnO_2, benzene; (v) allyl bromide, K_2CO_3; (vi) $Ph_2P{=}CH_2$.

Table 2. RCM of dienes **9**, **16**, **23**, **30** and **37** using catalysts **A** and **B**[a]

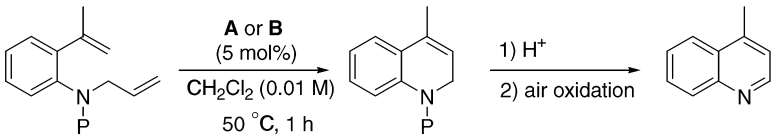
Run	Substrate		Ru-catalyst	Product		Yield (%)
1		**9**	**A**		**38**	90
2		**16**	**A**		**39**	95
3		**23**	**A**		**40**	90
4		**30**	**A**		**41**	74
5			**B**			100
6		**37**	**A**		**42**	98

[a] Conditions: 5 mol% of catalyst **A** or **B** in CH_2Cl_2 (0.01 M, degassed) under Ar for 1 h at reflux temperature.

efficacy, the desired chloroquinoline **41** was obtained in 100% yield.

Having established the RCM conditions, we next examined the effect of protecting groups on nitrogen. Dienes **43a**–**43c**, which were readily prepared from the commercially available *o*-aminostyrene, were reacted with both Grubbs' catalysts **A** and **B**. The reaction of *N*-benzyl derivative **43a** with catalyst **A** gave **44a** in excellent yield (Table 3, run 1), while *N*-acetyl derivative **43b** did not give the desired cyclized product (run 2). In this case, catalyst **A** probably reacted with the terminal double bond in **43b** to form a chelated intermediate **46**, which prohibited further RCM. When *N-tert*-butoxycarbonyl derivative **43c** was treated with catalyst **A** under similar conditions, 1,2-dihydroquinoline **44c** was obtained in modest yield. On the other hand, with catalyst **B**, the yields of **43b** and **43c** dramatically increased to give **44b** and **44c**, respectively, in almost quantitative yields (runs 3 and 5). The protective groups on nitrogen of products **44a**–**c** were readily removed during

Table 3. Effect of protective groups on nitrogen



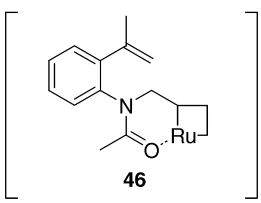
43

43a ; P = Bn
43b ; P = Ac
43c ; P = Boc

44

44a ; P = Bn
44b ; P = Ac
44c ; P = Boc

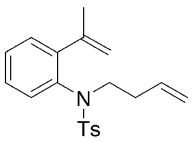
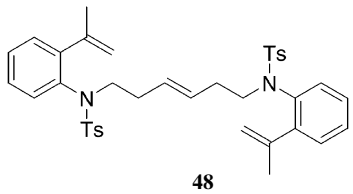
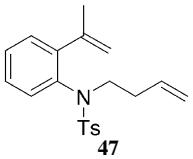
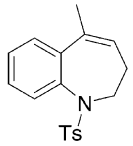
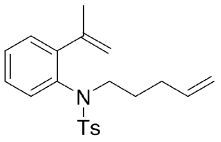
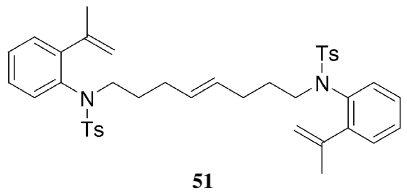
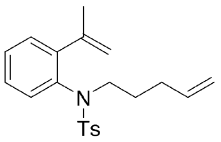
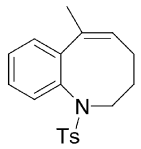
45



46

Run	Substrate	Ru-catalyst	Product (%)
1	**43a**	**A**	**45** (95)
2	**43b**	**A**	**45** (0)
3	**43b**	**B**	**45** (98)
4	**43c**	**A**	**45** (63)
5	**43c**	**B**	**45** (97)

Table 4. Effect of Ru-catalysts on the RCM of dienes **47** and **50**

Run	Substrate	Ru-catalyst	Product	Yield (%)
1	 **47**	**A**	 **48**	100
2	 **47**	**B**	 **49**	100
3	 **50**	**A**	 **51**	95
4	 **50**	**B**	 **52**	99

silica gel column chromatography to give 1,2-dihydroquinolines, which were spontaneously oxidized to give 4-methylquinoline **45** quantitatively.

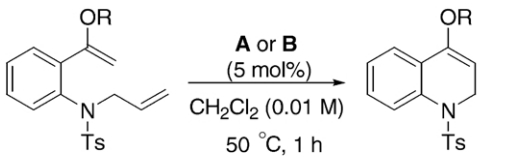
We next investigated a similar RCM for medium-sized rings such as in benzoazepine and benzoazocine. Dienes **47** and **50** were subjected to the above reaction conditions using both Grubbs' catalysts **A** and **B**. The reaction of **47** and **50** in the presence of catalyst **A** gave only the dimeric products **48** and **51**, respectively. In sharp contrast, the corresponding benzoazepine **49** and benzoazocine **52** were obtained with catalyst **B** in excellent yields (Table 4). Interestingly, isolated **48** and **51** were converted to **49** (5 h, 98%) and **52** (6 h, 97%), respectively, under the same conditions using catalyst **B**.

Many quinoline alkaloids which show important bioactivities, such as quinine and chloroquine, contain substituents at the 4-position. Therefore, we next focused our attention on extending this reaction to the synthesis of 4-substituted quinolines. For this purpose, we studied the synthesis of 4-methoxy- and 4-siloxy-1,2-dihydroquinolines, which, in turn, could be converted to various 4-substituted quinolines, using ene–enol ether metathesis (Table 5).

Enol methyl ether **53a** and enol silyl ether **53b** were prepared from commercially available *o*-aminoacetophenone and subjected to our reaction conditions using Grubbs' catalysts **A** and **B**, respectively. Surprisingly, when enol methyl ether **53a** and enol silyl ether **53b** were treated with **A**, the cyclized product was not obtained at all and the starting materials were recovered (runs 1 and 3). In contrast, treatment of the same substrates with Grubbs' catalyst **B** gave the corresponding 4-methoxy-1,2-dihydroquinoline **54a** and 4-siloxy-1,2-dihydroquinoline **54b** in 95% yield, respectively (runs 2 and 4). This novel synthetic method could be applied to large-scale, multigram, syntheses.

In the general procedure for RCM, degassing of the solution is an important process to prevent deactivation of the catalyst, although the highly active catalyst **B** was designed to tolerate oxygen, moisture and some impurities in the solvent.[7] High dilution was also required, such as 0.01 and

Table 5. Effect of Ru-catalyst on the ene–enol metathesis of **53a** and **53b**



53a ; R = Me
53b ; R = TBS

54a ; R = Me
54b ; R = TBS

Run	Substrate	Ru-catalyst	Concentration (M)	Product (%)
1	**53a**	**A**	0.01[a]	**54a** (0)
2	**53a**	**B**	0.01[a]	**54a** (95)
3	**53b**	**A**	0.01[a]	**54b** (0)
4	**53b**	**B**	0.01[a]	**54b** (95)
5	**53b**	**B**	0.01[b]	**54b** (99)
6	**53b**	**B**	0.1[a]	**54b** (96)
7	**53b**	**B**	0.1[b]	**54b** (97)

[a] Degassed conditions.
[b] Without degassing.

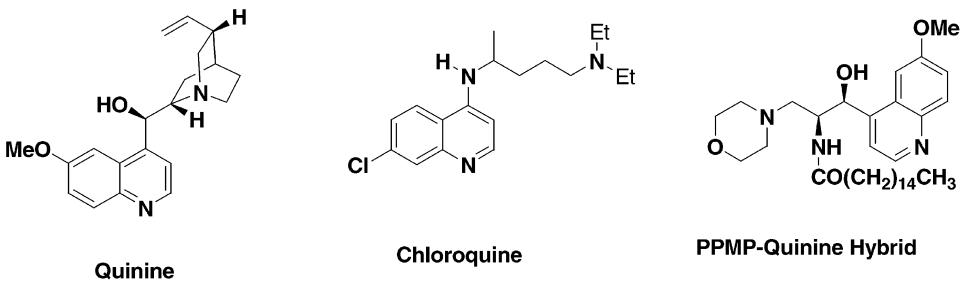


Figure 2. Natural products with anti-malarial activity.

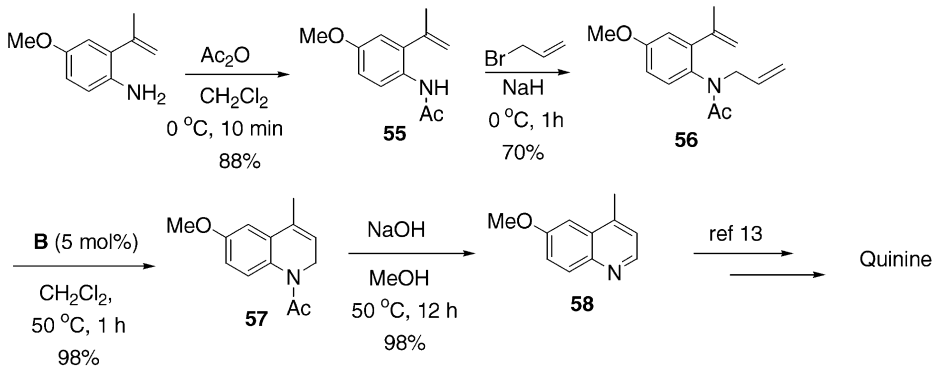
0.001 M, to prevent an intermolecular reaction, however this procedure is inconvenient, especially in large-scale synthesis. Thus, we tried this silyl enol ether–ene metathesis without degassing at a concentration of 0.1 M. As a result, the reaction of **53b** in 0.01 M solution gave **54b** in almost quantitative yield regardless of degassing the reaction mixture (runs 5 and 7).

Encouraged by these results, we applied this novel method to the synthesis of key intermediates of anti-malarial agents, such as quinine,[8] chloroquine,[9]and PPMP–quinine hybrid,[10] which are shown in Figure 2.

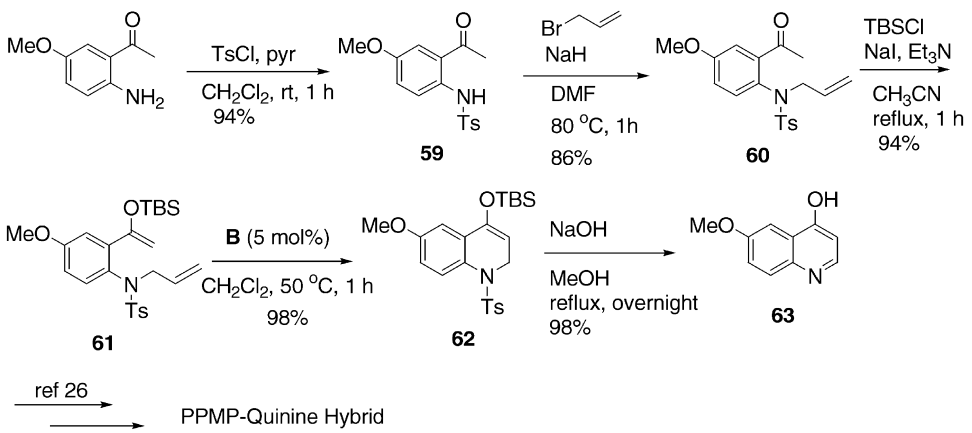
Malaria is one of the world's most devastating human infections and causes millions of deaths every year. Some effective anti-malarial agents are currently available, such as quinine, chloroquine, mefloquine, premaquine, and arteminicin. However, the development of new anti-malarial agent is still required against resistant Plasmodium species, the most virulent of malarias. We previously reported the synthesis of an inhibitor of sphingolipid synthase, PPMP (1-phenyl-2-palmitoylamino-3-morpholino-1-propanol),[10] which has been reported to have anti-malarial activity by Haldar.[11] A PPMP–quinine hybrid is an interesting potential anti-malarial agent.

Acetylation of 2-isopropenyl-4-methoxyaniline[12] gave **55** in 88% yield, which was in turn allylated with allyl bromide in the presence of sodium hydride to provide **56** in 70% yield. Highly efficient RCM was achieved by treatment of **56** with catalyst **B** (5 mol %) at 50 °C for 1 h to give the corresponding 1,2-dihydroquinoline **57** in 98% yield. The acetyl group was removed by treatment of NaOH in MeOH to give 4-methyl-6-methoxyquinoline (**58**),[13] a key intermediate for the synthesis of quinine, in 98% yield (Scheme 3).

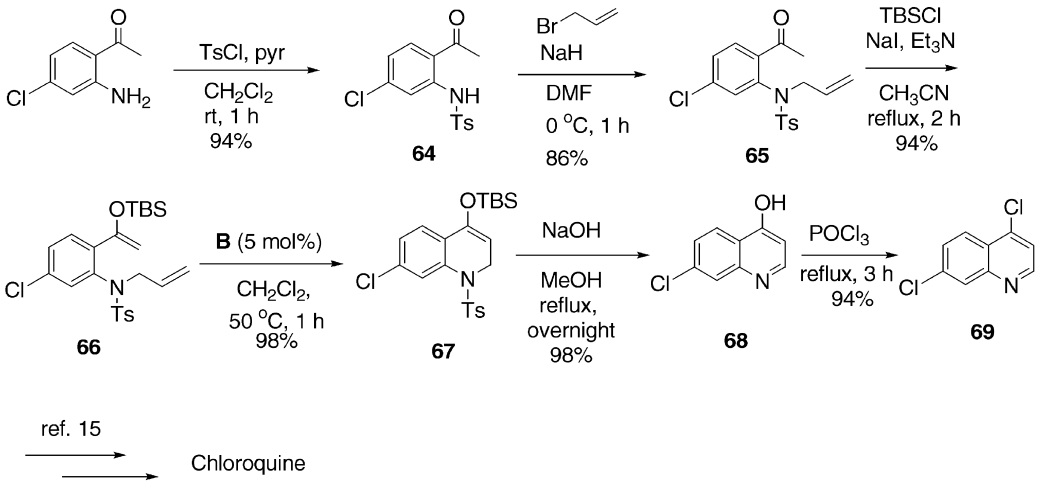
The synthesis of 4-hydroxy-6-methoxyquinoline as a key



Scheme 3. Preparation of 4-methyl-6-methoxy-quinoline (**58**).



Scheme 4. Preparation of 4-hydroxy-6-methoxy-quinoline (**63**).[26]



Scheme 5. Preparation of 4,7-dichloro-quinoline (**69**).

intermediate of PPMP–quinine hybrid is demonstrated to emphasize the effectiveness of RCM.

2-Amino-5-methoxyacetophenone, prepared according to a procedure developed by Fürstner and co-workers,[14] was converted to **60** by tosylation followed by allylation. Allylated **60** was transformed to silyl enol ether **61**, which was readily subjected to silyl enol ether–ene metathesis. The expected 1,2-dihydroquinoline (**62**) was obtained with catalyst **B** at 50 °C in CH_2Cl_2 (0.01 M) for 1 h. Subsequent deprotection of both the silyl and tosyl groups gave **63** in excellent yield (Scheme 4).

4,7-Dichloroquinoline (**69**), a key intermediate for chloroquine synthesis,[15] was also prepared in 6 steps from 2-amino-6-chloroacetophenone by a similar methodology (Scheme 5). Tosylation of 2-amino-6-chloroacetophenone[14] followed by *N*-allylation gave **65**, which was converted to silyl enol ether **66**. RCM of **66** using catalyst **B** at 50 °C in CH_2Cl_2 (0.01 M) for 1 h gave **67** in 98% yield. Deprotection of the silyl and tosyl groups of **67** afforded **68**. Treatment of **68** with $POCl_3$ gave the 4,7-dichloroquinoline (**69**)[16] in 92%.

1. Conclusion

The development of a novel method for synthesizing substituted quinolines and 1,2-dihydroquinolines was achieved by applying RCM using well-defined Grubbs' catalysts and α,ω-dienes, prepared from anthranilic acid, *o*-isopropylaniline and *o*-aminoacetophenone. The reaction proceeded efficiently under mild conditions, which are suitable for the large-scale synthesis of substituted quinolines. Moreover, the highly regioselective synthesis of cyclic silyl enol ether was also developed as a powerful method for synthesizing 4-hetero-substituted quinolines. The utility of this novel quinoline synthesis was demonstrated by the efficient synthesis of 4-methyl-6-methoxyquinoline, the key intermediate for quinine, 4,7-dichloroquinoline, the key intermediate of chloroquine, and 4-hydro-6-methoxyquinoline, the key intermediate of PPMP–quinine hybrid. We believe that these findings could lead to a new methodology for the synthesis of antimalarial agents as well as other biologically active natural products containing a quinoline ring system.

2. Experimental

2.1. General

All melting points are uncorrected. ^1H NMR (and ^{13}C NMR) spectra were recorded in $CDCl_3$ at 25 °C unless otherwise noted, at 400 MHz, with TMS as an internal standard. Silica gel 60 N (Spherical, neutral, Kanto Chemical Co., Inc.) was used for column chromatography and E. Merck precoated TLC plates, silica gel $60F_{254}$, were used for preparative thin layer chromatography. The organic layers were dried over anhydrous Na_2SO_4. Ruthenium carbene catalysts **A** and **B** and substrates **4**, **18**, **24**, and **31** were obtained commercially.

2.1.1. *N*-Allyl-*N*-*p*-toluenesulfonyl-2-isopropenylaniline (1). To a solution of 2-isopropenylaniline (400 mg, 3.00 mmol) in 20 mL of CH_2Cl_2 under an Ar atmosphere, were added pyridine (0.72 mL, 9.00 mmol) and TsCl (686 mg, 3.60 mmol). The mixture was stirred at room temperature for 1 h and the reaction was quenched by addition of water. The mixture was extracted with AcOEt and combined organic layers were washed with brine and dried over Na_2SO_4. After removal of the solvent, the residue was purified by column chromatography on silica gel (*n*-hexane/AcOEt=5:1) to give 838 mg (97%) of *N*-*p*-toluenesulfonyl-2-isopropenylaniline as off white solid.

To a solution of *N*-*p*-toluenesulfonyl-2-isopropenylaniline (241 mg, 0.84 mmol) and K_2CO_3 (174 mg, 1.26 mmol) in 10 mL of DMF under an Ar atmosphere, was added allyl bromide (0.15 mL, 1.26 mmol). The mixture was stirred at 80 °C for 1 h and the reaction was quenched by the addition of saturated aqueous $NaHCO_3$. The mixture was extracted with Et_2O and the combined organic layers were washed with brine and dried over Na_2SO_4. After removal of the solvent, the residue was purified by recrystallization from AcOEt to give 266 mg (97%) of **1** as white plates.

Mp 74–75 °C; ^{1}H NMR ($CDCl_3$) δ 7.67 (2H, d, J=8.3 Hz), 7.27–7.31 (4H, m), 7.12 (1H, ddd, J=2.4, 7.8, 6.6 Hz), 6.74 (1H, d, J=8.0 Hz), 5.69 (1H, dddd, J=6.8, 6.9, 11.2, 17.1 Hz), 5.22 (1H, dd, J=1.4, 1.6 Hz), 5.05 (1H, dd, J=0.9, 1.2 Hz), 4.98 (1H, d, J=3.1 Hz), 4.94 (1H, dd, J=1.4, 11.2 Hz), 4.12 (2H, d, J=6.9 Hz), 2.44 (3H, s), 2.18 (3H, s); ^{13}C NMR ($CDCl_3$) δ 144.9, 143.6, 143.4, 136.9, 136.4, 132.6, 130.1, 129.4, 128.6, 128.2, 128.1, 127.2, 119.2, 116.6, 54.6, 24.3, 21.5: IR (KBr) 3461, 3070, 2958, 2902, 2865, 1646, 1596, 1491, 1450, 1341; HRMS (FAB) calcd for $C_{19}H_{22}NO_2S$ 328.1371, found 328.1348.

2.1.2. *N*-*p*-Toluenesulfonyl-4-methyl-1,2-dihydroquinoline (2). To a solution of olefin **1** (80 mg, 0.24 mmol) in 24 mL of CH_2Cl_2 under an Ar atmosphere, was added Grubbs' catalyst **A** (10.2 mg, 0.012 mmol). The mixture was degassed and stirred at 50 °C for 1 h. After removal of the solvent, the residue was purified by column chromatography on silica gel (*n*-hexane/AcOEt=10:1), and then recrystallized from *n*-hexane/AcOEt to give 66 mg (92%) of **2** as colorless needles. Mp 82 °C (lit.[17] 105–106 °C from methanol); ^{1}H NMR ($CDCl_3$) δ 7.70 (1H, dd, J=1.5, 8.1 Hz), 7.30 (1H, ddd, J=1.4, 7.6, 7.6 Hz), 7.21–7.26 (3H, m), 7.11 (1H, dd, J=1.5, 7.6 Hz), 7.05 (2H, d, J=8.3 Hz), 5.31 (1H, t, J=1.5 Hz), 4.32 (2H, d, J=2.7 Hz), 2.33 (3H, s), 1.57 (3H, s); ^{13}C NMR ($CDCl_3$) δ 143.1, 136.1, 135.1, 131.6, 131.4, 128.8, 127.8, 127.4, 127.2, 126.7, 123.2, 120.3, 45.3, 21.4, 17.7; IR (KBr) 3395, 3042, 2921, 2846, 1609, 1451, 1321, 1153; LRMS (FAB) *m*/*z* 300 [10, M^++H], 299 [15, M^+], 144 [100].

2.1.3. *N*-*p*-Toluenesulfonyl-3,4,5-trimethoxyanthranilic acid methyl ester (5). To a solution of 3,4,5-trimethoxyanthranilic acid methyl ester (2.40 g, 10.0 mmol) in 40 mL of CH_2Cl_2 under an Ar atmosphere, were added pyridine (2.4 mL, 30.0 mmol) and TsCl (2.29 g, 12.0 mmol). The mixture was stirred at room temperature for 1 h and the reaction was quenched by the addition of water. The mixture was extracted with AcOEt and combined organic layers were washed with brine and dried over Na_2SO_4. After removal of the solvent, the residue was purified by recrystallization from acetone to give 3.28 g (83%) of **5** as white needles. Mp 107–108 °C; ^{1}H NMR ($CDCl_3$) δ 8.96 (1H, s), 7.71 (2H, d, J=8.3 Hz), 7.26 (2H, d, J=8.3 Hz), 7.16 (1H, s), 3.90 (3H, s), 3.86 (3H, s), 3.80 (3H, s), 3.41 (3H, s), 2.42 (3H, s); ^{13}C NMR ($CDCl_3$) δ 167.31, 150.43, 148.35, 146.76, 142.93, 137.72, 128.96, 127.17, 127.13, 117.66, 108.28, 60.90, 60.12, 56.08, 52.32, 21.38; IR (KBr) 3163, 2933, 1684; LRMS (FAB) *m*/*z* 396 [40, M^++H], 395 [40, M^+], 241 100]. Anal. Calcd for $C_{18}H_{21}NO_7S$; C, 54.67; H, 5.35; N, 3.54; found C, 54.64; H, 5.41; N, 3.52.

2.1.4. *N*-*p*-Toluenesulfonyl-2-hydroxymethyl-4,5,6-trimethoxyaniline (6). To a cooled (−78 °C) solution of ester **5** (3.28 g, 8.30 mmol) in 50 mL of toluene under an Ar atmosphere, was added a solution of DIBAL in toluene (1 M, 24.9 mL, 24.9 mmol). The mixture was stirred at −78 °C for 1 h and the reaction was quenched by the addition of MeOH and saturated aqueous Rochelle's salt, then the solution was allowed to stir at room temperature until it was separated into two layers. The mixture was extracted with AcOEt and the combined organic layers were washed with brine and dried over Na_2SO_4. After removal of the solvent, the residue was purified by recrystallization from *n*-hexane/AcOEt to give 222 mg (73%) of **6** as colorless needles. Mp 166–167 °C; ^{1}H NMR ($CDCl_3$) δ 7.51 (2H, d, J=8.3 Hz), 7.22 (2H, d, J=8.5 Hz), 6.82 (1H, s), 6.33 (1H, br), 4.75 (2H, s), 3.89 (3H, s), 3.60 (3H, s), 3.29 (3H, s), 2.38 (3H, s); ^{13}C NMR ($CDCl_3$) δ 153.21, 148.04, 143.65, 140.35, 136.25, 135.54, 129.19, 127.71, 119.36, 107.75, 61.60, 60.49, 60.15, 55.94, 21.35; IR (KBr) 3518, 3181, 2929; LRMS (FAB) *m*/*z* 368 [20, M^++H], 367 [57, M^+], 212 [100]. Anal. Calcd for $C_{17}H_{21}NO_6S$; C, 55.57; H, 5.76; N, 3.81; found C, 55.55; H, 5.75; N, 3.79.

2.1.5. *N*-*p*-Toluenesulfonyl-2-formyl-4,5,6-trimethoxyaniline (7). To a solution of alcohol **6** (500 mg, 1.36 mmol) in 70 mL of benzene, was added MnO_2 (355 mg, 4.08 mmol). The mixture was refluxed for 4 h and filtered through a celite pad. After removal of the solvent, the residue was purified by recrystallization from acetone to give 309 mg (62%) of **7** as a white amorphous solid. Mp 97–99 °C; ^{1}H NMR ($CDCl_3$) δ 10.20 (1H, s), 7.49 (2H, d, J=8.3 Hz), 7.22 (1H, s), 7.21 (2H, d, J=8.1 Hz), 7.03 (1H, br), 3.92 (3H, s), 3.75 (3H, s), 3.31 (3H, s), 2.38 (3H, s); ^{13}C NMR ($CDCl_3$) δ 189.53, 152.41, 147.09, 145.94, 144.06, 135.81, 129.42, 127.60, 127.52, 125.42, 105.42, 60.78, 60.51, 56.12, 21.48; IR (KBr) 3248, 1685, 1164; LRMS (FAB) *m*/*z* 366 [30, M^++H], 365 [30, M^+], 211 [100]. Anal. Calcd for $C_{17}H_{19}NO_6S$; C, 55.88; H, 5.24; N, 3.83; found C, 55.49; H, 5.43; N, 3.72.

2.1.6. *N*-Allyl-*N*-*p*-toluenesulfonyl-2-formyl-4,5,6-trimethoxyaniline (8). To a solution of aldehyde **7** (0.79 g, 2.17 mmol) and K_2CO_3 (0.45 g, 3.26 mmol) in 60 mL of DMF under an Ar atmosphere, was added allyl bromide (0.28 mL, 3.26 mmol). The mixture was stirred at 80 °C for 1 h and the reaction was quenched by the addition of saturated aqueous $NaHCO_3$. The mixture was extracted with Et_2O and the combined organic layers were washed with brine and dried over Na_2SO_4. After removal of the solvent, the residue was purified by column chromatography on silica gel (*n*-hexane/AcOEt=1:1) to give 875 mg (99%) of **8** as a pale yellow oil. ^{1}H NMR ($CDCl_3$) δ 10.04 (1H, s), 7.61 (2H, d, J=8.3 Hz), 7.29 (2H, d, J=8.4 Hz), 7.22 (1H, s), 5.71–5.81 (1H, m), 5.00–5.05 (2H, m), 4.59 (1H, dd, J=5.7, 14.1 Hz), 3.98 (1H, dd, J=8.4, 14.1 Hz), 3.92 (3H, s), 3.82 (3H, s), 3.52 (3H, s), 2.43 (3H, s); ^{13}C NMR ($CDCl_3$) δ 189.86, 154.03, 151.35, 146.53, 143.51, 136.91, 132.39, 131.95, 129.52, 127.55, 127.07, 120.02, 103.98, 60.74, 60.45, 56.03, 53.75, 21.49; IR (neat) 2945, 2845, 1688; HRMS (FAB) calcd for $C_{20}H_{24}NO_6S$ 406.1324, found 406.1314.

2.1.7. *N*-Allyl-*N*-*p*-toluenesulfonyl-2-ethenyl-4,5,6-trimethoxyaniline (9). To a cooled (−78 °C) solution of $BrPh_3PMe$ (2.30 g, 6.48 mmol) in 72 mL of THF under an Ar atmosphere, was added a solution of $KN(TMS)_2$ in THF (0.5 M, 13 mL, 6.48 mmol). The mixture was stirred at −78 °C for 15 min. Then, aldehyde **8** (875 mg, 2.16 mmol) was added to this solution, and the mixture was warmed to room temperature with stirring for 1 h. The solution was quenched by the addition of saturated aqueous Rochelle's salt. The mixture was extracted with AcOEt and the combined organic layers were washed with brine and dried over Na_2SO_4. After removal of the solvent, the residue

was purified by recrystallization from *n*-hexane/AcOEt to give 760 mg (87%) of **9** as white prisms. Mp 110–111 °C; ^{1}H NMR ($CDCl_3$) δ 7.72 (2H, d, J=8.3 Hz), 7.28 (2H, d, J=8.1 Hz), 6.88 (1H, dd, J=11.0, 17.8 Hz), 6.83 (1H, s), 5.70–5.77 (1H, m), 5.63 (1H, d, J=17.6 Hz), 5.22 (1H, d, J=12.0 Hz), 4.95–4.99 (2H, m), 4.29 (1H, dd, J=6.1, 14.2 Hz), 3.97 (1H, dd, J=7.8, 14.4 Hz), 3.90 (3H, s), 3.77 (3H, s), 3.63 (3H, s), 2.43 (3H, s); ^{13}C NMR ($CDCl_3$) δ 153.72, 151.81, 142.90, 141.24, 137.87, 134.72, 133.47, 133.12, 129.21, 127.80, 122.46, 118.68, 114.80, 102.04, 60.63, 60.41, 55.77, 53.71, 21.47; IR (KBr) cm^{-1} 2942, 1491, 1334; LRMS (FAB) *m/z* 404 [23, M$^+$+H], 149 [100]. Anal. Calcd for $C_{21}H_{25}NO_5S$; C, 62.51; H, 6.25; N, 3.47; found C, 62.29; H, 6.36; N, 3.42.

2.1.8. *N*-*p*-Toluenesulfonyl-6,7,8-trimethoxy-1,2-dihydroquinoline (38). To a solution of olefin **9** (100 mg, 0.29 mmol) in 29 mL of CH_2Cl_2 under an Ar atmosphere, was added catalyst **A** (12.2 mg, 0.0245 mmol). The mixture was degassed and stirred at 50 °C for 1 h. After removal of the solvent, the residue was purified by column chromatography on silica gel (*n*-hexane/AcOEt=1:1) to give 98 mg (90%) of **38** as a colorless amorphous solid. ^{1}H NMR ($CDCl_3$) δ 7.48 (2H, d, J=8.2 Hz), 7.15 (2H, d, J=8.2 Hz), 6.28 (1H, s), 5.94 (1H, d, J=9.5 Hz), 5.50 (1H, td, J=4.2, 9.5 Hz), 4.29 (2H, br), 4.00 (3H, s), 3.90 (3H, s), 3.85 (3H, s), 2.39 (3H, s); ^{13}C NMR ($CDCl_3$) δ 152.6, 150.6, 143.2, 142.0, 136.8, 128.9, 127.8, 126.9, 126.0, 124.6, 120.8, 104.2, 61.0, 60.8, 56.0, 45.5, 21.5; IR (KBr) 3451, 2930, 2837, 1560, 1458, 1348; LRMS (EI) *m/z* 375 [60, M$^+$], 221[100]. Anal. Calcd for $C_{19}H_{21}NO_5S$: C, 60.78; H, 5.64; N, 3.73, found: C, 60.72; H, 5.64; N, 3.60.

2.1.9. 5-Methoxyanthranilic acid (10). To a solution of 5-methoxy-2-nitrobenzoic acid (5.05 g, 25.6 mmol) in 100 mL of EtOH) was added 5% palladium on charcoal (105 mg and stirred at room temperature for 12 h under an Ar atmosphere. After the starting material was disappeared on TLC, the solution was filtered through a celite pad and solvent was removed to give 4.00 g (97%) of **10** as a violet solid. ^{1}H NMR ($CDCl_3$) δ 7.40 (1H, d, J=1.8 Hz), 7.03 (1H, dd, J=3.1, 9.0 Hz), 6.66 (1H, d, J=8.8 Hz), 3.78 (3H, s); ^{13}C NMR ($CDCl_3$) δ 172.7, 150.6, 145.8, 124.7, 118.5, 113.3, 109.4, 55.8; IR (KBr) 3500, 2951, 2598, 1930, 1707, 1583; HRMS (FAB) calcd for $C_8H_{10}NO_3$ 168.0661, found 168.0653.

2.1.10. 5-Methoxyanthranilic acid methyl ester (11).[18] To a solution of **10** (15.0 g, 89.7 mmol) in 550 mL of 2,3-dimethoxypropane, was added 79 mL of 36% hydrochloric acid. The mixture was stirred at room temperature for 12 h and the reaction was quenched by addition of saturated aqueous $NaHCO_3$. The product was extracted with AcOEt, and the combined organic layers were washed with brine and dried over Na_2SO_4. After removal of the solvent, the residue was purified by column chromatography on silica gel (*n*-hexane/AcOEt=3:1) to give 5.20 g (32%) of **11** as a yellow-orange oil. ^{1}H NMR ($CDCl_3$) δ 7.35 (1H, d, J=3.1 Hz), 6.96 (1H, dd, J=3.1, 8.8 Hz), 6.63 (1H, d, J=8.9 Hz), 5.42 (2H, br), 3.88 (3H, s), 3.76 (3H, s); ^{13}C NMR ($CDCl_3$) δ 168.3, 150.5, 145.1, 123.3, 118.2, 113.1, 110.7, 55.8, 51.6; IR (KBr) 3373, 2995, 2952, 2837, 1691, 1593; HRMS (FAB) calcd for $C_9H_{11}NO_3$; 181.0739, found 181.0747.

2.1.11. *N*-*p*-Toluenesulfonyl-5-methoxyanthranilic acid methyl ester (12). To a solution of ester **11** (100 mg, 0.55 mmol) in 4 mL of CH_2Cl_2 under an Ar atmosphere, were added pyridine (0.13 mL, 1.65 mmol) and TsCl (126 mg, 0.66 mmol). The mixture was stirred at room temperature for 1 h and the reaction was quenched by the addition of water. The mixture was extracted with AcOEt and the combined organic layers were washed with brine and dried over Na_2SO_4. After removal of the solvent, the residue was purified by recrystallization from AcOEt to give 150 mg (82%) of **12** as pale yellow prisms. Mp 110 °C; ^{1}H NMR ($CDCl_3$) δ 10.0 (1H, s), 7.66 (1H, d, J=9.2 Hz), 7.63 (2H, d, J=8.3 Hz), 7.34 (1H, d, J=2.9 Hz), 7.18 (2H, d, J=8.5 Hz), 7.04 (1H, dd, J=2.9, 9.0 Hz), 3.81 (3H, s), 3.76 (3H, s), 2.35 (3H, s); ^{13}C NMR ($CDCl_3$) δ 167.7, 155.4, 143.6, 136.1, 133.4, 129.4, 127.2, 122.6, 120.9, 118.1, 114.6, 55.6, 52.4, 21.5; IR (KBr) 3174, 2951, 2843, 1691, 1612; LRMS (FAB) *m/z* 336 [50, M$^+$+H], 335 [80, M$^+$], 181 [100]. Anal. Calcd for $C_{16}H_{17}NO_5S$: C, 57.30; H, 5.11; N, 4.18, found: C, 57.16; H, 5.06; N, 4.10.

2.1.12. *N*-*p*-Toluenesulfonyl-2-hydroxymethyl-4-methoxyaniline (13). To a cooled (−78 °C) solution of ester **12** (5.50 g, 16.4 mmol) in 120 mL of toluene under an Ar atmosphere, was added a solution of DIBAL in toluene (1 M, 54.1 mL, 54.1 mmol). The mixture was stirred at −78 °C for 1 h and the reaction was quenched by the addition of MeOH and saturated aqueous Rochelle's salt, then the solution was allowed to stir at room temperature until two layers were separated. The mixture was extracted with AcOEt and the combined organic layers were washed with brine and dried over Na_2SO_4. After removal of the solvent, the residue was purified by recrystallization from MeOH to give 4.57 g (91%) of **13** as colorless needles. Mp 130 °C; ^{1}H NMR ($CDCl_3$) δ 7.56 (2H, d, J=8.4 Hz), 7.30 (1H, br), 7.21 (2H, d, J=7.9 Hz), 7.10 (1H, d, J=8.4 Hz), 6.74 (1H, d, J=3.1 Hz), 6.72 (1H, dd, J=3.3 Hz), 4.30 (2H, s), 3.76 (3H, s), 2.39 (3H, s); ^{13}C NMR ($CDCl_3$) δ 158.0, 143.8, 136.6, 136.3, 129.6, 127.9, 127.4, 127.2, 114.7, 113.8, 63.1, 55.4, 21.5; IR (KBr) 3489, 3130, 2964, 2837, 1612, 1498; LRMS (FAB) *m/z* 308 [30, M$^+$+H], 307 [100, M$^+$]. Anal. Calcd for $C_{15}H_{17}NO_4S$: C, 58.61; H, 5.57; N, 4.56, found: C, 58.52; H, 5.53; N, 4.42.

2.1.13. *N*-*p*-Toluenesulfonyl-2-formyl-4-methoxyaniline (14). To a solution of alcohol **13** (75 mg, 0.24 mmol) in 10 mL of benzene, was added MnO_2 (510 mg, 0.59 mmol). The mixture was refluxed for 4 h and filtered through a celite pad. After removal of the solvent, the residue was purified by recrystallization from AcOEt to give 70 mg (91%) of **14** as yellow plates. Mp 110 °C; ^{1}H NMR ($CDCl_3$) δ 10.22 (1H, s), 9.74 (1H, s), 7.68 (2H, d, J=8.3 Hz), 7.67 (1H, d, J=9.2 Hz), 7.20 (2H, d, J=8.1 Hz), 7.09 (1H, dd, J=2.9, 9.0 Hz), 7.05 (1H, d, J=2.9 Hz), 3.81 (3H, s), 2.35 (3H, s); ^{13}C NMR ($CDCl_3$) δ 194.5, 155.7, 143.9, 136.2, 132.9, 129.6, 127.2, 123.5, 122.0, 121.0, 119.3, 55.7, 21.5; IR (KBr) 3390, 1652, 1583; LRMS (FAB) *m/z* 306 [5, M$^+$+H], 305 [7, M$^+$], 154 [100]. Anal. Calcd for $C_{15}H_{15}NO_5S$: C, 59.00; H, 4.95; N, 4.59, found: C, 58.87; H, 5.04; N, 4.49.

2.1.14. *N*-Allyl-*N*-*p*-toluenesulfonyl-2-formyl-4-methoxyaniline (15). To a solution of aldehyde **14** (100 mg, 0.33 mmol) and K_2CO_3 (68 mg, 0.50 mmol) in 10 mL of DMF under an Ar atmosphere, was added allyl bromide (0.04 mL, 0.50 mmol). The mixture was stirred at 80 °C for 1 h and the reaction was quenched by the addition of saturated aqueous $NaHCO_3$. The mixture was extracted with Et_2O and the combined organic layers were washed with brine and dried over Na_2SO_4. After removal of the solvent, the residue was purified by recrystallization from *n*-hexane/AcOEt to give 110 mg (97%) of **15** as orange needles. Mp 77 °C; ^{1}H NMR ($CDCl_3$) δ 10.27 (1H, s), 7.37 (2H, d, J=8.3 Hz), 7.33 (1H, d, J=3.2 Hz), 7.19 (2H, d, J=8.3 Hz), 6.88 (1H, dd, J=3.2, 8.8 Hz), 6.50 (1H, d, J=8.8 Hz), 5.62 (1H, dddd, J=6.8, 6.8, 8.5, 17.1 Hz), 4.95 (^{1}H, d, J=4.6 Hz), 4.92 (1H, d, J=11.6 Hz), 4.48 (2H, br), 3.71 (3H, br), 2.33 (3H, s); ^{13}C NMR (CDCl3) δ 190.1, 159.3, 144.1, 136.9, 134.5, 134.0, 131.7, 129.6, 129.2, 127.9, 121.5, 120.4, 110.6, 55.7, 54.5, 21.6; IR (KBr) 3367, 3068, 2864, 2750, 1693; LRMS (FAB) *m*/*z* 346 [40, M^++H], 191 [100]. Anal. Calcd for $C_{18}H_{19}NO_4S$: C, 62.59; H, 5.54; N, 4.06; found: C, 62.44; H, 5.44; N, 3.93.

2.1.15. *N*-Allyl-*N*-*p*-toluenesulfonyl-2-ethenyl-4-methoxyaniline (16). To a cooled (−78 °C) solution of $BrPh_3PMe$ (34.1 mg, 0.96 mmol) in 5 mL of THF under an Ar atmosphere, was added a solution of $KN(TMS)_2$ in THF (0.5 M, 1.91 mL, 0.96 mmol). The mixture was stirred at −78 °C for 15 min. To this solution, aldehyde **15** (110 mg, 0.32 mmol) was added and the mixture was warmed to room temperature with stirring for 1 h. The reaction was quenched by the addition of saturated aqueous Rochelle's salt. The mixture was extracted with AcOEt and combined organic layers were washed with brine and dried over Na_2SO_4. After removal of the solvent, the residue was purified by column chromatography on silica gel (*n*-hexane/AcOEt=10:1) to give 107 mg (98%) of **16** as a yellow oil. ^{1}H NMR ($CDCl_3$) δ 7.59 (2H, d, J=6.6 Hz), 7.28 (2H, d, J=7.9 Hz), 7.10 (1H, d, J=2.9 Hz), 7.00 (1H, dd, J=2.2, 7.8 Hz), 6.67 (1H, dd, J=2.9, 8.8 Hz), 6.57 (1H, d, J=8.8 Hz), 5.67–6.77 (2H, m), 5.29 (1H, dd, J=1.2, 11.2 Hz), 5.00 (1H, dd, J=1.2, 5.8 Hz), 4.96 (1H, dd, J=1.2, 4.9 Hz), 4.23 (1H, br), 3.93 (1H, br), 3.81 (3H, s), 2.44 (3H, s); ^{13}C NMR ($CDCl_3$) δ 159.2, 152.0, 143.4, 139.7, 136.1, 132.8, 132.5, 130.1, 129.4, 127.8, 119.2, 115.8, 113.9, 110.3, 55.3, 54.9, 21.5; IR (neat) 3091, 3012, 2939, 2837, 1603, 1571; LRMS (FAB) *m*/*z* 344 [25, M^++H], 188 [100]. Anal. Calcd for $C_{19}H_{21}NO_3S$: C, 66.45; H, 6.16; N, 4.08, found: C, 66.31; H, 6.09; N, 3.93.

2.1.16. *N*-*p*-Toluenesulfonyl-6-methoxy-1,2-dihydroquinoline (39). To a solution of olefin **16** (34 mg, 0.10 mmol) in 10 mL of CH_2Cl_2 under an Ar atmosphere, was added Grubbs' catalyst **A** (4.11 mg, 0.005 mmol). The mixture was degassed and stirred at 50 °C for 1 h. After removal of the solvent, the residue was purified by column chromatography on silica gel (*n*-hexane/AcOEt=3:1) followed by recrystallization from *n*-hexane/AcOEt to give 30 mg (95%) of **39** as colorless needles. Mp 152 °C; ^{1}H NMR ($CDCl_3$) δ 7.61 (1H, d, J=8.8 Hz), 7.27 (2H, d, J=8.2 Hz), 7.07 (2H, d, J=8.4 Hz), 6.81 (1H, dd, J=2.9, 8.8 Hz), 6.46 (1H, d, J=2.9 Hz), 5.94 (1H, d, J=9.7 Hz), 5.55 (1H, td, J=4.0, 9.7 Hz), 4.40 (2H, d, J=4.0 Hz), 3.80 (3H, s), 2.35 (3H, s); ^{13}C NMR ($CDCl_3$) δ 158.1, 143.2, 136.1, 130.6, 129.0, 128.3, 127.7, 127.3, 125.8, 124.5, 112.9, 111.5, 55.4, 45.5, 21.5; IR (KBr) 3383, 2962, 1574, 1485; HRMS (FAB) calcd for $C_{17}H_{17}NO_3S$ 315.0929, found 315.0943.

2.1.17. *N*-*p*-Toluenesulfonyl-5-chloro-anthranilic acid methyl ester (19). To a solution of commercially available 5-chloro-anthranilic acid methyl ester (0.50 g, 2.69 mmol) in 20 mL of CH_2Cl_2 under an Ar atmosphere, were added pyridine (0.64 mL, 8.08 mmol) and TsCl (0.62 g, 3.23 mmol). The mixture was stirred at room temperature for 1 h and the reaction was quenched by the addition of water. The mixture was extracted with AcOEt and the combined organic layers were washed with brine and dried over Na_2SO_4. After removal of the solvent, the residue was purified by recrystallization from acetone to give 0.83 g (91%) of **19** as colorless needles. Mp 115 °C; ^{1}H NMR ($CDCl_3$) δ 10.50 (1H, s), 7.87 (1H, d, J=2.4 Hz), 7.71 (2H, d, J=8.5 Hz), 7.66 (1H, d, J=9.0 Hz), 7.39 (1H, dd, J=2.4, 9.0 Hz), 7.22 (2H, d, J=8.1 Hz), 3.88 (3H, s), 2.36 (3H, s); ^{13}C NMR ($CDCl_3$) δ 167.1, 144.1, 139.0, 136.1, 134.3, 130.7, 129.7, 128.1, 127.2, 120.4, 117.0, 52.7, 21.5; IR (KBr) 3451, 3170, 2954, 1935, 1696; LRMS (FAB) *m*/*z* 342 [25, M^++H], 340 [63, M^++H], 154 [100]. Anal. Calcd for $C_{15}H_{14}ClNO_4S$: C, 53.02; H, 4.15; N, 4.12, found: C, 52.94; H, 4.28; N, 4.05.

2.1.18. *N*-*p*-Toluenesulfonyl-4-chloro-2-hydroxymethylaniline (20). To a cooled (−78 °C) solution of ester **19** (0.74 g, 2.17 mmol) in 10 mL of toluene under an Ar atmosphere, was added a solution of DIBAL in toluene (1 M, 6.51 mL, 6.51 mmol). The mixture was stirred at −78 °C for 1 h and the reaction was quenched by the addition of MeOH and Rochelle's salt, and then the solution was allowed to stir at room temperature until two layers were separated. The mixture was extracted with AcOEt and combined organic layers were washed with brine and dried over Na_2SO_4. After removal of the solvent, the residue was purified by recrystallization from MeOH to give 417 mg (62%) of **20** as colorless prisms. Mp 174 °C; ^{1}H NMR (acetone-d_6) δ 8.58 (1H, br), 7.60 (2H, d, J=6.4 Hz), 7.30 (2H, d, J=7.9 Hz), 7.26 (1H, d, J=7.1 Hz), 7.23 (1H, s), 7.19 (1H, dd, J=2.6, 8.6 Hz), 4.73 (1H, br), 4.44 (2H, s), 2.34 (3H, s); ^{13}C NMR (acetone-d_6) δ 144.3, 137.7, 137.1, 134.9, 130.6, 130.0, 128.2, 128.0, 127.4, 125.5, 61.6, 20.9; IR (KBr) 3468, 3120, 2921, 2809, 1586, 1480, 1327; LRMS (FAB) *m*/*z* 314 [8, M^++H], 312 [20, M^++H], 154 [100]. Anal. Calcd for $C_{14}H_{14}ClNO_3S$: C, 53.93; H, 4.53; N, 4.49, found: C, 53.80; H, 4.63; N, 4.49.

2.1.19. *N*-*p*-Toluenesulfonyl-4-chloro-2-formylaniline (21). To a solution of alcohol **20** (0.22 g, 0.69 mmol) in 10 mL of benzene, was added MnO_2 (0.18 g, 2.07 mmol). The mixture was refluxed for 4 h and filtered through a celite pad. After removal of the solvent, the residue was purified by recrystallization from acetone to give 116 mg (54%) of **21** as colorless needles. Mp 146 °C; ^{1}H NMR ($CDCl_3$) δ 10.88 (1H, s), 9.79 (1H, s), 7.79 (2H, d, J=6.6 Hz), 7.72 (1H, d, J=1.7 Hz), 7.51 (1H, d, J=8.3 Hz), 7.28 (2H, d, J=8.1 Hz), 7.12 (1H, dd, J=1.7, 8.1 Hz), 2.34 (3H, s); ^{13}C NMR ($CDCl_3$) δ 193.7, 144.4, 138.4, 136.0, 135.6, 135.1, 129.8, 128.3, 127.2, 122.8, 119.5, 21.5; IR (KBr) 3433, 3178, 3051, 2753, 1667, 1573, 1489; LRMS

(FAB) *m/z* 312 [20, M^++H], 310 [50, M^++H], 154 [100]. Anal. Calcd for $C_{14}H_{12}ClNO_3S$: C, 54.28; H, 3.90; N, 4.52, found: C, 54.28; H, 4.03; N, 4.47.

2.1.20. *N*-Allyl-*N*-*p*-toluenesulfonyl-4-chloro-2-formylaniline (22). To a solution of aldehyde **21** (0.24 g, 0.77 mmol) and K_2CO_3 (0.16 g, 1.16 mmol) in 20 mL of DMF under an Ar atmosphere, was added allyl bromide (0.1 mL, 1.16 mmol). The mixture was stirred at 80 °C for 1 h and the reaction was quenched by the addition of saturated aqueous $NaHCO_3$. The mixture was extracted with Et_2O and the combined organic layers were washed with brine and dried over Na_2SO_4. After removal of the solvent, the residue was purified by column chromatography on silica gel (*n*-hexane/AcOEt=2:1) to give 260 mg (97%) of **22** as a pale yellow oil. ^{1}H NMR ($CDCl_3$) δ 10.32 (1H, s), 7.94 (1H, d, *J*=2.6 Hz), 7.48 (2H, d, *J*=8.1 Hz), 7.40 (1H, dd, *J*=2.5, 8.4 Hz), 7.30 (2H, d, *J*=8.4 Hz), 6.64 (1H, d, *J*=8.6 Hz), 5.70 (1H, dddd, *J*=6.8, 6.9, 10.1, 17.0 Hz), 5.08 (1H, d, *J*=10.1 Hz), 5.03 (1H, d, *J*=17.0 Hz), 4.68 (1H, br), 3.89 (1H, br), 2.46 (3H, s); ^{13}C NMR ($CDCl_3$) δ 188.7, 144.5, 139.6, 137.2, 135.0, 134.1, 133.8, 131.3, 129.8, 129.3, 128.4, 127.9, 120.9, 54.3, 21.6; IR (neat) 3451, 3070, 2921, 2874, 1690; HRMS (FAB) calcd for $C_{17}H_{17}ClNO_3S$ 350.0618, found 350.0586.

2.1.21. *N*-Allyl-*N*-*p*-toluenesulfonyl-4-chloro-2-ethenylaniline (23). To a cooled (−78 °C) solution of $BrPh_3PMe$ (270 mg, 0.75 mmol) in 20 mL of THF under an Ar atmosphere, was added a solution of $KN(TMS)_2$ in THF (0.5 M, 1.5 mL, 0.75 mmol). After the mixture was stirred at −78 °C for 15 min, aldehyde **22** (220 mg, 0.63 mmol) was added and the mixture was warmed to room temperature for 1 h. The reaction was quenched by the addition of Rochelle's salt. The mixture was extracted with AcOEt and combined organic layers were washed with brine and dried over Na_2SO_4. After removal of the solvent, the residue was purified by column chromatography on silica gel (*n*-hexane/AcOEt=2:1) to give 210 mg (96%) of **23** as a yellow oil. ^{1}H NMR ($CDCl_3$) δ 7.59 (1H, s), 7.57 (2H, d, *J*=6.6 Hz), 7.29 (2H, d, *J*=7.9 Hz), 7.09 (1H, dd, *J*=2.5, 8.6 Hz), 6.96 (1H, dd, *J*=11.0, 17.6 Hz), 6.60 (1H, d, *J*=8.4 Hz), 5.65–5.75 (2H, m), 5.34 (1H, d, *J*=11.1 Hz), 5.00 (1H, dd, *J*=1.1, 8.7 Hz), 4.96 (1H, dd, *J*=1.3, 7.0 Hz), 4.23 (1H, br), 3.94 (1H, s), 2.44 (3H, s); ^{13}C NMR ($CDCl_3$) δ 143.8, 140.4, 135.7, 135.1, 134.4, 132.0, 131.7, 130.3, 129.6, 127.9, 127.8, 126.1, 119.6, 117.0, 54.7, 21.5.; IR (neat) 3087, 3023, 2977, 2923, 2856, 1477; HRMS (FAB) calcd for $C_{18}H_{19}ClNO_2S$ 348.0825, found: 348.0825.

2.1.22. *N*-*p*-Toluenesulfonyl-6-chloro-1,2-dihydroquinoline (40). To a solution of olefin **23** (100 mg, 0.29 mmol) in 29 mL of CH_2Cl_2 under an Ar atmosphere, was added catalyst **A** (12.2 mg, 0.0245 mmol). The mixture was degassed and stirred at 50 °C for 1 h. After removal of the solvent, the residue was purified by column chromatography on silica gel (*n*-hexane/AcOEt=1:1) to give 84 mg (90%) of **40** as a colorless amorphous solid. ^{1}H NMR ($CDCl_3$) δ 7.63 (1H, d, *J*=8.5 Hz), 7.30 (2H, d, *J*=8.3 Hz), 7.20 (1H, dd, *J*=2.4, 8.5 Hz), 7.09 (2H, d, *J*=8.1 Hz), 6.92 (1H, d, *J*=2.4 Hz), 5.96 (1H, d, *J*=9.8 Hz), 5.63 (1H, td, *J*=4.1, 4.2 Hz), 4.42 (2H, dd, *J*=1.7, 4.1 Hz), 2.35 (3H, s); ^{13}C NMR ($CDCl_3$) δ 143.6, 135.9, 133.3, 132.0, 130.7, 129.1, 128.0, 127.6, 127.1, 126.1, 125.4, 124.8, 60.3, 21.4; IR (KBr) 3451, 3060, 2921, 1560, 1179, 1354; HRMS (FAB) calcd for $C_{16}H_{14}ClNO_2S$ 319.0434, found: 319.0427.

2.1.23. 4-Chloro-anthranilic acid methyl ester (25). To solution of purified 2-amino-4-chlorobenzoic acid **24** (5.00 g, 29.1 mmol) in 291 mL of 2,2-dimethoxypropane, was added 58.2 mL of hydrochloric acid (36%). The mixture was stirred at 50 °C for 12 h and the reaction was quenched by addition of saturated aqueous $NaHCO_3$. The product was extracted with AcOEt and the combined organic layers were washed with brine and dried over Na_2SO_4. After removal of the solvent, the residue was purified by recrystallization from *n*-hexane to give 3.59 g (67%) of **25** as white needles. Mp 60–61 °C (lit.[19] 66–68 °C); ^{1}H NMR ($CDCl_3$) δ 7.77 (1H, d, *J*=8.5 Hz), 6.66 (1H, d, *J*=2.2 Hz), 6.60 (1H, dd, *J*=2.2, 8.5 Hz), 5.80 (2H, s), 3.86 (3H, s); ^{13}C NMR ($CDCl_3$) δ 149.3, 138.9, 131.9, 118.8, 115.4, 115.2, 67.5, 51.1; IR (KBr) 3454, 3357, 1685; LRMS (EI) *m/z* 187 [10, M^+], 185 [40, M^+], 98 [100]. Anal. Calcd for $C_8H_8ClNO_2$: C, 51.77; H, 4.34; N, 7.55, found: C, 51.76; H, 4.29; N, 7.42.

2.1.24. *N*-*p*-Toluenesulfonyl-4-chloro-anthranilic acid methyl ester (26). To a solution of ester **25** (1.80 g, 9.70 mmol) in 30 mL of CH_2Cl_2 under an Ar atmosphere, were added pyridine (2.31 mL, 29.1 mmol) and TsCl (2.22 g, 11.6 mmol). The mixture was stirred at room temperature for 1 h and the reaction was quenched by the addition of water. The mixture was extracted with AcOEt and the combined organic layers were washed with brine and dried over Na_2SO_4. After removal of the solvent, the residue was purified by recrystallization from acetone to give 2.37 g (72%) of **26** as colorless needles. Mp 143 °C (lit.[20] 134–136 °C from ethanol); ^{1}H NMR ($CDCl_3$) δ 10.72 (1H, s), 7.84 (1H, d, *J*=8.4 Hz), 7.77 (2H, d, *J*=8.0 Hz), 7.72 (1H, d, *J*=1.8 Hz), 7.25 (2H, d, *J*=8.0 Hz), 6.98 (1H, dd, *J*=1.8, 8.5 Hz), 3.88 (3H, s), 2.38 (3H, s); ^{13}C NMR ($CDCl_3$) δ 168.1, 143.7, 136.3, 136.0, 133.5, 128.9, 128.7, 127.3, 125.8, 116.9, 116.5, 52.6, 21.4; IR (KBr) 3114, 2956, 1687, 1597; LRMS (FAB) *m/z* 342 [25, M^++H], 340 [65, M^++H], 154 [100]. Anal. Calcd for $C_{15}H_{14}ClNO_4S$: C, 53.02; H, 4.15; N, 4.12, found: C, 52.84; H, 4.09; N, 3.84.

2.1.25. *N*-*p*-Toluenesulfonyl-5-chloro-2-hydroxymethylaniline (27). To a cooled (−78 °C) solution of ester **26** (0.16 g, 0.47 mmol) in 5 mL of toluene under an Ar atmosphere, was added a solution of DIBAL in toluene (1 M, 1.55 mL, 1.55 mmol). After the mixture was stirred at −78 °C for 1 h, the reaction was quenched by the addition of MeOH and saturated aqueous Rochelle's salt. Then the solution was allowed to stir at room temperature until two layers were separated. The mixture was extracted with AcOEt and the combined organic layers were washed with brine and dried over Na_2SO_4. After removal of the solvent, the residue was purified by recrystallization from MeOH to give 100 mg (70%) of **27** as colorless prisms. Mp 123–124 °C (lit.[20] 108–110 °C from ethanol); ^{1}H NMR ($CDCl_3$) δ 7.65 (2H, d, *J*=8.4 Hz), 7.45 (1H, d, *J*=1.5 Hz), 7.24 (2H, d, *J*=8.4 Hz), 7.02 (1H, dd, *J*=1.5, 8.1 Hz), 6.99 (1H, d, *J*=8.1 Hz), 4.37 (2H, s), 2.39 (3H, s); ^{13}C NMR ($CDCl_3$) δ 144.2, 137.6, 136.5, 134.7, 129.9, 129.8, 129.4, 127.0, 125.0, 122.7, 63.3, 21.5; IR (KBr) 3500, 3249, 1600, 1491;

LRMS (FAB) *m/z* 314 [8, M^++H], 312 [20, M^++H], 154 [100]. Anal. Calcd for $C_{14}H_{14}ClNO_3S$: C, 53.93; H, 4.53; N, 4.49, found: C, 53.78; H, 4.52; N, 4.37.

2.1.26. *N*-*p*-Toluenesulfonyl-5-chloro-2-formylaniline (28). To a solution of alcohol **27** (590 mg, 1.89 mmol) in 100 mL of benzene, was added MnO_2 (400 mg, 4.54 mmol). The mixture was refluxed for 4 h and filtered through a celite pad. After removal of the solvent, the residue was purified by recrystallization from acetone to give 420 mg (71%) of **27** as colorless prisms. Mp 139–140 °C (lit.[20] 138–140 °C from ethanol); ^{1}H NMR ($CDCl_3$) δ 10.88 (1H, s), 9.78 (1H, s), 7.79 (2H, d, *J*=6.6 Hz), 7.72 (1H, d, *J*=1.7 Hz), 7.51 (1H, d, *J*=8.3 Hz), 7.28 (2H, d, *J*=8.2 Hz), 7.12 (1H, dd, *J*=1.7, 8.1 Hz), 2.39 (3H, s); ^{13}C NMR ($CDCl_3$) δ 193.9, 144.6, 142.6, 141.0, 137.0, 136.1, 129.9, 127.3, 123.2, 120.1, 117.7, 21.6; IR (KBr) 3153, 3105, 2858, 1672, 1597; LRMS (FAB) *m/z* 312 [20, M^++H], 310 [50, M^++H], 154 [100]. Anal. Calcd for $C_{14}H_{12}ClNO_3S$: C, 54.28; H, 3.90; N, 4.52, found: C, 54.17; H, 3.90; N, 4.35.

2.1.27. *N*-Allyl-*N*-*p*-toluenesulfonyl-5-chloro-2-formylaniline (29). To a solution of aldehyde **28** (1.11 g, 3.58 mmol) and K_2CO_3 (740 mg, 5.38 mmol) in 100 mL of DMF under an Ar atmosphere, was added allyl bromide (0.47 mL, 5.38 mmol). The mixture was stirred at 80 °C for 1 h and the reaction was quenched by the addition of saturated aqueous $NaHCO_3$. The mixture was extracted with Et_2O and the combined organic layers were washed with brine and dried over Na_2SO_4. After removal of the solvent, the residue was purified by recrystallization from AcOEt to give 1.15 g (92%) of **29** as white prisms. Mp 117–118 °C; ^{1}H NMR ($CDCl_3$) δ 10.31 (1H, s), 7.94 (1H, d, *J*=2.6 Hz), 7.50 (2H, d, *J*=8.3 Hz), 7.42 (1H, dd, *J*=2.0, 8.3 Hz), 7.33 (2H, d, *J*=8.0 Hz), 6.67 (1H, d, *J*=8.6 Hz), 5.22 (1H, dddd, *J*=3.4, 6.6, 10.0, 17.0 Hz), 5.10 (1H, dd, *J*=0.7, 10.0 Hz), 5.06 (1H, dd, *J*=1.2, 17.1 Hz), 4.53 (1H, br), 3.82 (1H, br), 2.47 (3H, s); ^{13}C NMR ($CDCl_3$) δ 188.9, 144.7, 142.4, 134.6, 131.2, 129.9, 129.6, 129.1, 128.3, 127.9, 121.0, 60.4, 54.4, 21.6, 14.2; IR (KBr) 3089, 3068, 2924, 2870, 1691; LRMS (FAB) *m/z* 352 [40, M^++H], 350 [100, M^++H]. Anal. Calcd for $C_{17}H_{16}ClNO_3S$: C, 58.37; H, 4.61; N, 4.00; found: C, 58.30; H, 4.59; N, 3.82.

2.1.28. *N*-Allyl-*N*-*p*-toluenesulfonyl-5-chloro-2-ethenylaniline (30). To a cooled (−78 °C) solution of $BrPh_3PMe$ (613 mg, 1.72 mmol) in 20 mL of THF under an Ar atmosphere, was added a solution of $KN(TMS)_2$ in THF (0.5 M, 3.43 mL, 1.72 mmol). The mixture was stirred at −78 °C for 15 min. Then, to the mixture, aldehyde **29** (200 mg, 0.57 mmol) was added and the reaction mixture was stirred at room temperature for 1 h. The solution was quenched by the addition of saturated aqueous Rochelle's salt and MeOH. The mixture was extracted with AcOEt and the combined organic layers were washed with brine and dried over Na_2SO_4. After removal of the solvent, the residue was purified by recrystallization from *n*-hexane to give 193 mg (97%) of **30** as orange prisms. Mp 115 °C; ^{1}H NMR ($CDCl_3$) δ 7.59 (3H, m), 7.29 (2H, d, *J*=7.9 Hz), 7.09 (1H, dd, *J*=2.4, 8.6 Hz), 6.97 (1H, dd, *J*=11.0, 17.6 Hz), 6.60 (1H, d, *J*=8.4 Hz), 5.65–5.75 (2H, m), 5.34 (1H, d, *J*=11.0 Hz), 4.94–5.02 (2H, m), 4.23 (1H, br), 3.94 (1H, br), 2.44 (3H, s); ^{13}C NMR ($CDCl_3$) δ 143.9, 137.5, 137.3, 135.5, 132.9, 131.8, 131.7, 129.6, 129.1, 128.7, 127.8, 127.0, 119.6, 116.3, 54.6, 21.7; IR (KBr) 3448, 3074, 2925, 2867, 1699, 1595, 1352; LRMS (FAB) *m/z* 350 [20, M^++H], 348 [40, M^++H], 192 [100]. Anal. Calcd for $C_{18}H_{18}ClNO_2S$: C, 62.15; H, 5.22; N, 4.03, found: C, 62.27; H, 5.40; N, 3.94.

2.1.29. *N*-*p*-Toluenesulfonyl-7-chloro-1,2-dihydroquinoline (41). To a solution of olefin **30** (197 mg, 0.57 mmol) in 57 mL of CH_2Cl_2 under an Ar atmosphere, was added catalyst **B** (24 mg, 0.0285 mmol). The mixture was degassed and stirred at 50 °C for 1 h. After removal of the solvent, the residue was purified by column chromatography on silica gel (*n*-hexane/AcOEt=5:1) and recrystallization from MeOH to give 181 mg (100%) of **41** as colorless needles. Mp 156 °C; ^{1}H NMR ($CDCl_3$) δ 7.73 (1H, d, *J*=2.0 Hz), 7.35 (2H, d, *J*=8.1 Hz), 7.14 (1H, dd, *J*=2.0, 8.2 Hz), 7.10 (2H, d, *J*=8.2 Hz), 6.86 (1H, d, *J*=8.0 Hz), 6.01 (1H, d, *J*=9.5 Hz), 5.60 (1H, td, *J*=4.2, 9.4 Hz), 4.43 (2H, d, *J*=4.2 Hz), 2.35 (3H, s); ^{13}C NMR ($CDCl_3$) δ 143.8, 136.2, 136.1, 133.2, 129.3, 127.4, 126.8, 125.2, 124.2, 45.3, 29.8, 21.6, 1.09, 0.07; IR (KBr) 3448, 3065, 2926, 2858, 1593; LRMS (FAB) *m/z* 322 [10, M^++H], 320 [35, M^++H], 164 [100]. Anal. Calcd for $C_{16}H_{14}ClNO_2S$: C, 60.09; H, 4.41; N, 4.38, found: C, 59.97; H, 4.51; N, 4.28.

2.1.30. 2-Aminonaphthalene-3-carboxylic acid methyl ester (32). To a solution of 2-aminonaphthalene-3-carboxylic acid (0.10 g, 0.53 mmol) in 5 mL of 2,2-dimethoxypropane, was added 1 mL of 36% hydrochloric acid. The mixture was stirred at room temperature for 12 h and the reaction was quenched by addition of saturated aqueous $NaHCO_3$. The product was extracted with AcOEt and the combined organic layers were washed with brine and dried over Na_2SO_4. After removal of the solvent, the residue was purified by recrystallization from *n*-hexane to give 43 mg (40%) of **32** as yellow needles. Mp 102 °C (lit.[21] 104–105 °C); ^{1}H NMR ($CDCl_3$) δ 8.49 (1H, s), 7.71 (1H, d, *J*=8.3 Hz), 7.52 (1H, d, *J*=8.3 Hz), 7.38 (1H, dd, *J*=7.6, 8.3 Hz), 7.17 (1H, dd, *J*=7.6, 8.3 Hz), 6.95 (1H, s), 5.56 (2H, br), 3.94 (3H, s); ^{13}C NMR ($CDCl_3$) δ 168.3, 145.9, 137.3, 133.4, 129.2, 128.8, 126.0, 125.1, 122.5, 114.7, 109.9, 51.9; IR (KBr) 3496, 3389, 2961, 1694; LRMS (FAB) *m/z* 202 [50, M^++H]. Anal. Calcd for $C_{12}H_{11}NO_2$: C, 71.63; H, 5.51; N, 6.96, found: C, 71.48; H, 5.51; N, 6.86.

2.1.31. *N*-*p*-Toluenesulfonyl-2-aminonaphthalene-3-carboxylic acid methyl ester (33). To a solution of ester **32** (50 mg, 0.25 mmol) in 5 mL of CH_2Cl_2 under an Ar atmosphere, were added pyridine (0.06 mL, 0.75 mmol) and TsCl (57.2 mg, 0.30 mmol). The mixture was stirred at room temperature for 1 h and the reaction was quenched by the addition of water. The mixture was extracted with AcOEt and the combined organic layers were washed with brine and dried over Na_2SO_4. After removal of the solvent, the residue was purified by recrystallization from acetone to give 40 mg (78%) of **33** as colorless needles. Mp 136–137 °C; ^{1}H NMR ($CDCl_3$) δ 10.39 (1H, s), 8.50 (1H, s), 8.07 (1H, s), 7.77 (2H, d, *J*=9.1 Hz), 7.73 (2H, d, *J*=8.2 Hz), 7.56 (1H, dd, *J*=7.1, 8.1 Hz), 7.42 (1H, dd, *J*=7.3, 8.3 Hz), 7.17 (2H, d, *J*=8.4 Hz), 3.92 (3H, s), 2.31 (3H, s); ^{13}C NMR ($CDCl_3$) δ 168.1, 143.7, 136.3, 136.0, 135.2, 133.5, 129.5, 129.4, 128.9, 128.7, 127.32, 127.30, 125.8, 116.9, 116.5,

52.6, 21.4; IR (KBr) 3445, 3173, 2952, 1941, 1830, 1682; LRMS (FAB) *m/z* 356 [60, M^++H], 355 [65, M^+], 154 [100]. Anal. Calcd for $C_{19}H_{17}NO_4S$: C, 64.21; H, 4.82; N, 3.94, found: C, 64.05; H, 4.95; N, 3.85.

2.1.32. *N*-(*p*-Toluenesulfonyl)-2-amino-3-hydroxymethylnaphthalene (34). To a cooled (−78 °C) solution of ester **33** (0.10 g, 0.28 mmol) in 3 mL of toluene under an Ar atmosphere, was added a solution of DIBAL in toluene (1 M, 1.13 mL, 1.13 mmol). The mixture was stirred at −78 °C for 1 h and the reaction was quenched by the addition of MeOH and saturated aqueous Rochelle's salt. Then the solution was allowed to stir at room temperature until two layers were separated. The mixture was extracted with AcOEt and the combined organic layers were washed with brine and dried over Na_2SO_4. After removal of the solvent, the residue was purified by recrystallization from MeOH to give 88 mg (96%) of **34** as light brown needles. Mp 183–185 °C; ^{1}H NMR ($CDCl_3$) δ 8.08 (1H, s), 7.94 (1H, s), 7.78 (1H, d, *J*=8.0 Hz), 7.72 (1H, d, *J*=8.0 Hz), 7.68 (2H, d, *J*=8.3 Hz), 7.54 (1H, s), 7.48 (2H, dd, *J*=7.1, 7.9 Hz), 7.42 (1H, dd, *J*=7.8, 6.8 Hz), 7.18 (2H, d, *J*=8.0 Hz), 4.52 (2H, d, *J*=4.9 Hz), 2.35 (3H, s); ^{13}C NMR ($CDCl_3$) δ 144.6, 140.9, 136.3, 131.6, 126.5, 126.3, 125.9, 125.8, 125.4, 124.0, 123.9, 120.9, 116.3, 106.6, 59.8, 21.1; IR (KBr): 3455, 3110, 2917, 2867, 2806, 2710, 1597; LRMS (FAB) *m/z* 328 [10, M^++H], 327 [25, M^+], 154 [100]. Anal. Calcd for $C_{18}H_{17}NO_3S$: C, 66.03; H, 5.23; N, 4.28, found: C, 65.85; H, 5.14; N, 4.14.

2.1.33. *N*-(*p*-Toluenesulfonyl)-2-amino-3-formylnaphthalene (35). To a solution of alcohol **34** (0.42 g, 1.28 mmol) in 100 mL of benzene, was added MnO_2 (0.40 g, 3.08 mmol). The mixture was refluxed for 4 h and filtered through a celite pad. After removal of the solvent, the residue was purified by recrystallization from AcOEt to give 350 mg (84%) of **35** as yellow prisms. Mp 163 °C; ^{1}H NMR ($CDCl_3$) δ 10.44 (1H, s), 9.95 (1H, s), 8.12 (1H, s), 8.03 (1H, s), 7.85 (1H, d, *J*=8.3 Hz), 7.79 (1H, d, *J*=2.3 Hz), 7.76 (2H, d, *J*=8.3 Hz), 7.62 (1H, dd, *J*=7.1, 7.1 Hz), 7.45 (1H, dd, *J*=7.1, 7.1 Hz), 7.18 (2H, d, *J*=7.1 Hz), 2.31 (3H, s); ^{13}C NMR ($CDCl_3$) δ 194.9, 144.0, 140.3, 136.6, 136.4, 134.7, 130.7, 129.7, 129.2, 128.9, 127.7, 127.4, 126.1, 123.1, 115.9, 21.6; IR (KBr) 3204, 3066, 2843, 1670; LRMS (FAB) *m/z* 326 [60, M^++H], 325 [50, M^+], 154 [100]. Anal. Calcd for $C_{18}H_{15}NO_3S$: C, 66.44; H, 4.65; N, 4.30, found: C, 66.15; H, 4.62; N, 4.20.

2.1.34. *N*-Allyl-*N*-(*p*-toluenesulfonyl)-2-amino-3-formylnaphthalene (36). To a solution of aldehyde **35** (36 mg, 0.11 mmol) and K_2CO_3 (23 mg, 0.17 mmol) in 10 mL of DMF, was added allyl bromide (0.01 mL, 0.17 mmol) under an Ar atmosphere. The mixture was stirred at 80 °C for 1 h and quenched by the addition of saturated aqueous $NaHCO_3$. The mixture was extracted with Et_2O and the combined organic layers were washed with brine and dried over Na_2SO_4. After removal of the solvent, the residue was purified by recrystallization from AcOEt to give 35.7 mg (89%) of **36** as colorless prisms. Mp 137–138 °C; ^{1}H NMR ($CDCl_3$) δ 10.49 (1H, s), 8.52 (1H, s), 8.00 (1H, dd, *J*=3.6, 6.0 Hz), 7.66 (1H, dd, *J*=4.8, 4.9 Hz), 7.58–7.61 (2H, m), 7.51 (2H, d, *J*=8.4 Hz), 7.28 (2H, d, *J*=8.1 Hz), 7.19 (1H, s), 5.80 (1H, dddd, *J*=6.8, 6.8, 10.2, 16.8 Hz), 5.05 (1H, d, *J*=3.1 Hz), 5.01 (1H, d, *J*=7.9 Hz), 4.58 (1H, s), 4.02 (1H, s), 2.46 (3H, s); ^{13}C NMR ($CDCl_3$) δ 190.3, 144.1, 136.8, 135.4, 134.5, 132.9, 131.9, 131.7, 130.6, 129.9, 129.6, 129.0, 128.0, 127.9, 127.7, 127.6, 120.4, 55.0, 21.6; IR (KBr) 3447, 3055, 2979, 2892, 1685; LRMS (FAB) *m/z* 366 [40, M^++H], 211 [100]. Anal. Calcd for $C_{21}H_{19}NO_3S$: C, 69.02; H, 5.24; N, 3.83, found: C, 68.92; H, 5.22; N, 3.77.

2.1.35. *N*-Allyl-*N*-(*p*-toluenesulfonyl)-2-amino-3-ethenylnaphthalene (37). To a cooled (−78 °C) solution of $BrPh_3PMe$ (68 mg, 0.19 mmol) in 5 mL of THF, was added a solution of $KN(TMS)_2$ in THF (0.5 M, 0.38 mL, 0.19 mmol) under an Ar atmosphere. After the mixture was stirred at −78 °C for 15 min, aldehyde **36** (35 mg, 0.10 mmol) in THF (5 mL) was added and the mixture warmed to room temperature for 1 h. The solution was quenched by the addition of saturated aqueous Rochelle's salt. The mixture was extracted with AcOEt and the combined organic layers were washed with brine and dried over Na_2SO_4. After removal of the solvent, the residue was purified by recrystallization from *n*-hexane to give 34 mg (97%) of **37** as white needles. Mp 145 °C; ^{1}H NMR ($CDCl_3$) δ 8.06 (1H, s), 7.83 (1H, d, *J*=7.5 Hz), 7.61 (2H, d, *J*=8.2 Hz), 7.58 (1H, d, *J*=8.2 Hz), 7.48 (1H, ddd, *J*=1.3, 6.8, 6.8 Hz), 7.43 (1H, ddd, *J*=1.3, 6.8, 6.8 Hz), 7.29 (2H, d, *J*=7.9 Hz), 7.24 (1H, s), 7.13 (1H, dd, *J*=11.0, 17.4 Hz), 5.86 (1H, dd, *J*=1.3, 16.3 Hz), 5.72–5.82 (1H, m), 5.35 (1H, dd, *J*=1.3, 11.0 Hz), 4.99 (1H, d, *J*=1.3 Hz), 4.95 (1H, dd, *J*=1.3, 6.4 Hz), 4.29 (1H, br), 4.13 (1H, br), 2.46 (3H, s); ^{13}C NMR ($CDCl_3$) δ 143.6, 136.4, 136.1, 135.3, 133.3, 133.0, 132.6, 132.3, 129.5, 128.4, 128.0, 127.8, 127.4, 126.9, 126.2, 125.4, 119.4, 116.1, 55.1, 21.6; IR (KBr) 3447, 3059, 2918, 2849, 1645, 1596; LRMS (FAB) *m/z* 364 [25, M^++H], 208 [100]. Anal. Calcd for $C_{22}H_{21}NO_2S$: C, 72.70; H, 5.82; N, 3.58, found: C, 72.55; H, 5.79; N, 3.77.

2.1.36. *N*-(*p*-Toluenesulfonyl)-1,2-dihydrobenzo[*g*]quinoline (42). To a solution of olefin **37** (20 mg, 0.055 mmol) in 5.5 mL of CH_2Cl_2, was added catalyst **A** (2.26 mg, 0.00275 mmol) under an Ar atmosphere. The mixture was degassed and stirred at 50 °C for 1 h. After removal of the solvent, the residue was purified by column chromatography (*n*-hexane/AcOEt=4:1) on silica gel followed by recrystallization from *n*-hexane/AcOEt to give 19.1 mg (98%) of **42** as pale yellow needles. Mp 156 °C; ^{1}H NMR ($CDCl_3$) δ 8.15 (1H, s), 7.87 (1H, d, *J*=9.0 Hz), 7.73 (1H, d, *J*=7.0 Hz), 7.43–7.49 (2H, m), 7.36 (1H, s), 7.29 (2H, d, *J*=8.4 Hz), 7.03 (2H, d, *J*=7.9 Hz), 6.23 (1H, d, *J*=9.7 Hz), 5.72 (1H, ddd, *J*=1.3, 4.0, 9.7 Hz), 4.51 (2H, dd, *J*=1.3, 4.0 Hz), 2.32 (3H, s); ^{13}C NMR ($CDCl_3$) δ 143.4, 136.4, 132.9, 132.7, 131.9, 129.1, 128.3, 127.6, 127.5, 127.3, 126.4, 126.3, 126.2, 125.3, 125.1, 125.0, 45.5, 21.5; IR (KBr) 3347, 3052, 2923, 2865, 1918, 1636, 1598; LRMS (FAB) *m/z* 336 [35, M^++H], 335 [40, M^+], 180 [100]. Anal. Calcd for $C_{20}H_{17}NO_2S$: C, 71.62; H, 5.11; N, 4.18, found: C, 71.60; H, 5.11; N, 4.13.

2.1.37. *N*-Allyl-*N*-benzyl-2-isopropenylaniline (43a). To a solution of 2-isopropenylaniline (400 mg, 3.00 mmol) in 2 mL of CH_2Cl_2 under an Ar atmosphere, was added BnBr (0.31 mL, 3.30 mmol). The mixture was stirred at room temperature for 4 h and the reaction was quenched by the addition of saturated aqueous $NaHCO_3$. The mixture was

extracted with CH_2Cl_2 and the combined organic layers were washed with brine and dried over Na_2SO_4. After removal of the solvent, the residue was purified by column chromatography on silica gel (*n*-hexane/AcOEt=10:1) to give 315 mg (61%) of *N*-benzyl-2-isopropenylaniline as a pale yellow oil. To a mixture of *N*-benzyl-2-isopropenylaniline (223 mg, 1.00 mmol) and 60% NaH in mineral oil (43.9 mg, 1.10 mmol) in 10 mL of DMF under an Ar atmosphere, was added allyl bromide (0.1 mL, 1.10 mmol). The mixture was stirred at 80 °C for 1 h and the reaction was quenched by the addition of saturated aqueous $NaHCO_3$. The mixture was extracted with Et_2O and the combined organic layers were washed with brine and dried over Na_2SO_4. After removal of the solvent, the residue was purified by column chromatography on silica gel (*n*-hexane/AcOEt=20:1) to give 54 mg (20%) of **43a** as a yellow oil. ^{1}H NMR ($CDCl_3$) δ 7.13–7.28 (7H, m), 6.95 (1H, dd, *J*=1.2, 7.3 Hz), 6.90 (1H, d, *J*=8.1 Hz), 5.71–5.81 (1H, m), 5.05–5.22 (4H, m), 4.21 (2H, s), 3.60 (2H, d, *J*=6.3 Hz), 2.24 (3H, s); ^{13}C NMR ($CDCl_3$) δ 148.1, 147.8, 138.5, 138.4, 124.8, 130.3, 128.9, 128.1, 127.4, 126.8, 122.3, 121.1, 117.5, 114.7, 56.1, 54.3, 22.3: IR (KBr) 3080, 2975, 2924, 1661, 1488 cm^{-1}; HRMS (FAB) calcd for $C_{19}H_{22}N$ 264.1752, found 264.1771.

2.1.38. *N*-Allyl-*N*-acetyl-2-isopropenylaniline (43b). To a solution of 2-isopropenylaniline (266 mg, 2.00 mmol) in 2 mL of CH_2Cl_2, was added Ac_2O (0.20 mL, 2.20 mmol). The mixture was stirred at 0 °C for 10 min and the reaction was quenched by the addition of saturated aqueous $NaHCO_3$. The mixture was extracted with CH_2Cl_2 and the combined organic layers were washed with brine and dried over Na_2SO_4. After removal of the solvent, the residue was purified by column chromatography on silica gel (*n*-hexane/AcOEt=5:1) to give 316 mg (90%) of *N*-acetyl-2-isopropenylaniline as a colorless oil. To a solution of *N*-acetyl-2-isopropenylaniline (250 mg, 1.43 mmol) and NaH (60% in mineral oil, 114 mg, 2.86 mmol) in 10 mL of DMF under an Ar atmosphere, was added allyl bromide (0.25 mL, 2.86 mmol). The mixture was stirred at 80 °C for 1 h and the reaction was quenched by the addition of saturated aqueous $NaHCO_3$. The mixture was extracted with Et_2O and the combined organic layers were washed with brine and dried over Na_2SO_4. After removal of the solvent, the residue was purified by column chromatography on silica gel (*n*-hexane/AcOEt=5:1) to give 209 mg (68%) of **43b** as a yellow oil. ^{1}H NMR ($CDCl_3$) δ 7.28–7.32 (3H, m), 7.07 (1H, d, *J*=7.3 Hz), 5.82–5.92 (1H, m), 5.21 (1H, t, *J*=1.7 Hz), 4.95–5.10 (3H, m), 4.92 (1H, dd, *J*=5.2, 14.6 Hz), 3.45 (1H, dd, *J*=7.8, 14.8 Hz), 2.04 (3H, s), 1.87 (3H, s); ^{13}C NMR ($CDCl_3$) δ 170.1, 143.1, 141.1, 139.5, 133.0, 130.0, 129.7, 128.1, 127.9, 117.7, 116.9, 51.2, 22.9, 22.5: IR (KBr) 3080, 2975, 2924, 1661, 1488 cm^{-1}; HRMS (FAB) calcd for $C_{14}H_{18}NO$ 216.1388, found 216.1394.

2.1.39. *N*-Allyl-*N*-(*t*-butoxycarbonyl)-2-isopropenylaniline (43c). To a solution of 2-isopropenylaniline (266 mg, 2.00 mmol) in 3 mL of 1 N NaOH, was added di-*t*-butyl dicarbonate (655 mg, 3.00 mmol). The mixture was stirred at 50 °C for 3 h and the reaction was quenched by the addition of water. The mixture was extracted with CH_2Cl_2 and the combined organic layers were washed with brine and dried over Na_2SO_4. After removal of the solvent, the residue was purified by column chromatography on silica gel (*n*-hexane/AcOEt=10:1) to give 234 mg (50%) of *N*-(*t*-butoxycarbonyl)-2-isopropenylaniline as yellow oil. To a solution of *N*-(*t*-butoxycarbonyl)-2-isopropenylaniline (233 mg, 1.00 mmol) and NaH (60% in mineral oil, 43.9 mg, 1.10 mmol) in 10 mL of DMF under an Ar atmosphere, was added allyl bromide (0.10 mL, 1.10 mmol). The mixture was stirred at 80 °C for 1 h and the reaction was quenched by the addition of saturated aqueous $NaHCO_3$. The mixture was extracted with Et_2O and the combined organic layers were washed with brine and dried over Na_2SO_4. After removal of the solvent, the residue was purified by column chromatography on silica gel (*n*-hexane/AcOEt=20:1) to give 52 mg (19%) of **43c** as a yellow oil. ^{1}H NMR ($CDCl_3$) δ 7.26 (4H, br), 5.82–5.92 (1H, m), 5.15 (1H, s), 5.06 (2H, d, *J*=11.2 Hz), 4.98 (1H, s), 4.55 (1H, d, *J*=2.8 Hz), 3.57 (1H, dd. *J*=6.8, 15.6 Hz), 2.04 (3H, s), 1.34 (9H, s); ^{13}C NMR ($CDCl_3$) δ 153.7, 143.8, 141.3, 139.5, 134.0, 129.6, 128.6, 127.4, 126.3, 116.0, 114.7, 78.7, 52.2, 27.6, 22.3: IR (KBr) 3080, 2976, 2928, 1698, 1490 cm^{-1}; HRMS (FAB) calcd for $C_{17}H_{24}NO_2$ 274.1807, found 274.1780.

2.1.40. 4-Methylquinoline (45).[12] *Method A*. To a solution of olefin **43a** (65 mg, 0.25 mmol) in 25 mL of CH_2Cl_2 under an Ar atmosphere, was added Grubbs' catalyst **A** (10.5 mg, 0.012 mmol). The mixture was degassed and stirred at 50 °C for 1 h. After removal of the solvent, the residue was purified by column chromatography on silica gel (*n*-hexane/AcOEt=5:1) to give 34 mg (95%) of **45** as a colorless oil.

Method B. To a solution of olefin **43b** (86 mg, 0.40 mmol) in 40 mL of CH_2Cl_2 under an Ar atmosphere, was added Grubbs' catalyst **B** (17 mg, 0.02 mmol). The mixture was degassed and stirred at 50 °C for 1 h. After removal of the solvent, the residue was purified by column chromatography on silica gel (*n*-hexane/AcOEt=5:1) to give 55.6 mg (97%) of **45** as a colorless oil.

Method C. To a solution of olefin **43c** (49.2 mg, 0.18 mmol) in 18 mL of CH_2Cl_2 under an Ar atmosphere, was added Grubbs' catalyst **B** (7.64 mg, 0.009 mmol). The mixture was degassed and stirred at 50 °C for 1 h. After removal of the solvent, the residue was purified by column chromatography on silica gel (*n*-hexane/AcOEt=20:1) to give 25 mg (97%) of **45** as a colorless oil. ^{1}H NMR ($CDCl_3$) δ 8.74 (1H, d, *J*=8.1 Hz), 8.10 (1H, d, *J*=7.6 Hz), 7.92 (1H, d, *J*=4.4 Hz), 7.67 (1H, dd, *J*=8.3, 8.3 Hz), 7.53 (1H, dd, *J*=8.1, 8.1 Hz), 7.15 (1H, d, *J*=4.1 Hz), 2.62 (3H, s); ^{13}C NMR ($CDCl_3$) δ 150.1, 148.0, 144.1, 130.0, 129.0, 128.2, 126.2, 123.7, 121.7, 18.5; IR (KBr) 3408, 3397, 3061, 2981, 2924, 1618, 1597, 1571; LRMS (EI) *m*/*z* 143 [100, M$^+$].

2.1.41. *N*-*n*-Butenyl-*N*-*p*-toluenesulfonyl-2-isopropenylaniline (47). To a solution of *N*-*p*-toluenesulfonyl-2-isopropenylaniline (287 mg, 1.00 mmol) and K_2CO_3 (207 mg, 1.50 mmol) in 10 mL of DMF under an Ar atmosphere, was added 4-bromo-1-butene (0.15 mL, 1.50 mmol). The mixture was stirred at 80 °C for 1 h and the reaction was quenched by the addition of saturated aqueous $NaHCO_3$. The mixture was extracted with Et_2O and the combined organic layers were washed with brine and dried over Na_2SO_4. After removal of the solvent, the residue was

purified by column chromatography on silica gel (*n*-hexane/AcOEt=5:1) to give 266 mg (97%) of **47** as a colorless oil. ^{1}H NMR ($CDCl_3$) δ 7.66 (2H, d, *J*=8.3 Hz), 7.27–7.31 (4H, m), 7.16 (1H, dd, *J*=2.7, 8.0 Hz), 6.80 (1H, d, *J*=7.6 Hz), 5.54–5.64 (1H, m), 5.22 (1H, s), 5.05 (1H, s), 4.91–4.96 (2H, m), 3.53 (2H, br), 2.44 (3H, s), 2.18 (3H, s), 2.08 (2H, br); ^{13}C NMR ($CDCl_3$) δ 144.9, 143.6, 143.4, 136.7, 136.4, 134.5, 130.2, 129.4, 128.3, 128.2, 128.1, 127.4, 116.9, 116.7, 50.8, 32.3, 24.4, 21.5; IR (neat) 3461, 3070, 2958, 2902, 2865, 1646, 1596, 1491, 1450, 1341, 1158, 1091 cm^{-1}; LRMS (EI) *m/z* 341 [20, M$^+$], 186 [100]. Anal. Calcd for $C_{20}H_{23}NO_2S$: C, 70.35; H, 6.79; N, 4.10; found: C, 70.26; H, 6.94; N, 3.96.

2.1.42. [*N*,*N*′-Bis(*o*-isopropenylphenyl)-*N*,*N*′-bis-*p*-toluenesulfonyl]hex-3-ene-1,6-diamine (48). To a solution of olefin **47** (102 mg, 0.30 mmol) in 30 mL of CH_2Cl_2 under an Ar atmosphere, was added catalyst **A** (12.3 mg, 0.006 mmol). The mixture was degassed and stirred at 50 °C for 1 h. After removal of the solvent, the residue was purified by column chromatography on silica gel (*n*-hexane/CH_2Cl_2=1:1) to give 36 mg (70%, *E*/*Z* mixture) of **48** as a colorless oil. ^{1}H NMR ($CDCl_3$) δ 7.62 (4H, dd, *J*=8.3, 11.5 Hz), 7.26–7.30 (8H, m), 7.09–7.16 (2H, m), 6.72 (2H, dd, *J*=4.9, 7.6 Hz), 5.14–5.19 (4H, m), 5.01 (2H, s), 3.40 (4H, br), 2.44 (6H, s), 2.15 (6H, s), 1.97 (4H, br); ^{13}C NMR ($CDCl_3$) δ 144.8, 143.6, 143.4, 136.6, 130.2, 129.5, 128.5, 128.2, 128.1, 128.0, 127.6, 127.4, 127.3, 116.7, 53.4, 51.1, 50.8, 31.2, 26.2, 24.3, 21.5, 14.1; IR (neat) 3451, 3060, 3023, 2921, 2846, 1637, 1598, 1489, 1346, 1160 cm^{-1}; LRMS (FAB) *m/z* 655 [10, M$^+$+H], 144 [100]. Anal. Calcd for $C_{38}H_{42}N_2O_4S_2$: C, 69.69; H, 6.46; N, 4.28; found: C, 69.35; H, 6.54; N, 4.15.

2.1.43. 5-Methyl-1-*p*-toluenesulfonyl-2,3-dihydro-1*H*-benzo[*b*]azepine (49). To a solution of olefin **47** (102 mg, 0.30 mmol) in 30 mL of CH_2Cl_2 under an Ar atmosphere, was added catalyst **B** (12.7 mg, 0.006 mmol). The mixture was degassed and stirred at 50 °C for 1 h. After removal of the solvent, the residue was purified by column chromatography on silica gel (*n*-hexane/AcOEt=1:1), followed by recrystallization from *n*-hexane/AcOEt to give 90 mg (96%) of **49** as white prisms. Mp 92 °C; ^{1}H NMR ($CDCl_3$) δ 7.52 (1H, dd, *J*=1.7, 7.5 Hz), 7.42 (2H, d, *J*=8.3 Hz), 7.23–7.34 (2H, m), 7.15–7.17 (3H, m), 5.61 (1H, dd, *J*=1.2, 6.6 Hz), 4.13 (2H, br), 2.37 (3H, s), 2.05–2.10 (2H, m), 1.54 (3H, s); ^{13}C NMR ($CDCl_3$) δ 142.6, 140.8, 137.8, 136.5, 136.2, 131.9, 129.0, 128.1, 127.5, 127.4, 127.1, 125.6, 57.2, 26.3, 22.0, 21.4; IR (KBr) 3451, 2921, 2884, 2846, 1655, 1339, 1160 cm^{-1}; LRMS (EI) *m/z* 313 [100, M$^+$]. Anal. Calcd for $C_{18}H_{19}NO_2S$ C, 68.98; H, 6.11; N, 4.47; found C, 68.76; H, 6.07; N, 4.33.

2.1.44. *N*-*n*-Pentenyl-*N*-*p*-toluenesulfonyl-2-isopropenylaniline (50). To a solution of *N*-*p*-toluenesulfonyl-2-isopropenylaniline (287 mg, 1.00 mmol) and K_2CO_3 (207 mg, 1.50 mmol) in 10 mL of DMF under an Ar atmosphere, was added 5-bromo-1-pentene (0.18 mL, 1.50 mmol). The mixture was stirred at 80 °C for 1 h and the reaction was quenched by the addition of saturated aqueous $NaHCO_3$. The mixture was extracted with Et_2O and the combined organic layers were washed with brine and dried over Na_2SO_4. After removal of the solvent, the residue was purified by column chromatography on silica gel (*n*-hexane/AcOEt=5:1) to give 347 mg (98%) of **50** as a colorless oil. ^{1}H NMR ($CDCl_3$) δ 7.66 (2H, d, *J*=8.3 Hz), 7.25–7.31 (4H, m), 7.16 (1H, dd, *J*=2.7, 6.3 Hz), 6.78 (1H, d, *J*=8.3 Hz), 5.60–5.70 (1H, m), 5.21 (1H, s), 5.05 (1H, s), 4.91 (2H, d, *J*=12.4 Hz), 3.47 (2H, br), 2.44 (3H, s), 2.18 (3H, s), 1.94 (2H, d, *J*=7.0 Hz), 1.48 (2H, br); ^{13}C NMR ($CDCl_3$) δ 145.0, 143.6, 143.3, 137.3, 136.72, 136.69, 130.2, 129.4, 128.2, 128.12, 128.07, 127.4, 116.7, 115.2, 51.2, 30.9, 26.9, 24.4, 21.5; IR (neat) 3461, 3076, 2977, 2924, 1638, 1598, 1488, 1347, 1162, 1092 cm^{-1}; LRMS (EI) *m/z* 355 [10, M$^+$], 200 [100]. Anal. Calcd for $C_{21}H_{25}NO_2S$ C, 70.95; H, 7.09; N, 3.94; found C, 71.03; H, 7.31; N, 3.81.

2.1.45. [*N*,*N*′-Bis(*o*-isopropenylphenyl)-*N*,*N*′-bis-*p*-toluenesulfonyl]oct-4-ene-1,8-diamine (51). To a solution of olefin **50** (60 mg, 0.17 mmol) in 17 mL of CH_2Cl_2 under an Ar atmosphere, was added catalyst **A** (7.0 mg, 0.0085 mmol). The mixture was degassed and stirred at 50 °C for 4 h. After removal of the solvent, the residue was purified by column chromatography on silica gel (*n*-hexane/CH_2Cl_2=1:1) to give 26 mg (70%, *E*/*Z* mixture) of **51** as a colorless oil. ^{1}H NMR ($CDCl_3$) δ 7.64 (4H, dd, *J*=1.7, 8.2 Hz), 7.24–7.30 (8H, m), 7.11–7.15 (2H, m), 6.77 (2H, dd, *J*=8.1, 8.1 Hz), 5.16–5.19 (4H, m), 5.01 (2H, s), 4.43 (4H, br), 2.43 (6H, s), 2.16 (6H, s), 1.82 (4H, s), 1.39 (4H, br); ^{13}C NMR ($CDCl_3$) δ 144.9, 143.62, 143.61, 143.4, 143.3, 136.6, 136.66, 136.63, 130.2, 129.6, 129.4, 129.2, 128.2, 128.17, 128.09, 128.05, 127.4, 116.6, 51.24, 51.18, 29.7, 27.7, 27.5, 24.5, 24.4, 21.5; IR (neat) 3442, 2921, 2856, 1637, 1441, 1345, 1159 cm^{-1}; LRMS (EI) 682 [15, M$^+$] 158 [100]. Anal. Calcd for $C_{40}H_{46}N_2O_4S_2$1/2H_2O C, 69.43; H, 6.85; N, 4.05; found C, 69.17; H, 6.94; N, 3.77.

2.1.46. 6-Methyl-1-*p*-toluenesulfonyl-1,2,3,4-tetrahydro-1*H*-benzo[*b*]azocine (52). To a solution of olefin **50** (275 mg, 0.77 mmol) in 77 mL of CH_2Cl_2 under an Ar atmosphere, was added catalyst **B** (32.9 mg, 0.015 mmol). The mixture was degassed and stirred at 50 °C for 4 h. After removal of the solvent, the residue was purified by column chromatography on silica gel (*n*-hexane/AcOEt=10:1) followed by recrystallization from *n*-hexane/AcOEt to give 234 mg (86%) of **52** as white prisms. Mp 111 °C; ^{1}H NMR ($CDCl_3$) δ 7.62 (2H, d, *J*=7.9 Hz), 7.25–7.34 (4H, m), 7.15 (1H, dd, *J*=2.4, 8.3 Hz), 6.76 (1H, d, *J*=7.6 Hz), 5.73 (1H, dd, *J*=1.2, 7.9 Hz), 4.21 (1H, br), 2.84 (1H, br), 2.43 (3H, s), 2.18 (1H, br), 2.06 (3H, s), 1.60 (3H, br); ^{13}C NMR ($CDCl_3$) δ 143.7, 142.8, 138.6, 138.1, 133.7, 129.3, 129.0, 128.6, 128.3, 127.8, 127.3, 126.9, 51.5, 26.7, 26.4, 24.3, 21.5; IR (KBr) 3451, 2934, 2856, 1488, 1342, 1159 cm^{-1}; LRMS (EI) *m/z* 327 [3, M$^+$], 91 [100]. Anal. Calcd for $C_{19}H_{21}NO_2S$: C, 69.69; H, 6.46; N, 4.28; found C, 69.72; H, 6.47; N, 4.23.

2.1.47. *N*-Allyl-*N*-*p*-toluenesulfonyl-2-(1-methoxyvinyl)-aniline (53a). To a solution of 2-aminoacetophenone (400 mg, 3.00 mmol) in 20 mL of CH_2Cl_2 under an Ar atmosphere, were added pyridine (0.72 mL, 9.00 mmol) and TsCl (686 mg, 3.60 mmol). The mixture was stirred at room temperature for 1 h and the reaction was quenched by the addition of water. The mixture was extracted with AcOEt and the combined organic layers were washed with brine and dried over Na_2SO_4. After removal of the solvent, the

residue was purified by column chromatography on silica gel (*n*-hexane/AcOEt=5:1) to give 838 mg (97%) of *N*-*p*-toluenesulfonyl-2-aminoacetophenone as off white solid. To a solution of *N*-*p*-toluenesulfonyl-2-aminoacetophenone (241 mg, 0.84 mmol) and K_2CO_3 (174 mg, 1.26 mmol) in 10 mL of DMF under an Ar atmosphere, was added allyl bromide (0.15 mL, 1.26 mmol). The solution was stirred at 80 °C for 1 h and the reaction was quenched by the addition of saturated aqueous $NaHCO_3$. The mixture was extracted with Et_2O and the combined organic layers were washed with brine and dried over Na_2SO_4. After removal of the solvent, the residue was purified by column chromatography on silica gel (*n*-hexane/AcOEt=5:1) to give 266 mg (97%) of *N*-allyl-*N*-*p*-toluenesulfonyl-2-aminoacetophenone as a white solid. To a solution of *N*-allyl-*N*-*p*-toluenesulfonyl-2-aminoacetophenone (50 mg, 0.15 mmol) and trimethoxymethane (0.04 mL, 0.38 mmol), was added *p*-toluenesulfonic acid monohydrate (2.85 mg, 0.15 mmol) in 3 mL of MeOH. The solution was stirred at room temperature for 4 h and the reaction was quenched by the addition of Et_3N. The mixture was extracted with Et_2O and the combined organic layers were washed with brine and dried over Na_2SO_4. After removal of the solvent, the residue was purified by column chromatography on silica gel (*n*-hexane/AcOEt=5:1) to give 55 mg (99%) of *N*-allyl-*N*-*p*-toluenesulfonyl-2-(1,1-dimethoxyethyl)aniline as a yellow solid. To *N*-allyl-*N*-*p*-toluenesulfonyl-2-(1,1-dimethoxyethyl)aniline (55 mg, 0.15 mL), were added pyridine (1.0 mL), TMSCl (1.0 mL, 0.80 mmol) and benzoic acid (1.83 mg, 0.015 mmol). The solution was stirred at 65 °C for 2 h and the reaction was quenched by the addition of saturated aqueous $NaHCO_3$. The mixture was extracted with Et_2O and the combined organic layers were washed with brine and dried over Na_2SO_4. After removal of the solvent, the residue was purified by column chromatography on silica gel (*n*-hexane/AcOEt=5:1) to give 41 mg (80%) of **53a** as a yellow oil. ^{1}H NMR ($CDCl_3$) δ 7.66 (2H, d, J=8.2 Hz), 7.43 (1H, dd, J=1.7, 7.5 Hz), 7.27–7.31 (4H, m), 6.94 (1H, dd, J=1.1, 7.7 Hz), 5.54–5.64 (1H, m), 4.91–4.96 (2H, m), 4.40 (1H, s), 4.31 (1H, s), 4.13 (2H, d, J=6.6 Hz), 3.59 (3H, s), 2.43 (3H, s); ^{13}C NMR ($CDCl_3$) δ 160.2, 143.1, 138.5, 137.5, 136.8, 133.1, 130.6, 130.4, 129.3, 128.6, 128.1, 128.0, 118.8, 86.4, 55.1, 54.2, 21.5: IR (neat) 3070, 2933, 2846, 1597, 1490, 1474, 1347 cm^{-1}; LRMS (EI) *m*/*z* 343 [100, M^+]. HRMS (FAB) calcd for $C_{19}H_{21}NO_3SK$ 382.0879, found 382.0873.

2.1.48. *N*-*p*-Toluenesulfonyl-4-methoxy-1,2-dihydroquinoline (54a). To a solution of olefin **53a** (24 mg, 0.07 mmol) in 7 mL of CH_2Cl_2 under an Ar atmosphere, was added catalyst **B** (3.1 mg, 0.0035 mmol). The mixture was degassed and stirred at 50 °C for 1 h. After removal of the solvent, the residue was purified by column chromatography on silica gel (*n*-hexane/AcOEt=5:1) to give 21 mg (97%) of **54a** as a colorless oil. ^{1}H NMR ($CDCl_3$) δ 7.69 (1H, dd, J=1.1, 8.1 Hz), 7.38 (1H, dd, J=1.7, 7.7 Hz), 7.34 (1H, dd, J=1.6, 7.5 Hz), 7.30 (2H, d, J=8.2 Hz), 7.23 (1H, ddd, J=1.2, 7.5, 15.0 Hz), 7.07 (2H, d, J=7.9 Hz), 4.44 (3H, s), 3.31 (3H, s), 2.34 (3H, s); ^{13}C NMR ($CDCl_3$) δ 151.1, 143.3, 136.4, 135.8, 128.9, 128.6, 127.5, 127.4, 126.7, 126.5, 122.2, 91.2, 54.4, 44.9, 21.4; IR (neat) 3447, 3086, 3020, 2985, 2869, 2840, 1920, 1651, 1599 cm^{-1}; HRMS (FAB) calcd for $C_{17}H_{18}NO_3S$ 316.1007, found 316.1013.

2.1.49. *N*-Allyl-*N*-*p*-toluenesulfonyl-2-[1-(*t*-butyldimethylsilyloxy)vinyl]aniline (53b). To *N*-allyl-*N*-*p*-toluenesulfonyl-2-aminoacetophenone (100 mg, 0.30 mmol) under an Ar atmosphere, were added NaI (180 mg, 1.20 mmol) and TBSCl (180.8 mg, 1.20 mmol) in 10 mL of CH_3CN and Et_3N (0.18 mL, 1.32 mmol). The mixture was stirred at 100 °C for 2 h. and quenched by the addition of Et_3N. The mixture was extracted with Et_2O and the combined organic layers were washed with brine and dried over Na_2SO_4. After removal of the solvent, the residue was purified by column chromatography on basic alumina (*n*-hexane/acetone=5:1) to give 106 mg (85%) of **53b** as a colorless oil. ^{1}H NMR ($CDCl_3$) δ 7.69 (2H, d, J=8.1 Hz), 7.51 (1H, dd, J=1.4, 7.0 Hz), 7.28 (2H, d, J=8.1 Hz), 7.26 (1H, d, J=7.0 Hz), 7.52 (1H, ddd, J=1.6, 7.7, 10.7 Hz), 6.81 (1H, d, J=7.1 Hz), 5.75 (1H, dddd, J=4.4, 6.7, 11.4, 17.0 Hz), 4.97 (1H, d, J=4.4 Hz), 4.93 (1H, d, J=11.4 Hz), 4.74 (2H, dd, J=1.3, 17.0 Hz), 4.17 (2H, dd, J=6.7 Hz), 2.43 (3H, s), 0.95 (9H, s), 0.22 (6H, s); ^{13}C NMR ($CDCl_3$) δ 153.2, 143.3, 139.6, 137.3, 136.3, 132.7, 129.9, 129.6, 129.4, 128.0, 127.9, 119.1, 96.3, 54.5, 29.6, 25.8, 21.5, 18.2, −4.6: IR (neat) 3429, 3084, 2924, 2867, 1697, 1596, 1487 cm^{-1}; HRMS (FAB) calcd for $C_{24}H_{34}NO_3SSi$ 444.2029, found 444.2030.

2.1.50. *N*-*p*-Toluenesulfonyl-4-(*tert*-butyldimethylsilyloxy)-1,2-dihydroquinoline (54b). To a solution of olefin **53b** (31 mg, 0.07 mmol) in 7 mL of CH_2Cl_2 under an Ar atmosphere, was added catalyst **B** (3.12 mg, 0.0035 mmol). The mixture was degassed and stirred at 50 °C for 1 h. After removal of the solvent, the residue was purified by column chromatography on basic alumina gel (*n*-hexane/acetone=5:1) to give 21 mg (95%) of **54b** as a yellow oil. ^{1}H NMR ($CDCl_3$) δ 7.92 (1H, dd, J=1.3, 8.1 Hz), 7.57 (1H, dd, J=1.7, 7.7 Hz), 7.48–7.55 (3H, m), 7.43 (1H, ddd, J=1.3, 7.5, 7.5 Hz), 7.29 (2H, d, J=8.6 Hz), 4.83 (1H, t, J=4.4 Hz), 4.67 (2H, d, J=4.4 Hz), 2.53 (3H, s), 1.11 (9H, s), 0.15 (6H, s); ^{13}C NMR ($CDCl_3$) δ 155.1, 141.2, 136.3, 129.5, 128.5, 127.0, 125.4, 116.8, 112.3, 88.0, 42.6, 42.5, 40.9, 20.8, 20.5, 15.1, −6.1; IR (neat) 3422, 2956, 2856, 1920, 1686, 1597 cm^{-1}; LRMS (EI) *m*/*z* 415 [15, M^+], 374 [100]. HRMS (FAB) calcd for $C_{22}H_{30}NO_3SSi$ 416.1716, found 416.1727.

2.1.51. *N*-Acetyl-2-isopropenyl-4-methoxyaniline (55). To the stirring solution of 2-isopropenyl-4-methoxyaniline[7] (40 mg, 0.25 mmol) in 5 mL of CH_2Cl_2 at 0 °C, was added Ac_2O (0.25 mL, 0.27 mmol) and the mixture was stirred at 0 °C for 10 min. The reaction mixture was quenched by $NaHCO_3$ until pH 8 and was extracted with CH_2Cl_2, washed with brine and dried over Na_2SO_4. After removal of solvent, the residue was recrystallized from AcOEt to give 45 mg (88%) of **55** as pale yellow plates. Mp 73 °C; ^{1}H NMR ($CDCl_3$) δ 8.01 (1H, d, J=8.8 Hz), 7.31 (1H, br), 6.81 (1H, dd, J=3.0, 9.0 Hz), 6.69 (1H, d, J=2.9 Hz), 5.35 (1H, s), 5.05 (1H, s), 3.79 (3H, s), 2.13 (3H, s), 2.05 (3H, s); ^{13}C NMR ($CDCl_3$) δ 168.0, 156.0, 142.9, 135.7, 127.0, 123.3, 116.6, 113.4, 112.6, 55.4, 24.4, 24.2; IR (KBr) 3451, 3237, 1641, 1545 cm^{-1}; HRMS (FAB) calcd for $C_{12}H_{16}NO_2$ 206.1181, found 206.1191.

2.1.52. *N*-Allyl-*N*-acetyl-2-isopropenyl-4-methoxyaniline (56). To a solution of **55** (44 mg, 0.21 mmol) and NaH (60% in mineral oil, 11.3 mg, 0.26 mmol) in 5 mL of DMF under

an Ar atmosphere, was added allyl bromide (0.01 mL, 0.26 mmol). The mixture was stirred at 0 °C for 1 h and quenched by the addition of saturated aqueous $NaHCO_3$. The mixture was extracted with Et_2O and the combined organic layers were washed with brine and dried over Na_2SO_4. After removal of the solvent, the residue was purified by column chromatography on silica gel (*n*-hexane/AcOEt=1:1) to give 35 mg (70%) of **56** as a yellow oil. ^1H NMR ($CDCl_3$) δ 6.97 (1H, d, J=8.4 Hz), 6.82 (1H, d, J=2.9 Hz), 6.79 (2H, dd, J=2.9, 8.4 Hz), 5.85 (1H, dddd, J=5.1, 11.0, 14.6, 17.0 Hz), 5.20 (1H, dd, J=1.7, 1.7 Hz), 5.08 (1H, d, J=11.0 Hz), 5.00 (1H, d, J=17.0 Hz), 4.90 (1H, dd, J=5.1, 14.6 Hz), 3.83 (3H, s), 3.40 (1H, dd, J=7.9, 14.6 Hz), 2.03 (3H, s), 1.86 (3H, s); ^{13}C NMR ($CDCl_3$) δ 170.78, 158.89, 143.27, 142.42, 133.18, 132.51, 130.85, 117.76, 116.92, 115.14, 112.95, 55.39, 51.54, 23.03, 22.60; IR (neat) 2921, 1655, 1491, 1395, 1311 cm^{-1}; HRMS (FAB) calcd for $C_{15}H_{20}NO_2$ 246.1494, found 246.1513.

2.1.53. *N*-Acetyl-4-methyl-6-methoxy-1,2-dihydroquinoline (57). To a solution of olefin **56** (35 mg, 0.14 mmol) in 14 mL of CH_2Cl_2 under an Ar atmosphere, was added catalyst **B** (6.1 mg, 0.007 mmol). The mixture was degassed and stirred at 50 °C for 1 h. After removal of the solvent, the residue was purified by column chromatography on silica gel (*n*-hexane/AcOEt=3:1) to give 30 mg (98%) of **57** as a pale yellow oil. ^1H NMR ($CDCl_3$) δ 7.04 (1H, d, J=8.4 Hz), 6.84 (1H, d, J=2.7 Hz), 6.77 (1H, dd, J=2.7, 8.6 Hz), 5.91 (1H, s), 4.39 (2H, s), 3.88 (3H, s), 2.15 (3H, s), 2.04 (3H, s); ^{13}C NMR ($CDCl_3$) δ 169.91, 157.32, 132.35, 131.28, 130.26, 125.20, 124.51, 111.28, 109.48, 55.47, 41.23, 21.97, 18.07; IR (neat) 3448, 2921, 2856, 1655, 1237 cm^{-1}; HRMS (FAB) calcd for $C_{13}H_{15}NO_2$ 217.1103, found 217.1098.

2.1.54. 6-Methoxy-4-methylquinoline (58). A solution of **57** (10 mg, 0.05 mmol) in a mixture of 1 mL of 10% aq. NaOH and 2 mL of MeOH was stirred at 50 °C overnight. The reaction was diluted with water and extracted with CH_2Cl_2. Combined organic layers were washed with brine and dried over Na_2SO_4. After removal of the solvent, the residue was purified by column chromatography on silica gel (*n*-hexane/acetone=5:2) followed by recrystallization from acetone to give 8.0 mg (98%) of **58** as white prisms. Mp 55–56 °C (lit.[22] 52 °C); ^1H NMR ($CDCl_3$) δ 8.65 (1H, d, J=4.4 Hz), 8.01 (1H, d, J=9.2 Hz), 7.36 (1H, dd, J=2.8, 9.2 Hz), 7.20 (2H, dd, J=4.8, 3.2 Hz), 3.96 (3H, s), 2.67 (3H, s); ^{13}C NMR ($CDCl_3$) δ 157.6, 147.7, 144.0, 142.7, 131.5, 129.1, 122.1, 121.4, 101.8, 55.5, 18.9; IR (KBr) 3372, 3209 2921, 2828, 1619, 1509 cm^{-1}; HRMS (FAB) calcd for $C_{11}H_{12}NO$ 174.0919, found 174.0927.

2.1.55. *N*-*p*-Toluenesulfonyl-2-acetyl-4-methoxyaniline (59). To a solution of 2-acetyl-4-methoxyaniline[13] (100 mg, 0.61 mmol) in 10 mL of CH_2Cl_2 under an Ar atmosphere, were added pyridine (0.15 mL, 1.82 mmol) and TsCl (139 mg, 0.73 mmol). The mixture was stirred at room temperature for 1 h and the reaction was quenched by the addition of water. The mixture was extracted with AcOEt and combined organic layers were washed with brine and dried over Na_2SO_4. After removal of the solvent, the residue was recrystallized from AcOEt to give 184 mg (94%) of **59** as yellow crystals. Mp 120 °C; ^1H NMR ($CDCl_3$) δ 10.66 (1H, s), 7.86 (1H, d, J=9.0 Hz), 7.61 (2H, d, J=8.2 Hz), 7.21 (1H, d, J=2.9 Hz), 7.18 (2H, d, J=8.0 Hz), 7.05 (1H, dd, J=2.9, 9.8 Hz), 3.80 (3H, s), 2.43 (3H, s), 2.36 (3H, s); ^{13}C NMR ($CDCl_3$) δ 200.43, 155.23, 143.59, 136.34, 132.56, 129.47, 127.26, 124.90, 122.75, 119.84, 116.63, 55.67, 28.05, 21.49; IR (KBr) 3423, 3070, 2920, 2846, 1654, 1503 cm^{-1}; LRMS (EI) *m/z* 319 [20, M^++H], 317 [100, M^+]. Anal. Calcd for $C_{16}H_{17}NO_4S$: C, 60.17; H, 5.37; N, 4.39; found: C, 60.22; H, 5.56; N, 4.34.

2.1.56. *N*-Allyl-*N*-*p*-toluenesulfonyl-2-acetyl-4-methoxyaniline (60). To a solution of ketone **59** (180 mg, 0.56 mmol) and K_2CO_3 (117 mg, 0.85 mmol) in 10 mL of DMF under an Ar atmosphere, was added allyl bromide (0.07 mL, 0.85 mmol). The mixture was stirred at 80 °C for 1 h and reaction was quenched by the addition of saturated aqueous $NaHCO_3$. The mixture were extracted with Et_2O and combined organic layers were washed with brine and dried over Na_2SO_4. After removal of the solvent, the residue was purified by column chromatography on silica gel (*n*-hexane/AcOEt=2:1) to give 174 mg (86%) of **60** as a pale yellow oil. ^1H NMR ($CDCl_3$) δ 7.46 (2H, d, J=8.2 Hz), 7.25 (2H, d, J=9.2 Hz), 7.14 (1H, d, J=3.1 Hz), 6.82 (1H, dd, J=2.9, 8.8 Hz), 6.57 (1H, d, J=8.8 Hz), 5.80–5.90 (1H, m), 5.10 (1H, s), 5.06 (1H, d, J=5.9 Hz), 4.39 (1H, s), 4.00 (1H, s), 3.83 (3H, s), 2.64 (3H, s), 2.43 (3H, s); ^{13}C NMR ($CDCl_3$) δ 200.4, 158.9, 143.7, 142.7, 134.9, 132.3, 129.7, 129.4, 128.9, 128.0, 119.9, 116.8, 113.7, 55.6, 54.5, 30.3, 21.5; IR (neat) 3427, 3065, 3005, 2909, 2841, 1654, 1502 cm^{-1}; HRMS (FAB) calcd for $C_{19}H_{22}NO_4S$ 360.1270, found 360.1250.

2.1.57. *N*-Allyl-*N*-*p*-toluenesulfonyl-2-[1-(*tert*-butyldimethylsiloxy)-vinyl]-4-methoxyaniline (61). To a mixture of **60** (170 mg, 0.47 mmol), NaI (283 mg, 1.89 mmol) and Et_3N (0.28 mL, 2.07 mmol), was added a solution of TBSCl (285 mg, 1.89 mmol) in 20 mL of MeCN. The mixture was refluxed for 1 h and then the reaction was quenched by addition of saturated aqueous $NaHCO_3$. After the mixture was extracted with Et_2O, combined organic layers were washed with brine and dried over Na_2SO_4. After removal of the solvent, the residue was purified by column chromatography on alumina (*n*-hexane/AcOEt=3:1) to give 210 mg (94%) of **61** as a light brown oil. ^1H NMR ($CDCl_3$) δ 7.66 (2H, d, J=8.3 Hz), 7.26 (2H, d, J=8.0 Hz), 7.06 (1H, dd, J=1.7, 1.7 Hz), 6.65 (2H, d, J=1.7 Hz), 5.70–5.79 (1H, m), 4.96 (2H, d, J=1.5 Hz), 4.93 (2H, dd, J=1.5, 15.4 Hz), 4.57 (2H, d, J=1.7 Hz), 3.78 (3H, s), 2.41 (3H, s), 0.94 (9H, s), 0.85 (6H, s); ^{13}C NMR ($CDCl_3$) δ 158.7, 152.7, 143.2, 137.1, 132.7, 130.6, 129.4, 128.9, 128.0, 119.1, 114.4, 113.6, 96.5, 55.2, 54.6, 25.8, 21.5, 18.2, −3.0, −4.6; IR (neat) 2960, 2924, 2851, 1513, 1260 cm^{-1}; HRMS (FAB) calcd for $C_{25}H_{36}NO_4SSi$ 474.2134, found 474.2105.

2.1.58. *N*-*p*-Toluenesulfonyl-4-(*tert*-butyldimethylsiloxy)-6-methoxy-1,2-dihydroquinoline (62). To a solution of olefin **61** (100 mg, 0.21 mmol) in 21 mL of CH_2Cl_2 under an Ar atmosphere, was added catalyst **B** (8.9 mg, 0.01 mmol). The mixture was degassed and stirred at 50 °C for 1 h. After removal of the solvent, the residue was recrystallized from acetone to give 91 mg (98%) of **62** as pale yellow needles. Mp 108 °C; ^1H NMR ($CDCl_3$) δ 7.62 (1H, d, J=8.8 Hz), 7.30 (2H, d, J=8.1 Hz), 7.08 (2H, d,

J=8.1 Hz), 6.89 (1H, d, J=2.6 Hz), 6.85 (1H, dd, J=2.8, 8.8 Hz), 4.59 (1H, d, J=4.1 Hz), 4.22 (2H, d, J=4.2 Hz), 3.80 (3H, s), 2.32 (3H, s), 0.89 (9H, s), 0.08 (6H, s); ^{13}C NMR ($CDCl_3$) δ 158.00, 146.34, 143.04, 136.54, 130.29, 129.17, 128.75, 127.87, 127.25, 113.59, 107.65, 99.49, 55.30, 45.09, 25.43, 21.40, 17.94, −5.07; IR (KBr) 3428, 2949, 2860, 1639, 1604, 1491 cm^{-1}; HRMS (FAB) calcd for $C_{23}H_{31}NO_4SSi$ 445.1743, found 445.1700.

2.1.59. 4-Hydroxy-6-methoxyquinoline (63). A mixture of **62** (50 mg, 0.11 mmol), 2 mL of 20% aq. NaOH and 5 mL of MeOH was refluxed overnight. The reaction was diluted with water and the mixture was extracted with CH_2Cl_2. Combined organic layers were washed with brine and dried over Na_2SO_4. After removal of the solvent, the residue was purified by column chromatography on silica gel (AcOEt/MeOH=10:1) followed by recrystallization from acetone to give 17 mg (98%) of **63** as pale yellow prisms. Mp 246 °C (lit.[23] 244–247 °C from ethanol); ^{1}H NMR ($CDCl_3$) δ 119 (1H, s) 7.84 (1H, d, J=7.1 Hz), 7.52 (1H, d, J=9.0 Hz), 7.47 (1H, d, J=2.9 Hz), 7.27 (1H, dd, J=2.9, 9.0 Hz), 5.99 (1H, d, J=7.3 Hz), 3.81 (3H, s); ^{13}C NMR ($CDCl_3$) δ 176.12, 155.44, 138.40, 134.70, 126.78, 122.08, 120.09, 107.45, 104.12, 55.30; IR (KBr) 3428, 3076, 1594, 1385, 1229 cm^{-1}.

2.1.60. *N*-*p*-Toluenesulfonyl-2-acetyl-5-chloroaniline (64). To a solution of 2-acetyl-5-chloroaniline[14] (280 mg, 1.65 mmol) in 20 mL of CH_2Cl_2 under an Ar atmosphere, were added pyridine (0.41 mL, 4.95 mmol) and TsCl (378 mg, 1.98 mmol). The mixture was stirred at room temperature for 1 h and the reaction was quenched by the addition of water. The mixture was extracted with AcOEt and combined organic layers were washed with brine and dried over Na_2SO_4. After removal of the solvent, the residue was purified by recrystallization from AcOEt to give 400 mg (75%) of **64** as yellow needles. Mp 182 °C; ^{1}H NMR ($CDCl_3$) δ 11.59 (1H, s), 7.76 (2H, dd, J=2.0, 8.3 Hz), 7.73 (1H, d, J=3.9 Hz), 7.71 (1H, d, J=2.7 Hz), 7.27 (2H, d, J=8.5 Hz), 7.00 (1H, dd, J=2.1, 8.7 Hz), 2.55 (3H, s), 2.38 (3H, s); ^{13}C NMR ($CDCl_3$) δ 201.4, 144.2, 141.3, 141.2, 136.3, 133.0, 129.8, 127.2, 122.6, 120.2, 118.6, 28.1, 21.5; IR (KBr) 3451, 3060, 1656, 1572, 1497, 1405 cm^{-1}; LRMS (EI) m/z 325 [45, M^+], 323 [100, M^+]. Anal. Calcd for $C_{15}H_{14}ClNO_3S$: C, 55.64; H, 4.36; N, 4.33; Found: C, 55.67; H, 4.41; N, 4.29.

2.1.61. *N*-Allyl-*N*-*p*-toluenesulfonyl-2-acetyl-5-chloroaniline (65). To a solution of aldehyde **64** (300 mg, 0.93 mmol) and K_2CO_3 (192 mg, 1.40 mmol) in 10 mL of DMF under an Ar atmosphere, was added allyl bromide (0.11 mL, 1.40 mmol). The mixture was stirred at 80 °C for 1 h and the reaction was quenched by the addition of saturated aqueous $NaHCO_3$. The mixture was extracted with Et_2O and combined organic layers were washed with brine and dried over Na_2SO_4. After removal of the solvent, the residue was purified by recrystallization from AcOEt to give 320 mg (95%) of **65** as pale yellow plates. Mp 103 °C; ^{1}H NMR ($CDCl_3$) δ 7.62 (1H, d, J=8.3 Hz), 7.45 (2H, d, J=8.3 Hz), 7.34 (1H, dd, J=2.0, 8.3 Hz), 7.30 (2H, d, J=7.8 Hz), 6.63 (1H, d, J=2.2 Hz), 5.77–5.87 (1H, m), 5.13 (1H, s), 5.09 (1H, dd, J=1.2, 6.8 Hz), 4.09 (2H, br), 2.64 (3H, s), 2.45 (3H, s); ^{13}C NMR ($CDCl_3$) δ 199.2, 144.2, 139.9, 137.9, 136.6, 134.3, 131.7, 130.4, 129.6, 128.6, 128.4, 127.9, 120.4, 54.3, 30.1, 21.5; IR (KBr) 3442, 1693, 1646, 1591, 1469, 1404 cm^{-1}; LRMS (EI) m/z 365 [2, M^+], 363 [3, M^+], 210 [100]. Anal. Calcd for $C_{18}H_{18}ClNO_3S$: C, 59.42; H, 4.99; N, 3.85; Found: C, 59.60; H, 5.05; N, 3.83.

2.1.62. *N*-Allyl-*N*-*p*-toluenesulfonyl-2-[1-(*tert*-butyldimethylsilyloxy)vinyl]-5-chloroaniline (66). To a mixture of **65** (290 mg, 0.80 mmol), NaI (480 mg, 3.20 mmol) and Et_3N (0.47 mL, 3.52 mmol), was added a solution of TBSCl (482 mg, 3.20 mmol) in 20 mL of MeCN. The mixture was refluxed for 1 h and then the reaction was quenched by addition of saturated aqueous $NaHCO_3$. After the mixture was extracted with Et_2O, combined organic layers were washed with brine and dried over Na_2SO_4. After removal of the solvent, the residue was purified by recrystallization from CH_2Cl_2 to give 375 mg (98%) of **66** as light brown needles. Mp 99 °C; ^{1}H NMR ($CDCl_3$) δ 7.67 (2H, d, J=8.2 Hz), 7.45 (1H, d, J=8.4 Hz), 7.29 (2H, d, J=8.4 Hz), 7.23 (1H, dd, J=2.0, 8.4 Hz), 6.75 (1H, d, J=2.0 Hz), 5.65–5.75 (1H, m), 4.97 (2H, d, J=9.8 Hz), 4.70 (2H, dd, J=1.6, 26.1 Hz), 4.11 (2H, d, J=6.8 Hz), 2.42 (3H, s), 0.92 (9H, s), 0.20 (6H, s); ^{13}C NMR ($CDCl_3$) δ 152.2, 143.7, 138.2, 137.4, 136.7, 133.0, 132.1, 130.8, 129.5, 128.2, 128.0, 119.6, 96.7, 54.4, 25.7, 25.6, 21.5, 18.2, −3.0, −4.6; IR (KBr) 3433, 1693, 1656, 1590, 1367 cm^{-1}; LRMS (FAB) m/z 480 [1, M^++H], 478 [3, M^++H], 364 [100].

2.1.63. *N*-*p*-Toluenesulfonyl-4-(*t*-butyldimethylsilyloxy)-7-chloro-1,2-dihydroquinoline (67). To a solution of olefin **66** (200 mg, 0.42 mmol) in 42 mL of CH_2Cl_2 under an Ar atmosphere, was added catalyst **B** (17.8 mg, 0.02 mmol). The mixture was degassed and stirred at 50 °C for 1 h. After removal of the solvent, the residue was purified by column chromatography on silica gel (*n*-hexane/AcOEt=10:1) followed by recrystallization from CH_2Cl_2 to give 180 mg (95%) of **67** as pale yellow crystals. Mp 124 °C; ^{1}H NMR ($CDCl_3$) δ 7.80 (1H, d, J=2.2 Hz), 7.44 (2H, d, J=8.4 Hz), 7.34 (1H, d, J=8.2 Hz), 7.24 (1H, dd, J=2.2, 8.2 Hz), 7.17 (2H, d, J=8.2 Hz), 4.71 (1H, dd, J=4.4, 4.4 Hz), 4.52 (2H, d, J=4.2 Hz), 2.40 (3H, s), 0.95 (9H, s), 0.00 (6H, s); ^{13}C NMR ($CDCl_3$) δ 146.0, 143.5, 137.0, 136.5, 133.6, 129.3, 127.4, 127.1, 126.3, 126.2, 123.5, 99.3, 60.3, 45.1, 25.4, 21.4, 17.9, 14.1, −5.1; IR (KBr) 3442, 2958, 2926, 2856, 1641, 1596, 1474, 1352 cm^{-1}; LRMS (EI) m/z 451 [50, M^+], 449 [100, M^+]. Anal. Calcd for $C_{22}H_{28}ClNO_3SSi$: C, 58.71; H, 6.27; N, 3.11; Found: C, 58.74; H, 6.27; N, 3.13.

2.1.64. 4-Hydroxy-7-chloroquinoline (68). A mixture of **67** (100 mg, 0.22 mmol), 1.1 mL of aq NaOH, and 5 mL MeOH was refluxed overnight. The reaction was quenched by water and the mixture was extracted with CH_2Cl_2. Combined extracts were washed with brine and dried over Na_2SO_4. After removal of the solvent, the residue was purified by column chromatography on silica gel (*n*-hexane/AcOEt=10:1) followed by recrystallized from MeOH to give 32 mg (81%) of **68** as white prisms. Mp 272 °C (lit.[24] 277–279 °C from water); ^{1}H NMR (DMSO-d_6) δ 11.76 (1H, br), 8.06 (1H, d, J=8.8 Hz), 7.92 (1H, d, J=7.1 Hz), 7.57 (1H, s), 7.31 (1H, d, J=7.3 Hz), 7.04 (1H, d, J=6.8 Hz); ^{13}C NMR (DMSO-d_6) 176.3, 145.2, 139.9, 136.2, 127.3, 124.4, 123.4, 117.4, 109.3; IR (KBr) 3421, 3239,

3056, 2801, 2634, 1635, 1555, 1458, 1361 cm^{-1}; LRMS (EI) *m/z* 181 [35, M^+], 179 [100, M^+], 163 [100].

2.1.65. 4,7-Dichloroquinoline (69). A solution of **68** (180 mg, 1.00 mmol) in 2 mL of $POCl_3$ was refluxed for 1 h. To this mixture, was added 10% HCl and the mixture was extracted with Et_2O. Combined organic layers were washed with brine and dried over Na_2SO_4. After removal of the solvent, the residue was purified by column chromatography on silica gel (AcOEt/MeOH=10:1) followed by recrystallization from CH_2Cl_2 to give 186 mg (94%) of **69** as white needles. Mp 84–85 °C (lit.[25] 84–85.5 °C from aqueous ethanol): ^1H NMR ($CDCl_3$) δ 8.77 (1H, d, J=4.8 Hz), 8.17 (1H, d, J=9.0 Hz), 8.14 (1H, d, J=2.0 Hz), 7.59 (1H, dd, J=2.2, 9.0 Hz), 7.47 (1H, d, J=4.8 Hz); ^{13}C NMR ($CDCl_3$) δ 150.4, 149.4, 142.5, 136.4, 128.7, 128.5, 125.5, 124.9, 121.3; IR (KBr) 3449, 3057, 2924, 1609, 1556, 1488 cm^{-1}; LRMS (EI) *m/z* 201 [10, M^+], 199 [65, M^+], 197 [100, M^+].

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References and notes

1. For examples, (a) Skraup, Z. H. *Ber.* **1880**, *13*, 2086–2087. (b) Doebner, O.; Miller, W. V. *Ber* **1883**, *16*, 2464–2472. (c) Comb, A. *Bull. Soc. Chim. Fr.* **1888**, *49*, 89–92. (d) Friedländer, P. *Ber.* **1882**, *15*, 2572–2575. (e) Pfitzinger, W. *J. Prakt. Chem.* **1886**, *33*(2), 100. (f) Niementowski, W. V. *Ber.* **1894**, *27*, 1394–1403.
2. For examples, ruthenium-catalyzed versions; (a) Tsuji, Y.; Huh, K. T.; Watanabe, Y. *J. Org. Chem.* **1987**, *52*, 1673–1680. (b) Cho, C. S.; Oh, B. H.; Kim, J. S.; Kim, T. J.; Shim, S. C. *Chem. Commun.* **2000**, 1885–1886. (c) Evans, P. A.; Robinson, J. E.; Moffett, K. K. *Org. Lett.* **2001**, *3*, 3269–3271. Palladium-catalyzed versions; (d) Cortese, N. A.; Ziegler, C. B.; Hrnjez, B. J.; Heck, R. F. *J. Org. Chem.* **1978**, *43*, 2952–2958. (e) Hegedus, L. S.; Allen, G. F.; Bozell, J. J.; Waterman, E. L. *J. Am. Chem. Soc.* **1978**, *100*, 5800–5807. (f) Laborde, E.; Lesheski, L. E.; Kiely, J. S. *Tetrahedron Lett.* **1990**, *31*, 1837–1840. (g) Larock, R. C.; Kuo, M. Y. *Tetrahedron Lett.* **1991**, *32*, 569–572. (h) Kundu, N. G.; Mahanty, J. S.; Das, P.; Das, B. *Tetrahedron Lett.* **1993**, *34*, 1625–1628. (i) Dupont, J.; Halfen, R. A. P.; Zinn, F. K.; Pfeffer, M. *J. Organomet. Chem.* **1994**, *484*, c8–c9. (j) Cacchi, S.; Fabrizi, G.; Marinelli, F. *Synlett* **1999**, 401–404. (k) Pita, B.; Masaguer, C. F.; Raviña, E. *Tetrahedron Lett.* **2002**, *43*, 7929–7932. (l) Hatano, M.; Mikami, K. *J. Am. Chem. Soc.* **2003**, *125*, 4704–4705. Rhodium-catalyzed versions; (m) Diamond, S. E.; Szalkiewicz, A.; Mares, F. *J. Am. Chem. Soc.* **1979**, *101*, 490–491. (n) Watanabe, Y.; Yamamoto, M.; Shim, S. C.; Mitsudo, T.; Takegami, Y. *Chem. Lett.* **1979**, 1025–1026. (o) Watanabe, Y.; Suzuki, N.; Shim, S. C.; Yamamoto, M.; Mitsudo, T.; Takegami, Y. *Chem. Lett.* **1980**, 429–430. (p) Boyle, W. J.; Mares, F. *Organometallics* **1982**, *1*, 1003–1006. (q) Amii, H.; Kishikawa, Y.; Uneyama, K. *Org. Lett.* **2001**, *3*, 1109–1112. Iron-catalyzed version; (r) Watanabe, Y.; Takatsuki, K.; Shim, S. C.; Mitsudo, T.; Takegami, Y. *Bull. Chem. Soc. Jpn* **1978**, *51*, 3397–3398. Copper-catalyzed version; (s) Huma, H. Z. S.; Halder, R.; Kalra, S. S.; Das, J.; Iqbal, J. *Tetrahedron Lett.* **2002**, *43*, 6485–6488. (6) Manganese-catalyzed version; (t) Kobayashi, K.; Nakahashi, R.; Mano, M.; Morikawa, O.; Konishi, H. *Bull. Chem. Soc. Jpn* **2003**, *76*, 1257–1259. Cobalt-catalyzed version; (u) Domínguez, G.; Casarrubios, L.; Rodríguez-Noriega, J.; Pérez-Castells, J. *Helv. Chim. Acta* **2002**, *85*, 2856–2861.
3. (a) Schwab, P.; France, M. B.; Ziller, J. W.; Grubbs, R. H. *Angew. Chem. Int. Ed. Engl.* **1995**, *34*, 2039–2041. (b) Novak, B. M.; Grubbs, R. H. *J. Am. Chem. Soc.* **1988**, *110*, 960–961.
4. Scholl, M.; Ding, S.; Lee, C. W.; Grubbs, R. H. *Org. Lett.* **1999**, *1*, 953–956.
5. (a) Arisawa, M.; Takezawa, E.; Nishida, A.; Mori, M.; Nakagawa, M. *Synlett* **1997**, 1179–1180. (b) Nakagawa, M.; Torisawa, Y.; Uchida, H.; Nishida, A. *J. Synth. Org. Chem. Jpn* **1999**, *57*, 1004–1015. (c) Arisawa, M.; Kato, C.; Kaneko, H.; Nishida, A.; Nakagawa, M. *J. Chem. Soc. Perkin Trans. 1* **2000**, 1873–1876. (d) Arisawa, M.; Kaneko, H.; Nishida, A.; Yamaguchi, K.; Nakagawa, M. *Synlett* **2000**, 841–843. (e) Arisawa, M.; Takahashi, M.; Takezawa, E.; Yamaguchi, T.; Torisawa, Y.; Nishida, A.; Nakagawa, M. *Chem. Pharm. Bull.* **2000**, *48*, 1593–1596. (f) Arisawa, M.; Kaneko, H.; Nishida, A.; Nakagawa, M. *J. Chem. Soc. Perkin Trans. 1* **2002**, 959–964. (g) Arisawa, M.; Terada, Y.; Nakagawa, M.; Nishida, A. *Angew. Chem. Int. Ed. Engl.* **2002**, *41*, 4732–4734.
6. Arisawa, M.; Theeraladanon, C.; Nishida, A.; Nakagawa, M. *Tetrahedron Lett.* **2001**, *42*, 8029–8033.
7. For reviews, see (a) Trnka, T. M.; Grubbs, R. H. *Acc. Chem. Res.* **2001**, *34*, 18–29. (b) Grubbs, R. H.; Chang, S. *Tetrahedron* **1998**, *54*, 4413–4450. (c) Fürstner, A. *Angew. Chem. Int. Ed. Engl.* **2000**, *39*, 3012–3043. (d) Connon, S. J.; Blechert, S. *Angew. Chem. Int. Ed. Engl.* **2003**, *42*, 1900–1923.
8. (a) Turner, R. B.; Woodward, R. B. In *The chemistry of the cinchona alkaloids. The alkaloids*; Manske, R. H. F., Ed.; Academic: New York, 1953; Vol. 3, pp 1–63 Chapter 16. (b) Uskokoviac, M. R.; Grethe, G. In *The cinchona alkaloids. The alkaloids*; Manske, R. H. F., Ed.; Academic: New York, 1973; Vol. 14, pp 181–223. (c) Grethe, G.; Uskokovic, M. R. *The chemistry of heterocyclic compounds*; Sexton, J. E., Ed.; Wiley-Interscience: New York, 1983; Vol. 23, p 279 Part 4. (d) Dutta, N. L.; Quasim, C. *Indian J. Chem.* **1968**, *6*, 566–567. For stereoselective total synthesis (e) Stork, G.; Niu, D.; Fujimoto, A.; Koft, E. R.; Balkovec, J. M.; Tata, J. R.; Dake, G. R. *J. Am. Chem. Soc.* **2001**, *123*, 3239–3242.
9. (a) Andersag, H.; Breitner, S.; Jung, H. German Patent 683, 692, October 26, 1939; *C.A.* **1942**, *36*, 4973. (b) Andersag, H.; Breitner, S.; Jung, H. US Patent 2,233,970, March 4, 1941; *C.A.* **1941**, *35*, 3771.
10. Nishida, A.; Sorimachi, H.; Iwaida, M.; Matsumizu, M.; Kawate, T.; Nakagawa, M. *Synlett* **1998**, 389–390.
11. (a) Lauer, S. A.; Ghori, N.; Haldar, K. *Proc. Natl. Acad. Sci.*

U. S. A. **1995**, *92*, 9181–9185. (b) Lauer, S. A.; Rathod, P. K.; Ghori, N.; Haldar, K. *Science* **1997**, *276*, 1122–1125. (c) Akompong, T.; VanWye, J.; Ghori, N.; Haldar, K. *Mol. Biochem. Parasitol.* **1999**, *101*, 71–79.
12. Shishido, K.; Azuma, T.; Shibuya, M. *Tetrahedron Lett.* **1990**, *31*, 219–220.
13. Wilson, S. R.; Grandi, M. J. D. *J. Org. Chem.* **1991**, *56*, 4766–4772.
14. Fürstner, A.; Jumbam, D. N.; Seidel, G. *Chem. Ber.* **1994**, *127*, 1125–1130.
15. Bailey, D. M. *J. Med. Chem.* **1969**, *12*, 184–185.
16. Heindel, N. D.; Bechara, I. S.; Ohnmacht, C. J.; Molnar, J.; Lemke, T. F.; Kennewell, P. D. *J. Med. Chem.* **1969**, *12*, 797–801.
17. Schweizer, E. E.; Smucker, L. D. *J. Org. Chem.* **1966**, *31*, 3146–3149.
18. Rewcastle, G. W.; Denny, W. A. *Synthesis* **1985**, *2*, 220–222.
19. Cai, S. X.; Zhon, Z.; Huang, J.; Whittemore, E. R.; Egbuwoku, Z. O.; Lü, Y.; Hawkinson, J. E.; Woodward, R. M.; Weber, E.; Keana, J. F. W. *J. Med. Chem.* **1996**, *39*, 3248–3255.
20. Hewson, A. T.; Hughes, K.; Richardson, S. K.; Sharpe, D. A.; Wadsworth, A. H. *J. Chem. Soc. Perkin Trans. 1* **1991**, *6*, 1565–1569.
21. Hambly, A. N.; O'Grady, B. V. *Aust. J. Chem.* **1963**, *16*, 459–474.
22. Campbell, K. N.; Schaffner, I. J. *J. Am. Chem. Soc.* **1945**, *67*, 86–89.
23. Elderfield, R. C.; Maggiolo, A. *J. Am. Chem. Soc.* **1949**, *71*, 1906–1911.
24. Surrey, A. R.; Hammer, H. F. *J. Am. Chem. Soc.* **1946**, *68*, 113–116.
25. Kwart, H.; Miller, L. J. *J. Am. Chem. Soc.* **1958**, *80*, 884–887.
26. Unpublished results.