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Cyclic Carbopalladation of Alkynes Terminated by Carbonylative Amidation

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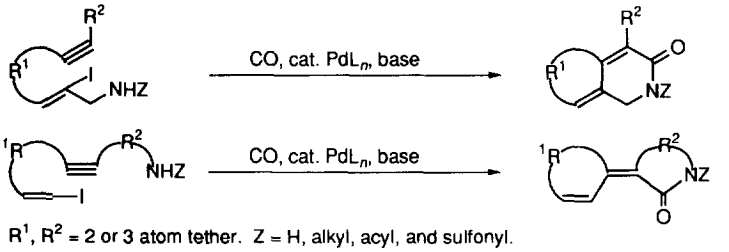
Abstract: Termination of cyclic carbopalladation of alkynes via carbonylative lactamization can be achieved more satisfactorily with alkenyl or aryl halides containing an ω-carboxamido or ω-sulfonamido group than with those containing an ω-amino group. The method appears to be generally satisfactory for the preparation of fused cyclic systems consisting of six-membered rings, while the other cases require further development.

INTRODUCTION

As part of our systematic investigation of a cyclization methodology based on "living and hence potentially cascading" carbopalladation processes involving alkynes and 1,1-disubstituted alkenes,[1-4] it became of interest to terminate "living" carbopalladation processes with carbonylative amidation producing lactams.[1,5] As with any other termination processes,[3] it was essential for the termination step to be sufficiently slow so as to permit the desired cyclic carbopalladation to complete without premature termination. In this regard, one of our concerns was if amines which are generally more nucleophilic than alcohols would allow preferential carbopalladation in their presence. To probe this matter, we chose to investigate the cyclic carbopalladation of alkynes. With alkynes, the cascading *syn*-carbopalladation reaction may participate in the "zipper"-mode and "dumbbell"-mode cascades,[3] and the shortest versions of the cyclic alkyne carbopalladation-carbonylative amidation cascade processes are shown in Scheme 1. In this paper, we describe full details of the previous communication[1] as well as some additional new results, especially some insights into the nature of amidation with amides and sulfonamides, and the feasibility of the use of aryl halides in addition to alkenyl halides.

Scheme 1



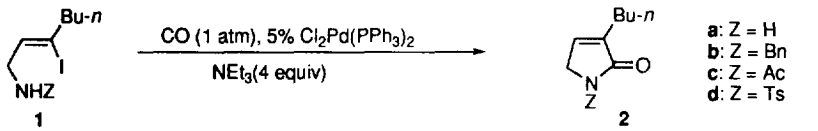
R^1, R^2 = 2 or 3 atom tether. Z = H, alkyl, acyl, and sulfonyl.

RESULTS AND DISCUSSION

Carbonylative lactamization of ω-amino- and ω-amidoalkenyl iodides

Carbonylative amidation of aryl and alkenyl halides with amines[6] and its application to the synthesis of lactams[7] are well documented. In view of the concern discussed above, however, we first examined the ability of ω-amidoalkenyl iodides, vis-à-vis ω-aminoalkenyl iodides, to undergo carbonylative lactamization. To this end, the acetyl and tosyl as well as benzyl derivatives of (*Z*)-3-iodo-2-heptenylamine (**1a**) were prepared and treated with CO (1 atm) in the presence of 5 mol % of $Cl_2Pd(PPh_3)_2$ and Et_3N (4 equiv) in MeOH, *i*-PrOH, or DMF at 65-80 °C. As the results summarized in Eq. 1 and Table 1 indicate, all three derivatives (**1b-1d**) as well as the parent amine (**1a**) gave the desired γ-lactams in high yields. To our knowledge, the Pd-catalyzed carbonylative lactamization via trapping with carboxamides and sulfonamides had not been reported prior to our recent communication.[1] The lactamization reaction of the acetyl derivative **1c** has revealed some interesting features. First, deacetylation does not appear to take place before cyclization, since (*E*)-*N*-(2-heptenyl)acetamide is not deacetylated under the carbonylation conditions. Second, treatment of **2c** with ~100 equiv of MeOH at 65 °C did deacetylate it to give **2a** to the extent of 62% over 24 h. During the same period, the formation of **2a** in 85% yield from **1c** was complete. When this reaction was examined by NMR spectroscopy after 6 h, **2a** was present to the extent of 30% yield along with a small amount (4%) of **2c** and the unreacted **1c** (45%). Third, the reaction run in the presence of 1 molar equiv of added **2c** under otherwise the same conditions was slower, requiring 48 h for completion, after which time all of **2c** was deacetylated. The results suggest, that **2c** exerts some inhibitory influence, presumably through complexation with Pd, *e.g.*, **3**. It is still not clear whether deacetylation takes place during and/or after cyclization. However, if it occurs mainly or exclusively after cyclization, it must be accelerated by other reagents present in the reaction mixture, *e.g.*, Pd complex and Et_3N. We suggest the two paths shown in Scheme 2 as likely courses of deacetylation.

Table 1. Pd-Catalyzed Carbonylation of (*E*)-3-Iodo-2-heptenylamine and Its Derivatives

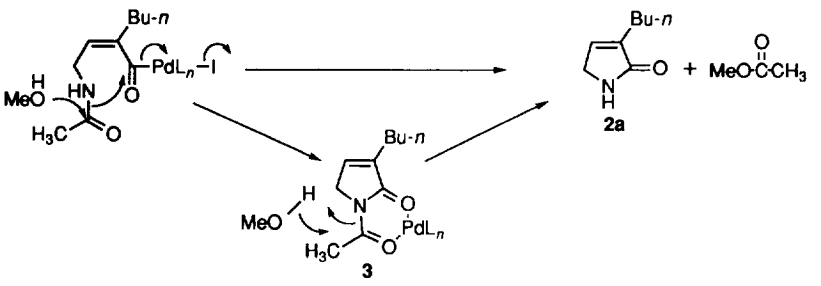


(1)

Starting compound	Solvent	Temp, °C	Time, h	Product	Yield, %
1a	*i*-PrOH[a]	75	20	**2a**	85
1b	MeOH	65	18	**2b**	93
1c	MeOH	65	24	**2a**	85
1c	MeOH[b]	65	48	**2a**	*c*
1c	*i*-PrOH	75	8	**2c**	78
1c	DMF	75	6	**2c**	82
1d	MeOH	65	8	**2d**	95

[a] *i*-Pr_2NEt (4 equiv) was used in place of Et_3N. [b] One equivalent of **2c** was added.
[c] The amount of **2a** corresponded to 61% of the possible maximum yield.

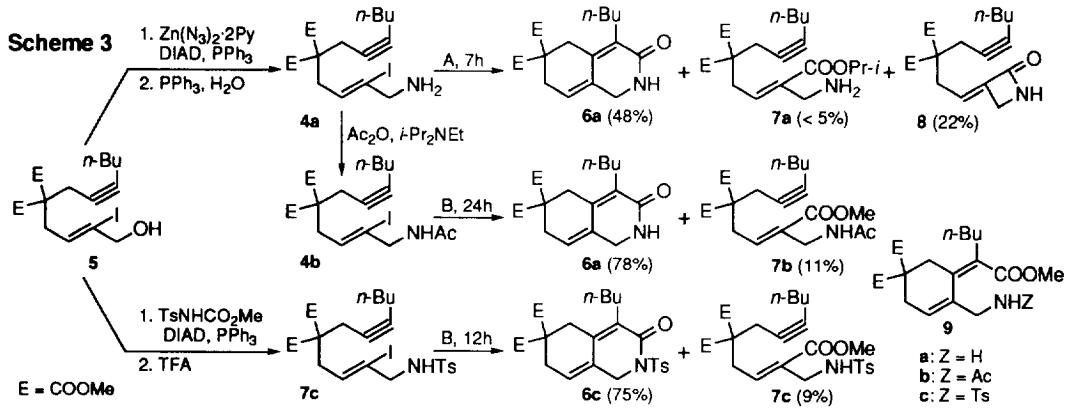
Scheme 2



"Zipper"-mode cyclic carbopalladation-carbonylative lactamization cascade

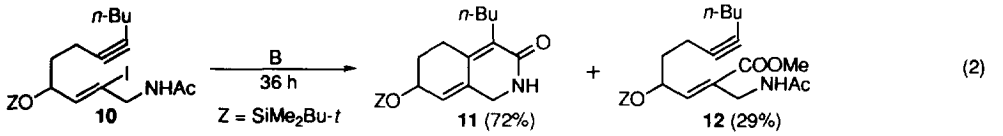
The first test substrate (**4a**) for developing a cyclic carbopalladation-carbonylative lactamization cascade was prepared from a recently reported malonate derivative **5**[2h] by its successive treatment with (i) $Zn(N_3)_2(Py)_2$ and PPh_3, followed by *i*-PrOOCN=NCOOPr-*i* (DIAD)[8] (90% yield) and (ii) PPh_3 and H_2O in THF (100% yield).[9] The reaction of **4a** with CO (1 atm) in the presence of 5 mol % of $Cl_2Pd(PPh_3)_2$ and Et_3N (4 equiv) in *i*-PrOH at 75 °C (Condition A hereafter) produced the desired bicyclization product **6a** in 48% yield. The amount of the premature esterification product **7a** was ≤5%. However, a ß-lactam **8** arising via premature lactamization was formed in 22% yield. Thus, the intrinsically high nucleophilicity of free amines is indeed a cause for concern. On the other hand, the acetyl derivative of **4a**, *i.e.*, **4b**, reacted with CO (1 atm) in the presence of 5 mol % of $Cl_2Pd(PPh_3)_2$ and Et_3N (4 equiv) in MeOH at 65 °C (Condition B) to give **6a** in 78% yield, the only other detectable monomeric byproduct being **7b** formed in 11% yield. It should be noted that conversion of **4b** into **6a** involves deacetylation similar to that discussed in the previous section. Another possible premature esterification product **9b** was not detectable. Similarly, carbonylation (Condition B) of **4c**, prepared by successive treatment of **5** with (i) TsNHCOOBu-*t*, DIAD, and PPh_3 and (ii) CF_3COOH (95% over two steps), gave **6c** in 75% yield along with a 9% yield of **7c**. The amount of **9c** was ≤2% (Scheme 3).

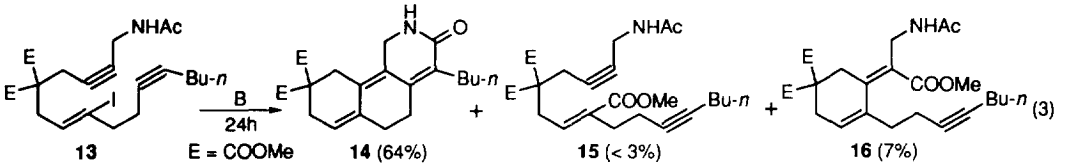
Scheme 3



The presence of the geminal diester groups is not essential to this cascade cyclization process. Thus, **10**, prepared from the corresponding allylic alcohol in a similar manner as described above, gave after 36 h under Condition B a 72% isolated yield of **11** along with a 29% yield of **12** (Eq. 2). The feasibility of applying the procedure reported here to the synthesis of more extensively fused compounds is indicated by the conversion of **13** into **14** in 64% yield (NMR)

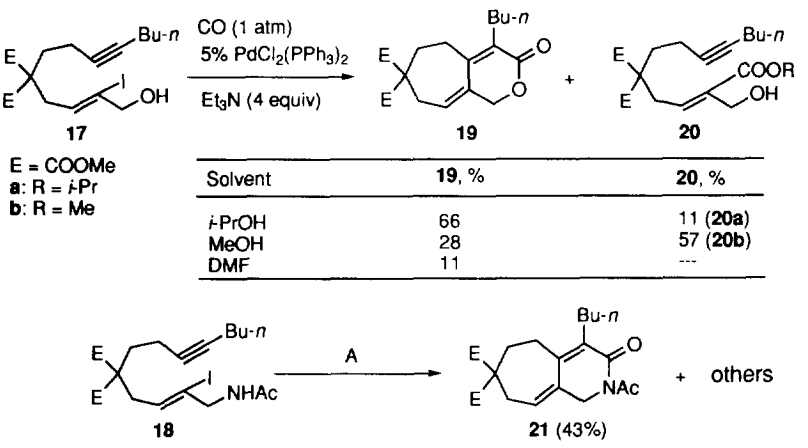
under Condition B. In this case, the amounts of premature esterification products **15** and **16** were <3 and 7%, respectively (Eq. 3). The results presented above indicate that the "zipper"-mode cyclic carbopalladation–carbonylative lactamization cascade is widely applicable to the synthesis of fused bicycles and polycycles consisting of six-membered rings.





Since five- and seven-membered rings can also be readily synthesized by cyclic carbopalladation,[3] the feasibility of cascading their formation and lactamization or lactonization was examined. To this end, **17** was prepared and converted to **18** as in other cases discussed above. Cyclization of **17** under Condition A proceeded smoothly at 75 °C to give after 50 h the desired lactone **19** in 66% yield along with an 11% yield of **20a**. On the other hand, its cyclization reaction under Condition B afforded **19** only in 28% yield, the major product being **20b** produced in 57% yield. To avoid altogether premature esterification, the reaction was run in DMF in the absence of an alcohol under otherwise the same conditions. However, the yield of **19** was only 11%, and the rest of the product appeared to be polymeric. Thus, despite the complication due to premature esterification, the use of an alcohol, especially *i*-PrOH in this case, as a solvent seems advantageous.[2h] With these results in mind, cyclization of **18** was carried out in *i*-PrOH under Condition A. The reaction was relatively messy, but it provided, after 30 h at 75 °C, the desired lactam **21** in 43% yield. The other products were not identified.

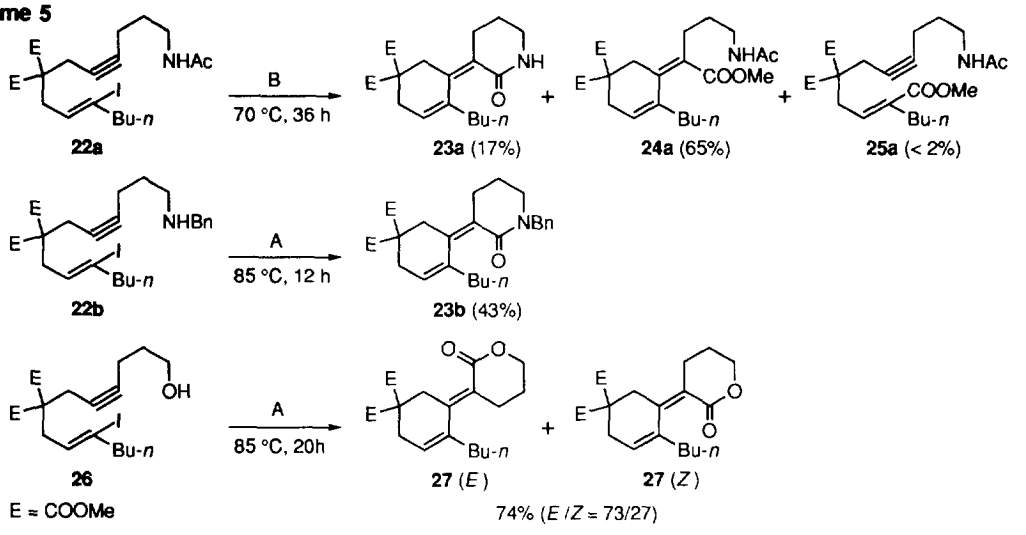
Scheme 4



"Dumbbell"-mode cyclic carbopalladation-carbonylative lactamization cascade

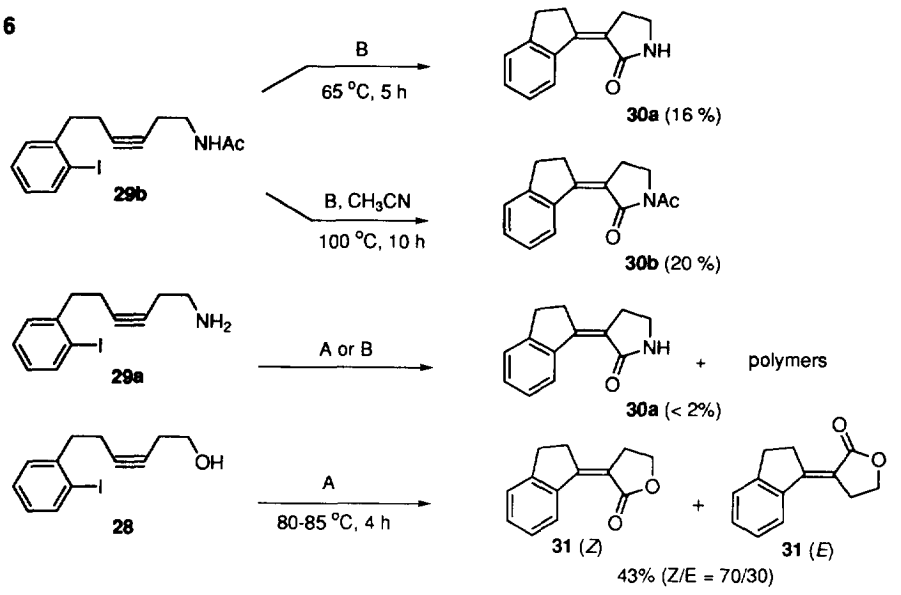
Exploration of the "dumbbell"-mode cyclic carbopalladation-lactamization cascade has yielded some mixed but interesting results. In the reaction of **22a** under Condition B the desired product **23a** was obtained only in 17% yield, the major product being **24a** (65% yield), which should be readily convertible to **23a**. The amount of the other premature esterification product **25a** was <2%. The reaction of **22b** under Condition A at 85 °C provided **23b** in 43% yield, the extents of the two premature esterification reactions being <2% each. Both **23a** and **23b** were ≥95% *Z* as judged by detailed examination of their ^{1}H and ^{13}C NMR spectra including NOE difference. On the other hand, the corresponding reaction of **26** gave a 73/27 mixture of the *E* and *Z* isomers of **27** in 74% combined yield (Scheme 5).

Scheme 5



To probe the feasibility of achieving similar cyclization reactions with aryl halides, **28** was prepared and further converted to **29a** and **29b** as in the related cases discussed above. Under Condition B, **29b** afforded a 19% yield of **30a**, which exhibited a strongly deshielded aromatic proton signal at δ 9.1-9.2 ppm (m, 1 H), supporting the assignment of the *Z* configuration. Examination by NMR spectroscopy of the crude product indicated the absence of the *E* isomer of **30a**. Although unidentified, some other byproducts were also present. When acetonitrile was used as a cosolvent in addition to MeOH, the bicyclization product obtained in 26% yield under otherwise the same conditions was **30b**, which was ≥98% *Z*. On the other hand, the parent amino derivative **29a** did not yield a detectable amount of **30a** under either Condition A or Condition B. The product appears to be largely polymeric. The reaction of **28** under Condition A gave after 4 h the expected lactone **31** in 43% yield, which was a roughly 70/30 mixture of the *Z* and *E* isomers (Scheme 6). When the reaction was run for 26 h, the only bicyclization product observed was the *E* isomer of **31**. Evidently, these lactones, *i.e.*, **27** and **31**, are configurationally much less stable than the corresponding lactams. The results shown in Schemes 5 and 6 point to some advantages of the direct lactam synthesis over the indirect route via lactones. The feasibility of the "dumbbell"-mode cyclic cascade carbopalladation-carbonylative lactamization cascade has been demonstrated, but its further improvement is clearly necessary for use in practical synthesis.

Scheme 6



EXPERIMENTAL

General Procedures. All reactions were conducted under a dry Ar atmosphere. ^{1}H and ^{13}C NMR spectra were recorded in $CDCl_3$ on Varian Gemini-200, VXR-500, and GE QE-300 NMR spectrometers using Me_4Si and $CDCl_3$ as internal standards for ^{1}H and ^{13}C NMR respectively unless otherwise noted. All commercially available reagents were used without further purification unless otherwise noted. THF was distilled from sodium benzophenone ketyl. $Cl_2Pd(PPh_3)_2$ was prepared according to a reported procedure.[10]

(Z)-1-Amino-3-iodo-2-heptene (1a). Representative Procedure for the Preparation of Primary Amines. A mixture of (Z)-3-iodo-2-hepten-1-ol (480 mg, 2.0 mmol), Ph_3P (1.05 g, 4.0 mmol), and $Zn(N_3)_2(Py)_2$[8] (0.46 g, 1.5 mmol) in toluene (10 mL) was treated with diisopropyl azodicarboxylate (DIAD) (0.80 mL, 4.0 mmol, 0 °C, 2 h). The reaction mixture was evaporated and dissolved in CH_2Cl_2 (3 mL). Chromatography of this mixture on silica gel (95/5 *n*-pentane-Et_2O) afforded 490 mg (92%) of (Z)-1-azido-3-iodo-2-heptene. A mixture of this compound (416 mg, 1.6 mmol), Ph_3P (0.79 g, 3.0 mmol), and H_2O (0.5 mL) in THF (5 mL) was stirred for 12 h at 23 °C.[9] After evaporation, chromatography on silica gel (94/6/0.1 CH_2Cl_2-MeOH-Et_2NH) afforded 376 mg (99%) of **1a**: ^{1}H NMR δ 0.91 (t, J = 7.3 Hz, 3 H), 1.2-1.4 (m, 2 H), 1.40 (s, 2 H), 1.45-1.6 (m, 2 H), 2.47 (t, J =

7.2 Hz, 2 H), 3.34 (d, J = 6.2 Hz, 2 H), 5.67 (t, J = 6.2 Hz, 1 H); ^{13}C NMR δ 13.85, 21.29, 31.30, 44.77, 47.93, 109.81, 135.19; IR (neat) 3250 cm^{-1}.

(*Z*)-1-Benzylamino-3-iodo-2-heptene (1b). To oxalyl chloride (0.17 mL, 0.25 g, 2.0 mmol) dissolved in CH_2Cl_2 were successively added DMSO (0.28 mL, 0.31g, 4.0 mmol, -78 °C, 10 min), (*Z*)-3-iodo-2-hepten-1-ol[12] (240 mg, 1.0 mmol, -78 °C, 1 h) dissolved in CH_2Cl_2 (1 mL), and Et_3N (0.56 mL, 4.0 mmol, -78 °C, 5 min).[11] The reaction mixture was warmed to 0 °C, diluted with Et_2O, washed with H_2O, dried over $MgSO_4$, and evaporated. Chromatography on silica gel (97/3 *n*-pentane-Et_2O) afforded 215 mg (92%) of (*Z*)-3-iodo-2-hepten-1-al. To this aldehyde (215 mg, 0.92 mmol) dissolved in EtOH (3 mL) were successively added powdered molecular sieves 4A (0.2 g), benzylamine (0.10 mL, 0.10 g, 0.95 mmol, 23 °C, 15 min), and $NaBH_4$ (144 mg, 0.80 mmol, 30 min). After evaporation, chromatography on silica gel (9/1 Et_2O-*n*-pentane) afforded 328 mg (99%) of **1b**: ^{1}H NMR δ 0.91 (t, J = 7.3 Hz, 3 H), 1.2-1.4 (m, 2 H), 1.4-1.6 (m, 3 H), 2.48 (t, J = 7.2 Hz, 2 H), 3.33 (d, J = 6.0 Hz, 2 H), 3.79 (s, 2 H), 5.70 (t, J = 6.0 Hz, 1 H), 7.2-7.4 (m, 5 H); ^{13}C NMR δ 13.85, 21.31, 31.32, 44.94, 53.48, 54.76, 111.02, 127.00, 128.20, 120.39, 132.85, 140.01.

(*Z*)-1-Acetamido-3-iodo-2-heptene (1c). Representative Procedure for the Acetylation of Amines. A mixture of **1a** (165 mg, 0.42 mmol) and *i*-Pr_2NEt (0.38 mL, 284 mg, 2.2 mmol) in CH_2Cl_2 (2 mL) was treated with Ac_2O (0.13 mL, 143 mg, 1.4 mmol, 23 °C, 2 h). Filtration of this mixture on silica gel (9/1 Et_2O-*n*-pentane) afforded 194 mg (99%) of **1c**: ^{1}H NMR δ 0.91 (t, J = 7.3 Hz, 3 H), 1.29 (sex, J = 7.3 Hz, 2 H), 1.4-1.6 (m, 2 H), 1.99 (s, 3 H), 2.47 (t, J = 7.3 Hz, 2 H), 3.89 (d, J = 6.0 Hz, 2 H), 5.67 (t, J = 6.0 Hz, 1 H), 6.45 (bs, 1 H); ^{13}C NMR δ 13.85, 21.34, 23.10, 31.32, 44.82, 45.63, 111.86, 130.69, 170.30.

(*Z*)-1-(*p*-Toluenesulfonamido-3-iodo-2-heptene (1d). A mixture of **1a** (100 mg, 0.42 mmol) and Et_3N (0.8 mL, 0.61 g, 0.6 mmol) in CH_2Cl_2 (3 mL) was treated with *p*-toluenesulfonyl chloride (103 mg, 0.54 mmol, 0 °C, 2 h). Chromatography of this mixture on silica gel (9/1 Et_2O-*n*-pentane) afforded 133 mg (81%) of **1d**: ^{1}H NMR δ 0.87 (t, J = 7.2 Hz, 3 H), 1.1-1.5 (m, 4 H), 2.38 (t, J = 7.2 Hz, 2 H), 2.43 (s, 3 H), 3.62 (t, J = 6.2 Hz, 2 H), 4.83 (t, J = 6.1 Hz, 1 H), 5.55 (t, J = 6.2 Hz, 1 H), 7.32 (d, J = 8.1 Hz, 2 H), 7.77 (t, J = 8.1 Hz, 2 H); ^{13}C NMR δ 13.80, 21.28, 21.54, 31.16, 44.79, 48.96, 112.99, 127.24, 129.59, 129.74, 136.79, 143.56.

(*Z*)-1-Amino-5,5-bis(methoxycarbonyl)-2-iodo-2-dodecen-7-yne (4a). To (*Z*)-3-iodo-4-(triphenylmethanoxy)-2-buten-1-ol[2h] (3.82 g, 8.4 mmol) dissolved in CH_2Cl_2 (20 mL) were successively added at 0 °C Et_3N (2.25 mL, 1.62 g, 16 mmol) and methanesulfonyl chloride (1.08 mL, 1.59 g, 11 mmol, 2 h). The reaction mixture was diluted with Et_2O, washed with H_2O, evaporated, filtered on a short path of silica gel to afford 1.8 g (40%) of the mesylated alcohol. To a suspension of NaH (154 mg, 3.85 mmol, 60% dispersion in mineral oil) in THF (5 mL) were successively added methyl 2-(methoxycarbonyl)-4-nonynoate (791 mg, 3.5 mmol, 0 °C then 30 min at 23 °C) dissolved in THF (3 mL), NaI (52 mg, 0.35 mmol), and the mesylated alcohol (1.8 g, 3.4 mmol, 0 °C then 23 °C, 2 h) in THF (4 mL). The reaction mixture was diluted with Et_2O, washed with H_2O, dried over $MgSO_4$, and evaporated. A mixture of the crude product and pyridinium *p*-toluenesulfonate (PPTS) (151 mg, 0.6 mmol) in 20 mL of 1/1 MeOH-EtOH was stirred at 23 °C for 12 h. After evaporation, chromatography on silica gel (80/20 *n*-pentane-Et_2O)of the crude oil afforded 1.13 g (90%) of (*Z*)-5,5-bis(methoxycarbonyl)-2-iodo-2-dodecen-7-yn-1-ol (**5**): ^{1}H NMR δ 0.90 (t, J = 7.2 Hz, 3 H), 1.3-1.6 (m, 4 H), 2.1-2.2 (m, 2 H), 2.48 (bt, J = 6.0 Hz, 1 H), 2.78 (t, J = 3.4 Hz, 2 H), 2.95 (d, J = 6.9 Hz, 3 H), 3.75 (s, 6 H), 4.24 (d, J = 6.0 Hz, 2 H), 5.86 (dt, J = 6.9, 1.1 Hz, 1 H); ^{13}C NMR δ 13.59, 18.36, 21.83, 23.94, 30.87, 38.74, 52.87, 56.94, 71.68, 73.68, 84.32, 111.62, 129.62, 170.29; IR (neat) 3360 cm^{-1}. Using the procedure described for the preparation of **1a**, (*Z*)-5,5-

bis(methoxycarbonyl)-2-iodo-2-dodecen-7-yn-1-ol[2h] (348 mg, 0.82 mmol) gave after 3 h 328 mg (90%) of (*Z*)-1-azido-5,5-bis(methoxycarbonyl)-2-iodo-2-dodecen-7-yne: ^{1}H NMR δ 0.89 (t, *J* = 7.1 Hz, 3 H), 1.3-1.5 (m, 4 H), 2.1-2.2 (m, 2 H), 2.80 (t, *J* = 1.3 Hz, 1 H), 2.95 (d, *J* = 6.8 Hz, 3 H), 3.75 (s, 6 H), 4.09 (s, 2 H), 5.86 (dt, *J* = 6.9 Hz, 1 H); ^{13}C NMR δ 13.59, 18.36, 21.83, 24.13, 30.86, 39.21, 52.89, 56.78, 62.58, 73.77, 84.42, 102.81, 133.92, 170.06; This azide (255 mg, 0.57 mmol) was further treated with Ph_3P and H_2O to yield 240 mg (quant) of **4a**: ^{1}H NMR δ 0.90 (t, *J* = 7.1 Hz, 3 H), 1.3-1.6 (m, 6 H), 2.05-2.2 (m, 2 H), 2.78 (t, *J* = 2.2 Hz, 2 H), 2.92 (d, *J* = 6.9 Hz, 2 H), 3.46 (s, 2 H), 3.74 (s, 6 H), 5.66 (t, *J* = 6.9 Hz, 1 H); ^{13}C NMR δ 13.48, 18.25, 21.71, 23.80, 30.76, 38.93, 52.70, 55.30, 56.79, 73.83, 84.11, 117.31, 128.21, 170.12.

(*Z*)-1-Acetamido-5,5-bis(methoxycarbonyl)-2-iodo-2-dodecen-7-yne (4b). Acetylation of **4a** (178 mg, 0.42 mmol), using the procedure described for the preparation of **1c**, yielded 192 mg (99%) of **4b**: ^{1}H NMR δ 0.90 (t, *J* = 7.1 Hz, 3 H), 1.3-1.6 (m, 6 H), 2.02 (s, 3 H), 2.05-2.2 (m, 2 H), 2.76 (t, *J* = 6.8 Hz, 2 H), 3.73 (s, 6 H), 4.14 (d, *J* = 5.9 Hz, 2 H), 5.72 (t, *J* = 6.8 Hz, 1 H), 6.12 (t, *J* = 5.6 Hz, 1 H); ^{13}C NMR δ 13.63, 18.44, 21.95, 23.19, 31.03, 32.68, 39.43, 51.42, 52.70, 56.57, 78.29, 81.13, 107.66, 131.61, 169.79, 170.88(2C); IR (neat) 3650(bs), 1734 (s), 1654(s) cm^{-1}.

(*Z*)-1-(*p*-Toluenesulfonamido-5,5-bis(methoxycarbonyl)-2-iodo-2-dodecen-7-yne (4c). A mixture of (*Z*)-5,5-bis(methoxycarbonyl)-2-iodo-2-dodecen-7-yn-1-ol (295 mg, 0.70 mmol), Ph_3P (551 mg, 2.1 mmol), and *N*-BOC-*p*-toluenesulfonamide[13] (304 mg, 12 mmol) was treated with diethyl azadicarboxylate (0.28 mL, 0.31 g, 1.8 mmol, 23 °C, 6 h). The reaction mixture was filtered through silica gel. This crude product dissolved in CH_2Cl_2 was treated with trifluoroacetic acid (20 μl) and filtered through silica gel to yield 381 mg (95%) of **4c**: ^{1}H NMR δ 0.89 (t, *J* = 6.9 Hz, 3 H), 1.3-1.5 (m, 4 H), 2.05-2.2 (m, 2 H), 2.43 (s, 3 H), 2.6-2.75 (m, 2 H), 2.78 (d, *J* = 6.7 Hz, 2 H), 3.73 (s, 6 H), 3.8-3.95 (m, 2 H), 5.5-5.65 (m, 1 H), 5.71 (t, *J* = 6.7 Hz, 1 H), 7.30 (d, *J* = 8.1 Hz, 2 H), 7.73 (d, *J* = 8.1 Hz, 2 H); ^{13}C NMR δ 13.42, 18.17, 21.35, 21.62, 23.69, 30.67, 38.83, 52.73, 54.91, 56.57, 73.70, 84.07, 105.74, 127.02, 129.48, 132.26, 137.07, 143.31, 169.94; IR (neat) 1736 cm^{-1}.

(*Z*)-1-Acetamido-4-(*t*-butyldimethylsilyloxy)-2-iodo-2-dodecen-7-yne (10). Swern oxidation of 4-nonyn-1-ol (1.40 g, 10 mmol) using the procedure described for the preparation of **1b** yielded 0.97 g (70%) of 4-nonyn-1-al: ^{1}H NMR δ 0.83 (t, *J* = 7.2 Hz, 3 H), 1.2-1.5 (m, 4 H), 2.0-2.15 (m, 2 H), 2.35-245 (m, 2 H), 2.5-2.65 (m, 2 H), 9.72 (t, *J* = 1.3 Hz, 1 H); ^{13}C NMR δ 12.08, 13.49, 18.24, 21.80, 30.90, 42.91, 77.65, 81.41, 200.98. To 1-tetrahydropyranyloxy-2-propyne (1.68 g, 12 mmol) in THF (15 mL) were successively added a 2.5 M solution of *n*-BuLi in hexane (4.8 mL, 12 mmol, -78 °C, 1 h), and 4-nonyn-1-al (0.97 g, 7.0 mmol, -78 °C, 10 mn) dissolved in THF (7 mL). The reaction mixture was warmed to 0 °C, diluted with Et_2O, washed with H_2O, dried over $MgSO_4$, and evaporated. Chromatography on silica gel (80/20 *n*-pentane-Et_2O) afforded 5.35 g (81%) of 1-tetrahydropyranyloxy-2,7-dodecadiyn-4-ol: ^{1}H NMR δ 0.90 (t, *J* = 7.0 Hz, 3 H), 1.2-2.0 (m, 11 H), 2.05-2.2 (m, 2 H), 2.2-2.5 (m, 2 H), 2.57 (bs, 1 H), 3.4-3.6 (m, 1 H), 3.8-3.95 (m, 1 H), 4.2-4.35 (m, 2 H), 4.4-4.55 (m, 1 H), 5.8-6.0 (m, 1 H); ^{13}C NMR δ 13.63, 14.88, 18.42, 18.99, 21.96, 25.34, 30.22, 31.11, 36.75, 54.30, 61.46, 61.96, 78.73, 80.99, 81.31, 86.54, 96.80. To a suspension of NaOMe (130 mg, 2.4 mmol) in THF (2 mL) were successively added a 1.0 M THF solution of $LiAlH_4$ (1.2 mL, 1.2 mmol, 0 °C, 30 min) and 1-tetrahydropyranyloxy-2-7-dodecadiyn-4-ol (300 mg, 1.08 mmol, -10 °C, over 10 min) dissolved in THF (2.0 mL). The reaction mixture was stirred at 0 °C for 20 h, treated with I_2 (762 mg, 3.0 mmol, -78 °C, 10 min) dissolved in THF (3 mL), stirred at 23 °C for 30 min, treated successively with a concentrated aqueous NH_4OH, aqueous $Na_2S_2O_3$, diluted with Et_2O, filtered through cotton wool, washed successively with 1 M HCl, aqueous $NaHCO_3$,

dried over $MgSO_4$, and evaporated. Chromatography on silica gel afforded 220 mg (54%) of (*Z*)-1-tetrahydropyranyloxy-2-iodo-2-dodecen-7-yn-4-ol. A mixture of this compound (0.22 g, 0.58 mmol), imidazole (82 mg, 1.2 mmol), and *t*-butylchlorodimethylsilane (120 mg, 0.8 mmol) in DMF (2.0 mL) was stirred for 12 h at 23 °C. The reaction mixture was diluted with *n*-pentane, washed with H_2O, dried over $MgSO_4$, and evaporated. Chromatography on silica gel (97/3 *n*-pentane-Et_2O) afforded 214 mg (71%) of (*Z*)-1-tetrahydropyranyloxy-2-iodo-4-(*t*-butyldimethylsilyloxy)-2-dodecen-7-yne. A mixture of this compound (214 mg, 0.41 mmol) and PPTS (10 mg, 0.04 mmol) in MeOH was stirred at 23 °C for 20 h and then evaporated. Chromatography on silica gel (85/15 *n*-pentane-Et_2O) afforded 101 mg (58%) of (*Z*)-4-(*t*-butyldimethylsilyloxy)-2-iodo-2-dodecen-7-yn-1-ol: ^1H NMR δ 0.05 (s, 3 H), 0.11 (s, 3 H), 0.8-1.0 (m, 12 H), 1.35-1.5 (m, 4 H), 1.6-1.7 (m, 3 H), 1.9-2.05 (m, 1 H), 2.1-2.35 (m, 4 H), 4.15-4.3 (m , 2 H), 4.4 (m, 1 H), 5.9-6.0 (m, 1 H); ^{13}C NMR δ -4.75, -4.12, 13.68, 14.77, 18.06, 18.47, 22.01, 25.84, 31.20, 36.18, 71.36, 75.50, 79.38, 80.85, 105.47, 138.62. Using the procedure described for the preparation of **1a**, this alcohol (225 mg, 0.53 mmol) was converted to 203 mg (83%) of (*Z*)-1-azido-4-(*t*-butyldimethylsilyloxy)-2-iodo-2-dodecen-7-yne: ^1H NMR δ 0.06 (s, 3 H), 0.11 (s, 3 H), 0.8-1.0 (m, 12 H), 1.35-1.55 (m, 4 H), 1.55-1.75 (m, 2 H), 2.1-2.3 (m, 4 H), 4.06 (s , 2 H), 4.4-4.55 (m, 1 H), 5.94 (d, *J*= 7.4 Hz, 1 H); ^{13}C NMR δ -4.79, -4.20, 13.68, 14.77, 18.01, 18.46, 22.00, 25.79, 31.18, 36.09, 62.15, 75.56, 79.17, 80.94, 96.84, 142.38. This azide (203 mg, 0.44 mmol) was treated with Ph_3P and H_2O to yield 175 mg (91%) of (Z)-1-amino-4-(*t*-butyldimethylsilyloxy)-2-iodo-2-dodecen-7-yne: ^1H NMR δ 0.05 (s, 3 H), 0.11 (s, 3 H), 0.8-1.0 (m, 12 H), 1.35-1.55 (m, 6 H), 1.55-1.7 (m, 2 H), 2.1-2.3 (m, 4 H), 3.45 (3 , 2 H), 4.35-4.5 (m, 1 H), 5.75 (d, *J*= 7.4 Hz, 1 H); ^{13}C NMR ($CDCl_3$) δ -4.74, -4.08, 13.69, 14.78, 18.03, 18.46, 21.99, 25.84, 31.19, 36.23, 55.04, 75.85, 79.38, 80.74, 111.33, 137.25. Acetylation of this amine (175 mg, 0.40 mmol) using the procedure described for the preparation of **1c** yielded 190 mg (99%) of **10**: ^1H NMR δ 0.04 (s, 3 H), 0.10 (s, 3 H), 0.80-0.95 (m, 12 H), 1.35-1.55 (m, 4 H), 1.55-1.7 (m, 2 H), 2.03 (s, 3 H), 2.05-2.3 (m, 4 H), 4.14 (d, *J*= 6.0 Hz, 2 H), 4.35-4.5 (m, 1 H), 5.84 (d, *J*= 7.5 Hz, 1 H), 6.00-6.15 (m, 1 H); ^{13}C NMR δ -4.86, -4.22, 13.62, 14.69, 17.96, 18.39, 21.93, 23.15, 25.76 (3C), 31.11, 35.98, 50.97, 75.61, 79.26, 80.76, 101.44, 140.15, 169.62.

(Z)-1-Acetamido-5,5-bis(methoxycarbonyl)-8-iodo-7-hexadecene-2,11-diyne (13). To a suspension of NaH (42 mg, 1.05 mmol, 60% dispersion in mineral oil) in THF (2 mL) were successively added 2-(methoxycarbonyl)-6-(triphenylmethoxy)-4-hexynoate[2h] (428 mg, 0.95 mmol, 0 °C then 23 °C, 30 min) dissolved in THF (2 mL), NaI (15 mg, 0.1 mmol), (*Z*)-1-(methanesulfonyloxy)-2-undecen-6-yne (339 mg, 0.92 mmol, 0 °C then 23 °C, 2 h) dissolved in THF (2 mL). The reaction mixture was diluted with Et_2O, washed with H_2O, dried over $MgSO_4$, and evaporated. Chromatography on silica gel (90/10 *n*-pentane-Et_2O) afforded 470 mg (69%) of (*Z*)-1-(triphenylmethoxy)-5,5-bis(methoxycarbonyl)-8-iodo-7-hexadecen-2,11-diyne. A mixture of this compound (470 mg, 0.66 mmol) and PPTS (26 mg, 0.1 mmol) in EtOH (20 mL) was stirred at 50 °C for 14 h and then evaporated. Chromatography on silica gel (60/40 *n*-pentane-Et_2O) afforded 222 mg (71%) of (*Z*)-5,5-bis(methoxycarbonyl)-8-iodo-7-hexadecene-2,11-diyn-1-ol: ^1H NMR δ 0.91 (t, *J*= 7.1 Hz, 3 H), 1.3-1.5 (m, 4 H), 2.0-2.4 (m, 5 H), 2.64 (t, *J*= 7.1 Hz, 2 H), 2.85 (t, *J*= 2 Hz, 2 H), 2.91 (d, *J*= 6.8 Hz, 2 H), 3.76 (s, 6 H), 4.21 (s, 2 H), 5.45 (t, *J*= 7.0 Hz, 1 H); ^{13}C NMR δ 13.64, 18.38, 19.62, 21.93, 23.62, 31.08, 39.51, 45.26, 51.12, 52.98, 56.61, 77.68, 80.31, 81.70, 82.16, 110.88, 129.80, 170.10. Using the procedure described for the preparation of **1a**, this alcohol (222 mg, 0.47 mmol) was converted to 222 mg (92%) of (*Z*)-1-azido-5,5-bis(methoxycarbonyl)-8-iodo-7-hexadecene-2,11-diyne after 3 h at 23 °C. Its treatment with Ph_3P and H_2O yielded 170 mg (77%) of (*Z*)-1-amino-5,5-bis(methoxycarbonyl)-8-iodo-7-hexadecene-2,11-diyne. Acetylation of this amine (170 mg, 0.36 mmol), using

the procedure described for the preparation of **1c**, yielded 185 mg (99%) of **13**: ^{1}H NMR δ 0.91 (t, *J*= 7.1 Hz, 3 H), 1.3-1.5 (m, 4 H), 1.99 (s, 3 H), 2.1-2.2 (m, 2 H), 2.35-2.45 (m, 2 H), 2.63 (t, *J*= 7.0 Hz, 2 H), 2.81 (s, 2 H), 2.90 (d, *J*= 6.9 Hz, 2 H), 3.76 (s, 6 H), 4.95-5.05 (m, 2 H), 5.43 (t, *J*= 6.9 Hz, 1 H), 5.89 (bs, 1 H); ^{13}C NMR δ 13.64, 18.38, 19.60, 21.93, 23.02, 23.46, 29.75, 31.08, 39.52, 45.21, 52.97, 53.56, 77.64, 78.28, 79.30, 81.75, 110.83, 129.83, 169.62, 170.03.

(*Z*)-2-Iodo-5,5-bis(methoxycarbonyl)-2-tridecen-8-yn-1-ol (17) and (*Z*)-1-Acetamido-2-iodo-5,5-bis (methoxycarbonyl)-2-tridecen-8-yne (18). To a suspension of NaH (220 mg, 5.5 mmol, 60% dispersion in mineral oil) in THF (5 mL) were successively added methyl 2-(methoxycarbonyl)-4-decynoate (1.20 g, 5.0 mmol, 0 °C then 23 °C, 30 min) dissolved in THF (5 mL), NaI (75 mg, 0.5 mmol), and (*Z*)-1-(methanesulfonyloxy)-3-iodo-4-(triphenylmethoxy)-2-butene (2.54 g, 4.8 mmol, 0 °C, 10 mn then 23 °C, 2 h) dissolved in THF (5 mL). The reaction mixture was diluted with Et_2O, washed with H_2O, dried over $MgSO_4$, and evaporated. Chromatography on silica gel (90/10 *n*-pentane-Et_2O) afforded 2.97 g (91%) of (*Z*)-1-(triphenylmethoxy)-2-iodo-5,5-bis(methoxycarbonyl)-2-tridecen-8-yne. A mixture of this compound (2.97 g, 4.34 mmol) and PPTS (0.44 mmol) in EtOH (50 mL) was stirred at 50 °C for 20 h and then evaporated. Chromatography on silica gel (70/30 *n*-pentane-Et_2O) afforded 1.69 g (89%) of **17**: ^{1}H NMR δ 0.89 (t, *J*= 7.1 Hz, 3 H), 1.3-1.5 (m, 2 H), 1.71 (s, 1 H), 2.0-2.3 (m, 7 H), 2.80 (d, *J*= 4.0 Hz, 2 H), 3.73 (s, 6 H), 4.23 (d,*J*= 6.3 Hz, 2 H), 5.83 (t, *J*= 7.0 Hz, 1 H); ^{13}C NMR δ 13.84, 16.62, 21.23, 23.83, 28.91, 31.41, 39.48, 45.34, 48.13, 52.78(2C), 53.84, 56.90, 74.59, 83.42, 113.45, 126.98, 128.18(2C), 128.40(3C), 140.05, 170.31(2C). Using the procedure described for the preparation of **1a**, this alcohol (456 mg, 1.05 mmol) was converted to 437 mg (89%) of (*Z*)-1-azido-2-iodo-5,5-bis(methoxycarbonyl)-2-tridecen-8-yne: ^{1}H NMR δ 0.89 (t, *J*= 7.1 Hz, 3 H), 1.3-1.5 (m, 4 H), 2.0-2.2 (m, 6 H), 2.81 (d, *J*= 6.7 Hz, 2 H), 3.74 (s, 6 H), 4.08 (s, 2 H), 5.83 (t, *J*= 6.7 Hz, 1 H), ; ^{13}C NMR δ 13.63, 14.53, 18.46, 21.97, 31.04, 32.84, 39.56, 52.73, 56.59, 62.53, 78.21, 81.24, 102.85, 133.90, 170.80. This compound was further treated with Ph_3P to yield 380 mg (92%) of (*Z*)-1-amino-2-iodo-5,5-bis(methoxycarbonyl)-2-tridecen-8-yne. Acetylation of this amine (195 mg, 0.45 mmol), using the procedure described for the preparation of **1c**, yielded 207 mg (96%) of (*Z*)-*N*-acetyl-1-amino-2-iodo-5,5-bis(methoxycarbonyl)-2-tridecen-8-yne: ^{1}H NMR δ 0.89 (t, *J*= 7.1 Hz, 3 H), 1.3-1.5 (m, 4 H), 2.0-2.2 (m, 6 H), 2.81 (d, *J*= 6.7 Hz, 2 H), 3.74 (s, 6 H), 4.08 (s, 2 H), 5.83 (t, *J*= 6.7 Hz, 1 H), ; ^{13}C NMR δ 13.63, 14.51, 18.44, 21.95, 23.19, 31.02, 32.68, 39.43, 51.42, 52.70, 56.57, 78.29, 81.13, 107.66, 131.61, 169.78, 170.88. IR (neat) 3288 (s), 2244 (w), 1734 (s), 1654 (s) cm^{-1}.

(*Z*)-1-Acetamido-7,7-bis(methoxycarbonyl)-10-iodo-9-tetradecen-4-yne (22a) and (*Z*)-7,7-Bis(methoxy carbonyl)-10-iodo-9-tetradecen-4-yn-1-ol (26). To a suspension of NaH (52 mg, 1.3 mmol, 60% dispersion in mineral oil) in THF (3 mL) were succesively added methyl 2-(methoxycarbonyl)-8-tetrahydropyranyloxy-4-octynoate (370 mg, 1.2 mmol, 0 °C, 1 h) dissolved in THF (3 mL), NaI (15 mg, 0.1 mmol), and (*Z*)-1-(methanesulfonyloxy)-3-iodo-2-heptene (480 mg, 1.5 mmol, 0 °C, 10 mn then 23 °C, 2 h) dissolved in THF (2 mL). The reaction mixture was diluted with Et_2O, washed with H_2O, dried over $MgSO_4$, and evaporated. A mixture of the crude product, PPTS (56 mg, 0.2 mmol), and MeOH (10 mL) was stirred for 20 h at 23 °C and then evaporated. Chromatography on silica gel (80/20 *n*-pentane-Et_2O) yielded 380 mg (98%) of (*Z*)-7,7-bis(methoxycarbonyl)-10-iodo-9-tetradecen-4-yn-1-ol (**26**): ^{1}H NMR δ 0.90 (t, *J*= 7.3 Hz, 3 H), 1.28 (sex, *J*= 7.3 Hz, 2 H), 1.4-1.6 (m, 2 H), 1.73 (pent, *J*= 6.5 Hz, 2 H), 2.11 (bs, 1 H), 2.2-2.35 (m, 2 H), 2.47 (t, *J*= 7.2 Hz, 2 H), 2.76 (t, *J*= 2.2 Hz, 2 H), 2.89 (d, *J*= 6.8 Hz, 2 H), 3.71 (t, *J*= 6.2 Hz, 2 H), 3.74 (s, 6 H), 5.37 (t, *J*= 6.8 Hz, 1 H); ^{13}C NMR δ 13.84, 15.28, 21.21, 23.53, 31.35, 31.38, 39.49, 45.31, 52.83, 56.91, 61.45, 74.77, 83.31, 113.53,

128.30, 170.36. Using the procedure described for the preparation of **1a**, **26** (255 mg, 0.57 mmol) was converted to 235 mg (87%) of (Z)-1-azido-7,7-bis(methoxycarbonyl)-10-iodo-9-tetradecen-4-yne, which was further treated with Ph_3P and H_2O to give a crude reaction mixture. Acetylation of this mixture using the procedure described for the preparation of **1c** yielded 221 mg (91%) of **22a**: ^1H NMR δ 0.90 (t, *J*= 7.2 Hz, 3 H), 1.28 (t, *J*= 7.6 Hz, 2 H), 1.48 (pent, *J*= 7.3 Hz, 2 H), 1.68 (pent, *J*= 6.8 Hz, 2 H), 1.99 (s, 3 H), 2.1-2.3 (m, 2 H), 2.47 (t, *J*= 7.2 Hz, 2 H), 2.76 (s, 2 H), 2.89 (d, *J*= 6.8 Hz, 2 H), 3.31 (q, *J*= 6.4 Hz, 2 H), 3.75 (s, 6 H), 5.35 (t, *J*= 6.9 Hz, 1 H), 6.0-6.15 (m, 1 H); ^{13}C NMR δ 13.84, 16.33, 21.23, 23.27, 23.84, 28.11, 31.41, 38.67, 39.55, 45.33, 52.87, 56.91, 75.23, 82.93, 113.73, 128.20, 170.38.

(Z)-1-Benzylamino-7,7-bis(methoxycarbonyl)-10-iodo-9-tetradecen-4-yne (22b). A solution of the crude primary amine, used in the preparation of **22a**, in EtOH (3 mL) was treated successively with powdered molecular sieves 4A (100 mg), benzaldehyde (61 μL, 64 mg, 0.6 mmol, 2 h), and $NaBH_4$ (114 mg, 3 mmol, 0 °C, 15 mn) to yield 146 mg (54%) of **22b** after chromatography on silica gel (98/2 CH_2Cl_2-MeOH): ^1H NMR δ 0.90 (t, *J*= 7.2 Hz, 3 H), 1.2-1.35 (m, 2 H), 1.4-1.55 (m, 2 H), 1.68 (pent, *J*= 7.0 Hz, 2 H), 1.93 (bs, 1 H), 2.15-2.25 (m, 2 H), 2.46 (t, *J*= 7.3 Hz, 2 H), 2.71 (t, *J*= 7.0 Hz, 2 H), 2.76 (t, *J*= 2.2 Hz, 2 H), 2.89 (d, *J*= 6.9 Hz, 2 H), 3.72 (s, 6 H), 3.74 (s, 2 H), 5.37 (t, *J*= 6.9 Hz, 1 H), 7.2-7.4 (m, 5 H); ^{13}C NMR δ 13.84, 16.62, 21.23, 23.83, 28.91, 31.41, 39.48, 45.34, 48.13, 52.78, 53.84, 56.90, 74.59, 83.42, 113.45, 126.98, 128.18, 128.40, 140.05, 170.31.

6-(2'-Iodophenyl)-3-hexyn-1-ol (28). To *i*-Pr_2NH (0.30 mL, 2.1 mmol) dissolved in THF (2 mL) were successively added a 2.5 M solution of *n*-BuLi in hexane (0.84 mL, 2.1 mmol, -50 °C, 20 min), 4-(2'-iodophenyl)-1-butyne (512 mg, 2 mmol, -65 °C, 20 min) in THF (4 mL), ethylene oxide (3 mL, -70 °C, 5 min), and HMPA (3 mL) at -70 °C. The reaction mixture was warmed to 23 °C, quenched with aqueous NH_4Cl, extracted with Et_2O, washed with H_2O, dried over $MgSO_4$, and evaporated. Chromatography on silica gel (5/1 *n*-hexane-ethyl acetate) afforded 0.53 g (90%) of **28**: ^1H NMR δ 2.2-2.45 (m, 4 H), 2.78 (t, *J* = 7.0 Hz, 2 H), 3.53 (t, *J* = 7.0 Hz, 2 H), 6.7-6.85 (m, 1 H), 7.04-7.25 (m, 2 H), 7.67 (d, *J* = 7.1 Hz, 1 H); ^{13}C NMR δ 19.5, 23.0, 40.0, 61.0, 77.8, 80.5, 100.2, 128.0, 129.5, 129.6, 139.0, 142.7.

(6-(2'-iodophenyl)-3-hexynyl)amine (29a). Using the procedure described for the preparation of **1a**, **28** (0.90 g, 3.0 mmol) was converted to 0.87 g (89%) of 6-(2'-iodophenyl)-3-hexynyl azide. This azide (177 mg, 0.54 mmol) was then further treated with PPh_3 and H_2O to yield 113 mg (70%) of **29a**: ^1H NMR δ 1.67 (bs, 2 H), 2.2-2.4 (m, 2 H), 2.4-2.6 (m, 2 H), 2.75 (t, *J* = 6.7 Hz, 2 H), 2.95 (t, *J* = 6.7 Hz, 2 H), 6.85-7.0 (m, 1 H), 7.2-7.4 (m, 2 H), 7.85 (d, *J* = 8.3 Hz, 1 H); ^{13}C NMR δ 19.41, 23.64, 40.02, 41.15, 78.89, 80.40, 100.35, 128.12128.34, 129.74, 139.40, 143.03.

***N*-(6-(2'-Iodophenyl)-3-hexynyl)acetamide (29b).** Acetylation of **29a**, using the procedure described for the preparation of **1c**, yielded 110 mg (96 %) of **29b**: ^1H NMR δ 1.95 (s, 3 H), 2.25-2.4 (m, 2 H), 2.4-2.6 (m, 2 H), 2.92 (t, *J* = 6.9 Hz, 2 H), 3.26-3.4 (m, 2 H), 5.66 (bs, 1 H), 7.85-7.0 (m, 1 H), 7.2-7.4 (m, 2 H), 7.82 (d, *J* = 8.6 Hz, 1 H); ^{13}C NMR δ 19.33, 19.67, 23.33, 38.39, 39.82, 78.34, 80.60, 100.45, 128.17, 129.77, 139.47, 143.02, 169.99.

Pd-Catalyzed Carbonylation of (Z)-3-Iodo-2-heptenylamine and Its Derivatives. (a) Carbonylation of 1c. Representative Procedure. A mixture of **1c** (65 mg, 0.23 mmol), Et_3N (0.13 mL, 93 mg, 0.92 mmol), $Cl_2Pd(PPh_3)_2$ (35 mg, 5 mol%), and MeOH (1 mL) was stirred at 65 °C under 1 atm of CO for 20 h. The resulting reaction mixture was concentrated, diluted with Et_2O, washed with H_2O, dried over $MgSO_4$, and evaporated.

Analysis of the crude reaction mixture by ^{1}H NMR spectroscopy showed the formation of 3-(*n*-butyl)-5-hydro-2-oxo-1*H*-pyrrole (**2a**) in 85% yield. Chromatography on silica gel (95/5 CH_2Cl_2-MeOH) afforded 26 mg (81%) of **2a**: H NMR δ 0.93 (t, *J*= 7.2 Hz, 3 H), 1.3-1.45 (m, 2 H), 1.45-1.65 (m, 2 H), 2.2-2.4 (m, 2 H), 2.57 (s, 3 H), 4.2-4.3 (m, 2 H), 6.90 (t, *J*= 1.5 Hz, 1 H); ^{13}C NMR δ 13.70, 22.26, 24.24, 25.07, 29.38, 48.22, 138.33, 139.74, 170.21, 170.53; High-resolution MS calcd for $C_{18}H_{13}NO$ 140.1075, found 140.1069. Using *i*-PrOH (2 mL) in place of MeOH, the compound **1c** (143 mg, 0.52 mmol) gave after 8 h at 75 °C *N*-acetyl-3-(*n*-butyl)-5-hydro-2-oxo-1*H*-pyrrole (**2c**) in 78% NMR yield. Chromatography on silica gel (80/20 *n*-pentane-Et_2O) afforded 76 mg (80%) of **2c**: ^{1}H NMR δ 0.94 (t, *J*= 7.2 Hz, 3 H), 1.3-1.45 (m, 2 H), 1.45-1.65 (m, 2 H), 2.25-2.4 (m, 2 H), 3.73 (d, *J*= 1.8 Hz, 2 H), 4.64 (s, 2 H), 6.60 (t, *J*= 1.8 Hz, 1 H), 7.2-7.4 (m, 5 H); ^{13}C NMR δ 13.90, 22.46, 25.62, 29.64, 46.28, 50.22, 127.45, 127.97, 128.68, 134.23, 137.48, 140.22, 171.70; High resolution MS calcd for $C_{15}H_{19}NO$ 229.1467, found 229.1467. Using DMF (1.5 mL) in place of MeOH, the compound **1c** (158 mg, 0.57 mmol) gave after 6 h at 75 °C **2c** in 82% NMR yield.

(b) Carbonylation of 1a. Using *i*-PrOH (5 mL) and *i*-Pr_2NEt (4 equiv) in place of MeOH and Et_3N, **1a** (249 mg, 1.04 mmol) gave after 20 h at 75 °C **2a** in 85% NMR yield. Chromatography on silica gel (95/5 Et_2O-*n*-pentane) afforded 119 mg (81%) of **2a**.

(c) Carbonylation of 1b. Under the same conditions described for the carbonylation of **1c**, the compound **1b** (82 mg, 0.24 mmol) gave after 18 h *N*-benzyl-3-(*n*-butyl)-5-hydro-2-oxo-1*H*-pyrrole (**2b**) in 95% NMR yield: ^{1}H NMR δ 0.93 (t, *J*= 7.3 Hz, 3 H), 1.3-1.45 (m, 2 H), 1.45-1.65 (m, 2 H), 2.25-2.4 (m, 2 H), 3.73 (d, *J*= 1.8 Hz, 2 H), 4.64 (s, 2 H), 6.60 (t, *J*= 1.8 Hz, 1 H), 7.2-7.4 (m, 5 H); ^{13}C NMR δ 13.90, 22.46, 25.62, 29.64, 46.28, 50.22, 127.45, 127.97, 128.68, 134.23, 137.48, 140.22, 171.70; IR (neat) 3484 (bs), 1684 (s) cm^{-1}; High resolution MS calcd for $C_{15}H_{19}NO$ 229.1467, found 229.1467.

(d) Carbonylation of 1d. Under the same conditions described for the carbonylation of **1c**, the compound **1d** (78 mg, 0.20 mmol) gave after 8 h *N*-(*p*-toluenesulfonyl)-3-(*n*-butyl)-5-hydro-2-oxo-1*H*-pyrrole (**2d**) in 95% NMR yield: ^{1}H NMR δ 0.87 (t, *J*= 7.3 Hz, 3 H), 1.2-1.5 (m, 4 H), 2.05-2.2 (m, 2 H), 2.42 (s, 3 H), 4.36 (d, *J*= 1.8 Hz, 2 H) 6.81 (bs, 1 H), 7.32 (d, *J*= 8.2 Hz, 2 H), 7.85 (d, *J*= 8.2 Hz, 2 H); ^{13}C NMR δ 13.74, 21.67, 22.29, 25.10, 29.20, 50.24, 128.00, 129.72, 135.44, 138.28, 139.63, 145.03, 168.99.

"Zipper"-mode Cyclic Carbopalladation-Carbonylative Lactamization and Lactonization Cascades (a) Carbonylation of 4a. 6,6-Bis(methoxycarbonyl)-4-(*n*-butyl)-1,2,5,6,7-pentahydroisoquinolin-3-one (6a). Representative Procedure under Condition A. A mixture of **4a** (148 mg, 0.35 mmol), Et_3N (0.2 mL, 142 mg, 1.4 mmol), $Cl_2Pd(PPh_3)_2$ (12 mg, 5 mol%) in *i*-PrOH (1.3 mL) was stirred for 6 h at 75 °C under 1 atm of CO. The reaction mixture was concentrated, diluted with Et_2O, washed with H_2O, dried over $MgSO_4$, and evaporated. Analysis of the crude reaction mixture by ^{1}H NMR spectroscopy showed the formation of 6,6-bis(methoxycarbonyl)-4-(*n*-butyl)-1,2,5,6,7-pentahydroisoquinolin-3-one (**6a**) in 48 % NMR yield along with a 22 % yield of (*Z*)-2-(3',3'-bis(methoxycarbonyl)-5'-decynylidene)-3-propanelactam (**8**). Chromatography on silica gel (90/10 Et_2O-*n*-pentane) afforded 48 mg (43%) of **6a** and 20 mg (18%) of **8**. **6a**: ^{1}H NMR δ 0.92 (t, *J*= 6.6 Hz, 3 H), 1.3-1.5 (m, 4 H), 2.35-2.5 (m, 2 H), 2.7-2.85 (m, 2 H), 3.03 (s, 2 H), 3.73 (s, 6 H), 4.05 (bs, 2 H), 5.69 (bs, 1 H), 6.17 (bs, 1 H); ^{13}C NMR δ 14.06, 22.96, 25.78, 30.85, 31.37, 31.70, 44.68, 52.98 (2C), 53.57, 122.63, 128.97, 130.24, 137.22, 166.18, 170.88 (2C); IR (neat) 3254 (bs), 1736 (s), 1654 (s) cm^{-1}; High resolution MS calcd for $C_{17}H_{23}NO_5$ 321.1576, found 321.1574. **8**: ^{1}H NMR δ 0.92 (t, *J*= 6.6 Hz, 3 H), 1.3-1.5

(m, 4 H), 2.35-2.5 (m, 2 H), 2.7-2.85 (m, 2 H), 3.03 (s, 2 H), 3.73 (s, 6 H), 4.05 (bs, 2 H), 5.69 (bs, 1 H), 6.17 (bs, 1 H); ^{13}C NMR ($CDCl_3$) δ 13.58, 18.32, 21.82, 23.93, 30.86, 31.39, 43.78, 52.76, 57.49, 73.75, 84.24, 125.15, 141.28, 164.01, 170.27 (2C); IR (neat) 3288 (bs), 1736 (bs) cm^{-1}.

(b) Carbonylation of 4b. Representative Procedure under Condition B. A mixture of **4b** (178 mg, 0.38 mmol), Et_3N (0.21 mL, 153 mg, 1.5 mmol), $Cl_2Pd(PPh_3)_2$ (13 mg, 5 mol%) in MeOH (1.3 mL) was stirred for 30 h at 65 °C under 1 atm of CO. The resultant reaction mixture was concentrated, diluted with Et_2O, washed with H_2O, dried over $MgSO_4$, and evaporated. Analysis of the crude reaction mixture by 1H NMR spectroscopy showed the formation **6a** in 78% NMR yield along with an 11% yield of (Z)-1-acetamido-2,5,5-tris(methoxycarbonyl)-2-dodecen-8-yne (**7b**). Chromatography on silica gel (20/80 *n*-pentane-Et_2O) afforded 125 mg (78%) of **6a** and 16 mg (8%) of **7b**: ^{1}H NMR δ 0.89 (t, *J*= 7.0 Hz, 3 H), 1.25-1.5 (m, 4 H), 1.97 (s, 3 H), 2.0-2.2 (m, 2 H), 2.77 (bs, 2 H), 3.24 (d, *J*= 7.3 Hz, 3 H), 3.73 (s, 6 H), 3.78 (s, 3 H), 5.8-6.0 (m, 1 H), 6.21(t, *J*= 7.3 Hz, 1 H); ^{13}C NMR δ 13.57, 18.32, 21.80, 23.33, 24.19, 30.90, 32.50, 43.07, 51.70, 52.78, 57.21, 73.89, 84.04, 130.73, 139.49, 167.08, 169.59, 170.27; IR (neat) 3254 (bs), 1736 (s), 1654 (s) cm^{-1}; High resolution MS calcd for $C_{20}H_{29}NO_7$ 396.2022, found, 396.2014.

(c) Carbonylation of 4c. Under Condition B, **4c** (89 mg, 0.15 mmol) gave after 20 h at 65 °C *N*-(*p*-toluenesulfonyl)-6,6-bis(methoxycarbonyl)-4-(*n*-butyl)-1,2,5,6,7-pentahydroisoquinolin-3-one (**6c**) in 75% NMR yield along with a 9% yield of (Z)-1-(*p*-toluenesulfonamide)-2,5,5-tris(methoxycarbonyl)-2-dodecen-7-yne. **6c** : ^{1}H NMR δ 0.87 (t, *J* = 6.5 Hz, 3 H), 1.2-1.4 (m, 4 H), 2.25-2.4 (m, 2 H), 2.42 (s, 3 H), 2.8-2.85 (m, 2 H), 3.01 (s, 2 H), 3.72 (s, 6 H), 4.55 (d, *J* = 1.5 Hz, 2 H), 5.95-6.05 (m, 1 H), 7.31 (d, *J* = 8.2 Hz, 2 H), 7.90 (d, *J* = 8.2 Hz, 2 H); ^{13}C NMR δ 13.84, 21.58, 22.84, 25.83, 30.77, 31.73, 47.77, 53.07, 53.30, 126.12, 127.85, 128.41, 129.29, 130.35, 135.85, 140.40, 144.48, 163.27, 170.41; IR (neat) 1736, 1674 cm^{-1}; High resolution MS calcd for $C_{24}H_{29}NO_7S$ 475.1665, found 475.1650.

(d) Carbonylation of 10. Under Condition B, **10** (151 mg, 0.32 mmol) gave after 36 h at 65 °C 7-(*t*-butyldimethylsilyloxy)-4-(*n*-butyl)-1,2,5,6,7-pentahydroisoquinolin-3-one (**11**) in 72% NMR yield along with a 29% yield of *N*-acetyl-1-amino-4-(*t*-butyldimethylsilyloxy)-2-(methoxycarbonyl)-2-dodecen-7-yne (**12**). Chromatography on silica gel afforded 76 mg (71%) of **11** and 39 mg (28%) of **12**. **11**:^{1}H NMR δ 0.09 (bs, 6 H), 0.85-1.0 (m, 12 H), 1.25-1.5 (m, 4 H), 1.55-1.75 (m, 1 H), 1.9-2.05 (m, 1 H), 2.25-2.45 (m, 3 H), 2.6-2.75 (m, 1 H), 4.0-4.15 (m, 2 H), 4.3-4.4 (m, 1 H), 5.50-5.55 (m, 1 H), 6.50 (s, 1 H); ^{13}C NMR δ -4.68 (2C), 13.96, 18.15, 22.82, 23.72, 25.71, 25.81 (3C), 31.48, 31.81, 44.68, 66.65, 128.93, 129.65, 130.17, 140.61, 166.65. IR(neat) 1654 (brs) cm^{-1}; High resolution MS calcd for $C_{19}H_{33}NOSi$ 336.2359, found 336.2325. **12**: ^{1}H NMR δ 0.02 (s, 3 H), 0.05 (s, 3 H), 0.8-1.0 (m, 12 H), 1.35-1.55 (m, 4 H), 1.6-1.75 (m, 2 H), 1.99 (s, 3 H), 2.05-2.35 (m, 4 H), 3.81 (s, 3 H), 3.95-4.15 (m, 2 H), 5.05-5.15 (m, 1 H), 5.90-6.05 (m, 1 H), 6.21 (d, *J*= 7.01 Hz, 1 H); ^{13}C NMR δ -4.96, -4.48, 13.66, 14.86, 18.51, 21.98, 23.32, 25.80, 31.25, 36.45, 42.44, 51.74, 68.52, 79.55, 80.43, 126.12, 149.76, 166.83, 169.56; IR (neat) 3292 (bs), 1718 (s), 1654 (s) cm^{-1}; High resolution MS calcd for $C_{22}H_{39}NO_4Si$ 410.2727, found 410.2719.

(e) Carbonylation of 13. Under Condition B, **13** (169 mg, 0.33 mmol) gave after 24 h at 65 °C 9,9-bis(methoxycarbonyl)-4-(*n*-butyl)-1,2,5,6,8,9,10-heptahydrobenzo[h]isoquinolin-3-one (**14**) in 64% NMR yield. The compounds **15** and **16** were present in less than 3 and 7%, respectively. Chromatography on silica gel (Et_2O) afforded 76 mg (57%) of **14**: ^{1}H NMR δ 0.90 (t, *J*= 6.7 Hz, 3 H), 1.3-1.5 (m, 4 H), 2.3-2.5 (m, 6 H), 2.7-2.8 (m, 4 H), 3.72 (s, 6 H), 4.30 (s, 2 H), 5.5-5.6 (m, 1 H), 6.52 (bs, 1 H); ^{13}C NMR δ 13.97, 22.84, 26.01, 26.25, 28.90,

30.72, 31.20, 31.79, 42.44, 52.85, 53.88, 120.75, 124.46, 127.50, 128.22, 133.03, 141.51, 166.08, 171.08; IR(neat) 3196 (bs), 1740 (s), 1664 (s) cm^{-1}; High resolution MS calcd for $C_{21}H_{27}NO_5$ 373.1889, found 373.1881.

(f) Carbonylation of 17. Under Condition A, **17** (156 mg, 0.40 mmol) gave after 24 h at 75 °C a 66% NMR of **19** along with an 11% of 2-(isopropoxycarbonyl)-5,5-bis(methoxycarbonyl)-2-tridecen-8-yn-1-ol (**20a**). Chromatography on silica gel afforded 80 mg (66%) of 4-(*n*-butyl)-6,6-bis(methoxycarbonyl)-1,5,6,7,8-pentahydrocyclohepta[c]pyran-3-one (**19**): ^1H NMR δ 0.85-1.0 (m, 3 H), 1.2-1.5 (m, 4 H), 2.0-2.45 (m, 2 H), 2.35-2.45 (m, 2 H), 2.65-2.75 (m, 2 H), 2.79 (d, *J*= 6.0, 2 H), 3.73 (s, 6 H), 4.62 (s, 2 H), 5.92 (t, *J*= 6.0 Hz, 1 H), ; ^{13}C NMR δ 13.94, 22.88, 25.80, 26.91, 29.98, 30.17, 31.18, 52.92, 56.92, 70.93, 127.58, 129.04, 132.51, 149.09, 164.61, 171.30. IR (neat) 1702 (bs)cm^{-1}; High-resolution MS calcd for $C_{18}H_{24}O_6$ 336.1573, found 336.1571. **20a**: ^1H NMR δ 0.8-1.0 (m, 3 H), 1.2-1.6 (m, 10 H), 2.0-2.2 (m, 6 H), 2.43 (bs, 1 H), 3.17 (d, J= 7.1 Hz, 2 H), 3.72 (s, 6 H), 3.79 (s, 3 H), 4.22 (s, 1 H), 5.14 (sept, *J*= 6.3 Hz, 1 H), 6.08 (t, J= 7.2 Hz, 1 H). Under Condition B, **17** (176 mg, 0.40 mmol) gave **19** after 50 h at 65 °C in 28% NMR yield along with a 57% of 2,5,5-tris(methoxycarbonyl)-2-tridecen-8-yn-1-ol (**20b**): ^1H NMR δ 0.8-1.0 (m, 3 H), 1.2-1.6 (m, 4 H), 2.0-2.2 (m, 6 H), 2.43 (bs, 1 H), 3.16 (d, J= 6.8 Hz, 2 H), 3.72 (s, 6 H), 3.79 (s, 3 H), 4.24 (s, 1 H), 6.13 (t, J= 7.2 Hz, 1 H) ; ^{13}C NMR δ 13.62, 14.33, 18.44, 21.96, 31.05, 32.52, 32.94, 51.67, 52.64, 56.93, 64.67, 78.36, 81.05, 133.64, 138.03, 166.91, 171.02. Under Condition A where DMF was used in place of *i*-PrOH, **17** (156 mg, 0.35 mmol) gave **19** after 36 h at 70 °C in 11% NMR yield along with polymeric materials.

"Dumbbell"-mode Cyclic Carbopalladation-Carbonylative Lactamization and Lactonization Cascades (a) Carbonylation of 18. Under Condition A, **18** (120 mg, 0.30 mmol) gave after 30 h at 75 °C *N*-acetyl-4-(*n*-butyl)-6,6-bis(methoxycarbonyl)-5,6,7,8-tetrahydro-1*H*-cyclohepta[c]pyridin-3-one (**21**) in 43% NMR yield along with a 30% of a premature trapping product, presumably (*Z*)-1-acetamido-2,5,5-tris(methoxycarbonyl)-2-tridecen-8-yne. Thick layer chromatography (Et_2O) afforded 31 mg (39%) of **21**: ^1H NMR δ 0.85-1.0 (m, 3 H), 1.3-1.45 (m, 4 H), 2.2-2.35 (m, 2 H), 2.35-2.5 (m, 2 H), 2.54 (s, 3 H), 2.65-2.80 (m, 4 H), 3.72 (s, 6 H), 4.30 (s, 2 H), 5.90 (t, *J*= 2.4 Hz, 1 H), ; ^{13}C NMR δ 13.95, 23.03, 26.15, 26.54, 27.52, 29.94, 30.11, 31.32, 48.32, 52.87, 56.77, 127.07, 133.05, 133.32, 149.09, 165.26, 171.70,172.86.

(b) Carbonylation of 22a. Under Condition B, **22a** (142 mg, 0.29 mmol) gave after 24 h at 65 °C methyl 2-(2'-(*n*-butyl)-5',5'-bis(methoxycarbonyl)-2'-cyclohexenylidene)-5-acetamidopentanoate (**24a**) in a 65% NMR yield along with a 17% yield of **23a**. **24a**: ^1H NMR δ 0.85 (t, *J*= 7.3 Hz, 3 H), 1.2-1.4 (m, 4 H), 1.6-1.8 (m, 2 H), 2.3-2.45 (m, 2 H), 2.87 (s, 2 H), 3.29 (q, *J*= 6.4 Hz, 2 H), 3.72 (s, 3 H), 3.76 (s, 6 H), 5.6-5.65 (m, 1 H), 6.2-6.3 (m, 1 H); ^{13}C NMR δ 13.91, 22.38, 23.29, 28.30, 28.47, 31.45, 31.55, 33.62, 34.04, 38.72, 51.97, 52.89, 54.19, 125.57, 128.96, 134.66, 138.03, 170.24, 171.32, 172.35; IR(neat) 3300 (bs), 1736 (s), 1654 (s) cm^{-1}; High resolution MS calcd for $C_{22}H_{33}NO_7$ 423.2279, found 423.2270.

(c) Carbonylation of 22b. Under Condition B, **22b** (79 mg, 0.15 mmol) gave after 12 h at 75 °C (*Z*)-*N*-benzyl-2-(2'-(*n*-butyl)-5',5'-bis(methoxycarbonyl)-2'-cyclohexenylidene)-5-pentanelactam (**23b**) in 43 % NMR yield. Chromatography on silica gel (90/10 Et_2O-*n*-pentane) afforded 26.0 mg (40%) of **23b**: ^1H NMR δ 0.82 (t, *J*= 7.0 Hz, 3 H), 1.1-1.3 (m, 4 H), 1.81 (pent, *J*= 6.2 Hz, 2 H), 2.2-2.35 (m, 2 H), 2.55 (t, *J*= 6.8 Hz, 2 H), 2.69 (t, *J*= 4.5 Hz, 2 H), 2.87 (s, 2 H), 3.2-3.3 (m, 2 H), 3.71 (s, 6 H), 4.62 (s, 2 H), 5.68 (t, *J*= 4.5 Hz, 1 H), 7.2-7.4 (m, 5 H); ^{13}C NMR δ 14.02, 22.46, 23.47, 26.46, 31.09, 32.15, 34.44, 35.88, 46.28, 50.14, 52.74, 54.23, 124.81, 127.24,

127.51, 128.17, 128.45, 137.52, 137.74, 141.71, 166.89, 171.63 ; IR(neat) 1664 (s) cm^{-1}; High resolution MS calcd for $C_{26}H_{33}NO_5$ 439.2359 found, 439.2368.

(d) Carbonylation of 26. Under Condition A, **26** (112 mg, 0.25 mmol) gave after 20 h at 80 °C 2-(2'-(*n*-butyl)-5',5'-bis(methoxycarbonyl)-2'-cyclohexenylidene)-5-pentanolide (**27**) in 74% NMR yield as a 73/27 mixture of the *E* and *Z* isomers. Chromatography on silica gel afforded 63 mg (72%) of **27** as a 73/27 mixture of *E*- and *Z*-isomer: ***E*-27**: ^1H NMR δ 0.86 (t, *J*= 7.0 Hz, 3 H), 1.1-1.4 (m, 4 H), 1.8-2.0 (m, 2 H), 2.25-2.35 (m, 2 H), 2.5-2.8 (m, 4 H), 3.24 (s, 2 H), 3.70 (s, 6 H), 4.13 (t, *J*= 7.3 Hz, 2 H), 5.75-5.85 (m, 1 H); ^{13}C NMR δ 14.01, 22.52, 23.59, 26.52, 31.24, 31.68, 35.32, 35.98, 52.83, 54.55, 67.13, 125.01, 129.33, 139.03, 143.84, 168.51, 171.51; IR(neat) 1736 (s) cm^{-1}; High resolution MS calcd for $C_{19}H_{26}O_6$ 350.1729, found 350.1736; ***Z*-27**: ^1H NMR δ 0.84 (t, *J*= 7.0 Hz, 3 H), 1.1-1.4 (m, 4 H), 1.9-2.05 (m, 2 H), 2.2-2.3 (m, 2 H), 2.5-2.8 (m, 4 H), 2.88 (s, 2 H), 3.72 (s, 6 H), 4.21 (t, *J*= 5.3 Hz, 2 H), 5.75-5.85 (m, 1 H); ^{13}C NMR δ 14.01, 22.42, 23.42, 25.13, 31.30, 31.84, 34.01, 35.18, 53.01, 53.94, 67.25, 122.80, 127.52, 140.09, 143.23, 168.72, 171.33.

(e) Carbonylation of 29b. Under Condition B, **29b** (19 mg, 0.056 mmol) yielded 1.8 mg (16 %) of (*Z*)-2-(1'-indanylidene)-4-butanelactam (**30a**): ^1H NMR δ 2.65-2.8 (m, 2 H), 2.85-3.0 (m, 3 H), 3.0-3.1 (m, 2 H), 3.53 (t, *J* = 7.5 Hz, 2 H), 5.65 (bs, 1 H), 7.2-7.4 (m, 3 H), 9.2-9.3 (m, 1 H). ^{13}C NMR δ 29.5, 29.6, 33.6, 39.7, 110,0, 112.2, 118.8, 121,8, 124.8, 126.6, 129.2, 138.4, 171.00; IR (neat) 1720, 1666, 1622 cm^{-1}; High resolution MS calcd for $C_{13}H_{13}NO$ 199.0997, found 199.1003. Under Condition B except that a mixture of acetonitrile (1 mL) and MeOH (4 equiv) was used in place of pure methanol, **29b** (26 mg, 0.076 mmol) gave, after 10 h at 100 °C, 3.6 mg (20 %) of 2-(1'-indanylidene)-4-butanelactam (**30b**): ^1H NMR δ 2.65 (s, 3 H), 2.72-2.9 (m, 4 H), 3.05-3.2 (m, 2 H), 3.90 (t, *J* = 8.0 Hz, 2 H), 7.2-7.5 (m, 3H), 9.15 (d, *J* = 7.3 Hz, 1H). This compound isomerized to a 78:22 mixture of its *E* and *Z* isomer in $CDCl_3$ after 1 week at room temperature. *Z*-isomer: ^1H NMR δ 2.60 (s, 3 H), 3.05-3.2 (m, 2 H), 3.38-3.5 (m, 2 H), 3.8-4.0 (m, 2 H), 7.2-7.5 (m, 3 H), 7.6 (d, J = 7.2 Hz, 1 H); ^{13}C NMR (*Z* + *E*) δ 23.64, 24.93, 25.12, 25.22, 29.77, 30.81, 31.08, 34.37, 41.92, 42.21, 121.99, 124.96, 125.73, 126.76, 126.80, 129.12, 130.35, 130.60, 137.97, 150.67, 156.28, 167.29, 172.25; IR (paraffin oil) 1698, 1680, 1616, 1594cm^{-1}; High resolution MS calcd for $C_{15}H_{15}NO_2$ 241.1103, found 241.1113.

(f) Carbonylation of 29a. Under condition A or B, **29a** did not yield **30a**. The products were apparently polymeric.

(g) Carbonylation of 28. Using Condition A, **28** (150 mg, 0.5 mmol) gave after 4 h at 80 °C 2-(1'-indanylidene)-4-butanolide (**31**) in a 43% NMR yield as a 2:1 mixture. Chromatography on silica gel (5/1 hexane-ethyl acetate) afforded 50 mg (43 %) of **31** as a 2:1 mixture of stereoisomers. ***E*-31**: ^1H NMR δ 3.0-3.15 (m, 2 H), 3.2-3.3 (m, 2 H), 3.3-3.45 (m, 2H), 4.35-4.5 (m, 2 H), 7.2-7.7 (m, 3 H), 7.8 (d, *J*= 7.8 Hz, 1 H); ^{13}C NMR δ 27.99, 30.43, 30.69, 65.04, 113.55, 125.15, 125.56, 126.65, 130.30, 131.77, 150.95, 155.47, 176.30; IR (neat) 1772, 1720, 1636 cm^{-1}; High resolution MS calcd for $C_{13}H_{12}O_2$ 200.0837, found 200.0843. ***Z*-31**: ^1H NMR δ 2.3-2.5 (m, 6 H), 4.35-4.5 (m, 2 H), 7.2-7.7 (m, 3 H), 9.15 (d, *J*= 7.8 Hz, 1 H).

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