Synthesis of 3-Acylpyrroles, 3-(Alkoxycarbonyl)pyrroles, 1,5,6,7-Tetrahydro-4*H*-indol-4-ones and 3-Benzoylpyridines Based on Staudinger–Aza-Wittig Reactions of 1,3-Dicarbonyl Compounds with 2- and 3-Azido-1,1-dialkoxyalkanes

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Abstract: The Staudinger–aza-Wittig reaction of 1,3-dicarbonyl compounds with 2-azido-1,1-diethoxyethane and subsequent cyclization allowed an efficient synthesis of a variety of pyrroles, 1,5,6,7-tetrahydro-4*H*-indol-4-ones, and of a pyridine.

Key words: cyclization, N-heterocycles, pyrroles, azides

Pyrroles, indoles and pyridines are present in many pharmacologically active natural products. This includes, for example, the antibiotic pyrrolnitrin, the pyrrolomycins, various tetrapyrrole pigments (e.g., bilirubin), and various other natural products and their analogues.[1,2] Pentasubstituted pyrroles are potent hypocholesterolemic agents which act by inhibition of HMG-CoA reductase – a key enzyme in the biosynthesis of cholesterol.[1i] For example, atorvastatin is used today in the clinic for the treatment of hyperlipidemias.[1i] Pyrroles have also found many other applications in medicinal chemistry. For example, the synthetic pyrrole zomepirac has been used in the clinic as an analgetic and antiphlogistic agent.[1]

Most pyrrole syntheses rely on classical condensation reactions, such as the Hantzsch reaction (condensation of α-haloketones with 1,3-dicarbonyl compounds and amines), the Paal–Knorr reaction (cyclocondensation of 1,4-diketones with amines) or the Knorr reaction (cyclocondensation of α-aminoketones with β-keto esters). In addition, various other synthetic approaches have been developed.[3,4] Intramolecular aza-Wittig reactions[5] provide a versatile approach to pyrroles under mild conditions.[6] Recently, we have reported that functionalized pyrroles can be prepared by reaction of α-azidoketones with 1,3-dicarbonyl dianions and subsequent *intra*molecular Staudinger–aza-Wittig reaction.[7] Pyrroles are also available by Lewis acid catalyzed condensation of 2-azido-1,1-dimethoxyethane with silyl enol ethers or 1,3-bis(silyloxy)-1,3-butadienes and subsequent *intra*molecular Staudinger–aza-Wittig reaction.[8] Recently, we have reported a convenient and versatile approach to pyrroles by *inter*molecular Staudinger–aza-Wittig reaction of 2-azido-1,1-diethoxyethane with 1,3-dicarbonyl compounds and subsequent cyclization.[9] Herein, we report full details related to the scope of this method. With regard to our preliminary communication,[9] the scope was considerably extended. In addition, the strategy could be successfully applied to the synthesis of a functionalized pyridine. All reactions proceed with very good chemo- and regioselectivity under mild conditions and complement known reactions of 2-amino-1,1-dialkoxyethanes.[10]

2-Azido-1,1-diethoxyethane (**2a**) and 2-azido-1,1-dimethoxyethane (**2b**) were prepared by reaction of sodium azide with 2-bromo-1,1-diethoxyethane and 2-bromo-1,1-dimethoxyethane, respectively.[8,11] The aza-Wittig reaction of **2a** with methyl acetoacetate (**1a**) afforded enamine **3a** (Scheme 1, Tables 1 and 2). Related enamines, prepared from 2-amino-1,1-dimethoxyethane, have been used for the synthesis of isoquinolines.[10b]

Optimal results were obtained when the reaction was carried out using a small excess of **2** (1.2 equiv) and of Ph_3P (1.3 equiv) (THF, reflux, 8 h). The transformation of **3a** into the desired pyrrole **4a** required a thorough optimization of the conditions (Table 1). Treatment of a CH_2Cl_2 solution of **3a**, prepared from methyl acetoacetate (**1a**), with TFA at 0–20 °C afforded **4a** in 22% yield (method A). The yield was increased to 35% by treatment of **3a** in CH_2Cl_2 with Me_3SiOTf at –78 to 20 °C (method B). Heating of **3a** in DMSO at 150 °C for 24 h afforded **4a** in 40% yield (method C); pyrrole **4a′** was isolated as a side-product in 19% yield (Figure 1). The use of other solvents than DMSO (e.g., THF, MeCN or 1,4-dioxane) proved to be unsuccessful.

Products **3a**–**z** were prepared by reaction of **1a**–**w** with 2-azido-1,1-diethoxyethane (**2a**) and 2-azido-1,1-dimethoxyethane (**2b**) in 50–98% yields (Table 2). Most yields were above 80%. Pyrroles **4a**–**t** were successfully prepared from **3a**–**z** using methods A, B, or C in 22–82% optimized yields. Methods B and C were successfully employed for the synthesis of ester-substituted pyrroles (**4a**–**n**). It is worth to be mentioned that pyrroles **4i** and **4k** were independently prepared from **2a** and **2b**. The yields of the condensation steps (to give enamines **3k**,**l** and **3o**,**p**)

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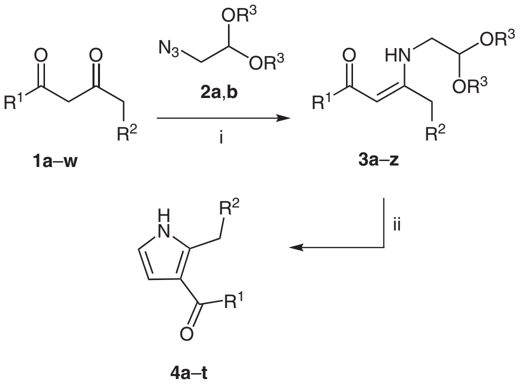
were quite similar. Likewise, the yields of the cyclization steps (to give pyrroles **4i** and **4k**) were again in the same range (method B). These experiments show that equally successful results are obtained starting with azides **2a** and **2b**. The reaction of **2a** with acetylacetone (**1s**) afforded 4-(2,2-diethoxyethylamino)pent-3-en-2-one (**3v**) which was transformed into pyrrole **4o** (68%) by method A. It is noteworthy that the Staudinger–aza-Wittig reaction of unsymmetrical 1,3-diketones **1u–w** proceeded with very good regioselectivity. The cyclization generally occurred via the central carbon atom of the 1,3-dicarbonyl unit.



Scheme 1 Synthesis of **3a–z** and **4a–t**; *Reagents and conditions*: i: Ph_3P, THF, reflux, 8 h; ii: see Table 1 and 2. Method A: TFA (10 equiv), CH_2Cl_2, 0–20 °C, 12 h; method B: Me_3SiOTf (1 equiv), CH_2Cl_2, –78 to 20 °C (for β-keto esters) or 0–20 °C (for 1,3-diketones), 12 h; method C: DMSO, 150 °C, 24 h.

Table 1 Optimization for the Synthesis of Pyrroles **4a** and **4r**

3	4	Solvent	Time (h)	Conditions	Yield (%)[a]
a	**a**	CH_2Cl_2	12	TFA, 20 °C	0
a	**a**	CH_2Cl_2	12	TFA, 0–20 °C	22
a	**a**	CH_2Cl_2	12	Me_3SiOTf, –78 to 20 °C	35
a	**a**	DMSO	24	150 °C	40[b]
x	**r**	CH_2Cl_2	12	TFA, 0–20 °C	82
x	**r**	CH_2Cl_2	12	Me_3SiOTf, 0–20 °C	79
x	**r**	DMSO	24	150 °C	72

[a] Yields of isolated products.

[b] Besides, **4a′** was formed, see footnote in Table 2.

The application of method C gave **4o** in 60% yield; besides, a small amount of pyrrole **4o′** was isolated (5%). The cyclization of **3w**, derived from heptane-3,5-dione (**1t**), gave **4p** in good yield when method A was applied. The TFA-mediated cyclization of **3x**, prepared from benzoylacetone (**1u**), afforded the 3-benzoylpyrrole **4r** in 82% yield (method A). The use of Me_3SiOTf (0–20 °C, method B) and heating of **3m** in DMSO (method C) also proved to be successful (Table 2, footnote e). However,

Table 2 Yields of Condensation Products (**3**) and Pyrroles (**4**)

1	3	4	R1	R2	R3	Yield (%) (**3**)[a]	Yield (%) (**4**)[a]	Cond.[e]
a	**a**	**a**	OMe	H	Et	86	22 35 40[b]	A B C
b	**b**	**b**	OEt	H	Et	89	58	C
c	**c**	**c**	O*i*-Pr	H	Et	87	50	B
d	**d**	**d**	O*i*-Bu	H	Et	88	42	B
e	**e**	–	O*t*-Bu	H	Et	62	–[d]	–
f	**f**	**e**	$O(CH_2)_2OMe$	H	Et	89	51	C
g	**g**	**f**	OAllyl	H	Et	90	37	B
h	**h**	**g**	OMe	Me	Et	82	39	B
i	**i**	**h**	OEt	Et	Et	75	55	B
j	**j**	–	O*t*-Bu	Pr	Et	78	–[d]	–
k	**k**	**i**	OEt	*n*-C_6H_{13}	Me	89	60	B
k	**l**	**i**	OEt	*n*-C_6H_{13}	Et	84	58	B
l	**m**	**j**	OEt	*n*-C_8H_{17}	Et	86	57	B
m	**n**	–	O*t*-Bu	*n*-C_8H_{17}	Et	88	–[d]	–
n	**o**	**k**	OEt	*n*-C_9H_{19}	Me	86[b]	57	B
n	**p**	**k**	OEt	*n*-C_9H_{19}	Et	91	54	B
o	**q**	**l**	OEt	*n*-$C_{10}H_{21}$	Me	90[b]	57	B
o	**r**	**l**	OEt	*n*-$C_{10}H_{21}$	Et	91	56	B
p	**s**	–	OEt	$(CH_2)_3Cl$	Et	83	–[d]	–
q	**t**	**m**	OEt	$(CH_2)_5Cl$	Et	81	41	B
r	**u**	**n**	OEt	$(CH_2)_6Cl$	Et	83	47	B
s	**v**	**o**	Me	H	Et	98	68 60[c]	A C
t	**w**	**p**	Et	Me	Et	98	70	A
u	**x**	**r**	Ph	H	Et	97	82 79 72	A B C
v	**y**	**s**	2-$MeOC_6H_4$	H	Me	50	79	B
w	**z**	**t**	2-ClC_6H_4	H	Me	53	63	B

[a] Yields of isolated products.

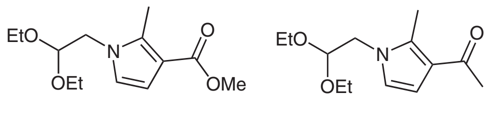
[b] Besides, **4a′** was isolated in 19% yield (Figure 1).

[c] Besides, **4o′** was isolated in 5% yield (Figure 1).

[d] Failed.

[e] Conditions: method A: TFA (10 equiv), CH_2Cl_2, 0–20 °C, 12 h; method B: Me_3SiOTf (1 equiv), CH_2Cl_2, –78 to 20 °C (for β-keto esters) or 0–20 °C (for 1,3-diketones), 12 h; method C: DMSO, 150 °C, 24 h.

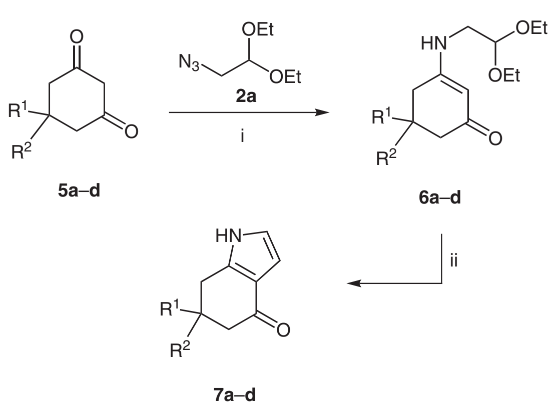
slightly lower yields were obtained. Pyrroles **4s** and **4t** were prepared in good yields starting from substituted benzophenones **1v** and **1w**, respectively. Method B seems to be the most general procedure to induce the cyclization step. For aliphatic 1,3-diketones (**1s**,**t**) the application of method A gave best results. For benzoylacetone derivatives (**1u**–**w**) all three methods gave satisfactory results.



4a' **4o'**

Figure 1 Structures of **4a′** and **4o′**

Enamines **6a**–**d** were prepared by reaction of **2a** with cyclohexane-1,3-diones **5a**–**d** (Scheme 2, Table 3). Treatment of **6a**–**d** with TFA afforded 6,7-dihydro-1*H*-indol-4(5*H*)-ones **7a**–**d** in very good yields (method A). Compound **7a**[12] was also successfully prepared, albeit in lower yield, by application of method C.



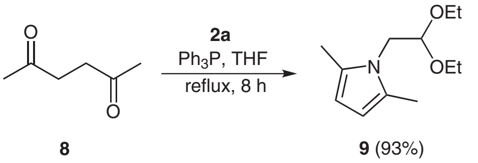
Scheme 2 Synthesis of 1,5,6,7-tetrahydro-4*H*-indol-4-ones **7a**–**d**; *Reagents and conditions*: i: Ph_3P, THF, reflux, 8 h; ii: method A: TFA (10 equiv), CH_2Cl_2, 0–20 °C, 12 h; method C: DMSO, 150 °C, 24 h.

Table 3 Yields of Enamines **6** and 1,5,6,7-Tetrahydro-4*H*-indol-4-ones **7**

6, **7**	R^1	R^2	Yield (%) (**6**)^a	Yield (%) (**7**)^a	Method
a	H	H	97	95 71	A C
b	Me	Me	92	60	A
c	Me	H	94	75	A
d	Ph	H	92	73	A

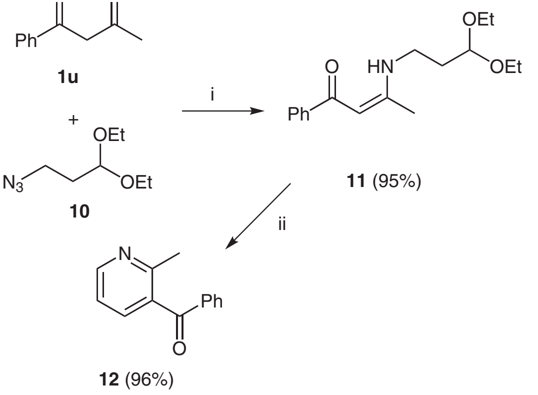
[a] Yields of isolated products.

The Ph_3P-mediated reaction of hexane-2,5-dione (**8**) with **2a** afforded pyrrole **9** in excellent yield by Staudinger–aza-Wittig reaction and subsequent cyclization (Scheme 3).



Scheme 3 Synthesis of 1-(2,2-diethoxyethyl)-2,5-dimethyl-1*H*-pyrrole (**9**)

The Ph_3P-mediated reaction of benzoylacetone (**1u**) with 1,1-diethoxy-3-azido-propane (**10**), available by reaction of 1-chloro-3,3-diethoxypropane with sodium azide, gave product **11**. The TFA-mediated cyclization of the latter afforded pyridine **12** in excellent yield (Scheme 4).



Scheme 4 Synthesis of **12**; *Reagents and conditions*: i: Ph_3P, THF, reflux, 8 h; ii: TFA (10 equiv), CH_2Cl_2, 0–20 °C, 12 h.

In conclusion, a variety of pyrroles and 1,5,6,7-tetrahydro-4*H*-indol-4-ones were prepared by condensation of 1,3-dicarbonyl compounds with 2-azido-1,1-diethoxyethane and subsequent cyclization. The best conditions for the cyclization step (acid, Lewis acid or heating) depend on the substitution pattern of the intermediate. The strategy could be successfully applied to the synthesis of a functionalized pyridine.

All moisture-free solvents (>99.9 grade) were used as purchased and all reactions were carried out under Argon atmosphere. For ^1H and ^{13}C NMR spectra the deuterated solvents indicated were used. Mass spectrometric data (MS) were obtained by electron ionization (EI, 70 eV), chemical ionization (CI, H_2O) or electrospray ionization (ESI). For preparative scale chromatography, silica gel (60–200 mesh) was used. Melting points are uncorrected.

CAUTION: The handling of low-molecular weight azides is dangerous due to their potentially explosive character. Although, in our hands, neat **2a**,**b** and **8** did not appear to be shock-sensitive, the compounds should be handled with great care. Neat azides must not be heated or distilled and all reactions should be carried out on small scale. The use of a safety shield is highly recommended.

2-Azido-1,1-diethoxyethane (2a)

Starting with 2-bromo-1,1-diethoxyethane (31 mL, 200 mmol), sodium azide (19.50 g, 300 mmol) and potassium iodide (3.32 g, 20 mmol) in DMSO (150 mL), **2b** was isolated without further purification as a colorless oil (30.629 g, 96%).

IR (neat): 2980 (s), 2932 (m), 2884 (m), 2104 (s, N_3), 1479 (w), 1446 (w), 1376 (w), 1348 (w), 1273 (s), 1233 (w), 1130 (s), 1067 (s), 946 (w), 921 (w), 844 cm^{-1} (w).

^1H NMR ($CDCl_3$, 300 MHz): δ = 1.25 (t, J = 7.2 Hz, 6 H, 2 × CH_3), 3.25 (d, J = 5.4 Hz, 2 H, CH_2N_3), 3.54–3.64 (m, 2 H, OCH_2), 3.68–3.78 (m, 2 H, OCH_2), 4.61 (t, J = 5.4 Hz, 1 H, OCH).

^{13}C NMR ($CDCl_3$, 75 MHz): δ = 15.0 (2 C, CH_3), 52.2 (CH_2N_3), 62.7 (2 C, OCH_2), 101.21 (OCH).

MS (EI, 70 eV): m/z (%) = 160 (M^+, 100), 145 (31), 114 (17), 91 (24).

2-Azido-1,1-dimethoxyethane (2b)

Sodium azide (19.503 g, 300 mmol) and potassium iodide (3.32 g, 20 mmol) were added to 1-bromo-2,2-dimethoxyethane (824 mL, 200 mmol) in DMSO (140 mL) at r.t. The reaction mixture was heated to 90 °C and stirred for 5 d at 90 °C. After cooling to r.t., H_2O (200 mL) and Et_2O (200 mL) were added, the organic layer was separated and the aqueous layer was repeatedly extracted with Et_2O (4 × 200 mL). The combined organic extracts were dried over Na_2SO_4, filtered, and the filtrate was concentrated to dryness in vacuo. Product **2a** was isolated without further purification as a slightly yellow oil (22.31 g, 85%).

IR (neat): 2995 (w), 2939 (m), 2837 (w, C–H), 2102 (s, N_3), 1444 (m), 1311 (w), 1275 (s), 1196 (m), 1129 (s), 1089 (s), 1064 (s), 1035 (m), 979 (w), 922 cm^{-1} (w).

^1H NMR ($CDCl_3$, 300 MHz): δ = 3.27 (d, J = 5.3 Hz, 2 H, CH_2N_3), 3.43 (s, 6 H, 2 × OCH_3), 4.48 (t, J = 5.3 Hz, 1 H, CH).

^{13}C NMR ($CDCl_3$, 75 MHz): δ = 51.66 (CH_2N_3), 54.25 (2 C, OCH_3), 103.08 (CH).

MS (EI, 70 eV): m/z (%) = 75 ($[M - CH_2N_3]^+$, 100).

Synthesis of Enamines 3; Typical Procedure

Synthesis of 3-[(2,2-Diethoxyethyl)amino]-1-phenylbut-2-en-1-one (3x)

To benzoylacetone (0.200 g, 1.2 mmol) and 2-azido-1,1-diethoxyethane (**2**) (0.236 g, 1.5 mmol) in THF (10 mL) was added Ph_3P (0.656 g, 2.5 mmol) at 20 °C. The reaction mixture was heated and stirred for 8 h at reflux. After cooling to 20 °C, the solvent was removed in vacuo and the residue was purified by column chromatography (silica gel, n-hexane–EtOAc, 100:1 → 1:1) to give **3x** as a lightly yellow oil (0.322 g, 97%).

Methyl 3-[(2,2-Diethoxyethyl)amino]but-2-enoate (3a)

Starting with methyl acetoacetate (**1a**) (0.19 mL, 1.72 mmol), 2-azido-1,1-diethoxyethane (**2a**) (0.329 g, 2.1 mmol) and Ph_3P (0.677 g, 2.6 mmol) in THF (10 mL), **3a** was isolated after chromatography (silica gel, n-hexane–EtOAc, 100:1 → 1:1) as a colorless oil (0.333 g, 86%).

IR (neat): 3291 (w), 2978 (m), 2884 (w), 1658 (s), 1608 (s), 1504 (m), 1443 (m), 1382 (m), 1352 (w), 1291 (s), 1239 (s), 1177 (s), 1136 (s), 1058 (s), 787 (m), 703 cm^{-1} (w).

^1H NMR ($CDCl_3$, 300 MHz): δ = 1.23 (t, J = 7.2 Hz, 6 H, 2 × CH_3), 1.94 (s, 3 H, CH_3), 3.33 (dd, J = 6.3, 5.4 Hz, 2 H, NCH_2), 3.51–3.61 (m, 2 H, OCH_2), 3.62 (s, 3 H, OCH_3), 3.68–3.76 (m, 2 H, OCH_2), 4.48 (d, J = 2.7 Hz, 1 H, CH=C), 4.51 (d, J = 5.4 Hz, 1 H, OCH), 8.61 (br s, 1 H, NH).

^{13}C NMR ($CDCl_3$, 75 MHz): δ = 15.2 (2 C), 19.6 (CH_3), 46.0 (NCH_2), 49.8 (OCH_3), 63.1 (2 C, OCH_2), 82.6 (*C*H=C), 102.0 (OCH), 161.6 (N–*C*=CH), 170.6 (O=C–O).

MS (EI, 70 eV): m/z (%) = 231 (M^+, 11), 200 (5), 186 (11), 140 (4), 128 (5), 103 (100), 96 (25), 84 (11), 75 (70).

Anal. Calcd for $C_{11}H_{21}NO_4$ (231.292): C, 57.12; H, 9.15. Found: C, 56.94; H, 9.23.

Ethyl 3-[(2,2-Diethoxyethyl)amino]but-2-enoate (3b)

Starting with ethyl acetoacetate (**1b**) (0.4 mL, 3.0 mmol), 2-azido-1,1-diethoxyethane (**2a**) (0.573 g, 3.6 mmol) and Ph_3P (1.180 g, 4.5 mmol) in THF (15 mL), **3b** was isolated after chromatography (silica gel, n-hexane–EtOAc, 100:1 → 5:1) as a colorless oil (0.656 g, 89%).

IR (neat): 3289 (w), 2980 (s), 2932 (m), 2898 (m), 1741 (m), 1725 (m), 1656 (s), 1609 (s), 1502 (m), 1447 (s), 1381 (m), 1288 (s), 1240 (s), 1176 (s), 1136 (s), 1061 (s), 975 (w), 935 (w), 849 (w), 791 (s), 706 cm^{-1} (w).

^1H NMR ($CDCl_3$, 300 MHz): δ = 1.23 (t, J = 7.2 Hz, 6 H, 2 × CH_3), 1.25 (t, J = 7.2 Hz, 3 H, CH_3), 1.94 (s, 3 H, CH_3), 3.33 (dd, J = 6.3, 5.4 Hz, 2 H, NCH_2), 3.51–3.61 (m, 2 H, OCH_2), 3.68–3.78 (m, 2 H, OCH_2), 4.09 (q, J = 7.2 Hz, 2 H, OCH_2), 4.47 (s, 1 H, CH), 4.50 (t, J = 5.4 Hz, 1 H, OCH), 8.61 (br s, 1 H, NH).

^{13}C NMR ($CDCl_3$, 75 MHz): δ = 13.9, 14.6 (2 C), 18.8 (CH_3), 45.2 (NCH_2), 57.3, 62.3 (2C, OCH), 82.4 (*C*H=C), 101.3 (OCH), 160.7 (N–*C*=CH), 169.5 (O=C–O).

MS (EI, 70 eV): m/z (%) = 245 (M^+, 14), 200 (21), 154 (6), 126 (7), 103 (100), 96 (34), 88 (12), 75 (64).

HRMS (ESI): m/z calcd for $C_{12}H_{23}NO_4$ [M^+]: 245.16271; found: 245.16282.

Isopropyl 3-[(2,2-Diethoxyethyl)amino]but-2-enoate (3c)

Starting with isopropyl acetoacetate (**1c**) (0.44 mL, 3.0 mmol), 2-azido-1,1-diethoxyethane (**2a**) (0.573 g, 3.6 mmol) and Ph_3P (1.180 g, 4.5 mmol) in THF (15 mL), **3c** was isolated after chromatography (silica gel, n-hexane–EtOAc, 100:1 → 3:1) as a colorless oil (0.673 g, 87%).

IR (neat): 3288 (w), 2980 (s), 2932 (s), 2882 (m), 1651 (s), 1608 (s), 1502 (m), 1451 (s), 1377 (s), 1284 (s), 1241 (s), 1176 (s), 1140 (s), 1113 (s), 1067 (s), 993 (m), 948 (w), 790 (m), 705 cm^{-1} (w).

^1H NMR ($CDCl_3$, 300 MHz): δ = 1.21 (d, J = 6.0 Hz, 6 H, 2 × CH_3), 1.25 (t, J = 7.2 Hz, 6 H, 2 × CH_3), 1.93 (s, 3 H, CH_3), 3.33 (dd, J = 6.3, 5.7 Hz, 2 H, NCH_2), 3.51–3.61 (m, 2 H, OCH_2), 3.68–3.78 (m, 2 H, OCH_2), 4.44 (s, 1 H, CH=C), 4.50 (t, J = 5.7 Hz, 1 H, OCH), 4.99 (sept, J = 6.0 Hz, 1 H, OCH), 8.63 (br s, 1 H, NH).

^{13}C NMR ($CDCl_3$, 75 MHz): δ = 14.8 (2 C), 19.1, 21.7 (2 C, CH_3), 45.5 (NCH_2), 62.6 (2 C, OCH_2), 64.3 (OCH), 83.2 (*C*H=C), 101.6 (OCH), 160.8 (N–*C*=CH), 169.4 (O=C–O).

MS (EI, 70 eV): m/z (%) = 259 (M^+, 7), 214 (6), 200 (9), 172 (3), 154 (3), 126 (8), 113 (13), 103 (100), 96 (31), 85 (16), 75 (65).

HRMS (ESI): m/z calcd for $C_{13}H_{25}NO_4$ [M^+]: 259.17836; found: 259.17861.

Isobutyl 3-[(2,2-Diethoxyethyl)amino]but-2-enoate (3d)

Starting with *iso*butyl acetoacetate (**1d**) (0.48 mL, 3.0 mmol), 2-azido-1,1-diethoxyethane (**2a**) (0.573 g, 3.6 mmol) and Ph_3P (1.180 g, 4.5 mmol) in THF (15 mL), **3d** was isolated after chromatography (silica gel, n-hexane–EtOAc, 100:1 → 5:1) as a colorless oil (0.723 g, 88%).

IR (neat): 3289 (w), 2970 (m), 2933 (m), 2880 (m), 1725 (m), 1655 (s), 1609 (s), 1542 (w), 1501 (m), 1449 (s), 1381 (m), 1285 (s), 1239 (s), 1173 (s), 1135 (s), 1057 (s), 967 (w), 937 (w), 790 (m), 704 cm^{-1} (w).

^1H NMR ($CDCl_3$, 300 MHz): δ = 0.92 (d, J = 6.9 Hz, 6 H, 2 × CH_3), 1.22 (t, J = 7.2 Hz, 6 H, 2 × CH_3), 1.92 (m, J = 6.9 Hz, 1 H, CH), 1.94 (s, 3 H, CH_3), 3.32 (dd, J = 6.0, 5.7 Hz, 2 H, NCH_2), 3.50–3.60 (m, 2 H, OCH_2), 3.70–3.79 (m, 2 H, OCH_2), 3.80 (d, J = 6.9 Hz, 2 H, OCH_2), 4.48 (s, 1 H, CH), 4.50 (t, J = 5.7 Hz, 1 H, OCH), 8.61 (br s, 1 H, NH).

^{13}C NMR ($CDCl_3$, 75 MHz): δ = 14.9 (2 C), 18.8 (2 C), 19.1 (CH_3), 27.6 (CH), 45.6 (NCH_2), 62.7 (2C), 68.2 (OCH_2), 82.7 (*C*H=C), 101.6 (OCH), 161.0 (N–*C*=CH), 170.0 (O=C–O).

MS (EI, 70 eV): *m*/*z* (%) = 273 (M^+, 6), 228 (4), 200 (5), 126 (3), 113 (5), 103 (100), 96 (11), 85 (16), 75 (44).

HRMS (ESI): *m*/*z* calcd for $C_{14}H_{27}NO_4$ [M^+]: 273.19401; found: 273.19403.

tert-Butyl 3-[(2,2-Diethoxyethyl)amino]but-2-enoate (3e)

Starting with *tert*-butyl acetoacetate (**1e**) (0.33 mL, 2.0 mmol), 2-azido-1,1-diethoxyethane (**2a**) (0.382 g, 2.4 mmol) and Ph_3P (0.787 g, 3.0 mmol) in THF (10 mL), **3e** was isolated after chromatography (silica gel, *n*-hexane–EtOAc, 100:1 → 5:1) as a colorless oil (0.341 g, 62%).

IR (neat): 2976 (w), 2927 (w), 1722 (w), 1651 (s), 1610 (s), 1498 (w), 1449 (w), 1369 (w), 1292 (m), 1244 (m), 1141 (s), 1068 (m), 986 (w), 791 cm^{-1} (w).

^{1}H NMR ($CDCl_3$, 300 MHz): δ = 1.25 (t, *J* = 7.2 Hz, 6 H, 2 × CH_3), 1.47 (s, 9 H, *t*-Bu), 1.91 (s, 3 H, CH_3), 3.30 (dd, *J* = 6.6, 5.7 Hz, 2 H, NCH_2), 3.50–3.60 (m, 2 H, OCH_2), 3.68–3.78 (m, 2 H, OCH_2), 4.40 (s, 1 H, CH), 4.49 (t, *J* = 5.7 Hz, 1 H, OCH), 8.59 (br s, 1 H, NH).

^{13}C NMR ($CDCl_3$, 75 MHz): δ = 15.0 (2 C), 19.2, 28.3 (3 C, 3 × CH_3), 45.6 (NCH_2), 62.9 (2 C, OCH_2), 81.4 (C), 84.6 (*C*H=C), 101.9 (OCH), 160.4 (N–*C*=CH), 170.0 (O=C–O).

MS (EI, 70 eV): *m*/*z* (%) = 273 (M^+, 100), 246 (1), 229 (5), 200 (96).

HRMS (EI, 70 eV): *m*/*z* calcd for $C_{14}H_{27}NO_4$ [M^+]: 273.19400; found: 273.19415.

2-Methoxyethyl 3-[(2,2-Diethoxyethyl)amino]but-2-enoate (3f)

Starting with 2-methoxyethyl acetoacetate (**1f**) (0.495 g, 3.0 mmol), 2-azido-1,1-diethoxyethane (**2a**) (0.573 g, 3.6 mmol) and Ph_3P (1.180 g, 4.5 mmol) in THF (15 mL), **3f** was isolated after chromatography (silica gel, *n*-hexane–EtOAc, 100:1 → 3:1) as a colorless oil (0.736 g, 89%).

IR (neat): 3292 (w), 2978 (s), 2932 (s), 2885 (s), 1743 (m), 1722 (m), 1655 (s), 1603 (s), 1503 (s), 1448 (s), 1381 (s), 1290 (s), 1241 (s), 1169 (s), 1121 (s), 1064 (s), 978 (m), 938 (w), 849 (m), 787 (s), 705 (m), 554 cm^{-1} (w).

^{1}H NMR ($CDCl_3$, 300 MHz): δ = 1.24 (t, *J* = 7.2 Hz, 6 H, 2 × CH_3), 1.93 (s, 3 H, CH_3), 3.33 (dd, *J* = 6.6, 5.7 Hz, 2 H, NCH_2), 3.39 (s, 3 H, OCH_3), 3.50–3.63 (m, 4 H, 2 × OCH_2), 3.68–3.78 (m, 2 H, OCH_2), 4.18–4.21 (m, 2 H, OCH_2), 4.52 (t, *J* = 5.7 Hz, 1 H, OCH), 4.54 (s, 1 H, CH), 8.61 (br s, 1 H, NH).

^{13}C NMR ($CDCl_3$, 75 MHz): δ = 14.5 (2 C), 19.0 (CH_3), 45.4 (NCH_2), 58.3 (OCH_3), 60.9, 62.5 (2 C), 70.5 (OCH_2), 82.3 (*C*H=C), 101.4 (OCH), 161.3 (N–*C*=CH), 169.4 (O=C–O).

MS (EI, 70 eV): *m*/*z* (%) = 275 (M^+, 5), 259 (1), 230 (2), 200 (6), 154 (10), 126 (5), 103 (100), 96 (14), 75 (60).

Anal. Calcd for $C_{13}H_{25}NO_5$ (275.341): C, 56.71; H, 9.15. Found: C, 56.53; H, 9.43.

Allyl 3-[(2,2-Diethoxyethyl)amino]but-2-enoate (3g)

Starting with allyl acetoacetate (**1g**) (0.41 mL, 3.0 mmol), 2-azido-1,1-diethoxyethane (**2a**) (0.573 g, 3.6 mmol) and Ph_3P (1.180 g, 4.5 mmol) in THF (15 mL), **3g** was isolated after chromatography (silica gel, *n*-hexane–EtOAc, 100:1 → 3:1) as a colorless oil (0.695 g, 90%).

IR (neat): 3291 (w), 2978 (s), 2931 (m), 2884 (m), 1665 (s), 1606 (s), 1503 (m), 1446 (m), 1381 (m), 1359 (m), 1286 (s), 1238 (s), 1169 (s), 1130 (s), 1058 (s), 1000 (m), 931 (m), 787 (m), 705 cm^{-1} (w).

^{1}H NMR ($CDCl_3$, 300 MHz): δ = 1.23 (t, *J* = 7.2 Hz, 6 H, 2 × CH_3), 1.95 (s, 3 H, CH_3), 3.33 (dd, *J* = 6.3, 5.4 Hz, 2 H, NCH_2), 3.50–3.60 (m, 2 H, OCH_2), 3.68–3.78 (m, 2 H, OCH_2), 4.50 (t, *J* = 5.4 Hz, 1 H, OCH), 4.52 (s, 1 H, CH=C), 4.55 (dt, *J* = 5.4, 1.5 Hz, 2 H, OCH_2), 5.18 (dq, *J* = 10.5, 1.5 Hz, 1 H, C*H*$_2$=CH), 5.29 (dq, *J* = 17.4, 1.5 Hz, 1 H, C*H*$_2$=CH), 5.88–6.01 (m, 1 H, C*H*=CH_2), 8.61 (br s, 1 H, NH).

^{13}C NMR ($CDCl_3$, 75 MHz): δ = 14.7 (2 C), 19.0 (CH_3), 45.4 (NCH_2), 62.46, 62.48 (2 C, OCH_2), 82.2 (*C*H=C), 101.4 (OCH), 116.1 (*C*H$_2$=CH), 133.2 (*C*H=CH_2), 161.3 (N–*C*=CH), 169.2 (O=C–O).

MS (EI, 70 eV): *m*/*z* (%) = 257 (M^+, 6), 212 (11), 200 (5), 154 (7), 126 (4), 111 (2), 103 (100), 96 (17), 84 (100), 75 (64).

HRMS (ESI): *m*/*z* calcd for $C_{13}H_{23}NO_4$ [M^+]: 257.16271; found: 257.16325.

Methyl 3-[(2,2-Diethoxyethyl)amino]pent-2-enoate (3h)

Starting with methyl propionylacetate (**1h**) (0.38 mL, 3.0 mmol), 2-azido-1,1-diethoxyethane (**2a**) (0.573 g, 3.6 mmol) and Ph_3P (1.180 g, 4.5 mmol) in THF (15 mL), **3h** was isolated after chromatography (silica gel, *n*-hexane–EtOAc, 100:1 → 5:1) as a slightly light yellow oil (0.604 g, 82%).

IR (neat): 3288 (w), 2978 (w), 2932 (w), 1658 (s), 1606 (s), 1501 (m), 1444 (s), 1383 (m), 1324 (w), 1280 (m), 1236 (s), 1177 (s), 1136 (s), 1063 (s), 792 cm^{-1} (m).

^{1}H NMR ($CDCl_3$, 300 MHz): δ = 1.15 (t, *J* = 7.5 Hz, 3 H, CH_3), 1.23 (t, *J* = 7.2 Hz, 6 H, 2 × CH_3), 2.25 (q, *J* = 7.5 Hz, 2 H, CH_2), 3.33 (dd, *J* = 6.0, 5.7 Hz, 2 H, NCH_2), 3.54–3.64 (m, 2 H, OCH_2), 3.63 (s, 3 H, OCH_3), 3.68–3.79 (m, 2 H, OCH_2), 4.50 (s, 1 H, CH=C), 4.52 (t, *J* = 5.7 Hz, 1 H, OCH), 8.61 (br s, 1 H, NH).

^{13}C NMR ($CDCl_3$, 75 MHz): δ = 11.7, 14.8 (2 C, CH_3), 25.0 (CH_2), 44.9 (NCH_2), 49.3 (OCH_3), 62.5 (2 × OCH_2), 80.3 (*C*H=C), 101.4 (OCH), 166.1 (N–*C*=CH), 170.4 (O=C–O).

MS (EI, 70 eV): *m*/*z* (%) = 245 (M^+, 13), 214 (5), 200 (12), 142 (7), 130 (6), 109 (32), 103 (100), 75 (68).

Anal. Calcd for $C_{12}H_{23}NO_4$ (245.315): C, 58.75; H, 9.45. Found: C, 58.37; H, 9.41.

Ethyl 3-[(2,2-Diethoxyethyl)amino]hex-2-enoate (3i)

Starting with ethyl 3-oxohexanoate (**1i**) (0.500 g, 3.2 mmol), 2-azido-1,1-diethoxyethane (**2a**) (0.605 g, 3.8 mmol) and Ph_3P (1.243 g, 4.7 mmol) in THF (17 mL), **3i** was isolated after chromatography (silica gel, *n*-hexane–EtOAc, 100:1 → 10:1) as a slightly light yellow oil (0.657 g, 75%).

IR (neat): 3283 (w), 2974 (m), 2932 (w), 2878 (w), 1654 (s), 1607 (s), 1501 (w), 1452 (m), 1378 (w), 1296 (m), 1264 (m), 1234 (s), 1175 (s), 1135 (s), 1061 (s), 792 cm^{-1} (m).

^{1}H NMR ($CDCl_3$, 300 MHz): δ = 0.97 (t, *J* = 7.2 Hz, 3 H, CH_3), 1.22 (t, *J* = 7.2 Hz, 6 H, 2 × CH_3), 1.26 (t, *J* = 7.2 Hz, 3 H, CH_3), 1.55 (sext, *J* = 7.8 Hz, 2 H, CH_2), 2.17 (t, *J* = 7.8 Hz, 2 H, CH_2), 3.32 (dd, *J* = 6.0, 5.7 Hz, 2 H, NCH_2), 3.52–3.62 (m, 2 H, OCH_2), 3.68–3.78 (m, 2 H, OCH_2), 4.09 (q, *J* = 7.2 Hz, 2 H, OCH_2), 4.47 (s, 1 H, CH), 4.51 (t, *J* = 5.7 Hz, 1 H, OCH), 8.62 (br s, 1 H, NH).

^{13}C NMR ($CDCl_3$, 75 MHz): δ = 13.4, 14.2, 14.9 (2 C, CH_3), 20.8, 34.1 (CH_2), 45.2 (NCH_2), 57.8, 62.6 (2 C, OCH_2), 81.9 (*C*H=C), 101.5 (OCH), 164.6 (N–*C*=CH), 170.1 (O=C–O).

MS (EI, 70 eV): *m*/*z* (%) = 273 (M^+, 5), 228 (10), 200 (1), 182 (3), 170 (2), 154 (5), 124 (11), 109 (3), 103 (100), 96 (6), 84 (6), 75 (61).

HRMS (ESI): *m*/*z* calcd for $C_{14}H_{27}NO_4$ [M^+]: 273.19400; found: 273.19426.

tert-Butyl 3-[(2,2-Diethoxyethyl)amino]hept-2-enoate (3j)

Starting with *tert*-butyl 3-oxoheptanoate (**1j**) (0.401 g, 2.0 mmol), 2-azido-1,1-diethoxyethane (**2a**) (0.382 g, 2.4 mmol), and Ph_3P (0.787 g, 3.0 mmol) in THF (10 mL), **3j** was isolated after chromatography (silica gel, *n*-hexane–EtOAc, 100:1 → 5:1) as a colorless oil (0.490 g, 78%).

IR (neat): 2970 (s), 2934 (s), 2874 (m), 1736 (s), 1719 (s), 1649 (s), 1608 (s), 1459 (m), 1370 (m), 1314 (m), 1285 (m), 1247 (s), 1147 (s), 1068 (m), 1014 (w), 844 (w), 793 cm^{-1} (w).

^1H NMR ($CDCl_3$, 300 MHz): δ = 0.91 (t, *J* = 7.2 Hz, 3 H, CH_3), 1.23 (t, *J* = 7.2 Hz, 6 H, 2 × CH_3), 1.29–1.36 (m, 2 H, CH_2), 1.47 (s, 9 H, *t*-Bu), 1.58 (quint, *J* = 7.2 Hz, 2 H, CH_2), 2.18 (t, *J* = 7.2 Hz, 2 H, CH_2), 3.30 (dd, *J* = 6.1, 5.4 Hz, 2 H, NCH_2), 3.51–3.61 (m, 2 H, OCH_2), 3.68–3.78 (m, 2 H, OCH_2), 4.41 (s, 1 H, CH), 4.51 (t, *J* = 5.4 Hz, 1 H, OCH), 8.61 (br s, 1 H, NH).

^{13}C NMR ($CDCl_3$, 75 MHz): δ = 13.3, 14.8 (2 C, CH_3), 21.7, 25.1 (CH_2), 28.1 (3 × CH_3), 29.7 (CH_2), 45.2 (NCH_2), 62.6 (2 × OCH_2), 81.0 (C), 83.6 (*C*H=C), 101.7 (OCH), 164.1 (N–*C*=CH), 170.1 (O=C–O).

MS (EI, 70 eV): *m*/*z* (%) = 315 (M^+, 4), 242 (4), 214 (4), 156 (4), 138 (4), 124 (4), 103 (100), 85 (11), 75 (41).

HRMS (ESI): *m*/*z* calcd for $C_{17}H_{33}NO_4$ [M^+]: 315.24097; found: 315.24059.

Ethyl 3-[(2,2-Dimethoxyethyl)amino]dec-2-enoate (3k)

Starting with ethyl 3-oxodecanoate (**1k**) (0.257 g, 1.2 mmol), 2-azido-1,1-dimethoxyethane (**2b**) (0.189 g, 1.4 mmol) and Ph_3P (0.472 g, 1.8 mmol) in THF (8 mL), **3k** was isolated after chromatography (silica gel, *n*-hexane–EtOAc, 100:1 → 3:1) as a slightly light yellow oil (0.321 g, 89%).

IR (neat): 3282 (m), 2929 (s), 2861 (s), 1653 (s), 1605 (s), 1501 (s), 1456 (s), 1372 (s), 1290 (s), 1241 (s), 1182 (s), 1135 (s), 1079 (s), 1054 (s), 981 (s), 925 (w), 896 (w), 831 (w), 789 (s), 712 (m), 664 cm^{-1} (w).

^1H NMR ($CDCl_3$, 300 MHz): δ = 0.88 (t, *J* = 6.9 Hz, 3 H, CH_3), 1.25 (t, *J* = 7.2 Hz, 3 H, CH_3), 1.26–1.34 (m, 8 H, 4 × CH_2), 1.51 (quint, *J* = 7.5 Hz, 2 H, CH_2), 2.17 (t, *J* = 7.8 Hz, 2 H, CH_2), 3.32 (dd, *J* = 6.0, 5.4 Hz, 2 H, NCH_2), 3.42 (s, 6 H, 2 × OCH_3), 4.09 (q, *J* = 7.2 Hz, 2 H, OCH_2), 4.41 (t, *J* = 5.4 Hz, 1 H, OCH), 4.48 (s, 1 H, CH), 8.61 (br s, 1 H, NH).

^{13}C NMR ($CDCl_3$, 75 MHz): δ = 13.8, 14.3 (CH_3), 22.3, 27.7, 28.8, 29.1, 31.4, 32.3 (CH_2), 44.4 (CH_2), 54.0 (2 C, OCH_3), 58.0 (OCH_2), 82.1 (*C*H=C), 103.2 (OCH), 165.0 (N–*C*=CH), 170.4 (O=C–O).

MS (EI, 70 eV): *m*/*z* (%) = 301 (M^+, 8), 270 (5), 256 (4), 226 (20), 180 (13), 88 (28), 75 (100).

Anal. Calcd for $C_{16}H_{31}NO_4$ (301.426): C, 63.76; H, 10.37. Found: C, 63.91; H, 9.95.

Ethyl 3-[(2,2-Diethoxyethyl)amino]dec-2-enoate (3l)

Starting with ethyl 3-oxodecanoate (**1k**) (0.429 g, 2.0 mmol), 2-azido-1,1-diethoxyethane (**2a**) (0.382 g, 2.4 mmol) and Ph_3P (0.787 g, 3.0 mmol) in THF (10 mL), **3l** was isolated after chromatography (silica gel, *n*-hexane–EtOAc, 100:1 → 10:1) as a slightly light yellow oil (0.555 g, 84%).

IR (neat): 3280 (w), 2973 (s), 2928 (s), 2863 (s), 1655 (s), 1606 (s), 1501 (m), 1457 (m), 1376 (m), 1283 (s), 1233 (s), 1173 (s), 1135 (s), 1059 (s), 789 (m), 712 cm^{-1} (w).

^1H NMR ($CDCl_3$, 300 MHz): δ = 0.88 (t, *J* = 7.2 Hz, 3 H, CH_3), 1.24 (t, *J* = 7.2 Hz, 6 H, 2 × CH_3), 1.26 (t, *J* = 7.2 Hz, 3 H, CH_3), 1.20–1.33 (m, 8 H, 4 × CH_2), 1.51 (quint, *J* = 7.8 Hz, 2 H, CH_2), 2.19 (t, *J* = 7.8 Hz, 2 H, CH_2), 3.32 (dd, *J* = 6.0, 5.7 Hz, 2 H, NCH_2), 3.51–3.61 (m, 2 H, OCH_2), 3.68–3.78 (m, 2 H, OCH_2), 4.09 (q, *J* = 7.2 Hz, 2 H, OCH_2), 4.47 (s, 1 H, CH), 4.51 (t, *J* = 5.7 Hz, 1 H, OCH), 8.65 (br s, 1 H, NH).

^{13}C NMR ($CDCl_3$, 75 MHz): δ = 13.6, 14.2, 14.9 (2 C, CH_3), 22.2, 27.6, 28.7, 29.0, 31.3, 32.2 (CH_2), 45.3 (NCH_2), 57.8, 62.6 (2 C, OCH_2), 81.9 (*C*H=C), 101.6 (OCH), 164.9 (N–*C*=CH), 170.1 (O=C–O).

MS (EI, 70 eV): *m*/*z* (%) = 329 (M^+, 4), 284 (8), 226 (5), 143 (6), 130 (25), 103 (100), 75 (45).

Anal. Calcd for $C_{18}H_{35}NO_4$ (329.475): C, 65.62; H, 10.71. Found: C, 65.88; H, 10.42.

Ethyl 3-[(2,2-Diethoxyethyl)amino]dodec-2-enoate (3m)

Starting with ethyl 3-oxododecanoate (**1l**) (0,485 g, 2.0 mmol), 2-azido-1,1-diethoxyethane (**2a**) (0.382 g, 2.4 mmol) and Ph_3P (0.787 g, 3.0 mmol) in THF (10 mL), **3m** was isolated after chromatography (silica gel, *n*-hexane–EtOAc, 100:1 → 10:1) as a slightly light yellow oil (0.612 g, 86%).

IR (neat): 3280 (w), 2970 (s), 2927 (s), 2860 (s), 1654 (s), 1607 (s), 1501 (m), 1458 (m), 1376 (m), 1284 (s), 1234 (s), 1173 (s), 1134 (s), 1060 (s), 790 (m), 713 cm^{-1} (w).

^1H NMR ($CDCl_3$, 300 MHz): δ = 0.88 (t, *J* = 6.9 Hz, 3 H, CH_3), 1.15–1.33 (m, 21 H, 3 × CH_3, 6 × CH_2), 1.50 (quint, *J* = 7.5 Hz, 2 H, CH_2), 2.18 (t, *J* = 7.5 Hz, 2 H, CH_2), 3.32 (dd, *J* = 6.0, 5.7 Hz, 2 H, NCH_2), 3.52–3.62 (m, 2 H, OCH_2), 3.68–3.78 (m, 2 H, OCH_2), 4.09 (q, *J* = 7.2 Hz, 2 H, OCH_2), 4.47 (s, 1 H, CH), 4.51 (t, *J* = 5.7 Hz, 1 H, OCH), 8.62 (br s, 1 H, NH).

^{13}C NMR ($CDCl_3$, 75 MHz): δ = 13.9, 14.4, 15.1 (2 C, CH_3), 22.5, 27.8, 29.1, 29.2, 29.3, 29.4, 31.7, 32.4 (CH_2), 45.5 (NCH_2), 58.1, 62.9 (2 C, OCH_2), 82.0 (*C*H=C), 101.8 (OCH), 165.2 (N–*C*=CH), 170.4 (O=C–O).

MS (EI, 70 eV): *m*/*z* (%) = 357 (M^+, 1), 312 (2), 254 (2), 212 (5), 200 (4), 154 (5), 126 (3), 103 (100), 96 (12), 75 (55).

Anal. Calcd for $C_{20}H_{39}NO_4$ (357.528): C, 67.19; H, 10.99. Found: C, 67.24; H, 10.98.

tert-Butyl 3-[(2,2-Diethoxyethyl)amino]dodec-2-enoate (3n)

Starting with *tert*-butyl 3-oxododecanoate (**1m**) (0.200 g, 0.7 mmol), 2-azido-1,1-diethoxyethane (**2a**) (0.142 g, 0.9 mmol) and Ph_3P (0.291 g, 1.1 mmol) in THF (10 mL), **3n** was isolated after chromatography (silica gel, *n*-hexane–EtOAc, 100:1 → 5:1) as a slightly light yellow oil (0.250 g, 88%).

IR (neat): 3278 (w), 2970 (s), 2927 (s), 2859 (s), 1650 (s), 1607 (s), 1496 (m), 1458 (m), 1370 (m), 1288 (s), 1241 (s), 1140 (s), 1068 (s), 1013 (m), 949 (w), 848 (w), 791 (m), 714 cm^{-1} (w).

^1H NMR ($CDCl_3$, 300 MHz): δ = 0.88 (t, *J* = 6.9 Hz, 3 H, CH_3), 1.23 (t, *J* = 7.2 Hz, 6 H, 2 × CH_3), 1.23–1.39 (m, 14 H, 7 × CH_2), 1.46 (s, 9 H, 3 × CH_3), 2.15 (t, *J* = 7.8 Hz, 2 H, CH_2), 3.30 (dd, *J* = 6.0, 5.7 Hz, 2 H, NCH_2), 3.50–3.60 (m, 2 H, OCH_2), 3.68–3.78 (m, 2 H, OCH_2), 4.40 (s, 1 H, CH), 4.50 (t, *J* = 5.7 Hz, 1 H, OCH), 8.61 (br s, 1 H, NH).

^{13}C NMR ($CDCl_3$, 75 MHz): δ = 13.9, 15.1 (2 C, CH_3), 22.5, 27.9 (CH_2), 28.4 (3 × CH_3), 29.1, 29.2, 29.3, 31.7, 32.4, 42.7 (CH_2), 45.4 (NCH_2), 62.9 (2 × OCH_2), 81.5 (C), 83.8 (*C*H = C), 102.0 (OCH), 164.5 (N–*C*=CH), 170.5 (O=C–O).

MS (EI, 70 eV): *m*/*z* (%) = 385 (M^+, 4), 312 (1), 282 (2), 226 (8), 214 (31), 197 (27), 155 (60), 114 (12), 103 (100), 75 (31).

HRMS (ESI): *m*/*z* calcd for $C_{22}H_{43}NO_4$ [M^+]: 385.3187; found: 385.3178.

Ethyl 3-[(2,2-Dimethoxyethyl)amino]tridec-2-enoate (3o)

Starting with ethyl 3-oxotridecanoate (**1n**) (0.141 g, 0.6 mmol), 2-azido-1,1-dimethoxyethane (**2b**) (0.087 g, 0.7 mmol) and Ph_3P

(0.216 g, 0.8 mmol) in THF (5 mL), **3o** was isolated after chromatography (silica gel, *n*-hexane–EtOAc, 100:1 → 3:1) as a light yellow oil (0.163 g, 86%).

IR (neat): 3282 (w), 2928 (s), 2857 (s), 1655 (s), 1608 (s), 1501 (m), 1458 (m), 1372 (m), 1287 (m), 1242 (s), 1179 (s), 1135 (s), 1080 (s), 1056 (s), 981 (w), 790 (m), 713 cm^{-1} (w).

^{1}H NMR (CDCl$_3$, 300 MHz): δ = 0.88 (t, *J* = 6.9 Hz, 3 H, CH$_3$), 1.25 (t, *J* = 7.2 Hz, 3 H, CH$_3$), 1.26–1.33 (m, 14 H, 7 × CH$_2$), 1.51 (quint, *J* = 7.5 Hz, 2 H, CH$_2$), 2.17 (t, *J* = 7.8 Hz, 2 H, CH$_2$), 3.32 (dd, *J* = 6.0, 5.7 Hz, 2 H, NCH$_2$), 3.42 (s, 6 H, 2 × OCH$_3$), 4.09 (q, *J* = 7.2 Hz, 2 H, OCH$_2$), 4.41 (t, *J* = 5.7 Hz, 1 H, OCH), 4.48 (s, 1 H, CH), 8.60 (br s, 1 H, NH).

^{13}C NMR (CDCl$_3$, 75 MHz): δ = 14.0, 14.5 (CH$_3$), 22.6, 27.9, 29.20, 29.23, 29.3, 29.4, 29.5, 31.8, 32.5 (CH$_2$), 44.5 (NCH$_2$), 54.3 (2 C, OCH$_3$), 58.2 (OCH$_2$), 82.2 (*C*H=C), 103.4 (OCH), 165.2 (N–*C*=CH), 170.6 (O=C–O).

MS (EI, 70 eV): *m/z* (%) = 343 (M$^+$, 6), 312 (3), 298 (3), 268 (26), 222 (8), 130 (42), 88 (36), 75 (100).

HRMS (ESI): *m/z* calcd for C$_{19}$H$_{37}$NO$_4$ [M$^+$]: 343.2717; found: 343.2716.

Ethyl 3-[(2,2-Diethoxyethyl)amino]tridec-2-enoate (3p)

Starting with ethyl 3-oxotridecanoate (**1n**) (0.513 g, 2.0 mmol), 2-azido-1,1-diethoxyethane (**2a**) (0.382 g, 2.4 mmol) and Ph$_3$P (0.787 g, 3.0 mmol) in THF (10 mL), **3p** was isolated after chromatography (silica gel, *n*-hexane–EtOAc, 100:1 → 3:1) as a slightly light yellow oil (0.678 g, 91%).

IR (neat): 3281 (w), 2926 (s), 2858 (m), 1698 (m), 1654 (s), 1607 (s), 1499 (m), 1456 (s), 1378 (m), 1282 (m), 1233 (s), 1174 (s), 1133 (s), 1059 (s), 790 (m), 714 cm^{-1} (w).

^{1}H NMR (CDCl$_3$, 300 MHz): δ = 0.88 (t, *J* = 7.2 Hz, 3 H, CH$_3$), 1.16–1.32 (m, 23 H, 3 × CH$_3$, 7 × CH$_2$), 1.50 (quint, *J* = 7.5 Hz, 2 H, CH$_2$), 2.18 (t, *J* = 7.5 Hz, 2 H, CH$_2$), 3.32 (dd, *J* = 6.0, 5.7 Hz, 2 H, NCH$_2$), 3.51–3.62 (m, 2 H, OCH$_2$), 3.68–3.78 (m, 2 H, OCH$_2$), 4.09 (q, *J* = 7.2 Hz, 2 H, OCH$_2$), 4.47 (s, 1 H, CH = C), 4.51 (t, *J* = 5.7 Hz, 1 H, OCH), 8.62 (br s, 1 H, NH).

^{13}C NMR (CDCl$_3$, 75 MHz): δ = 13.8, 14.3, 15.0 (2 C, CH$_3$), 22.4, 27.7, 29.04, 29.09, 29.11, 29.22, 29.30, 31.6, 32.3 (CH$_2$), 45.4 (NCH$_2$), 57.9, 62.7 (2 C, OCH$_2$), 82.0 (*C*H=C), 101.7 (OCH), 165.1 (N–*C*=CH), 170.3 (O=C–O).

MS (EI, 70 eV): *m/z* (%) = 371 (M$^+$, 1), 326 (8), 281 (29), 268 (7), 199 (6), 186 (6), 167 (3), 154 (6), 125 (5), 116 (4), 103 (100), 75 (39).

HRMS (ESI): *m/z* calcd for C$_{21}$H$_{41}$NO$_4$ [M$^+$]: 371.3030; found: 371.3021.

Ethyl 3-[(2,2-Dimethoxyethyl)amino]tetradec-2-enoate (3q)

Starting with ethyl 3-oxotetradecanoate (**1o**) (0.135 g, 0.5 mmol), 2-azido-1,1-dimethoxyethane (**2b**) (0.079 g, 0.6 mmol) and Ph$_3$P (0.197 g, 0.8 mmol) in THF (5 mL), **3q** was isolated after chromatography (silica gel, *n*-hexane–EtOAc, 100:1 → 3:1) as a light yellow oil (0.160 g, 90%).

IR (neat): 3282 (w), 2926 (s), 2856 (s), 1743 (w), 1718 (w), 1654 (s), 1604 (s), 1501 (s), 1459 (s), 1371 (s), 1288 (s), 1240 (s), 1178 (s), 1134 (s), 1083 (s), 1055 (s), 982 (m), 831 (w), 789 (m), 714 (m), 664 cm^{-1} (w).

^{1}H NMR (CDCl$_3$, 300 MHz): δ = 0.88 (t, *J* = 6.9 Hz, 3 H, CH$_3$), 1.25 (t, *J* = 7.2 Hz, 3 H, CH$_3$), 1.26–1.34 (m, 16 H, 8 × CH$_2$), 1.51 (quint, *J* = 7.5 Hz, 2 H, CH$_2$), 2.17 (t, *J* = 7.8 Hz, 2 H, CH$_2$), 3.32 (dd, *J* = 6.0, 5.7 Hz, 2 H, NCH$_2$), 3.42 (s, 6 H, 2 × OCH$_3$), 4.09 (q, *J* = 7.2 Hz, 2 H, OCH$_2$), 4.41 (t, *J* = 5.7 Hz, 1 H, OCH), 4.48 (s, 1 H, CH), 8.60 (br s, 1 H, NH).

^{13}C NMR (CDCl$_3$, 75 MHz): δ = 14.0, 14.5 (CH$_3$), 22.6, 23.4, 27.9, 28.9, 29.2, 29.3, 29.4, 29.5, 31.8, 32.5 (CH$_2$), 44.6 (NCH$_2$), 54.3 (2 C, OCH$_3$), 58.2 (OCH$_2$), 82.2 (*C*H=C), 103.4 (OCH), 165.3 (N–=CH), 170.6 (O=C–O).

MS (EI, 70 eV): *m/z* (%) = 357 (M$^+$, 3), 343 (4), 326 (1), 312 (6), 282 (13), 268 (15), 222 (5), 88 (29), 75 (100).

Anal. Calcd for C$_{20}$H$_{39}$NO$_4$ (357.533): C, 67.19; H, 10.99. Found: C, 67.39; H, 11.19.

Ethyl 3-[(2,2-Diethoxyethyl)amino]tetradec-2-enoate (3r)

Starting with ethyl 3-oxotetradecanoate (**1o**) (0.541 g, 2.0 mmol), 2-azido-1,1-diethoxyethane (**2a**) (0.382 g, 2.4 mmol) and Ph$_3$P (0.787 g, 3.0 mmol) in THF (10 mL), **3r** was isolated after chromatography (silica gel, *n*-hexane–EtOAc, 100:1 → 3:1) as a slightly light yellow oil (0.703 g, 91%).

IR (neat): 3280 (w), 2926 (s), 2859 (s), 1700 (m), 1653 (s), 1607 (s), 1501 (m), 1458 (m), 1377 (m), 1283 (m), 1233 (s), 1172 (s), 1133 (s), 1059 (s), 789 (m), 715 cm^{-1} (w).

^{1}H NMR (CDCl$_3$, 300 MHz): δ = 0.88 (t, *J* = 7.5 Hz, 3 H, CH$_3$), 1.20–1.33 (m, 25 H, 3 × CH$_3$, 8 × CH$_2$), 1.48–1.59 (m, 2 H, CH$_2$), 2.18 (t, *J* = 7.5 Hz, 2 H, CH$_2$), 3.32 (dd, *J* = 6.0, 5.7 Hz, 2 H, NCH$_2$), 3.50–3.60 (m, 2 H, OCH$_2$), 3.68–3.78 (m, 2 H, OCH$_2$), 4.09 (q, *J* = 7.2 Hz, 2 H, OCH$_2$), 4.47 (s, 1 H, CH=C), 4.51 (t, *J* = 5.7 Hz, 1 H, OCH), 8.62 (br s, 1 H, NH).

^{13}C NMR (CDCl$_3$, 75 MHz): δ = 13.7, 14.2, 14.9 (2 C, CH$_3$), 22.3, 27.7, 29.01 (2 C), 29.03, 29.16, 29.28 (2 C), 31.6, 32.2 (CH$_2$), 45.3 (NCH$_2$), 57.8, 62.6 (2 C, OCH$_2$), 81.9 (*C*H=C), 101.6 (OCH), 164.9 (N–*C*=CH), 170.1 (O=C–O).

MS (EI, 70 eV): *m/z* (%) = 385 (M$^+$, 1), 340 (6), 326 82), 295 (22), 282 (6), 267 (2), 252 (2), 223 (2), 199 (6), 186 (6), 154 (7), 130 (8), 125 (6), 116 (5), 103 (100).

Anal. Calcd for C$_{22}$H$_{43}$NO$_4$ (385.581): C, 68.53; H, 11.24. Found: C, 68.58; H, 10.88.

Ethyl 7-Chloro-3-[(2,2-diethoxyethyl)amino]hept-2-enoate (3s)

Starting with ethyl 7-chloro-3-oxoheptanoate (**1p**) (0.413 g, 2.0 mmol), 2-azido-1,1-diethoxyethane (**2a**) (0.382 g, 2.4 mmol) and Ph$_3$P (0.787 g, 3.0 mmol) in THF (10 mL), **3s** was isolated after chromatography (silica gel, *n*-hexane–EtOAc, 100:1 → 5:1) as a light yellow oil (0.537 g, 83%).

IR (neat): 2976 (s), 2938 (s), 2876 (s), 1730 (w), 1682 (s), 1568 (s), 1449 (m), 1377 (m), 1354 (m), 1269 (s), 1139 (s), 1056 (s), 992 (m), 792 cm^{-1} (m).

^{1}H NMR (CDCl$_3$, 300 MHz): δ = 1.21 (t, *J* = 7.2 Hz, 6 H, 2 × CH$_3$), 1.24 (t, *J* = 7.2 Hz, 3 H, CH$_3$), 1.63 (quint, *J* = 6.6 Hz, 2 H, CH$_2$), 1.75 (quint, *J* = 6.6 Hz, 2 H, CH$_2$), 3.12 (t, *J* = 6.6 Hz, 2 H, CH$_2$), 3.30 (d, *J* = 5.4 Hz, 2 H, NCH$_2$), 3.36 (t, *J* = 6.6 Hz, 2 H, CH$_2$Cl), 3.50–3.60 (m, 2 H, OCH$_2$), 3.68–3.78 (m, 2 H, OCH$_2$), 4.07 (q, *J* = 7.2 Hz, 2 H, OCH$_2$), 4.61 (s, 1 H, CH), 4.77 (t, *J* = 5.4 Hz, 1 H, OCH), 8.62 (br s, 1 H, NH).

^{13}C NMR (CDCl$_3$, 75 MHz): δ = 14.6, 15.3 (2 C, CH$_3$), 19.1, 23.1, 26.2 (CH$_2$), 51.2 (NCH$_2$), 55.2 (CH$_2$Cl), 57.9, 63.3 (2 C, OCH$_2$), 81.3 (*C*H=C), 99.2 (OCH), 162.3 (N–*C*=CH), 168.8 (O=C–O).

MS (EI, 70 eV): *m/z* (%) = 285 ([M – Cl]$^+$, 8), 256 (19), 240 (60), 212 (7), 194 (11), 182 (51), 166 (16), 154 (29), 138 (12), 124 (8), 122 (29), 116 (82), 103 (100), 89 (31), 75 (92).

HRMS (ESI): *m/z* calcd for C$_{15}$H$_{28}$ClNO$_4$ [M$^+$]: 321.1701; found: 321.1702.

Ethyl 9-Chloro-3-[(2,2-diethoxyethyl)amino]non-2-enoate (3t)

Starting with ethyl 9-chloro-3-oxononanoate (**1q**) (0.470 g, 2.0 mmol), 2-azido-1,1-diethoxyethane (**2a**) (0.382 g, 2.4 mmol) and Ph$_3$P (0.787 g, 3.0 mmol) in THF (10 mL), **3t** was isolated after chromatography (silica gel, *n*-hexane–EtOAc, 100:1 → 5:1) as a slightly light yellow oil (0.569 g, 81%).

IR (neat): 2977 (s), 2935 (s), 2869 (s), 1741 (m), 1721 (m), 1652 (s), 1605 (s), 1501 (m), 1453 (m), 1347 (m), 1285 (s), 1235 (s), 1173 (s), 1132 (s), 1058 (s), 789 (m), 731 cm^{-1} (w).

^{1}H NMR (CDCl$_3$, 300 MHz): δ = 1.22 (t, *J* = 7.2 Hz, 6 H, 2 × CH$_3$), 1.24 (t, *J* = 7.2 Hz, 3 H, CH$_3$), 1.29–1.59 (m, 6 H, 3 × CH$_2$), 1.77 (quint, *J* = 7.2 Hz, 2 H, CH$_2$), 2.20 (t, *J* = 7.5 Hz, 2 H, CH$_2$), 3.32 (dd, *J* = 6.3, 5.7 Hz, 2 H, NCH$_2$), 3.53 (t, *J* = 6.6 Hz, 2 H, CHCl), 3.51–3.61 (m, 2 H, OCH$_2$), 3.68–3.78 (m, 2 H, OCH$_2$), 4.09 (q, *J* = 7.2 Hz, 2 H, OCH$_2$), 4.47 (s, 1 H, CH), 4.51 (t, *J* = 5.7 Hz, 1 H, OCH), 8.61 (br s, 1 H, NH).

^{13}C NMR (CDCl$_3$, 75 MHz): δ = 14.1, 14.8 (2 C, CH$_3$), 26.1, 27.3, 28.1, 31.9, 32.0 (CH$_2$), 44.4 (CH$_2$Cl), 45.1 (NCH$_2$), 57.6 (OCH$_2$), 62.5 (2 C, OCH$_2$), 81.8 (*C*H=C), 101.4 (OCH), 164.4 (N–*C*=CH), 169.9 (O=C–O).

MS (EI, 70 eV): *m*/*z* (%) = 349 (M$^+$, 2), 314 (1), 306 (2), 304 (7), 246 (1), 202 (1), 200 (3), 148 (1), 146 (4), 130 (13), 114 (2), 103 (100), 96 (2), 85 (3), 83 (6), 75 (40).

HRMS (ESI): *m*/*z* calcd for C$_{17}$H$_{32}$ClNO$_4$ [M$^+$]: 349.2014; found: 349.2007.

Ethyl 10-Chloro-3-[(2,2-diethoxyethyl)amino]dec-2-enoate (3u)
Starting with ethyl 10-chloro-3-oxodecanoate (**1r**) (0.600 g, 2.4 mmol), 2-azido-1,1-diethoxyethane (**2a**) (0.462 g, 2.9 mmol) and Ph$_3$P (0.949 g, 3.6 mmol) in THF (12 mL), **3u** was isolated after chromatography (silica gel, *n*-hexane–EtOAc, 100:1 → 3:1) as a slightly light yellow oil (0.727 g, 83%).

IR (neat): 3282 (w), 2978 (s), 2933 (s), 2864 (s), 1653 (s), 1603 (s), 1501 (s), 1452 (s), 1375 (s), 1282 (s), 1233 (s), 1174 (s), 1126 (s), 1059 (s), 939 (w), 850 (w),790 (s), 718 (m), 854 cm^{-1} (m).

^{1}H NMR (CDCl$_3$, 300 MHz): δ = 1.24 (t, *J* = 7.2 Hz, 6 H, 2 × CH$_3$), 1.26 (t, *J* = 7.2 Hz, 3 H, CH$_3$), 1.31–1.52 (m, 8 H, 4 × CH$_2$), 1.77 (quint, *J* = 7.5 Hz, 2 H, CH$_2$), 2.19 (t, *J* = 7.5 Hz, 2H, CH$_2$), 3.32 (dd, *J* = 6.0, 5.7 Hz, 2 H, NCH$_2$), 3.53 (t, *J* = 6.9 Hz, 2 H, CH$_2$Cl), 3.53–3.63 (m, 2 H, OCH$_2$), 3.69–3.79 (m, 2 H, OCH$_2$), 4.09 (q, *J* = 7.2 Hz, 2 H, OCH$_2$), 4.47 (s, 1 H, CH), 4.51 (t, *J* = 5.7 Hz, 1 H, OCH), 8.63 (br s, 1 H, NH).

^{13}C NMR (CDCl$_3$, 75 MHz): δ = 14.3, 15.0 (2 C, CH$_3$), 26.4, 27.5, 28.3, 28.9, 32.2, 32.3 (CH$_2$), 44.7 (CH$_2$Cl), 45.4 (NCH$_2$), 58.0, 62.8 (2 C, OCH$_2$), 82.0 (*C*H=C), 101.7 (OCH), 164.9 (N–*C*=CH), 170.2 (O=C–O).

MS (EI, 70 eV): *m*/*z* (%) = 363 (M$^+$, 1), 320 (1), 318 (4), 260 (1), 214 (2), 200 (2), 161 (2), 143 (2), 130 (10), 115 (2), 103 (100), 75 (45).

Anal. Calcd for C$_{18}$H$_{34}$ClNO$_4$ (363.920): C, 59.41; H, 9.42. Found: C, 59.06; H, 9.44.

4-[(2,2-Diethoxyethyl)amino]pent-3-en-2-one (3v)
Starting with acetyl acetone (**1s**) (0.300 g, 3.0 mmol), 2-azido-1,1-diethoxyethane (**2a**) (0.573 g, 3.6 mmol) and Ph$_3$P (1.180 g, 4.5 mmol) in THF (15 mL), **3v** was isolated after chromatography (silica gel, *n*-hexane–EtOAc, 100:1 → 1:1) as a slightly light yellow oil (0.635 g, 98%).

IR (neat): 2977 (s), 2928 (m), 2883 (m), 1616 (s), 1576 (s), 1514 (s), 1444 (s), 1375 (m), 1355 (s), 1293 (s), 1242 (m), 1127 (s), 1065 (s), 1024 (m), 979 (w), 797 (w), 741 cm^{-1} (m).

^{1}H NMR (CDCl$_3$, 300 MHz): δ = 1.24 (t, *J* = 7.2 Hz, 6 H, 2 × CH$_3$), 1.94 (s, 3 H, CH$_3$), 2.01 (s, 3 H, CH$_3$), 3.36 (dd, *J* = 6.3, 5.7 Hz, 2 H, NCH$_2$), 3.52–3.62 (m, 2 H, OCH$_2$), 3.69–3.79 (m, 2 H, OCH$_2$), 4.53 (t, *J* = 5.7 Hz, 1 H OCH), 4.99 (s, 1 H, CH=C), 10.80 (br s, 1 H, NH).

^{13}C NMR (CDCl$_3$, 75 MHz): δ = 14.5 (2 C), 18.3, 28.0 (CH$_3$), 45.3 (NCH$_2$), 62.4 (2 × OCH$_2$), 95.0 (*C*H=C), 101.0 (OCH), 162.0 (N–*C*=CH), 193.9 (C=O).

MS (EI, 70 eV): *m*/*z* (%) = 215 (M$^+$, 10), 170 (17), 140 (4), 126 (6), 111 (44), 103 (100), 96 (23), 82 (44), 75 (93).

HRMS (ESI): *m*/*z* calcd for C$_{11}$H$_{21}$NO$_3$ [M$^+$]: 215.1516; found: 215.1511.

5-[(2,2-Diethoxyethyl)amino]hept-4-en-3-one (3w)
Starting with 3,5-heptanedione (**1t**) (0.41 mL, 3.0 mmol), 2-azido-1,1-diethoxyethane (**2a**) (0.573 g, 3.6 mmol) and Ph$_3$P (1.180 g, 4.5 mmol) in THF (15 mL), **3w** was isolated after chromatography (silica gel, *n*-hexane–EtOAc, 100:1 → 3:1) as a slightly light yellow oil (0.713 g, 98%).

IR (neat): 3409 (br, w), 3183 (br, w), 2976 (m), 2933 (m), 2883 (w), 1613 (s), 1577 (s), 1516 (w), 1455 (w), 1376 (w), 1349 (w), 1280 (w), 1237 (w), 1128 (m), 1067 (s), 810 cm^{-1} (w).

^{1}H NMR (CDCl$_3$, 300 MHz): δ = 1.10 (t, *J* = 7.6 Hz, 3 H, CH$_3$), 1.14 (t, *J* = 7.6 Hz, 3 H, CH$_3$), 1.23 (t, *J* = 7.2 Hz, 6 H, 2 × CH$_3$), 2.22–2.31 (m, 4 H, 2 × CH$_2$), 3.36 (dd, *J* = 6.0, 6.0 Hz, 2 H, NCH$_2$), 3.52–3.61 (m, 2 H, OCH$_2$), 3.69–3.78 (m, 2 H, OCH$_2$), 4.54 (t, *J* = 5.4 Hz, 1 H OCH), 5.00 (s, 1 H, CH=C), 10.84 (br s, 1 H, NH).

^{13}C NMR (CDCl$_3$, 75 MHz): δ = 10.3, 12.2, 15.4 (2C, CH$_3$), 25.2, 35.1 (CH$_2$), 45.7 (NCH$_2$), 63.3 (2 × OCH$_2$), 92.6 (*C*H=C), 101.9 (OCH), 168.1 (N–*C*=CH), 198.7 (C=O).

MS (EI, 70 eV): *m*/*z* (%) = 243 (M$^+$, 7), 214 (2), 198 (7), 168 (3), 140 (15), 124 (7), 112 (9), 103 (100).

HRMS (ESI): *m*/*z* calcd for C$_{13}$H$_{25}$NO$_3$ [M$^+$]: 243.1829; found: 243.1833.

Anal. Calcd for C$_{13}$H$_{25}$NO$_3$ (243.342): C, 64.16; H, 10.36. Found: C, 64.16; H, 10.42.

3-[(2,2-Diethoxyethyl)amino]-1-phenylbut-2-en-1-one (3x)
Starting with benzoylacetone **1u** (0.200 g, 1.2 mmol), 2-azido-1,1-diethoxyethane (**2a**) (0.236 g, 1.5 mmol) and Ph$_3$P (0.656 g, 2.5 mmol) in THF (10 mL), **3x** was isolated after chromatography (silica gel, *n*-hexane–EtOAc, 100:1 → 1:1) as a light yellow oil (0.322 g, 97%).

IR (neat): 3060 (w), 2977 (m), 2930 (w), 2830 (w), 2883 (w), 1606 (s), 1550 (s), 1525 (m), 1483 (w), 1444 (m), 1378 (m), 1327 (s), 1294 (s), 1245 (m), 1172 (w), 1127 (s), 1065 (s), 1031 (m), 818 (w), 793 (w), 740 (m), 714 (w), 684 cm^{-1} (w).

^{1}H NMR (CDCl$_3$, 300 MHz): δ = 1.25 (t, *J* = 7.1 Hz, 6 H, 2 × CH$_3$), 2.10 (s, 3 H, CH$_3$), 3.46 (dd, *J* = 6.4, 5.6 Hz, 2 H, NCH$_2$), 3.59 (dq, *J* = 9.3, 7.1 Hz, 2 H, OCH$_2$), 3.76 (dq, *J* = 9.3, 7.1 Hz, 2 H, OCH$_2$), 4.59 (t, *J* = 5.6 Hz, 1 H, OCH), 5.68 (s, 1 H, CH=C), 7.40 (m, 3 H, 3 × CH of Ph), 7.86 (m, 2 H, 2 × CH of Ph), 11.42 (br s, 1 H, NH).

^{13}C NMR (CDCl$_3$, 75 MHz): δ = 15.2 (2C), 19.5 (CH$_3$), 46.3 (NCH$_2$), 63.3 (2 C, OCH$_2$), 92.5 (*C*H=C), 101.1 (OCH), 126.7 (2 C), 127.9 (2 C), 130.2 (CH of Ph), 140.3 (C of Ph), 164.7 (N–*C*=CH), 187.8 (C=O).

MS (EI, 70 eV): *m*/*z* (%) = 277 (M$^+$, 7), 232 (6), 199 (7), 174 (7), 160 (2), 158 (6), 144 (1), 117 (1), 103 (100), 91 (14), 77 (17).

HRMS (ESI): *m*/*z* calcd for C$_{16}$H$_{23}$NO$_3$ [M$^+$]: 277.16779; found: 277.16803.

Anal. Calcd for C$_{16}$H$_{23}$NO$_3$ (277.363): C, 69.29; H, 8.36. Found: C, 69.61; H, 8.37.

3-[(2,2-Dimethoxyethyl)amino]-1-(2-methoxyphenyl)but-2-en-1-one (3y)
Starting with benzoylacetone **1v** (1.153 g, 6.0 mmol), 2-azido-1,1-dimethoxyethane (**2b**) (0.983 g, 7.5 mmol) and Ph$_3$P (3.934 g, 15.0

mmol) in THF (10 mL), **3y** was isolated after chromatography (silica gel, *n*-hexane–EtOAc, 100:1 → 1:1) as a light yellow oil (0.800 g, 50%).

IR (neat): 3067 (w), 2991 (m), 2936 (w), 2833 (w), 1593 (s), 1580 (s), 1538 (m), 1434 (m), 1310 (m), 1070 (s), 1020 (m), 752 cm^{-1} (s).

^{1}H NMR (CDCl$_3$, 250 MHz): δ = 1.96 (s, 3 H, CH$_3$), 3.35 (m, 2 H, CH$_2$), 3.37 (s, 6 H, OCH$_3$), 3.78 (s, 3 H, OCH$_3$), 4.41 (t, ^{3}J = 6.0 Hz, 1 H, CH), 5.53 (s, 1 H, CH), 6.83 (d, ^{3}J = 8.2 Hz, 1 H, CH$_{\text{Ar}}$), 6.89 (d, ^{3}J = 7.5 Hz, 1 H, CH$_{\text{Ar}}$), 7.25 (dd, ^{3}J = 7.6 Hz, ^{4}J = 2.0 Hz, 1 H, CH$_{\text{Ar}}$), 7.51 (dd, ^{3}J = 7.8 Hz, ^{4}J = 2.0 Hz, 1 H, CH$_{\text{Ar}}$), 11.24 (br s, 1 H, NH).

^{13}C NMR (CDCl$_3$, 62 MHz): δ = 15.5 (CH$_3$), 45.4 (NCH$_2$), 54.2 (2 OCH$_3$), 55.6 (OCH$_3$), 97.5 (*C*H=C), 103.4 (CH), 111.3, 120.4, 129.6. 130.6 (CH$_{\text{Ar}}$), 131.3, 156.8 (C$_{\text{Ar}}$), 163.9 (N–*C*=CH), 188.9 (C=O).

MS (EI, 70 eV): *m*/*z* (%) = 279 (M$^+$, 17), 248 (9), 188 (15), 135 (27), 121 (38), 75 (100), 47 (7).

HRMS (ESI): *m*/*z* calcd for $C_{15}H_{21}NO_4$ [M$^+$]: 279.14651; found; 279.14672.

1-(2-Chlorophenyl)-3-[(2,2-dimethoxyethyl)amino]but-2-en-1-one (3z)

Starting with benzoylacetone **1w** (1.476 g, 7.5 mmol), 2-azido-1,1-dimethoxyethane (**2b**) (1.493 g, 9.3 mmol) and Ph$_3$P (4.921 g, 18.7 mmol) in THF (10 mL), **3z** was isolated after chromatography (silica gel, *n*-hexane–EtOAc, 100:1 → 1:1) as a light yellow oil (1.000 g, 52%).

IR (neat): 3067 (w), 2991 (m), 2936 (w), 2833 (w), 1593 (s), 1580 (s), 1538 (m), 1434 (m), 1310 (m), 1070 (s), 1020 (m), 752 cm^{-1} (s).

^{1}H NMR (CDCl$_3$, 250 MHz): δ = 1.97 (s, 3 H, CH$_3$), 3.36 (m, 2 H, CH$_2$), 3.37 (s, 6 H, OCH$_3$), 4.42 (t, ^{3}J = 6.0 Hz, 1 H, CH), 5.25 (s, 1 H, CH), 7.14–7.17 (m, 1 H, CH$_{\text{Ar}}$), 7.25–7.29 (m, 1 H, CH$_{\text{Ar}}$), 7.34–7.38 (m, 1 H, CH$_{\text{Ar}}$), 11.12 (br s, 1 H, NH).

^{13}C NMR (CDCl$_3$, 62 MHz): δ = 19.4 (CH$_3$), 45.5 (NCH$_2$), 54.8 (2 OCH$_3$), 96.8 (*C*H=C), 103.4 (CH), 112.4, 129.1, 129.7, 130.0 (CH$_{\text{Ar}}$), 130.8, 141.4 (C$_{\text{Ar}}$), 165.0 (N–*C*=CH), 188.9 (C=O).

MS (EI, 70 eV): *m*/*z* (%) = 285 (M$^+$, ^{37}Cl, 3), 283 (M$^+$, ^{35}Cl, 9), 252 (5), 208 (6), 188 (5), 125 (10), 111 (7), 75 (100), 47 (6).

HRMS (ESI): *m*/*z* calcd for $C_{14}H_{18}ClNO_3$ [M$^+$, ^{35}Cl]: 283.09752; found; 283.09752.

3-[(2,2-Diethoxyethyl)amino]cyclohex-2-en-1-one (6a)

Starting with 1,3-cyclohexanedione (**5a**) (0.336 g, 3.0 mmol), 2-azido-1,1-diethoxyethane (**2a**) (0.573 g, 3.6 mmol) and Ph$_3$P (1.180, 4.5 mmol) in THF (15 mL), **6a** was isolated after chromatography (silica gel, *n*-hexane–EtOAc, 50:1 → EtOAc → acetone) as a light brown oil (0.664 g, 97%).

IR (neat): 3260 (w), 3071 (w), 2976 (m), 2935 (m), 2880 (m), 1663 (w), 1551 (s), 1451 (m), 1372 (m), 1319 (w), 1290 (w), 1246 (m), 1190 (m), 1133 (s), 1065 cm^{-1} (s).

^{1}H NMR (CDCl$_3$, 300 MHz): δ = 1.23 (t, *J* = 7.2 Hz, 6 H, 2 × CH$_3$), 1.97 (t, *J* = 6.6 Hz, 2 H, CH$_2$), 2.32 (t, *J* = 6.6 Hz, 2 H, CH$_2$), 2.36 (t, *J* = 6.6 Hz, 2 H, CH$_2$), 3.21 (dd, *J* = 5.2, 5.2 Hz, 2 H, NCH$_2$), 3.50–3.60 (m, 2 H, OCH$_2$), 3.66–3.76 (m, 2 H, OCH$_2$), 4.64 (t, *J* = 5.2 Hz, 1 H, OCH), 4.75 (br s, 1 H, NH), 5.13 (s, 1 H, CH=C).

^{13}C NMR (CDCl$_3$, 75 MHz): δ = 14.2 (2 × CH$_3$), 21.0, 28.2, 35.5 (CH$_2$), 44.4 (NCH$_2$), 61.3 (OCH$_2$), 98.5 (*C*H=C), 101.9 (OCH), 164.8 (N–*C*=CH), 195.7 (C=O).

MS (EI, 70 eV): *m*/*z* (%) = 227 (M$^+$, 4), 186 (1), 136 (6), 124 (4), 103 (100), 75 (67).

Anal. Calcd for $C_{12}H_{21}NO_3$ (227.303): C, 63.41; H, 9.31: Found: C, 63.09; H, 9.12.

3-[(2,2-Diethoxyethyl)amino]-5,5-dimethylcyclohex-2-en-1-one (6b)

Starting with dimedone (**5b**) (0.421 g, 3.0 mmol), 2-azido-1,1-diethoxyethane (**2a**) (0.573 g, 3.6 mmol), and Ph$_3$P (1.180 g, 4.5 mmol) in THF (15 mL), **6b** was isolated after chromatography (silica gel, *n*-hexane–EtOAc, 50:1 → EtOAc → acetone) as a light yellow oil (0.703 g, 92%).

IR (neat): 3259 (m), 3069 (m), 2967 (s), 2935 (s), 2878 (s), 1738 (m), 1540 (s), 1452 (s), 1425 (m), 1410 (m), 1376 (s), 1271 (s), 1242 (s), 1131 (s), 1065 (s), 960 (w), 932 (w), 891 (w), 809 (m), 732 (m), 703 (w), 660 (w), 607 (m), 560 (m), 482 cm^{-1} (w).

^{1}H NMR (CDCl$_3$, 300 MHz): δ = 1.07 (s, 6 H, 2 × CH$_3$), 1.22 (t, *J* = 7.2 Hz, 6 H, 2 × CH$_3$), 2.17 (s, 2 H, CH$_2$), 2.27 (s, 2 H, CH$_2$), 3.23 (dd, *J* = 5.4, 5.4 Hz, 2 H, NCH$_2$), 3.50–3.60 (m, 2 H, OCH$_2$), 3.65–3.75 (m, 2 H, OCH$_2$), 4.67 (t, *J* = 5.4 Hz, 1 H, OCH), 5.12 (s, 1 H, CH=C), 5.89 (br s, 1 H, NH).

^{13}C NMR (CDCl$_3$, 75 MHz): δ = 14.9 (2 × CH$_3$), 27.8 (2 × CH$_3$), 32.3 (C), 42.8 (CH$_2$), 44.9 (NCH$_2$), 49.9 (CH$_2$), 62.2 (2 × OCH$_2$), 94.6 (*C*H=C), 99.1 (OCH), 163.2 (N–*C*=CH), 196.2 (C=O).

MS (EI, 70 eV): *m*/*z* (%) = 255 (M$^+$, 8), 210 (2), 181 (2), 164 (6), 151 (2), 138 (2), 122 (1), 103 (77), 84 (100), 75 (47).

HRMS (ESI): *m*/*z* calcd for $C_{14}H_{25}NO_3$ [M$^+$]: 255.1829; found: 255.1824.

3-[(2,2-Diethoxyethyl)amino]-5-methylcyclohex-2-en-1-one (6c)

Starting with 5-methyl-1,3-cyclohexanedione (**5c**) (0.386 g, 3.0 mmol), 2-azido-1,1-diethoxyethane (**2a**) (0.573 g, 3.6 mmol) and Ph$_3$P (1.180, 4.5 mmol) in THF (15 mL), **6c** was isolated after chromatography (silica gel, *n*-hexane–EtOAc, 50:1 → EtOAc → acetone) as a light brown oil (0.724 g, 94%).

IR (neat): 3260 (m), 3070 (m), 2968 (s), 2933 (s), 2882 (m), 1547 (s), 1451 (s), 1427 (m), 1412 (m), 1373 (m), 1272 (s), 1245 (m), 1134 (m), 1067 (s), 808 cm^{-1} (w).

^{1}H NMR (CDCl$_3$, 300 MHz): δ = 1.03–1.13 (m, 3 H, CH$_3$), 1.23 (dt, *J* = 7.2, 1.2 Hz, 6 H, 2 × CH$_3$), 2.00–2.34 (m, 5 H, 2 × CH$_2$, CH), 3.22 (dd, *J* = 5.4, 5.4 Hz, 2 H, NCH$_2$), 3.50–3.60 (m, 2 H, OCH$_2$), 3.65–3.75 (m, 2 H, OCH$_2$), 4.66 (t, *J* = 5.4 Hz, 1 H, OCH), 4.80 (br s, 1 H, NH), 5.13 (s, 1 H, CH=C).

^{13}C NMR (CDCl$_3$, 75 MHz): δ = 15.1 (2 × CH$_3$), 20.3 (CH$_3$), 27.5 (CH), 35.4, 42.1 (CH$_2$), 44.8 (NCH$_2$), 62.2 (2 × OCH$_2$), 95.8 (*C*H=C), 99.8 (OCH), 163.4 (N–*C*=CH), 196.0 (C=O).

MS (EI, 70 eV): *m*/*z* (%) = 241 (M$^+$, 5), 196 (1), 151 (5), 138 (3), 124 (2), 103 (100), 74 (38).

HRMS (ESI): *m*/*z* calcd for $C_{13}H_{23}NO_3$ [M$^+$]: 241.16779; 241.16770.

3-[(2,2-Diethoxyethyl)amino]-5-phenylcyclohex-2-en-1-one (6d)

Starting with 5-phenyl-1,3-cyclohexanedione (**5d**) (0.588 g, 3.0 mmol), 2-azido-1,1-diethoxyethane (**2a**) (0.573 g, 3.6 mmol) and Ph$_3$P (1.180, 4.5 mmol) in THF (15 mL), **6d** was isolated after chromatography (silica gel, *n*-hexane–EtOAc, 50:1 → EtOAc) as a light brown solid (0.838 g, 92%).

IR (KBr): 3243 (s), 3065 (s), 2975 (m), 2934 (m), 2888 (m), 1545 (s), 1441 (s), 1374 (m), 1274 (s), 1239 (s), 1133 (s), 1069 (s), 757 (w), 701 cm^{-1} (w).

^{1}H NMR (CDCl$_3$, 300 MHz): δ = 1.23 (dt, *J* = 7.2, 1.4 Hz, 6 H, 2 × CH$_3$), 2.44–2.75 (m, 4 H, 2 × CH$_2$), 3.24 (dd, *J* = 5.1, 5.1 Hz, 2 H, NCH$_2$), 3.29–3.41 (m, 1 H, C*H*Ph), 3.50–3.61 (m, 2 H, OCH$_2$), 3.66–3.76 (m, 2 H, OCH$_2$), 4.65 (t, *J* = 5.1 Hz, 1 H, OCH), 4.81 (br s, 1 H, NH), 5.22 (s, 1 H, CH = C), 7.23–7.27 (m, 3 H, 3 × CH of Ph), 7.31–7.34 (m, 2 H, 2 × CH of Ph).

^{13}C NMR ($CDCl_3$, 75 MHz): δ = 15.0 ($2 \times CH_3$), 36.8 (CH_2), 39.6 (*C*HPh), 43.3 (NCH_2), 45.1 (CH_2), 62.4 ($2 \times OCH_2$), 96.1 (*C*H=C), 99.2 (OCH), 126.4 (2 C), 126.6, 128.4 (2 C, CH of Ph), 142.9 (C of Ph), 163.6 (N–*C*=CH), 196.1 (C=O).

MS (EI, 70 eV): *m/z* (%) = 303 (M^+, 8), 258 (3), 213 (7), 200 (4), 170 (5), 103 (100), 91 (46), 77 (32).

HRMS (ESI): *m/z* calcd for $C_{18}H_{25}NO_3$ [M^+]: 303.18344; found: 303.18338.

UV/Vis (MeCN,): λ_{max} (log ε) = 280 nm (4.29).

Synthesis of Pyrroles (4); Representative Procedures

Method A: To **3x** (0.050 g, 0.18 mmol) in CH_2Cl_2 (3 mL) was added TFA (0.14 mL, 1.8 mmol) at 0 °C. The reaction mixture was allowed to warm to 20 °C during 12 h and was stirred for 4 h at 20 °C. The solvent was removed in vacuo and the residue was purified by column chromatography (silica gel, *n*-hexane–EtOAc, 50:1 → 3:1) to give **4r** as a light yellow solid (0.027 g, 82%).

Method B: To **3x** (0.050 g, 0.18 mmol) in CH_2Cl_2 (3 mL) was added Me_3SiOTf (0.050 g, 0.18 mmol) at 0 °C. The reaction mixture was allowed to warm to 20 °C during 12 h and was stirred for 4 h at 20 °C. The solvent was removed in vacuo and the residue was purified by column chromatography (silica gel, *n*-hexane–EtOAc, 50:1 → 1:1) to give **4r** as a light yellow solid (0.026 g, 79%).

Method C: A DMSO solution (5 mL) of **3x** (0.100 g, 0.36 mmol) was stirred at 150 °C for 24 h. After cooling to 20 °C, H_2O (10 mL) was added and the mixture was extracted with Et_2O (4 × 15 mL). The combined organic extracts were dried (Na_2SO_4), filtered and the filtrate was concentrated in vacuo. The residue was purified by column chromatography (silica gel, *n*-hexane–EtOAc, 50:1 → 1:1) to give **4r** as a light yellow solid (0.048 g, 72%).

Methyl 2-Methyl-1*H*-pyrrole-3-carboxylate (4a)

Method A: Starting with **3a** (0.100 g, 0.4 mmol) and TFA (0.33 mL, 4.3 mmol) in CH_2Cl_2 (5 mL), **4a** was isolated after chromatography (silica gel, *n*-hexane–EtOAc, 50:1 → 3:1) as a light brown solid (0.013 g, 22%).

Method B: Starting with **3a** (0.100 g, 0.43 mmol) and Me_3SiOTf (0.096 g, 0.43 mmol) in CH_2Cl_2 (5 mL) at 0 °C, **4a** was isolated after chromatography (silica gel, *n*-hexane–EtOAc, 50:1 → 1:1) as a light brown solid (0.021 g, 35%).

Method C: Starting with **3a** (0.100 g, 0.43 mmol) in DMSO (5 mL), **4a′** (0.021 g, 19%) and **4a** (0.024 g, 40%) were isolated after chromatography (silica gel, *n*-hexane–EtOAc, 100:1 → 1:1) as light brown oil and solid, respectively.

Methyl 1-(2,2-Diethoxyethyl)-2-methyl-1*H*-pyrrole-3-carboxylate (4a′)

IR (neat): 3410 (br), 3367 (br), 2977 (w), 2953 (w), 2929 (w), 2857 (w), 1725 (s), 1704 (s), 1630 (w), 1601 (w), 1556 (w), 1525 (w), 1508 (w), 1439 (m), 1401 (w), 1376 (w), 1293 (m), 1257 (s), 1227 (s), 1195 (m), 1114 (s), 1063 (s), 776 cm^{-1} (w).

^1H NMR ($CDCl_3$, 300 MHz): δ = 1.16 (t, *J* = 7.2 Hz, 6 H, $2 \times CH_3$), 2.55 (s, 3 H, CH_3), 3.32–3.42 (m, 2 H, OCH_2), 3.62–3.72 (m, 2 H, OCH_2), 3.79 (s, 3 H, OCH_3), 3.93 (d, *J* = 5.4 Hz, 2 H, NCH_2), 4.53,(t, *J* = 5.4 Hz, 1 H, OCH), 6.51 (d, *J* = 3.0 Hz, 1 H, CH), 6.55 (d, *J* = 3.0 Hz, 1 H, CH).

^{13}C NMR ($CDCl_3$, 75 MHz): δ = 11.1, 15.2 (2 C, CH_3), 50.0 (NCH_2), 50.7 (OCH_3), 63.9 (2 C, OCH_2), 102.2 (OCH), 109.5 (CH), 111.9 (C), 120.9 (CH), 136.3 (C), 166.0 (O=C–O).

MS (EI, 70 eV): *m/z* (%) = 255 (M^+, 15), 223 (60), 210 (4), 192 (80), 182 (3), 178 (4), 166 (4), 164 (27), 151 (3), 132 (5), 120 (11), 103 (100), 76 (63).

HRMS (ESI): *m/z* calcd for $C_{13}H_{21}NO_4$ [M^+]: 255.14706; found: 255.14772.

Methyl 2-Methyl-1*H*-pyrrole-3-carboxylate (4a)

IR (neat): 3312 (m), 2978 (s), 2952 (w), 2933 (w), 2867 (m), 1707 (s), 1680 (s), 1607 (w), 1580 (m), 1493 (w), 1452 (s), 1408 (w), 1381 (m), 1348 (w), 1329 (m), 1268 (m), 1226 (w), 1202 (m), 1177 (w), 1125 (s), 1076 (w), 1053 (w), 1026 (w), 900 (w), 844 (w), 790 (w), 726 cm^{-1} (w).

^1H NMR ($CDCl_3$, 300 MHz): δ = 2.53 (s, 3 H, CH_3), 3.80 (s, 3 H, OCH_3), 6.55 (d, *J* = 2.7 Hz, 1 H, CH), 6.56 (d, *J* = 2.7 Hz, 1 H, CH), 8.23 (br s, 1 H, NH).

^{13}C NMR ($CDCl_3$, 75 MHz): δ = 13.2 (CH_3), 50.8 (OCH_3), 110.4 (CH), 110.5 (C), 115.8 (CH), 135.3 (C), 166.1 (O=C–O).

MS (EI, 70 eV): *m/z* (%) = 139 (M^+, 46), 124 (19), 107 (100), 80 (33).

HRMS (EI, 70 eV): *m/z* calcd for $C_7H_9NO_2$: 139.0633 [M^+]; found: 139.0633 ± 2 ppm.

Ethyl 2-Methyl-1*H*-pyrrole-3-carboxylate (4b)

Starting with **3b** (0.100 g, 0.4 mmol) in DMSO (5 mL), **4b** was isolated after chromatography (silica gel, *n*-hexane–EtOAc, 100:1 → 1:1) as a light brown solid (0.036 g, 58%); mp 64 °C.

IR (KBr): 3294 (s), 2985 (m), 2938 (w), 2906 (w), 1697 (s), 1675 (s), 1578 (m), 1499 (m), 1447 (m), 1411 (m), 1369 (m), 1325 (s), 1267 (s), 1227 (w), 1201 (s), 1127 (s), 1095 (s), 1053 (s), 901 (m), 781 (m), 754 (m), 722 cm^{-1} (m).

^1H NMR ($CDCl_3$, 300 MHz): δ = 1.34 (t, *J* = 7.2 Hz, 3 H, OCH_2CH_3), 2.52 (s, 3 H, CH_3), 4.27 (q, *J* = 7.2 Hz, 2 H, OCH_2), 6.56 (d, *J* = 2.4 Hz, 2 H, 2 × CH), 8.51 (br s, 1 H, NH).

^{13}C NMR ($CDCl_3$, 75 MHz): δ = 13.2, 14.5 (CH_3), 59.4 (OCH_2), 110.4 (CH), 111.7 (C), 115.7 (CH), 135.2 (C), 165.8 (O=C–O).

MS (EI, 70 eV): *m/z* (%) = 153 (M^+, 95), 124 (61), 108 (100).

HRMS (EI, 70 eV): *m/z* calcd for $C_8H_{11}NO_2$: 153.0790 [M^+]; found: 153.0790 ± 2 ppm.

Isopropyl 2-Methyl-1*H*-pyrrole-3-carboxylate (4c)

Starting with **3c** (0.200 g, 0.8 mmol) and Me_3SiOTf (0.172 g, 0.8 mmol) in CH_2Cl_2 (10 mL), **4c** was isolated after chromatography (silica gel, *n*-hexane–EtOAc, 50:1 → 3:1) as a light brown oil (0.064 g, 50%).

IR (neat): 3318 (m), 2987 (s), 2936 (w), 2895 (w), 1707 (s), 1689 (s), 1672 (s), 1576 (m), 1495 (w), 1412 (w), 1373 (m), 1327 (m), 1268 (m), 1225 (w), 1202 (m), 1125 (s), 1086 (m), 1053 (m), 902 (w), 788 (w), 724 cm^{-1} (w).

^1H NMR ($CDCl_3$, 300 MHz): δ = 1.26 (d, *J* = 6.3 Hz, 6 H, $2 \times CH_3$), 2.53 (s, 3 H, CH_3), 5.04 (sept, *J* = 6.3 Hz, 1 H, OCH), 6.55 (d, *J* = 2.7 Hz, 1 H, CH), 6.58 (d, *J* = 2.7 Hz, 1 H, CH), 8.55 (br s, 1 H, NH).

^{13}C NMR ($CDCl_3$, 75 MHz): δ = 13.2, 21.8 (2 C, CH_3), 68.6 (OCH), 110.3 (CH), 111.9 (C), 115.8 (CH), 135.2 (C), 165.6 (O=C–O).

MS (EI, 70 eV): *m/z* (%) = 167 (M^+, 67), 124 (42), 108 (100), 80 (37).

HRMS (EI, 70 eV): *m/z* calcd for $C_9H_{13}NO_2$: 167.0946 [M^+]; found: 167.0946 ± 2 ppm.

Isobutyl 2-Methyl-1*H*-pyrrole-3-carboxylate (4d)

Starting with **3d** (0.200 g, 0.7 mmol) and Me_3SiOTf (0.163 g, 0.7 mmol) in CH_2Cl_2 (10 mL), **4d** was isolated after chromatography (silica gel, *n*-hexane–EtOAc, 50:1 → 3:1) as a light brown oil (0.059 g, 42%).

IR (neat): 3321 (m), 2983 (s), 2941 (w), 2897 (w), 1705 (s), 1691 (s), 1673 (s), 1577 (m), 1491 (w), 1414 (w), 1371 (m), 1331 (m), 1272 (m), 1223 (w), 1200 (m), 1126 (s), 1087 (m), 1054 (m), 901 (w), 786 (w), 722 cm^{-1} (w).

^{1}H NMR ($CDCl_3$, 300 MHz): δ = 0.98 (d, J = 6.9 Hz, 6 H, 2 × CH_3), CH_3), 1.98 (m, J = 6.9 Hz, 1 H, CH), 2.53 (s, 3 H, CH_3), 3.87 (d, J = 6.9 Hz, 2 H, OCH_2), 6.54–6.58 (m, 2 H, 2 × CH), 8.53 (br s, 1 H, NH).

^{13}C NMR ($CDCl_3$, 75 MHz): δ = 13.2, 19.1 (2 C, CH_3), 27.8 (CH), 70.4 (OCH_2), 110.5 (CH), 111.8 (C), 115.7 (CH), 135.2 (C), 165.4 (O=C–O).

MS (EI, 70 eV): m/z (%) = 181 (M^+, 70), 124 (45), 108 (100), 80 (42).

HRMS (ESI): m/z calcd for $C_{10}H_{15}NO_2$ [M^+]: 181.11028; found: 181.11042.

2-Methoxyethyl 2-Methyl-1*H*-pyrrole-3-carboxylate (4e)

Starting with **3f** (0.100 g, 0.4 mmol) in DMSO (2 mL), **4e** was isolated after chromatography (silica gel, *n*-hexane–EtOAc, 100:1 → 1:1) as a light brown solid (0.034 g, 51%).

IR (neat): 3319 (br), 2930 (w), 1684 (s), 1455 (m), 1322 (w), 1269 (m), 1231 (w), 1196 (w), 1126 (s), 1099 (m), 1060 cm^{-1} (w).

^{1}H NMR ($CDCl_3$, 300 MHz): δ = 2.52 (s, 3 H, CH_3), 3.42 (s, 3 H, OCH_3), 3.68–3.71 (m, 2 H, OCH_2), 4.36–4.39 (m, 2 H, OCH_2), 6.54–6.58 (m, 2 H, 2 × CH), 8.53 (br s, 1 H, NH).

^{13}C NMR ($CDCl_3$, 75 MHz): δ = 13.2 (CH_3), 58.9 (OCH_3), 62.4, 70.8 (OCH_2), 110.5 (CH), 111.3 (C), 115.8 (CH), 135.5 (C), 165.5 (O=C–O).

MS (EI, 70 eV): m/z (%) = 183 (M^+, 9), 125 (23), 108 (100), 80 (14).

HRMS (EI, 70 eV): m/z calcd for $C_9H_{13}NO_3$: 183.0895 [M^+]; found: 183.0895 ± 2 ppm.

Allyl 2-Methyl-1*H*-pyrrole-3-carboxylate (4f)

Starting with **3g** (0.100 g, 0.4 mmol) and Me_3SiOTf (0.087 g, 0.4 mmol) in CH_2Cl_2 (5 mL) at 0 °C, **4f** was isolated after chromatography (silica gel, *n*-hexane–EtOAc, 100:1 → 3:1) as a light brown oil (0.024 g, 37%).

IR (neat): 3337 (br, m), 2976 (w), 2928 (m), 1703 (s), 1581 (w), 1538 (w), 1447 (m), 1411 (m), 1267 (m), 1222 (s), 1175 (m), 1109 (m), 1012 (w), 994 (w), 933 cm^{-1} (w).

^{1}H NMR ($CDCl_3$, 300 MHz): δ = 2.53 (s, 3 H, CH_3), 4.62–4.74 (m, 2 H, OCH_2), 5.20–5.39 (m, 2 H, CH_2=CH), 5.91–6.09 (m, 1 H, CH=CH_2), 6.55–6.58 (m, 2 H, 2 × CH), 8.35 (br s, 1 H, NH).

Anal. Calcd for $C_{11}H_{15}NO_2$ (139.24): C, 68.37; H, 7.82. Found: C, 68.55; H, 7.58.

Methyl 2-Ethyl-1*H*-pyrrole-3-carboxylate (4g)

Starting with **3h** (0.100 g, 0.4 mmol) and Me_3SiOTf (0.091 g, 0.4 mmol) in CH_2Cl_2 (5 mL) at 0 °C, **4g** was isolated after chromatography (silica gel, *n*-hexane–EtOAc, 100:1 → 3:1) as a light brown solid (0.024 g, 39%).

IR (KBr): 3296 (br, w), 2954 (m), 2929 (m), 1715 (s), 1445 (m), 1371 (m), 1226 (s), 1102 cm^{-1} (m).

^{1}H NMR ($CDCl_3$, 300 MHz): δ = 1.25 (t, J = 7.2 Hz, 3 H, CH_3), 3.00 (q, J = 7.2 Hz, 2 H, CH_2), 3.79 (s, 3 H, OCH_3), 6.55–6.58 (m, 2 H, 2 × CH), 8.28 (br s, 1 H, NH).

MS (EI, 70 eV): m/z (%) = 153 (M^+, 49), 138 (1), 94 (100), 80 (2).

Anal. Calcd for $C_8H_{11}NO_2$ (153.181): C, 62.73; H, 7.24. Found: C, 63.04; H, 7.82.

Ethyl 2-Propyl-1*H*-pyrrole-3-carboxylate (4h)

Starting with **3i** (0.200 g, 0.7 mmol) and Me_3SiOTf (0.162 g, 0.7 mmol) in CH_2Cl_2 (10 mL) at 0 °C, **4h** was isolated after chromatography (silica gel, *n*-hexane–EtOAc, 50:1 → 3:1) as a light brown oil (0.073 g, 55%).

IR (neat): 3345 (m), 2959 (m), 2873 (w), 1645 (s), 1582 (m), 1551 (m), 1491 (w), 1459 (m), 1448 (m), 1375 (m), 1305 (m), 1251 (s), 1174 (s), 1131 (s), 1103 (m), 1040 (m), 1019 (m), 843 (w), 759 cm^{-1} (w).

^{1}H NMR ($CDCl_3$, 300 MHz): δ = 0.95 (t, J = 7.2 Hz, 3 H, CH_3), 1.34 (t, J = 7.2 Hz, 3 H, CH_3), 1.67 (sext, J = 7.5 Hz, 2 H, CH_2), 2.92 (t, J = 7.5 Hz, 2 H, CH_2), 4.27 (q, J = 7.2 Hz, 2 H, OCH_2), 6.54–6.58 (m, J = 2.7 Hz, 2 H, 2 × CH), 8.31 (br s, 1 H, NH).

^{13}C NMR ($CDCl_3$, 75 MHz): δ = 13.7, 14.4 (CH_3), 22.7, 29.2 (CH_2), 59.3 (OCH_2), 110.3 (CH), 111.1 (C), 115.8 (CH), 139.9 (C), 165.8 (O = C–O).

MS (EI, 70 eV): m/z (%) = 181 (M^+, 62), 166 (2), 152 (100), 136 (45), 124 (87), 120 (11), 108 (49).

HRMS (EI, 70 eV): m/z calcd for $C_{10}H_{15}NO_2$: 181.1103 [M^+]; found: 181.1103 ± 2 ppm.

Ethyl 2-Heptyl-1*H*-pyrrole-3-carboxylate (4i)

Route 1: Starting with **3k** (0.250 g, 0.8 mmol) and Me_3SiOTf (0.185 g, 0.8 mmol) in CH_2Cl_2 (10 mL), **4i** was isolated after chromatography (silica gel, *n*-hexane–EtOAc, 50:1 → 3:1) as a light brown oil (0.118 g, 60%).

Route 2: Starting with **3l** (0.350 g, 1.06 mmol) and Me_3SiOTf (0.236 g, 1.06 mmol) in CH_2Cl_2 (15 mL), **4i** was isolated after chromatography (silica gel, *n*-hexane–EtOAc, 50:1 → 3:1) as a light brown oil (0.146 g, 58%).

IR (neat): 3324 (s), 2956 (s), 2928 (s), 2871 (m), 2857 (m), 1726 (m), 1702 (s), 1673 (s), 1574 (m), 1496 (m), 1466 (s), 1394 (m), 1370 (m), 1331 (m), 1297 (m), 1264 (m), 1197 (m), 1181 (m), 1128 (s), 1096 (w), 1077 (w), 1049 (m), 1028 (w), 902 (w), 790 (w), 724 cm^{-1} (m).

^{1}H NMR ($CDCl_3$, 300 MHz): δ = 0.86 (t, J = 6.9 Hz, 3 H, CH_3), 1.15–1.40 (m, 11 H, CH_3, 4 × CH_2), 1.50–1.64 (m, 2 H, CH_2), 2.92 (t, J = 7.5 Hz, 2 H, CH_2), 4.27 (q, J = 7.2 Hz, 2 H, OCH_2), 6.56 (d, J = 3.0 Hz, 1 H, CH), 6.58 (d, J = 3.3 Hz, 1 H, CH), 8.21 (br s, 1 H, NH).

^{13}C NMR ($CDCl_3$, 75 MHz): δ = 13.9, 14.3 (CH_3), 22.5, 27.3, 29.0, 29.3, 29.5, 31.7 (CH_2), 59.2 (OCH_2), 110.5 (CH), 110.9 (C), 115.8 (CH), 140.1 (C), 165.8 (O=C–O).

MS (EI, 70 eV): m/z (%) = 237 (M^+, 40), 208 (18), 192 (12), 164 (39), 151 (38), 138 (6), 124 (100).

Anal. Calcd for $C_{14}H_{23}NO_2$ (237.342): C, 70.85; H, 9.77. Found: C, 70.47; H, 10.10.

Ethyl 2-Nonyl-1*H*-pyrrole-3-carboxylate (4j)

Starting with **3m** (0.300 g, 0.8 mmol) and Me_3SiOTf (0.187 g, 0.8 mmol) in CH_2Cl_2 (10 mL), **4j** was isolated after chromatography (silica gel, *n*-hexane–EtOAc, 50:1 → 3:1) as a light brown oil (0.127 g, 57%).

IR (neat): 3332 (m), 2957 (m), 2926 (s), 2855 (m), 1675 (s), 1464 (m), 1371 (w), 1329 (w), 1263 (w), 1196 (w), 1182 (w), 1128 (s), 1043 (w), 723 cm^{-1} (w).

^{1}H NMR ($CDCl_3$, 300 MHz): δ = 0.88 (t, J = 6.9 Hz, 3 H, CH_3), 1.19–1.39 (m, 12 H, 6 × CH_2), 1.34 (t, J = 7.2 Hz, 3 H, CH_3), 1.58–1.68 (m, 2 H, CH_2), 2.94 (t, J = 7.6 Hz, 2 H, CH_2), 4.27 (q, J = 7.2 Hz, 2 H, OCH_2), 6.57 (m, 2 H, 2 × CH), 8.20 (br s, 1 H, NH).

^{13}C NMR ($CDCl_3$), 75 MHz): δ = 14.1, 14.5 (CH_3), 22.6, 27.3, 29.3, 29.4, 29.47, 29.51, 29.7, 31.8 (CH_2), 59.3 (OCH_2), 110.5 (CH), 111.1 (C), 115.7 (CH), 140.0 (C), 165.5 (O=C–O).

MS (EI, 70 eV): *m/z* (%) = 265 (M$^+$, 64), 236 (8), 220 (5), 192 (52), 166 (98), 154 (22), 138 (6), 124 (37), 120 (17), 94 (100).

HRMS (EI, 70 eV): *m/z* calcd for $C_{16}H_{27}NO_2$: 265.20422 [M$^+$]; found: 265.2042 ± 2 ppm.

Anal. Calcd for $C_{16}H_{27}NO_2$ (265.395): C, 72.41; H, 10.25. Found: C, 72.59; H, 10.60.

Ethyl 2-Decyl-1*H*-pyrrole-3-carboxylate (4k)

Route 1: Starting with **3o** (0.130 g, 0.4 mmol) and Me_3SiOTf (0.085 g, 0.4 mmol) in CH_2Cl_2 (7 mL), **4k** was isolated after chromatography (silica gel, *n*-hexane–EtOAc, 50:1 → 3:1) as a light brown oil (0.061 g, 57%).

Route 2: Starting with **3p** (0.300 g, 0.81 mmol) and Me_3SiOTf (0.180 g, 0.81 mmol) in CH_2Cl_2 (15 mL), **4k** was isolated after chromatography (silica gel, *n*-hexane–EtOAc, 50:1 → 3:1) as a light brown oil (0.122 g, 54%).

IR (neat): 3369 (s), 2946 (s), 2925 (s), 2854 (s), 1676 (s), 1574 (w), 1463 (s), 1396 (w), 1371 (m), 1330 (m), 1300 (m), 1258 (m), 1192 (s), 1183 (s), 1130 (s), 1034 (m), 721 cm^{-1} (m).

^{1}H NMR ($CDCl_3$, 300 MHz): δ = 0.88 (t, *J* = 7.2 Hz, 3 H, CH_3), 1.20–1.36 (m, 17 H, CH_3, 7 × CH_2), 1.50–1.66 (m, 2 H, CH_2), 2.94 (t, *J* = 7.8 Hz, 2 H, CH_2), 4.27 (q, *J* = 7.2 Hz, 2 H, OCH_2), 6.57 (d, *J* = 2.7 Hz, 2 H, 2 × CH), 8.16 (br s, 1 H, NH).

^{13}C NMR ($CDCl_3$), 75 MHz): δ = 14.1, 14.5 (CH_3), 22.6, 27.3, 29.3, 29.41, 29.46, 29.52, 29.61, 31.2, 31.8 (CH_2), 59.3 (OCH_2), 110.5 (CH), 111.2 (C), 115.6 (CH), 140.0 (C), 165.5 (O=C–O).

MS (EI, 70 eV): *m/z* (%) = 279 (M$^+$, 55), 250 (5), 234 (3), 206 (42), 192 (7), 166 (100), 138 (6), 120 (12), 94 (98).

HRMS (EI, 70 eV): *m/z* calcd for $C_{17}H_{29}NO_2$: 279.2198 [M$^+$]; found: 279.2198 ± 2 ppm.

Ethyl 2-Undecyl-1*H*-pyrrole-3-carboxylate (4l)

Route 1: Starting with **3q** (0.130 g, 0.4 mmol) and Me_3SiOTf (0.081 g, 0.4 mmol) in CH_2Cl_2 (5 mL), **4l** was isolated after chromatography (silica gel, *n*-hexane–EtOAc, 50:1 → 5:1) as a light brown oil (0.060 g, 57%).

Route 2: Starting with **3r** (0.400 g, 1.04 mmol) and Me_3SiOTf (0.231 g, 1.04 mmol) in CH_2Cl_2 (15 mL), **4l** was isolated after chromatography (silica gel, *n*-hexane–EtOAc, 50:1 → 5:1) as a light brown oil (0.171 g, 56%).

IR (neat): 3377 (m), 2956 (s), 2926 (s), 2854 (s), 1676 (s), 1463 (s), 1371 (w), 1330 (w), 1300 (w), 1257 (m), 1185 (m), 1183 (m), 1131 (s), 1032 (m), 721 cm^{-1} (w).

^{1}H NMR ($CDCl_3$, 300 MHz): δ = 0.88 (t, *J* = 7.2 Hz, 3 H, CH_3), 1.21–1.36 (m, 19 H, CH_3, 8 × CH_2), 1.48–1.58 (m, 2 H, CH_2), 2.94 (t, *J* = 7.8 Hz, 2 H, CH_2), 4.27 (q, *J* = 7.2 Hz, 2 H, OCH_2), 6.57 (d, *J* = 2.7 Hz, 2 H, 2 × CH), 8.14 (br s, 1 H, NH).

^{13}C NMR ($CDCl_3$), 75 MHz): δ = 14.1, 14.5 (CH_3), 22.7, 27.3, 29.3, 29.43, 29.46, 29.57, 29.60 (2 C), 31.2, 31.9 (CH_2), 59.3 (OCH_2), 110.5 (CH), 111.3 (C), 115.6 (CH), 139.9 (C), 165.5 (O=C–O).

MS (EI, 70 eV): *m/z* (%) = 293 (M$^+$, 71), 264 (2), 220 (4), 166 (100), 138 (4), 120 (15), 94 (97).

HRMS (EI, 70 eV): *m/z* calcd for $C_{18}H_{31}NO_2$: 293.2355 [M$^+$]; found: 293.2355 ± 2 ppm.

Ethyl 2-(6-Chlorohexyl)-1*H*-pyrrole-3-carboxylate (4m)

Starting with **3t** (0.300 g, 0.9 mmol) and Me_3SiOTf (0.191 g, 0.9 mmol) in CH_2Cl_2 (15 mL), **4m** was isolated after chromatography (silica gel, *n*-hexane–EtOAc, 50:1 → 1:1) as a light brown oil (0.091 g, 41%).

IR (neat): 3327 (s), 2962 (s), 2928 (s), 2875 (m), 2863 (w), 1727 (m), 1701 (s), 1672 (s), 1576 (m), 1501 (m), 1456 (m), 1438 (m), 1402 (w), 1371 (w), 1329 (w), 1299 (w), 1271 (m), 1198 (m), 1167 (s), 1122 (m), 1093 (m), 1028 (m), 889 (w), 733 cm^{-1} (m).

^{1}H NMR ($CDCl_3$, 300 MHz): δ = 1.22–1.44 (m, 7 H, CH_3, 2 × CH_2), 1.55–1.80 (m, 4 H, 2 × CH_2), 2.92 (t, *J* = 7.2 Hz, 2 H, CH_2), 3.53 (t, *J* = 6.6 Hz, 2 H, CH_2Cl), 4.26 (q, *J* = 7.2 Hz, 2 H, OCH_2), 6.56 (d, *J* = 2.7 Hz, 1 H, CH), 6.58 (d, *J* = 2.7 Hz, 1 H, CH), 8.23 (br s, 1 H, NH).

^{13}C NMR ($CDCl_3$, 75 MHz): δ = 14.2 (CH_3), 26.5, 27.1, 28.5, 30.4, 31.6 (CH_2), 44.4 (CH_2Cl), 59.2 (OCH_2), 110.5 (CH), 110.8 (C), 115.8 (CH), 140.1 (C), 165.7 (O=C–O).

MS (EI, 70 eV): *m/z* (%) = 257 (M$^+$, 11), 228 (6), 222 (8), 212 (10), 184 (37), 149 (52), 135 (24), 121 (100).

Anal. Calcd for $C_{13}H_{20}NO_2Cl$ (257.75): C, 60.58; H, 7.82. Found: C, 60.42; H, 7.96.

Ethyl 2-(7-Chloroheptyl)-1*H*-pyrrole-3-carboxylate (4n)

Starting with **3u** (0.300 g, 0.8 mmol) and Me_3SiOTf (0.183 g, 0.8 mmol) in CH_2Cl_2 (15 mL), **4n** was isolated after chromatography (silica gel, *n*-hexane–EtOAc, 50:1 → 1:1) as a light brown oil (0.105 g, 47%).

IR (neat): 3326 (s), 2958 (s), 2926 (s), 2872 (m), 2856 (w), 1726 (m), 1703 (s), 1675 (s), 1573 (m), 1497 (m), 1461 (m), 1444 (m), 1400 (w), 1369 (w), 1335 (w), 1303 (w), 1269 (m), 1204 (m), 1164 (s), 1118 (m), 1092 (m), 1031 (m), 894 (w), 736 cm^{-1} (m).

^{1}H NMR ($CDCl_3$, 300 MHz): δ = 1.21–1.45 (m, 9 H, CH_3, 3 × CH_2), 1.50–1.73 (m, 4 H, 2 × CH_2), 2.91 (t, *J* = 7.2 Hz, 2 H, CH_2), 3.53 (t, *J* = 6.6 Hz, 2 H, CH_2Cl), 4.26 (q, *J* = 7.2 Hz, 2 H, OCH_2), 6.56 (d, *J* = 2.7 Hz, 1 H, CH), 6.58 (d, *J* = 2.7 Hz, 1 H, CH), 8.22 (br s, 1 H, NH).

^{13}C NMR ($CDCl_3$, 75 MHz): δ = 14.3 (CH_3), 26.7, 27.2, 28.6, 29.2, 30.6, 31.8 (CH_2), 44.6 (CH_2Cl), 59.3 (OCH_2), 110.5 (CH), 110.9 (C), 115.9 (CH), 140.2 (C), 165.9 (O=C–O).

MS (EI, 70 eV): *m/z* (%) = 271 (M$^+$, 12), 242 (8), 236 (6), 226 (6), 198 (35), 163 (52), 149 (12), 135 (100).

Anal. Calcd for $C_{14}H_{22}NO_2Cl$ (271.78): C, 61.87; H, 8.16. Found: C, 61.68; H, 8.28.

1-(2-Methyl-1*H*-pyrrol-3-yl)ethanone (4o)

Method A: Starting with **3v** (0.100 g, 0.5 mmol) and TFA (0.36 mL, 4.7 mmol) in CH_2Cl_2 (10 mL), **4o** was isolated after chromatography (silica gel, *n*-hexane–EtOAc, 50:1 → 1:1) as a light yellow solid (0.039 g, 68%).

Method C: Starting with **3v** (0.400 g, 1.86 mmol) in DMSO (5 mL), **4o′** (0.023 g, 5%) and **4o** (0.137 g 60%) were isolated after chromatography (silica gel, *n*-hexane–EtOAc, 100:1 → 1:1) as light brown oil and solid, respectively.

1-(1-(2,2-Diethoxyethyl)-2-methyl-1*H*-pyrrol-3-yl)ethanone (4o′)

IR (neat): 2977 (m), 2928 (m), 2921 (m), 2903 (m), 2899 (m), 2883 (m), 2750 (m), 2744 (m), 1733 (m), 1652 (s), 1597 (w), 1575 (w), 1558 (w), 1539 (s), 1505 (m), 1455 (m), 1435 (s), 1417 (m), 1372 (s), 1310 (m), 1266 (s), 1241 (s), 1219 (m), 1177 (m), 1151 (s), 1126 (s), 1065 (s), 952 (w), 919 (w), 902 (w), 723 (w), 684 (w), 675 cm^{-1} (w).

^{1}H NMR ($CDCl_3$, 300 MHz): δ = 1.16 (t, *J* = 7.2 Hz, 6 H, 2 × CH_3), 2.39 (s, 3 H, CH_3), 2.57 (s, 3 H, CH_3), 3.34–3.44 (m, 2 H, OCH_2), 3.63–3.73 (m, 2 H, OCH_2), 3.93 (d, *J* = 5.4 Hz, 2 H, NCH_2), 4.54 (t,

J = 5.4 Hz, 1 H, OCH), 6.47 (d, J = 3.3 Hz, 1 H, CH), 6.55 (d, J = 3.3 Hz, 1 H, CH).

^{13}C NMR ($CDCl_3$, 75 MHz): δ = 11.6, 15.2 (2 C), 29.7 (CH_3), 49.7 (NCH_2), 63.9 (2 C, OCH_2), 102.0 (OCH), 110.0, 120.8 (CH), 121.2, 135.6 (C), 195.1 (C=O).

MS (EI, 70 eV): m/z (%) = 239 (M^+, 31), 224 (2), 194 (6), 178 (2), 165 (18), 149 (10), 136 (5), 123 (14), 107 (60), 103 (100), 94 (14), 75 (83).

HRMS (ESI): m/z calcd for $C_{13}H_{21}NO_3$ [M^+]: 239.15214; found: 239.15119.

1-(2-Methyl-1*H*-pyrrol-3-yl)ethanone (4o)

Mp 75 °C.

IR (KBr): 3211 (s), 3110 (s), 3021 (m), 2981 (w), 2962 (m), 2926 (m), 2843 (w), 1636 (s), 1569 (s), 1491 (s), 1465 (s), 1402 (s), 1364 (s), 1333 (w), 1279 (m), 944 (m), 892 (m), 858 (w), 799 (w), 775 (w), 733 (m), 677 (w), 636 cm^{-1} (w).

^{1}H NMR ($CDCl_3$, 300 MHz): δ = 2.43 (s, 3 H, CH_3), 2.55 (s, 3 H, CH_3), 6.52–6.54 (m, 1 H, CH), 6.57–6.59 (m, 1 H, CH), 8.52 (br s, 1 H, NH).

^{13}C NMR ($CDCl_3$, 75 MHz): δ = 13.8, 28.3 (CH_3), 110.5, 115.9 (CH), 120.5, 135.4 (C), 195.8 (C=O).

MS (EI, 70 eV): m/z (%) = 123 (M^+, 44), 107 (100), 94 (3), 80 (25), 66 (2), 43 (11).

Anal. Calcd for C_7H_9NO (123.155): C, 68.27; H, 7.37. Found: C, 68.12; H, 7.15.

1-(2-Ethyl-1*H*-pyrrol-3-yl)propan-1-one (4p)

Starting with **3w** (0.300 g, 1.2 mmol) and TFA (0.96 mL, 12.3 mmol) in CH_2Cl_2 (15 mL), **4p** was isolated after chromatography (silica gel, *n*-hexane–EtOAc, 50:1 → 1:1) as a light yellow solid (0.130 g, 70%).

IR (KBr): 3213 (s), 3112 (s), 3023 (m), 2978 (m), 2959 (m), 2927 (m), 2851 (w), 1646 (s), 1571 (m), 1493 (s), 1475 (s), 1412 (s), 1367 (s), 1331 (w), 1282 (m), 1220 (m), 1150 (w), 954 (m), 902 (w), 885 (m), 796 (m), 739 (m), 675 cm^{-1} (w).

^{1}H NMR ($CDCl_3$, 300 MHz): δ = 1.18 (t, J = 7.2 Hz, 3 H, CH_3), 1.20 (t, J = 7.2 Hz, 3 H, CH_3), 2.70 (q, J = 7.2 Hz, 2 H, CH_2), 2.97 (q, J = 7.2 Hz, 2 H, CH_2), 6.38–6.41 (m, 1 H, CH), 6.45–6.49 (m, 1 H, CH), 8.27 (br s, 1 H, NH).

^{13}C NMR ($CDCl_3$, 75 MHz): δ = 10.1, 13.8, (CH_3), 20.2, 35.4 (CH_2), 110.7, 115.8 (CH), 119.8, 146.1 (C), 199.4 (C=O).

MS (EI, 70 eV): m/z (%) = 151 (M^+, 51), 122 (3), 107 (100), 94 (16), 80 (17), 66 (5), 57 (7).

Anal. Calcd for $C_9H_{13}NO$ (151.206): C, 71.49; H, 8.67. Found: C, 71.22; H, 8.35.

(2-Methyl-1*H*-pyrrol-3-yl)(phenyl)methanone (4r)

Method A: Starting with **3x** (0.050 g, 0.2 mmol) and TFA (0.14 mL, 1.8 mmol) in CH_2Cl_2 (3 mL), **4r** was isolated after chromatography (silica gel, *n*-hexane–EtOAc, 50:1 → 1:1) as a slightly light yellow solid (0.027 g, 82%).

Method B: Starting with **3x** (0.050 g, 0.2 mmol) and Me_3SiOTf (0.040 g, 0.2 mmol) in CH_2Cl_2 (3 mL), **4r** was isolated after chromatography (silica gel, *n*-hexane–EtOAc, 50:1 → 1:1) as a slightly light yellow solid (0.026 g, 79%).

Method C: Starting with **3x** (0.100 g, 0.4 mmol) in DMSO (5 mL), **4r** was isolated after chromatography (silica gel, *n*-hexane–EtOAc, 50:1 → 1:1) as a light brown solid (0.048 g, 72%).

IR (KBr): 3232 (w), 2924 (w), 1608 (s), 1561 (m), 1446 (s), 1367 (m), 1340 (w), 1277 (m), 1212 (w), 1180 (w), 1148 (w), 1101 (w), 1075 (w), 1032 (w), 880 (m), 792 (m), 743 (w), 712 (s), 702 (s), 672 (w), 612 cm^{-1} (w).

^{1}H NMR ($CDCl_3$, 300 MHz): δ = 2.54 (s, 3 H, CH_3), 6.40 (dd, J = 3.0, 2.7 Hz, 1 H, CH), 6.55 (dd, J = 3.0, 2.4 Hz, 1 H, CH), 7.41–7.51 (m, 3 H, 3 × CH of Ph), 7.78–7.81 (m, 2 H, 2 × CH of Ph), 9.06 (br s, 1 H, NH).

^{13}C NMR ($CDCl_3$, 75 MHz): δ = 13.7 (CH_3), 112.5, 115.6 (CH), 119.6 (C), 128.0 (2 C), 129.0 (2 C), 131.1 (CH of Ph), 136.7 (C of Ph), 140.6 (C), 192.8 (C=O).

MS (EI, 70 eV): m/z (%) = 185 (M^+, 73), 170 (3), 107 (100), 80 (13), 77 (24).

HRMS (ESI): m/z calcd for $C_{12}H_{11}NO$ [M^+]: 185.08406; found: 185.08483.

(2-Methoxyphenyl)(2-methyl-1*H*-pyrrol-3-yl)methanone (4s)

Starting with **3y** (0.120 g, 0.1 mmol) and TFA (0.32 mL, 4.3 mmol) in CH_2Cl_2 (6.4 mL), **4s** was isolated after chromatography (silica gel, *n*-hexane–EtOAc, 50:1 → 1:1) as a light yellow oil (0.70 g, 79%).

IR (KBr): 3270 (w), 3054 (w), 2926 (w), 1598 (m), 1498 (s), 1283 (s), 1021 (w), 735 cm^{-1} (s).

^{1}H NMR ($CDCl_3$, 250 MHz): δ = 2.43 (s, 3 H, CH_3), 3.72 (s, 3 H, OCH_3), 6.17–6.19 (m, 1 H, CH_{py}), 6.43–6.45 (m, 1 H, CH_{py}), 6.88–6.94 (m, 2 H, CH_{Ar}), 7.24 (dd, ^{3}J = 7.7 Hz, ^{4}J = 2.0 Hz, 1 H, CH_{Ar}), 8.35 (dd, ^{3}J = 7.4 Hz, ^{4}J = 2.0 Hz, 1 H, CH_{Ar}), 8.35 (br s, 1 H, NH).

^{13}C NMR ($CDCl_3$, 62 MHz): δ = 13.8 (CH_3), 55.7 (OCH_3), 111.3 (CH_{py}), 112.5 (CH_{Ar}), 120.2 (CH_{Ar}), 121.1 (C_{py}), 128.3, 128.7, 130.5 (C_{Ar}), 136.4 (C_{Py}), 156.5 (C_{Ar}), 192.1 (C = O).

Anal. Calcd for $C_{13}H_{13}NO_2$ (215.25): C, 72.54; H, 6.09. Found: C, 72.84; H, 6.22.

(2-Chlorophenyl)(2-methyl-1*H*-pyrrol-3-yl)methanone (4t)

Starting with **3w** (0.216 g, 0.8 mmol) and TFA (0.57 mL, 7.7 mmol) in CH_2Cl_2 (12 mL), **4t** was isolated after chromatography (silica gel, *n*-hexane–EtOAc, 50:1 → 1:1) as a light yellow oil (0.100 g, 63%).

IR (neat): 3350 (w), 2923 (w), 2826 (w), 1674 (m), 1642 (s), 1264 (s), 1072 (w), 749 cm^{-1} (s).

^{1}H NMR ($CDCl_3$, 250 MHz): δ = 2.44 (s, 3 H, CH_3), 6.15 (m, 1 H, CH_{py}), 6.48 (m, 1 H, CH_{py}), 7.25–7.28 (m, 2 H, CH_{Ar}), 7.30–7.33 (m, 1 H, CH_{Ar}), 7.35 (br m, 2 H, CH_{Ar}), 8.28 (br s, 1 H, NH).

^{13}C NMR ($CDCl_3$, 62 MHz): δ = 13.8 (CH_3), 112.4, 115.9 (CH_{py}), 120.4 (C_{Py}), 126.4, 128.3, 129.8, 130.1 (CH_{Ar}), 137.6 (C_{Ar}), 139.2 (C_{Ar}), 140.9 (C_{Ar}), 190.6 (C=O).

Anal. Calcd for $C_{12}H_{10}NOCl$ (219.66): C, 65.62; H, 4.59. Found: C, 65.88; H, 4.76.

1,5,6,7-Tetrahydro-4*H*-indol-4-one (7a)

Method A: Starting with **6a** (0.070 g, 0.3 mmol) and TFA (0.24 mL, 3.1 mmol) in CH_2Cl_2 (5 mL), **7a** was isolated after chromatography (silica gel, *n*-hexane–EtOAc, 50:1 → EtOAc) as a slightly light yellow solid (0.040 g, 95%).

Method C: Starting with **6a** (0.300 g, 1.32 mmol) in DMSO (10 mL), **7a** was isolated after chromatography (silica gel, *n*-hexane–EtOAc, 50:1 → EtOAc) as a light brown oil (0.126 g, 71%).

IR (KBr): 3183 (w), 3105 (s), 2949 (s), 2889 (w), 2846 (w), 1683 (w), 1622 (s), 1493 (s), 1477 (s), 1310 (w), 1197 (w), 1146 (w), 893 (w), 854 (w), 804 (w), 705 cm^{-1} (w).

^{1}H NMR ($CDCl_3$–DMSO-d_6, 1:1, 300 MHz): δ = 2.12 (quint, J = 6.3 Hz, 2 H, CH_2), 2.44 (t, J = 6.3 Hz, 2 H, CH_2), 2.81 (t, J = 6.3 Hz, 2 H, CH_2), 6.44 (m, 1 H, CH), 6.64 (m, 1 H, CH), 10.71 (br s, 1 H, NH).

^{13}C NMR ($CDCl_3$–DMSO-d_6, 1:1, 75 MHz): $\delta = 22.1$, 23.5, 37.4 (CH_2), 104.4, 118.2 (CH), 119.4, 143.5 (C), 194.0 (C=O).

MS (EI, 70 eV): *m/z* (%) = 135 (M^+, 29), 106 (29), 103 (100), 79 (30).

HRMS (ESI): *m/z* calcd for C_8H_9NO [M^+]: 135.06841; found: 135.06852.

6,6-Dimethyl-1,5,6,7-tetrahydro-4*H*-indol-4-one (7b)

Starting with **6b** (0.090 g, 0.4 mmol) and TFA (0.27 mL, 3.5 mmol) in CH_2Cl_2 (7 mL), **7b** was isolated after chromatography (silica gel, *n*-hexane–EtOAc, 50:1 → EtOAc) as a slightly light yellow solid (0.034 g, 60%).

IR (KBr): 3278 (w), 2962 (w), 1626 (s), 1472 (m), 1412 (m), 1203 (s), 1173 cm^{-1} (s).

^{1}H NMR ($CDCl_3$ + DMSO-d_6, 300 MHz): $\delta = 1.12$ (s, 6 H, $2 \times CH_3$), 2.37 (s, 2 H, CH_2), 2.68 (s, 2 H, CH_2), 6.56 (m, 1 H, CH), 6.68 (m, 1 H, CH), 8.50 (br s, 1 H, NH).

^{13}C NMR ($CDCl_3$ + DMSO-d_6, 75 MHz): $\delta = 28.6$ ($2 \times CH_3$), 35.9 (C), 36.9, 52.0 (CH_2), 105.8, 118.7 (CH), 119.2, 142.5 (C), 194.1 (C=O).

MS (EI, 70 eV): *m/z* (%) = 163 (M^+, 11), 106 (20), 95 (10), 83 (8), 79 (12), 70 (100).

HRMS (ESI): *m/z* calcd for $C_{10}H_{13}NO$ [M^+]: 163.09971; found: 163.09984.

6-Methyl-1,5,6,7-tetrahydro-4*H*-indol-4-one (7c)

Starting with **6c** (0.300 g, 1.2 mmol) and TFA (0.96 mL, 12.4 mmol) in CH_2Cl_2 (15 mL), **7c** was isolated after chromatography (silica gel, *n*-hexane–EtOAc, 30:1 → EtOAc) as a slightly light yellow solid (0.139 g, 75%).

IR (KBr): 3257 (w), 3070 (w), 2959 (m), 2879 (w), 1624 (s), 1475 (m), 1414 (m), 1204 (s), 1175 cm^{-1} (s).

^{1}H NMR ($CDCl_3$ + DMSO-d_6, 300 MHz): $\delta = 1.02$–1.12 (m, 3 H, CH_3), 2.22–2.86 (m, 5 H, $2 \times CH_2$, CH), 6.58 (m, 1 H, CH), 6.69 (m, 1 H, CH), 8.53 (br s, 1 H, NH).

^{13}C NMR ($CDCl_3$ + DMSO-d_6, 75 MHz): $\delta = 20.8$ (CH_3), 30.6 (CH), 33.4, 47.2 (CH_2), 106.1, 118.5 (CH), 119.3, 143.1 (C), 194.1 (C=O).

MS (EI, 70 eV): *m/z* (%) = 149 (M^+, 15), 108 (24), 93 (7), 79 (22), 70 (100).

Anal. Calcd for $C_9H_{11}NO$ (149.190): C, 72.46; H, 7.43. Found: C, 72.02; H, 7.73.

6-Phenyl-1,5,6,7-tetrahydro-4*H*-indol-4-one (7d)

Starting with **6d** (0.300 g, 1.0 mmol) and TFA (0.76 mL, 9.9 mmol) in CH_2Cl_2 (15 mL), **7d** was isolated after chromatography (silica gel, *n*-hexane–EtOAc, 30:1 → EtOAc) as a light yellow solid (0.153 g, 73%).

IR (KBr): 3285 (m), 3067 (m), 2971 (m), 2886 (m), 1625 (s), 1471 (m), 1410 (m), 1199 (w), 1171 (m), 759 (w), 705 cm^{-1} (w).

^{1}H NMR ($CDCl_3$– DMSO-d_6, 1:1, 300 MHz): $\delta = 2.65$–3.15 (m, 4 H, $2 \times CH_2$), 3.44–3.64 (m, 1 H, C*H*Ph), 6.53 (m, 1 H, CH), 6.63 (m, 1 H, NCH), 7.21–7.38 (m, 5 H, 5 × CH of Ph), 8.76 (br s, 1 H, NH).

^{13}C NMR ($CDCl_3$– DMSO-d_6, 1:1, 75 MHz): $\delta = 35.1$ (CH_2), 42.3 (*C*HPh), 45.2 (CH_2), 106.4, 118.3 (CH), 119.1, 143.0 (C), 126.3 (2 C), 126.8, 128.9 (2 C, CH of Ph), 143.9 (C of Ph), 194.0 (C=O).

MS (EI, 70 eV): *m/z* (%) = 211 (M^+, 21), 170 (5), 132 (100), 107 (21), 93 (5), 91 (19), 79 (26), 77 (12).

Anal. Calcd for $C_{14}H_{13}NO$ (211.259): C, 79.59; H, 6.20. Found: C, 79.17; H, 6.03.

1-(2,2-Diethoxyethyl)-2,5-dimethyl-1*H*-pyrrole (9)

Starting with acetonylacetone (**8**) (0.21 mL, 1.8 mmol), 2-azido-1,1-diethoxyethane (**2a**) (0.335 g, 2.1 mmol) and Ph_3P (0.708 g, 2.7 mmol) in THF (10 mL), **9** was isolated after chromatography (silica gel, *n*-hexane–EtOAc, 100:1 → 10:1) as a slightly light yellow oil (0.353 g, 93%).

IR (neat): 2976 (s), 2925 (s), 2901 (s), 1521 (w), 1447 (m), 1409 (s), 1383 (m), 1303 (m), 1130 (s), 1067 (s), 1019 (m), 752 cm^{-1} (s).

^{1}H NMR ($CDCl_3$, 300 MHz): $\delta = 1.16$ (t, *J* = 7.2 Hz, 6 H, $2 \times CH_3$), 2.24 (s, 6 H, $2 \times CH_3$), 3.29–3.39 (m, 2 H, OCH_2), 3.61–3.71 (m, 2 H, OCH_2), 3.87 (d, *J* = 5.4 Hz, 2 H, NCH_2), 4.49 (t, *J* = 5.4 Hz, 1 H, OCH), 5.75 (s, 2 H, 2 × CH).

^{13}C NMR ($CDCl_3$, 75 MHz): $\delta = 11.7$ (2 C), 14.2 (2 C, CH_3), 46.4 (NCH_2), 62.9 ($2 \times OCH_2$), 101.8 (OCH), 104.3 (2 × CH), 127.1 (2 × C).

MS (EI, 70 eV): *m/z* (%) = 211 (M^+, 58), 166 (21), 138 (10), 122 (12), 107 (39), 103 (100), 76 (94).

3-Azido-1,1-diethoxypropane (10)

Sodium azide (9.752 g, 150 mmol) and potassium iodide (1.669 g, 10 mmol) were added to 3-chloropropionaldehyde diethyl acetal (16.8 mL, 100 mmol) in DMSO (100 mL) at r.t. The reaction mixture was heated to 90 °C and stirred for 72 h at 90 °C. After cooling to r.t., H_2O (200 mL) and Et_2O (200 mL) were added, the organic layer was separated and the aqueous layer was repeatedly extracted with Et_2O (3 × 200 mL). The combined organic extracts were dried over Na_2SO_4, filtered, and the filtrate was concentrated to dryness in vacuo. Product **10** was isolated without further purification as a slightly light yellow oil (15.271 g, 88%).

IR (neat): 3415 (br), 2998 (w), 2950 (w), 2099 (m), 1653 (m), 1441 (m), 1411 (m), 1130 (m), 1062 (s), 1021 (s), 953 (m), 709 (w), 669 cm^{-1} (w).

^{1}H NMR ($CDCl_3$, 300 MHz): $\delta = 1.22$ (t, *J* = 7.2 Hz, 6 H, $2 \times CH_3$), 1.89 (dq, *J* = 5.7, 1.2 Hz, 2 H, CH_2), 3.38 (t, *J* = 6.9 Hz, 2 H, CH_2N_3), 3.47–3.57 (m, 2 H, OCH_2), 3.62–3.73 (m, 2 H, OCH_2), 4.60 (t, *J* = 5.7 Hz, 1 H, OCH).

^{13}C NMR ($CDCl_3$, 75 MHz): $\delta = 14.7$ (2 C, CH_3), 32.7 (CH_2), 46.9 (CH_2N_3), 61.2 (2 C, OCH_2), 99.9 (CH).

MS (EI, 70 eV): *m/z* (%) = 127 ([M – OEt]$^+$, 29), 116 (11), 103 (81), 73 (59), 57 (13), 45 (93), 28 (100).

3-[(3,3-Diethoxypropyl)amino]-1-phenylbut-2-en-1-one (11)

The reaction was carried by application of the procedure given for the synthesis of products **3**. Starting with benzoylacetone (**1u**) (0.487 g, 3.0 mmol), **10** (0.624 g, 3.6 mmol) and Ph_3P (1.180 g, 4.5 mmol) in THF (15 mL), **11** was isolated after chromatography (silica gel, *n*-hexane–EtOAc, 50:1 → 3:1) as a light yellow oil (0.805 g, 95%).

IR (neat): 3463 (br), 3061 (w), 2974 (m), 2929 (m), 2882 (m), 1601 (s), 1547 (s), 1442 (m), 1379 (m), 1317 (s), 1299 (s), 1226 (w), 1127 (s), 1064 (s), 809 (w), 739 (m), 688 cm^{-1} (w).

^{1}H NMR ($CDCl_3$, 300 MHz): $\delta = 1.22$ (t, *J* = 7.2 Hz, 6 H, $2 \times CH_3$), 1.96 (dq, *J* = 5.7, 1.2 Hz, 2 H, CH_2), 2.08 (s, 3 H, CH_3), 4.43 (dt, *J* = 6.9, 6.3 Hz, 2 H, NCH_2), 3.47–3.58 (m, 2 H, OCH_2), 3.63–3.73 (m, 2 H, OCH_2), 4.62 (t, *J* = 5.4 Hz, 1 H, OCH), 5.66 (s, 1 H, CH=C), 7.36–7.42 (m, 3 H, 3 × CH of Ph), 7.83–7.86 (m, 2 H, 2 × CH of Ph), 11.44 (br s, 1 H, NH).

^{13}C NMR ($CDCl_3$, 75 MHz): $\delta = 14.6$ (2 C), 18.4 (CH_3), 33.5 (CH_2), 38.3 (NCH_2), 61.0 (2 C, OCH_2), 91.2 (H*C*=C–N), 99.9 (OCH), 126.1 (2 C), 127.4 (2 C), 129.6 (CH of Ph), 139.8 (C of Ph), 164.1 (N–*C*=CH), 186.5 (C=O).

MS (EI, 70eV): m/z (%) = 291 (M^+, 60), 262 (10), 146 (10), 216 (32), 201 (8), 188 (42), 174 (83), 160 (4), 145 (12), 131 (15), 105 (100), 103 (17), 91 (38), 77 (37).

Anal. Calcd for $C_{17}H_{25}NO_3$ (291.390): C, 70.07; H, 8.65. Found: C, 70.03; H, 8.73.

(2-Methylpyridin-3-yl)(phenyl)methanone (12)

The reaction was carried by application of the procedures given for the synthesis of products **3** and **4** (method A). Starting with **11** (0.146 g, 0.5 mmol) and TFA (0.4 mL, 5.0 mmol) in CH_2Cl_2 (3 mL) (0–20 °C), **12** was isolated after chromatography (silica gel, *n*-hexane–EtOAc, 50:1 → EtOAc) as a light yellow solid (0.095 g, 96%).

IR (KBr): 3004 (w), 1721 (s), 1667 (s), 1616 (m), 1456 (m), 1414 (w), 1382 (w), 1283 (s), 1198 (s), 1131 (s), 1070 (m), 965 (m), 898 (w), 822 (s), 706 (m), 638 (m), 574 (w), 545 cm^{-1} (w).

^1H NMR ($CDCl_3$, 300 MHz): δ = 2.76 (s, 3 H, CH_3), 7.55 (t, J = 7.5 Hz, 2 H, 2 × CH), 7.69–7.79 (m, 4 H, 4 × CH), 8.16 (d, J = 7.5 Hz, 1 H, CH), 8.96 (d, J = 4.8 Hz, 1 H, CH).

^{13}C NMR ($CDCl_3$, 75 MHz): δ = 19.2 (CH_3), 123.1, 129.2 (2 C), 130.0 (2 C), 134.8 (CH), 135.4, 136.7 (C), 141.7, 144.7 (CH), 154.1 (C), 193.0 (C=O).

MS (EI, 70 eV): m/z (%) = 197 (M^+, 100), 182 (3), 120 (12), 105 (50), 92 (24), 77 (57).

HRMS (ESI): m/z calcd for $C_{13}H_{11}NO$ [M^+]: 197.0841; found: 197.0822.

UV/Vis (MeCN): λ_{max} (log ε) = 251 nm (3.90).

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References

(1) For pyrrole natural products: (a) Falk, H. *The Chemistry of Linear Oligopyrroles and Bile Pigments*; Springer-Verlag: Wien, **1989**, 355. (b) Montforts, F.-P.; Schwartz, U. M. *Angew. Chem., Int. Ed. Engl.* **1985**, *24*, 775; *Angew. Chem.* **1985**, *97*, 767. (c) Dutton, C. J.; Fookes, C. J. R.; Battersby, A. R. *J. Chem. Soc., Chem. Commun.* **1983**, 1237. (d) Stork, G.; Nakahara, Y.; Nakahara, Y.; Greenlee, W. J. *J. Am. Chem. Soc.* **1978**, *100*, 7775. (e) Stork, G.; Nakamura, E. *J. Am. Chem. Soc.* **1983**, *105*, 5510. (f) Bickmeyer, U.; Drechsler, C.; Köck, M.; Assmann, M. *Toxicon* **2004**, *44*, 45. (g) Lindel, T.; Breckle, G.; Hochgürtel, M.; Volk, C.; Grube, A.; Köck, M. *Tetrahedron Lett.* **2004**, *45*, 8149. (h) Feldman, K. S. *ARKIVOC* **2003**, *(vi)*, 179. (i) Holub, J. M.; O'Toole-Colin, K.; Getzel, A.; Argenti, A.; Evans, M. A.; Smith, D. C.; Dalglish, G. A.; Rifat, S.; Wilson, D. L.; Taylor, B. M.; Miott, U.; Glersaye, J.; Lam, K. S.; McCranor, B. J.; Berkowitz, J. D.; Miller, R. B.; Lukens, J. R.; Krumpe, K.; Gupton, J. T.; Burnham, B. S. *Molecules* **2004**, *9*, 135; and references cited therein.

(2) Books for pyrrole syntheses: (a) Eicher, T.; Hauptmann, S. *Chemie der Heterocyclen*; Thieme Verlag: Stuttgart, **1994**, 94. (b) Sundberg, R. J. In *Comprehensive Heterocyclic Chemistry*, Vol. 4; Bird, C. W.; Cheeseman, G. W. H., Eds.; Pergamon Press: Oxford, **1984**, 331. (c) Gribble, G. W. *Comprehensive Heterocyclic Chemistry II*, Vol. 2; Katritzky, A. R.; Rees, C. W.; Scriven, E. F. V., Eds.; Elsevier: Oxford, **1996**, 207. (d) Bean, G. P. *Pyrroles*; Jones, R. A., Ed.; Wiley: New York, **1990**, 105.

(3) For pyrrole syntheses: (a) Huisgen, R. *Angew. Chem., Int. Ed. Engl.* **1967**, *2*, 565. (b) Huisgen, R.; Gotthard, H.; Bayer, H. O.; Schäfer, F. C. *Chem. Ber.* **1970**, *103*, 2611. (c) Barnard, G. F.; Itoh, R.; Hohberger, L.; Shemin, D. *J. Biol. Chem.* **1977**, *252*, 8965. (d) Chiu, P.-K.; Lui, K.-H.; Maini, P. N.; Sammes, M. P. *J. Chem. Soc., Chem. Commun.* **1987**, 109. (e) Barton, D. H. R.; Kervagoret, J.; Zard, S. Z. *Tetrahedron* **1990**, *46*, 7587. (f) Roskamp, E. J.; Dragovich, P. S.; Hartung, J. B.; Pederson, S. F. *J. Org. Chem.* **1989**, *54*, 4736. (g) Tang, J.; Verkade, J. G. *J. Org. Chem.* **1994**, *59*, 7793. (h) De Kimpe, N.; Tehrani, K. A.; Stevens, C.; De Cooman, P. *Tetrahedron* **1997**, *53*, 3693. (i) Alberala, A.; Ortega, A. G.; Sádaba, M. L.; Snudo, C. *Tetrahedron* **1999**, *55*, 6555.

(4) For other pyrrole syntheses: (a) Grigg, R.; Savic, V. *Chem. Commun.* **2000**, 873. (b) Trofimov, B. A.; Tarasova, O. A.; Mikhaleva, A. I.; Kalinina, N. A.; Sinegovskaya, L. M.; Henkelmann, J. *Synthesis* **2000**, 1585. (c) Almerico, A. M.; Montalbano, A.; Diana, P.; Barraja, P.; Lauria, A.; Cirrincione, G.; Dattolo, G. *ARKIVOC* **2001**, *(vi)*, 129. (d) Trofimov, B. A.; Markova, M. V.; Morozova, L. V.; Mikhaleva, A. I. *ARKIVOC* **2001**, *(ix)*, 24. (e) Nair, V.; Vinod, A. U.; Rajesh, C. *J. Org. Chem.* **2001**, *66*, 4427. (f) Ranu, B. C.; Hajra, A. *Tetrahedron* **2001**, *57*, 4767. (g) Lagu, B.; Pan, M.; Wachter, M. P. *Tetrahedron Lett.* **2001**, *42*, 6027. (h) Quiclet-Sire, B.; Wendeborn, F.; Zard, S. Z. *Chem. Commun.* **2002**, 2214. (i) Demir, A. S.; Akhmedov, I. M.; Sesenoglu, *Tetrahedron* **2002**, *58*, 9793. (j) Yoshida, M.; Kitamura, M.; Narasaka, K. *Bull. Chem. Soc. Jpn.* **2003**, *76*, 2003. (k) Knight, D. W.; Sharland, C. M. *Synlett* **2003**, 2258. (l) Yu, M.; Pagenkopf, B. L. *Org. Lett.* **2003**, *5*, 5099. (m) Dhawan, R.; Arndtsen, B. A. *J. Am. Chem. Soc.* **2004**, *126*, 468. (n) Flögel, O.; Reissig, H.-U. *Synlett* **2004**, 895. (o) Song, Z.; Reiner, J.; Zhao, K. *Tetrahedron Lett.* **2004**, *45*, 3953. (p) Chien, T.-C.; Meade, E. A.; Hinkley, J. M.; Townsend, L. B. *Org. Lett.* **2004**, *6*, 2857. (q) Ramanathan, B.; Keith, A. J.; Armstrong, D.; Odom, A. L. *Org. Lett.* **2004**, *6*, 2957. (r) Trofimov, B. A.; Zaitsev, A. B.; Schmidt, E. Y.; Vasil'tsov, A. M.; Mikhaleva, A. I.; Ushakov, I. A.; Vashchenko, A. V.; Zorina, N. V. *Tetrahedron Lett.* **2004**, *45*, 3789. (s) Agarwal, S.; Knölker, H.-J. *Org. Biomol. Chem.* **2004**, *2*, 3060. (t) Dieltiens, N.; Stevens, C. V.; De Vos, D.; Allaert, B.; Drozdzak, R.; Verpoort, F. *Tetrahedron Lett.* **2004**, *45*, 8995. (u) Dieltiens, N.; Stevens, C. V.; Allaert, B.; Verpoort, F. *ARKIVOC* **2005**, *(i)*, 92. (v) Schmidt, E. Y.; Mikhaleva, A. I.; Vasil'tsov, A. M.; Zaitsev Zorina, A. B. N. V. *ARKIVOC* **2005**, *(vii)*, 11. (w) Tehrani, K. A.; Borremans, D.; De Kimpe, N. *Tetrahedron* **1999**, *55*, 4133. (x) Kesteleyn, B.; Alonso, E. R.; Stevens, C.; Dejaegher, Y.; Peristeropoulou, M.; Tuyen, N. V.; Kulinkovich, O.; De Kimpe, N. *Tetrahedron* **1999**, *55*, 4153.

(5) Reviews of aza-Wittig reactions: (a) Eguchi, S.; Okano, T.; Okawa, T. *Recent Res. Dev. Org. Chem.* **1997**, 337; *Chem. Abstr.* **1999**, *130*, 252510. (b) Fresneda, P. M.; Molina, P. *Synlett* **2004**, 1. (c) Eguchi, S. *ARKIVOC* **2005**, *(ii)*, 98. (d) Palacios, F.; Alonso, C.; Aparicio, D.; Rubiales, G.; de los Santos, J. M. *Tetrahedron* **2007**, *63*, 523.

(6) (a) Montforts, F.-P.; Schwartz, U. M.; Mai, G. *Liebigs Ann. Chem.* **1990**, 1037. (b) Gusar, N. I. *Russ. Chem. Rev.* **1991**, *60*, 146. (c) Eguchi, S.; Matsushita, Y.; Yamashita, K. *Org. Prep. Proced. Int.* **1992**, *24*, 211. (d) Eguchi, S.; Okano, T. *J. Synth. Org. Chem. Jpn.* **1993**, *51*, 203. (e) Molina, P.; Viliplana, M. J. *Synthesis* **1994**, 1197. (f) Wamhoff, H.; Richard, G.; Stoelben, S. *Adv. Heterocycl. Chem.* **1995**, *64*, 159. (g) Ming-Wu, D.; Zhao-Jie, L. *Chin. J. Org. Chem.* **2001**, *21*, 1.

(7) (a) Langer, P.; Freifeld, I. *Chem. Commun.* **2002**, 2668. (b) Freifeld, I.; Shojaei, H.; Langer, P. *J. Org. Chem.* **2006**, *71*, 4965.

(8) Bellur, E.; Görls, H.; Langer, P. *J. Org. Chem.* **2005**, *70*, 4751.

(9) Bellur, E.; Langer, P. *Tetrahedron Lett.* **2006**, *47*, 2151.

(10) (a) Parr, R. W.; Reiss, J. A. *Aust. J. Chem.* **1984**, *37*, 389. (b) Bridge, A. W.; Fenton, G.; Halley, F.; Hursthouse, M. B.; Lehmann, C. W.; Lythgoe, D. J. *J. Chem. Soc., Perkin Trans. 1* **1993**, *22*, 2761. (c) Kascheres, A.; Schumacher, H. C.; Rodrigues, R. A. F. *J. Heterocycl. Chem.* **1997**, *34*, 757.

(11) (a) Bertschy, H.; Meunier, A.; Neier, R. *Angew. Chem., Int. Ed. Engl.* **1990**, *29*, 777; *Angew. Chem.* **1990**, *102*, 828. (b) Carboni, B.; Vaultier, M.; Carrie, R. *Tetrahedron* **1987**, *43*, 1799. (c) Chavan, S. P.; Subbarao, Y. T. *Tetrahedron Lett.* **1999**, *40*, 5073.

(12) Bobbitt, J. M.; Kulkarni, C. L.; Dutta, C. P.; Kofod, H.; Chiong, K. N. *J. Org. Chem.* **1978**, *43*, 3541.