

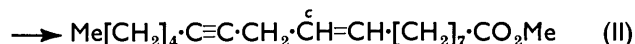
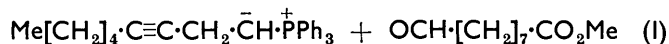
Natural Acetylenes. Part XL.¹ Syntheses of Polyacetylenic C₁₈ and C₁₆ Esters with 9-Ene-12,14-diyne Unsaturation, and their Labelling^{2,3}

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The esters R[C≡C]₂·CH₂·CH=CH·[CH₂]₇·CO₂Me {R = Me[CH₂]₂, MeC≡C, *cis*- or *trans*-MeCH=CH, *trans*-HO·CH₂·CH=CH, HO·CH₂·C≡C, *cis*- or *trans*-MeO₂C·CH=CH, MeO₂C·C≡C, (EtO)₂CH, OHC, or H₂N·OC} were prepared from the Wittig salt Me₃Si·C≡C·CH₂·CH₂·[†]PPh₃I⁻ via IC≡C·CH₂·CH=CH·[CH₂]₇·CO₂Me; several were specifically labelled [at C(9), C(17), and C(18)]. The Wittig salt offers a general route to 1-ene-4,6-diyne and more highly unsaturated skipped en-yne systems.

THE synthesis of labelled methyl crepenynate (II) in which the Wittig reaction between two C₉ fragments represents the last and crucial step has been described.¹ Preliminary experiments utilising an analogous sequence

acetylenes,⁴ were not promising.† Bohlmann *et al.*⁵ synthesised these two esters by coupling the C₁₃ ethynyl ester (V) with bromopentyne and bromopentadiyne respectively, but an improved route to the C₁₃ ester and



of reactions for the synthesis of the more acetylenic C₁₈ esters (III) and (IV), postulated to be intermediates in the biogenetic conversion of oleate into some poly-

better yields, especially in the stages likely to involve labelled intermediates, *e.g.* the coupling, were desirable.

† The esters (III) and (XII) have since been prepared by this route by Mr. I. W. Farrell in this laboratory.

¹ Part XXXIX, G. C. Barley, Sir Ewart R. H. Jones, V. Thaller, and R. A. Vere Hodge, *J.C.S. Perkin I*, 1973, 151.

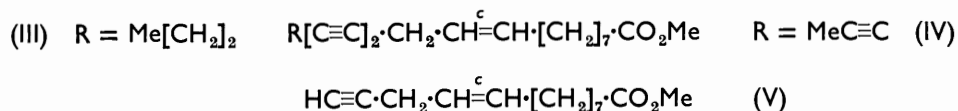
² Preliminary communication: A. G. Fallis, Sir Ewart R. H. Jones, and V. Thaller, *Chem. Comm.*, 1969, 924.

³ A more detailed account of the major part of the work described in this paper is in the D. Phil. Thesis of J. L. Turner, Oxford, 1972.

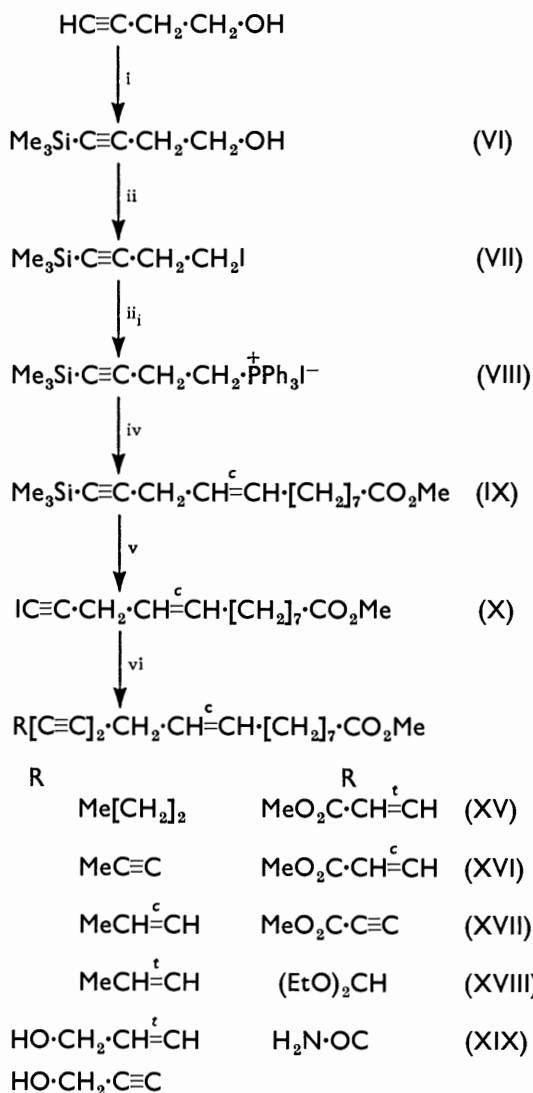
⁴ J. D. Bu'Lock, 'Comparative Phyto-chemistry,' ed. T. Swain, Academic Press, London, 1966, p. 79.

⁵ (a) F. Bohlmann, R. Jente, W. Lucas, J. Laser, and H. Schulz, *Chem. Ber.*, 1967, **100**, 3183; (b) F. Bohlmann, H. C. Hummel, and J. Laser, *ibid.*, 1968, **101**, 3562.

Both aims were achieved through the reaction sequence of Scheme 1. The C₁₃ iodo-ester (X) was coupled with the appropriate terminal acetylenes and the C₁₃ esters (III), (IV), and (XI)—(XVII) and the C₁₆ esters (XVIII) and (XIX) were prepared.



The Wittig salt (VIII) represents a stable intermediate of considerable scope for the synthesis of compounds containing the 1-ene-4,6-diyne and more highly unsaturated chromophores. The crude salt, suitably dried,



i, Reagents: EtMgBr, Me₃SiCl, dil.HCl; ii, (PhO)₃PMeI-CH₂Cl₂-Me₂N·CHO; iii, Ph₃P-EtOH; iv, NaH-Me₂SO-[CH₂]₄O-OCH·[CH₂]₇·CO₂Me(I); v, AgNO₃, I₂-CH₂Cl₂; vi, RC≡CH-CuCl-NH₂·OH-EtNH₂

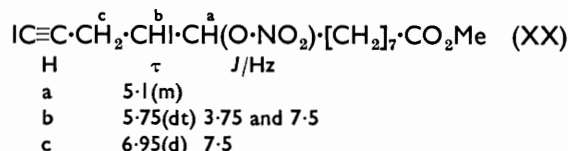
SCHEME 1

gave satisfactory yields in the Wittig reaction. For this, the salt (VIII), the aldehyde (I) and sodium hydride

were stirred together in tetrahydrofuran-dimethyl sulphoxide at 0° (similar reaction conditions were employed to prepare βγ-unsaturated acids⁶) for 20–70 h. The reaction time used depended on the scale of the reaction: better yields (ca. 80%) were obtained in

smaller scale (less than 1 g Wittig salt) than in larger scale (10 g) reactions. G.l.c. indicated that 95% of the double-bond product was *cis*; incomplete exclusion of moisture adversely affected the favourable *cis-trans* ratio and also resulted in the formation of by-products.

The carbon-silicon bond was cleaved with silver nitrate;⁷ the C₁₃ ester (V) was isolated but could not be converted with sodium hypobromite into the corresponding bromo-ester. The iodo-ester (X) was obtained, however, in acceptable yields (ca. 60%) by the action of iodine in dichloromethane on the silver acetylide, which precipitated during the carbon-silicon bond cleavage. Excess of silver nitrate had to be removed prior to the reaction with iodine to prevent the formation of the nitrate ester (XX) (the addition of iodonium nitrate to



double bonds has been reported before⁸). Although the formation of two iodo-nitrates could be expected, the n.m.r. signals given and the strong peak at *m/e* 305 (33%) assigned to the ion [IC≡C·CH₂·CHI]⁺ favour structure (XX).

The C₁₃ ethynyl ester (V) did not couple well with bromoacetylenes (yields of 24 and 14% were observed⁵ with bromopentyne and bromopentadiyne, respectively). In contrast, the C₁₃ iodo-ester (X) gave acceptable yields with ethynyl compounds. [The use of iodo-acetylenes in Chodkiewicz couplings has not been reported; they were assumed to be too reactive as they act as strong oxidising agents towards the copper(I) ion and favour the secondary self-coupling reaction.⁹] Different conditions were necessary for each of the terminal acetylenes used and yields were often improved (generally to 40–60%) by raising the concentrations of both copper(I) chloride and ethylamine. The iodo-ester (X), contaminated with the C₁₃ ethynyl ester (V), was often recovered from the reactions despite the presence of an excess of the ethynyl component in the reaction mixture.

⁶ H. S. Corey, jun., J. R. D. McCormick, and W. E. Swensen, *J. Amer. Chem. Soc.*, 1964, **86**, 1884.

⁷ H. M. Schmidt and J. F. Arens, *Rec. Trav. chim.*, 1967, **86**, 1138.

⁸ L. Birkenbach and J. Gonbeau, *Ber.*, 1934, **67**, 1420; L. J. Morris, *Chem. and Ind.*, 1958, 1291.

⁹ P. Cadiot and W. Chodkiewicz, in 'Chemistry of Acetylenes,' ed. H. G. Viehe, M. Dekker, New York, 1969, p. 616.

From the coupling product between the iodo-ester (X) and a mixture of methyl *cis*- and *trans*-pent-2-en-4-ynoate, only the *cis,cis*-diester (XVI) was isolated easily by chromatography. The *cis,trans*-diester (XV) was contaminated with a by-product, also an ester (most likely the C₂₆ diester resulting from self-coupling of the iodo-ester), from which it could not be separated. The products from the Wittig reaction between the C₁₆ aldehyde ester (XXI) [prepared from the C₁₆ acetal ester (XVIII)] and the phosphorane (XXII) on the other



hand were easily separated and the *cis,cis*-diester (XVI) and the *cis,trans*-diester (XV) were obtained in the ratio 1:4:1 (a ratio of 1:1:7 was obtained in the pentenyynoate route). Methyl pent-2-en-4-ynoate was prepared from prop-2-ynal and the phosphorane (XXII) and could be separated by chromatography into the *cis*- and *trans*-isomers.

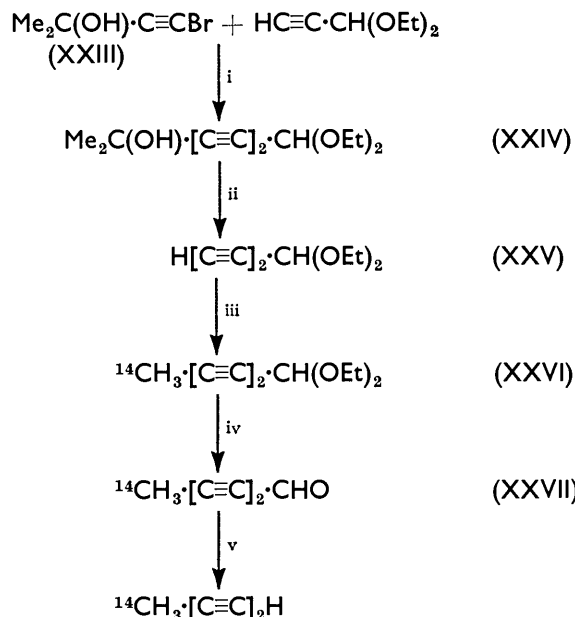
Propiolamide and the iodo-ester (X) did not couple under normal Chodkiewicz conditions; the iodo-ester was always recovered in high yield from the reaction mixture. The C₁₆ amide ester (XIX) was obtained, however, in 20% yield by using the reverse addition procedure for the reactants and a large excess of both catalyst and propiolamide; none of the latter was recovered from the reaction mixture. Propiolamide has been reported¹⁰ to couple normally with some bromoacetylenes and in our hands 4-bromo-2-methylbut-3-yn-2-ol gave a high yield of the expected diyne (the reaction was carried out at 20 and not 0–5° as described¹⁰).

All the 9-en-12,14-diyne compounds showed a characteristic two proton n.m.r. doublet for the 'skipped' en-yne methylene protons at τ 6.85–7.15 and a multiplet for the vinyl protons of the isolated double bond. Mass spectral molecular ions and strong peaks for fragments arising through loss of $[\text{CH}_2]_6 \cdot \text{CO}_2\text{Me}$ were obtained in all instances.

Several of the C₁₈ and C₁₆ compounds were synthesised radioactively labelled, either at C(9) or in the terminal C₅ fragment. For the former, the [9-¹⁴C]aldehyde ester, [9-¹⁴C]- (I),¹ was used and the C₁₈ ester [9-¹⁴C]- (IV) and the C₁₆ esters [9-¹⁴C]- (XVIII), [9-¹⁴C]- (XIX), and [9-¹⁴C]- (XXI) were prepared.

The labelling of potential precursors in the distal half of the C₁₈ esters was of special importance for biosynthetic experiments with C₈ polyacetylenes. The C₁₆ aldehyde ester (XXI) and the [2-¹⁴C]- and [³H]-labelled phosphorane (XXII)¹¹ gave the [17-³H]- and [17-¹⁴C]-labelled diesters (XV) and (XVI). Sodium butadiynide and [¹⁴C]paraformaldehyde gave [1-¹⁴C]-penta-2,4-diyne-1-ol which in turn was converted into the

labelled hydroxy-ester, [18-¹⁴C]- (XIV). The small scale synthesis of penta-1,3-diyne from sodium butadiynide and methyl iodide was not suitable for labelling purposes as the yields were unpredictable and very low. Several alternative routes to penta-1,3-diyne were tried and the one given in Scheme 2 was used to synthesise [5-¹⁴C]-penta-1,3-diyne which in turn was converted into the



Reagents: i, CuCl-NH₂·OH-EtNH₂; ii, KOH, 135°; iii, ¹⁴CH₃I-LiNH₂; iv, 2N-HCl; v, NaOH-MeOH-H₂O, 50°

SCHEME 2

labelled triyne ester [18-¹⁴C]- (IV) (overall activity yield from [¹⁴C]iodomethane was 30%).

EXPERIMENTAL

For general techniques see Part XXXIX.¹

[5-¹⁴C]Penta-1,3-diyne.—1,1-Diethoxyprop-2-yne¹² (6.4 g, 50 mmol) in MeOH (50 ml) containing CuCl (200 mg), NH₂·OH·HCl (7 g), and EtNH₂ (8 ml) and the bromoacetylene (XXIII) (8.3 g, 50 mmol; prepared from the terminal acetylene and NaOBr in 98% yield) in MeOH (100 ml) were coupled (general procedure for the coupling and work-up given later on). The Et₂O extract was chromatographed [SiO₂ (300 g) column]; elution with petrol-Et₂O (4:1) gave first 3,3-diethoxypropyne and then the diyne (XXIV) (7.05 g, 67%), b.p. 123–124° at 0.5 mmHg, n_D^{20} 1.4692 (lit.,¹³ b.p. 121–123° at 0.47 mmHg, n_D^{20} 1.4696), ν_{max} (CCl₄) 3620 (OH free), 3500 (OH bonded), and 2180 (C≡C) cm⁻¹, τ (CCl₄) 8.8 [t, *J* 7 Hz, (CH₃·CH₂·O)₂], 8.51 [s, (CH₃)₂COH·C≡C], 7.78br (OH), 6.41 [m, (CH₃·CH₂·O)₂], and 4.84 [s, (EtO)₂·CH]. This (1.0 g, 4.8 mmol) was converted¹³ into the diyne acetal (XXV) (374 mg, 52%), b.p. 76° at 11 mmHg, n_D^{20} 1.4711 (lit.,¹³ 82° at 15 mmHg, n_D^{20} 1.4708), ν_{max} (CCl₄) 3320 (C≡CH) and 2100 (C≡C) cm⁻¹, τ (CCl₄) 8.8 [t, *J* 7 Hz, (CH₃·CH₂·O)₂], 7.91 [s, C≡CH], 6.4 [m, (CH₃·CH₂·O)₂], and 4.83 [s, (EtO)₂·CH].

¹² J. P. Ward and D. A. van Dorp, *Rec. Trav. chim.*, 1966, **85**, 117; 1967, **86**, 545.

¹³ B. P. Gusev and V. F. Kucherov, *Izvest. Akad. Nauk S.S.S.R., Otdel. khim. Nauk*, 1965, **5**, 851.

¹⁰ W. Chodkiewicz, Ph.D. Thesis, Paris, 1957.

¹¹ G. C. Barley, A. C. Day, U. Graf, Sir Ewart R. H. Jones, I. O'Neill, R. Tachikawa, V. Thaller, and R. A. Vere Hodge, *J. Chem. Soc. (C)*, 1971, 3308.

The acetal (XXV) (160 mg, 1.05 mmol) in Et₂O (1.5 ml) was added at -70° to a stirred suspension of LiNH₂ (72 mg, 3.1 mmol) in dry NH₃ (12 ml) and stirring was continued for 0.5 h. [¹⁴C]Iodomethane [nominal 500 μCi; 55 mCi mmol⁻¹ (Radiochem. Centre, Amersham), diluted with MeI (141 mg)] in Et₂O (3 ml) was then added in portions from a cooled tube (solid CO₂-Me₂CO) connected to the flask by a flexible tube. After stirring for a further 0.5 h at -70° the solution was refluxed for 2.5 h, Et₂O (5 ml) and NH₄Cl were added and NH₃ was allowed to evaporate. The solution was filtered and concentrated, and the residual oil purified, first by shaking with CuCl (0.5 mg) in petrol (50 ml) in the dark for 2 h and then by p.l.c. The band with R_F 0.3 (petrol-Et₂O, 19:1) gave the liquid [¹⁴C]acetal (XXVI) (500 μCi; 520 μCi mmol⁻¹), b.p. 70–72° (block) at 0.5 mmHg, n_D²⁰ 1.4825 (lit.,¹⁴ b.p. 72–73° at 0.5 mmHg, n_D²⁰ 1.4815; lit.,¹³ b.p. 63–64° at 0.6 mmHg, n_D²⁰ 1.4838), ν_{max.} (CCl₄) 2300 and 2200 (C≡C) cm⁻¹, τ (CCl₄) 8.8 [t, J 7 Hz, (CH₃·CH₂·O)₂], 8.03 (s, CH₃·C≡C), 6.4 [m, (CH₃·CH₂·O)₂], and 4.85 [s, (EtO)₂·CH]. This and HCl (2N; 5 ml) were shaken for 15 min at 20°. Et₂O (4 ml) was added and the mixture was shaken again. The layers were separated; the aqueous layer was extracted with Et₂O (2 × 6 ml) and the combined Et₂O solutions gave on washing with NaHCO₃ (sat.; 3 ml) a solution of hexa-2,4-diyne (XXVII), λ_{max.} (Et₂O) 285 (rel. E 3.1), 268 (3.9), 255 (2.4), 242.5 (1.15), and 230 (1.0) nm. This was carefully concentrated (below 10°) and the residue was immediately redissolved in MeOH (5 ml) and warmed to 50° under reflux, NaOH (4N; 3 ml) was added down the condenser. Deformylation¹⁵ was complete in 12 min (u.v.) and the mixture was cooled quickly before Et₂O (10 ml) and H₂O (5 ml) were added. The layers were separated, and the aqueous layer was extracted with Et₂O (2 × 5 ml); [5-¹⁴C]penta-1,3-diyne (325 μCi; 65%) present in the combined ether layers was used directly in Chodkiewicz reactions.

[1-¹⁴C]Penta-2,4-diyne-1-ol.—This was prepared in a small-scale version of the described syntheses.¹⁶ 1,4-Dichlorobut-2-yne (200 mg, 1.6 mmol) in Et₂O (2 ml) was added dropwise to a stirred suspension of NaNH₂ in dry liquid NH₃ [from Na (113 mg, 4.9 mmol), Fe(NO₃)₃ (1 crystal), and NH₃ (12 ml)] at -70°. Stirring was continued for 5 min, more Et₂O (3 ml) was carefully added and then [¹⁴C]paraformaldehyde [0.5 mCi; 230 μCi mg⁻¹ (Radiochem. Centre, Amersham), diluted with paraformaldehyde (37 mg)] was introduced in one portion. After 1 h stirring at -50°, first NH₄Cl (400 mg) was added in portions and then Et₂O (5 ml). Evaporation of NH₃, filtration, concentration of the filtrate, and washing of the concentrate with cold petrol (2 × 2 ml) gave [1-¹⁴C]pentadiynol (245 μCi; 47%; 380 μCi mmol⁻¹), τ (CDCl₃) 7.74 (1H, s, C≡CH), 6.82 (1H, s, OH), and 5.65 (2H, s, CH₂·OH). The product was immediately dissolved in MeOH (5 ml) for storage.

Methyl Pent-cis-2-en-4-ynoate and Methyl Pent-trans-2-en-4-ynoate.—Prop-2-ynal¹⁷ (300 mg 5.5 mmol) in CH₂Cl₂ (8 ml) was added dropwise to the phosphorane (XXII)¹⁸ (1.68 g, 5 mmol) stirred in CH₂Cl₂ (8 ml) at -15°. Stirring was continued first at -15° for 0.5 h and then for 1 h with

slow warming up to 20°. The mixture was transferred directly to a SiO₂ column (30 g) and the products were eluted with petrol-Et₂O (2:1). The first 200 ml of eluant, evaporated at 50° gave methyl pent-trans-2-en-4-ynoate (230 mg), m.p. 19° (lit.,¹⁹ 19–20°), t_R (80°) 3 min, τ (CCl₄) 6.75 (1H, d, J 2.5 Hz, C≡CH), 6.26 (3H, s, CO₂·CH₃), 3.74 (1H, d, J 16 Hz, trans-CH=CH·CO₂Me), and 3.3 (1H, dd, J 16 and 2.5 Hz, trans-CH=CH·CO₂Me). The next 100 ml of eluant contained a mixture of cis- and trans-isomers, and was followed by 200 ml which contained methyl pent-cis-2-en-4-ynoate (110 mg), b.p. 120–124° at 765 mmHg (block) (lit.,²⁰ 55–60° at 12 mmHg), t_R (80°) 6.5 min, λ_{max.} (EtOH) 242.5 (ε 17,750) and 249 (16,500) nm, ν_{max.} (CCl₄) 3320 (C≡CH), 2125 (C=C), and 1740 and 1725 (ester C=O) cm⁻¹, ν_{max.} (CS₂) 790 (cis-CH=CH) cm⁻¹, τ (CCl₄) 6.55 (1H, d, J 2 Hz, HC=C), 6.25 (3H, s, CO₂·CH₃), 3.97 (1H, dd, J 2 and 11.7 Hz, cis-CH=CH·C≡C), and 3.84 (1H, d, J 11.7 Hz, cis-CH=CH·CO₂Me).

4-Iodo-1-trimethylsilylbut-1-yne (VII).—4-Trimethylsilylbut-3-yn-1-ol (VI)²¹ (14 g, 0.1 mmol) in CH₂Cl₂ (25 ml) was added over a few minutes to (PhO)₃MeP⁺I⁻ (53.6 g, 0.13 mol) in CH₂Cl₂ (25 ml)-Me₂N·CHO (10 ml) stirred at 20° in the dark. Stirring was continued for 4 h at 40–45° and the mixture was then left for 14 h at 20°. The solvent was evaporated, the residual oil was triturated with petrol (6 × 150 ml), and the concentrated petrol extracts were purified on a SiO₂ column (500 g); elution with petrol (ca. 1 l) and petrol-Et₂O (19:1; ca. 0.5 l), concentration of the eluate, and distillation of the residue yielded the iodide (VII) (17.5 g, 72%), b.p. 82–84° at 8.5 mmHg, n_D²⁰ 1.5100 (Found: C, 33.3; H, 5.5; I, 51.0. C₇H₁₃ISi requires C, 33.2; H, 5.2; I, 50.5%), ν_{max.} (CCl₄) 2175 (C≡C) cm⁻¹, τ (CCl₄) 9.88 [s, (CH₃)₃Si], 7.16 (m, CH₂·C≡C), and 6.83 (m, CH₂I).

Triphenyl-(4-trimethylsilylbut-3-ynyl)phosphonium Iodide (VIII).—Ph₃P (19.0 g, 73 mmol) and the iodide (VII) (18.2 g, 72 mmol) in abs. EtOH (200 ml) were heated under reflux for 68 h. After concentration the oily residue crystallised on trituration with Et₂O to give the crude Wittig salt (VIII) (35 g, 95%), m.p. 132–133°, which gave cubes (from [CH₂]₄O-EtOAc), m.p. 135.5–136.5° (dried at 70° and 0.5 mmHg) (Found: C, 58.6; H, 5.2. C₂₅H₂₈IPSi requires C, 58.4; H, 5.5%). The crude, dried (35° at 0.1 mmHg for 20 h) salt was used in the Wittig reaction.

Methyl 13-Trimethylsilyltridec-cis-9-en-12-ynoate (IX).—The Wittig salt (VIII) (31.2 g, 62 mmol) and methyl 8-formyloctanoate (I)²³ (11.5 g, 62 mmol) in cold (0°) Me₂SO (200 ml; dried over CaH₂ for several days)-[CH₂]₄O (300 ml; freshly distilled from LiAlH₄) were added to NaH granules (100%; 1.49 g, 62 mmol) kept in a 1 l flask under N₂ (anhydrous conditions) with stirring and cooling (0°). After 72 h the mixture was poured into Et₂O (1500 ml) and the filtered (Celite) solution was shaken with water (1 l)-HCl (conc.; 1.5 ml). The concentrated organic phase was triturated with boiling petrol (3 × 200 ml); the petrol solution was concentrated (100 ml) and left at 0° for 14 h. The separated solid was filtered off; the filtrate was concentrated and chromatographed on a SiO₂ column (500

¹⁴ J. Normant, *Bull. Soc. chim. France*, 1963, 1888.

¹⁵ R. F. Curtis and J. A. Taylor, *J. Chem. Soc. (C)*, 1971, 186.

¹⁶ E. R. H. Jones, J. M. Thompson, and M. C. Whiting, *J. Chem. Soc.*, 1957, 2012.

¹⁷ F. Wille, L. Saffer, and W. Weisskopf, *Annalen*, 1950, 568, 34.

¹⁸ O. Isler, H. Gutmann, M. Montavon, R. Rügge, G. Rysser, and P. Zeiler, *Helv. Chim. Acta*, 1957, 40, 1242.

¹⁹ L. J. Haynes, Sir Ian Heilbron, E. R. H. Jones, and F. Sondheimer, *J. Chem. Soc.*, 1947, 1586.

²⁰ F. Bohlmann, W. v. Kap-herr, C. Rybak, and J. Repplinger, *Chem. Ber.*, 1965, 98, 1736.

²¹ C. Eaborn, A. R. Thompson, and D. R. M. Walton, *J. Chem. Soc. (C)*, 1967, 1364; M. F. Shostakovskii, A. S. Atavin, and N. V. Egorov, *J. Gen. Chem., (U.S.S.R.)*, 1965, 35, 813.

²² S. R. Landauer and H. N. Rydon, *J. Chem. Soc.*, 1953, 2224.

g). Petrol-Et₂O (24 : 1; 4 l) eluted the crude liquid *trimethylsilyl ester* (IX) (9.3 g, 60%), R_F 0.4 (petrol-Et₂O, 9 : 1), t_R (158°) 14.2 min (ca. 94% pure *cis*), n_D^{20} 1.472. A sample was distilled at 70° (block) and 0.05 mmHg (Found: C, 69.7; H, 10.5. C₁₇H₃₀O₂Si requires C, 69.3; H, 10.3%), ν_{\max} (CCl₄) 3020 (CH=CH), 2160 (C≡C), 1740 (ester CO), and 858 [(Me)₃Si] cm⁻¹, ν_{\max} (CS₂) 725 (*cis*-CH=CH) cm⁻¹, τ (CCl₄) 9.86 [s, (CH₃)₃Si], 8.16—8.81 (m, CH₂[CH₂]₅·CH₂), 7.91 (m, CH=CH·CH₂·CH₂), 7.75 (t, J 7 Hz, CH₂·CH₂·CO₂Me), 7.06 (d, J 6 Hz, C≡C·CH₂·CH=CH), 6.35 (s, CO₂·CH₃), and 4.56 (m, *cis*-CH=CH), m/e 294 (M^+ , 25%), 159 (16), 109 (20.5), 105 (21), 94 (20), 91 (26), 89 (98), and 73 (100).

The Wittig salt (VIII) (200 mg, 0.39 mmol) and methyl 8-formyloctanoate²³ (73 mg, 0.39 mmol) in Me₂SO (4 ml)—[CH₂]₄O (6 ml) were added to NaH (15 mg, 0.63 mmol) as above and stirred for 22 h. Analogous work-up gave the trimethylsilyl ester (IX) (97% pure by g.l.c.) in 83% (95 mg) yield.

Methyl Tridec-cis-9-en-12-ynoate (V).—AgNO₃ (540 mg) in H₂O (10 ml) was added dropwise to the trimethylsilyl ester (IX) (350 mg) stirred in EtOH (30 ml). After 0.5 h KCN (1.0 g) in H₂O (10 ml) was added to the suspension, which was stirred until homogeneous. H₂O (50 ml) was added and the product was isolated with Et₂O and purified by p.l.c. (petrol-Et₂O, 9 : 1) yielding the liquid ethynyl ester (V)^{5a} (183 mg, 70%), ν_{\max} (CCl₄) 3330 (C≡CH), 2120 (C≡C), 1745 (ester CO), and 1665 (CH=CH) cm⁻¹, ν_{\max} (CS₂) 725 (*cis*-CH=CH) cm⁻¹, τ (CCl₄) 8.2—8.9 (10H, m, CH₂[CH₂]₅·CH₂·CO₂Me), 7.8—8.1 (2H, m, CH=CH·CH₂·CH₂), 7.78 (2H, t, J 7 Hz, CH₂·CH₂·CO₂Me), 7.11 (2H, m, C≡C·CH₂·CH=CH), 8.2 (1H, t, J 2 Hz, HC≡C), 6.4 (3H, s, CO₂·CH₃), and 4.5—4.7 (2H, m, CH=CH).

Methyl 13-Iodotridec-cis-9-en-12-ynoate (X).—AgNO₃ (1.2 g, 7 mmol) in EtOH (12 ml)—H₂O (12 ml) was added dropwise to the trimethylsilyl ester (IX) (1.0 g, 3.4 mmol) in EtOH (60 ml) stirred at 20° (under N₂ in the dark). After 0.5 h the mixture was cooled to 0° for 10 min and centrifuged, the liquid was decanted, and the Ag acetylide was immediately dissolved in CH₂Cl₂ (120 ml; decanted from anhyd. K₂CO₃). This solution was shaken thoroughly with H₂O (25 ml)—NH₃ aq. (35%; 0.1 ml); the layers were separated, and I₂ in CH₂Cl₂ was added dropwise to the dark, moist, organic phase stirred under N₂ (gradual lightening in colour and precipitation of AgI occurred) until a faint pink colouration was obtained. Stirring was continued for 0.75 h, the mixture was filtered (Celite; removal of AgI), washed with Na₂S₂O₃—H₂O (10%; 10 ml), dried, and concentrated to a sweet-smelling oil (1.2 g) which on p.l.c. (petrol-Et₂O, 19 : 1; 2 elutions) yielded the liquid *iodo-ester* (X) (635 mg, 54%), R_F 0.4, b.p. 100—110° (block) at 2.27 × 10⁻⁵ mmHg (Found: C, 47.9; H, 6.2; I, 36.25. C₁₄H₂₁IO₂ requires C, 48.3; H, 6.1; I, 36.4%), ν_{\max} (CCl₄) 3020 (CH=CH) and 1740 (ester CO) cm⁻¹, τ (CCl₄) 8.2—8.9 (m, CH₂[CH₂]₅·CH₂), 7.8—8.1 (m, CH=CH·CH₂·CH₂), 7.86 (t, J 7 Hz, CH₂·CH₂·CO₂Me), 6.93 (d, J 6.5 Hz, C≡C·CH₂·CH=CH), 6.38 (s, CO₂·CH₃), and 4.3—4.8 (m, CH₂·CH=CH·CH₂).

Methyl 10,13-di-iodo-9-nitro-xytridec-12-ynoate (XX). P.l.c. (petrol-Et₂O, 19 : 1; 2 elutions) of the crude iodo-ester (X) (R_F 0.4) gave a second band (R_F 0.3) most likely due to the *nitrate ester* (XX), ν_{\max} (CCl₄) 2200 (C=C), 1735 (ester CO), and 1640 and 1270 (O·NO₂) cm⁻¹, τ (CCl₄) 8.0—8.88 (12H, m, [CH₂]₆·CH₂·CO₂Me), 7.76 (2H, t, J 7 Hz, CH₂·CH₂·CO₂Me), 6.95 (2H, d, J 7.5 Hz, C≡C·CH₂·CHI),

6.38 (3H, s, CO₂·CH₃), 5.77 (1H, dt, J 3.75 and 7.5 Hz, CHI), and 5.1 (1H, dt, J 3.75 and 6.7 Hz, ·CH·O·NO₂), m/e 537 (M^+ , ca. 1%), 491 (27), 364 (20), 305 (33), 237 (36), 219 (45), 178 (100), 165 (76), and 145 (48).

[9-¹⁴C]Methyl 13-Iodotridec-cis-9-en-12-ynoate, [9-¹⁴C]- (X).—[9-¹⁴C]Methyl 8-formyloctanoate [9-¹⁴C]- (I)¹ (61 mg; 1 mCi; 3.07 mCi mmol⁻¹) and the Wittig salt (VIII) gave the [9-¹⁴C]trimethylsilyl ester [9-¹⁴C]- (IX) (76.5 mg; 791 μCi; 79%) and this yielded (1/13th scale of the 'cold' synthesis) the [9-¹⁴C]iodo-ester [9-¹⁴C]- (X) (383 μCi; 48%; 3.07 mCi mmol⁻¹).

General Reaction Procedure for the Chodkiewicz Coupling.—Unless stated otherwise the following procedure was used (solvent and quantities are stated for each reaction). To a solution of CuCl, NH₂·OH, HCl, and EtNH₂·H₂O (40%) stirred vigorously under N₂ at 20°, a solution of the terminal acetylene component and then after 5 min a solution of the halogenated acetylene were added dropwise. Stirring was continued for 1 h and KCN (ca. 0.1 g)—H₂O—ice and Et₂O were added. The product was isolated with Et₂O and purified as stated for each compound.

Methyl Octadec-cis-9-ene-12,14-diynoate (III).—Pent-1-yne (68 mg, 1 mmol) in MeOH (5 ml) containing CuCl (12 mg), NH₂·OH, HCl (120 mg), and EtNH₂ (0.5 ml) and the iodo-ester (X) (250 mg, 0.71 mmol) in MeOH (5 ml) were coupled. The Et₂O extract was dissolved in EtOH (10 ml) and added dropwise to AgNO₃ (250 mg, 1.5 mmol) stirred in EtOH (2 ml)—H₂O (2 ml)—NH₃ (35%; 0.2 ml). After 0.5 h the mixture was centrifuged and the liquid was decanted. It was extracted with Et₂O and the concentrated Et₂O extract was purified by repeated p.l.c. (petrol-Et₂O, 19 : 1, 3 elutions); the band with R_F 0.6 yielded the diyne ester (III)^{5a} (67 mg, 32.5%), R_F 0.4 (petrol-CH₂Cl₂, 3 : 2), λ_{\max} 254 and 235 nm, ν_{\max} (CS₂) 1750 (ester CO) and 735 (*cis*-CH=CH) cm⁻¹, τ (CCl₄) 9.0 (t, J 6 Hz, CH₃·CH₂), 8.55 (m, [CH₂]₅ and CH₃·CH₂), 7.65—8.15 (m, CH₂·CH₂·C≡C, CH=CH·CH₂·CH₂, and CH₂·CO₂·CH₃), 7.05 (d, J 5 Hz, C≡C·CH₂·CH=CH), 6.4 (s, O·CH₃), and 4.4—4.8 (m, CH₂·CH=CH·CH₂), m/e 288 (M^+ , 2%), 257 (5), 145 (40), 131 (40), 117 (100), and 91 (60).

Methyl Octadec-cis-9-ene-12,14,16-triynoate (IV).—Penta-1,3-diyne (38 mg, 0.6 mmol) in MeOH (6 ml)—Me₂N·CHO (0.25 ml) containing EtNH₂ (0.5 ml), CuCl (9 mg), and NH₂·OH, HCl (50 mg) was coupled with the iodo-ester (X) (168 mg, 0.48 mmol) in MeOH (6 ml) in a closed system. P.l.c. of the Et₂O extract (petrol-Et₂O, 19 : 1; 3 elutions) gave the liquid triyne ester (IV)^{5b} (61 mg, 45%), R_F 0.5, needles (from petrol at -40°), m.p. ca. 10°, b.p. 140—145° (block) at 2.3 × 10⁻⁵ mmHg, R_F 0.5 (petrol-EtOAc, 9 : 1), 0.5 (CH₂Cl₂), and 0.4 (petrol-MeOH, 97 : 3) (M^+ , 284.1786. Calc. for C₁₉H₂₄O₂: M , 284.1776), λ_{\max} (EtOH) 211 (ε 129,000) nm, ν_{\max} (CCl₄) 3020 (CH=CH), 2220 and 2030 (C≡C), 1740 (ester CO), and 1650 (CH=CH) cm⁻¹, ν_{\max} (CS₂) 710 (*cis*-CH=CH) cm⁻¹, τ (CCl₄) 8.2—8.9 (m, CH₂[CH₂]₅·CH₂), 7.3—8.15 (m, CH=CH·CH₂·CH₂), 7.26 (t, J 7 Hz, CH₂·CH₂·CO₂Me), 6.99 (d, J 6 Hz, C≡C·CH₂·CH=CH), 6.37 (s, CO₂·CH₃), and 4.55 (m, *cis*-CH₂·CH=CH·CH₂), m/e 284 (M^+ , 3%), 189 (9), 169 (27), 155 (63), 141 (100), and 128 (32).

[9-¹⁴C]Methyl Octadec-cis-9-ene-12,14,16-triynoate, [9-¹⁴C]- (IV).—[9-¹⁴C]Iodo-ester [9-¹⁴C]- (X) (100 μCi; 11.2 mg, 0.033 mmol) was coupled with penta-1,3-diyne (3.2 mg, 0.05 mmol) as described above and gave [9-¹⁴C]- (IV) (53

²³ E. H. Pryde, D. E. Anders, H. M. Teeter, and J. C. Cowan. *J. Org. Chem.*, 1960, **25**, 618.

μCi ; 3.07 mCi mmol^{-1} ; 53%). Unchanged iodo-ester [9- ^{14}C]- (X) (9.1 μCi) was recovered during the purification of the product.

[18- ^{14}C]Methyl Octadec-cis-9-ene-12,14,16-triynoate, [18- ^{14}C]- (IV).—[5- ^{14}C]Penta-1,3-diyne (325 μCi) was coupled with the iodo-ester (X) (348 mg, 1 mmol) as described above and gave [18- ^{14}C]methyl octadec-9-cis-ene-12,14,16-triynoate [18- ^{14}C]- (IV) (154 μCi ; 0.52 mCi mmol^{-1} ; 30% overall yield from $^{14}\text{CH}_3\text{I}$).

Methyl Octadeca-cis-9,cis-16-diene-12,14-diyynoate (XI).—cis-Pent-3-ene-1-yne 24 (35 mg, 0.53 mmol) in MeOH (5 ml)–Et $_2$ O (5 ml) containing $\text{NH}_2\text{OH}\cdot\text{HCl}$ (100 mg), CuCl (8 mg), and EtNH $_2$ (1 ml) was coupled with the iodo-ester (X) (150 mg, 0.43 mmol) in MeOH (10 ml) in a closed system. The concentrated Et $_2$ O extract, an oil (110 mg), was dissolved in EtOH (10 ml) and treated with AgNO $_3$ (150 mg) in H $_2$ O (10 ml)–EtOH (10 ml)–NH $_3$ (35%; 1 drop). After 0.5 h with occasional swirling the acetylide was filtered off (Celite); the filtrate was concentrated to 15 ml, and diluted with H $_2$ O (50 ml). Et $_2$ O extraction and p.l.c., first with petrol–Et $_2$ O (4 : 1; 1 elution) then with petrol–Et $_2$ O (9 : 1; 2 elutions; R_F 0.5) gave the liquid cis,cis-dienediynoate ester (XI) (53 mg, 44%), which crystallised from petrol at -70° , m.p. below 0° (M^+ , 286.1932. $\text{C}_{19}\text{H}_{26}\text{O}_2$ requires M , 286.1933, λ_{max} (EtOH) 281.5 (ϵ 11,750), 266 (15,000), 251.5 (10,250), 239 (5750), 227.5 (3250), and 213 (56,500) nm, ν_{max} (CCl $_4$) 3025 (CH=CH), 2220 and 2180 (C=C), and 1745 (ester CO) cm^{-1} , ν_{max} (CS $_2$) 705 (cis-CH=CH) cm^{-1} , τ (CCl $_4$) 8.85–7.8 (m, $[\text{CH}_2]_6\cdot\text{CH}_2\cdot\text{CO}_2\text{Me}$), 8.1 (d, J 6.4 Hz, $\text{CH}_3\cdot\text{CH}=\text{CH}$), 7.78 (t, J 7 Hz, $\text{CH}_2\cdot\text{CH}_2\cdot\text{CO}_2\text{Me}$), 6.96 (d, J 5.5 Hz, $\text{C}\equiv\text{C}\cdot\text{CH}_2\cdot\text{CH}=\text{CH}$), 6.39 (s, $\text{CO}_2\cdot\text{CH}_3$), 4.56 (m, $\text{CH}_2\cdot\text{CH}=\text{CH}\cdot\text{CH}_2$), 4.54 (d, J 10.4 Hz, cis- $\text{CH}_3\cdot\text{CH}=\text{CH}$), and 3.94 (dq, J 10.4 and 6.4 Hz, cis- $\text{CH}_3\cdot\text{CH}=\text{CH}$), m/e 286 (M^+ , 3%), 157 (38), 143 (98), 129 (98), 128 (100), 115 (43), 91 (42), 87 (32), and 79 (50).

Methyl Octadeca-cis-9,trans-16-diene-12,14-diyynoate (XII).—trans-Pent-3-en-1-yne 24 (50 mg, 0.75 mmol) similarly gave the cis,trans-dienediynoate ester (XII) (74 mg, 50%) which crystallised from petrol at -40° , m.p. below 0° , λ_{max} (EtOH) 282 (ϵ 17,000), 266.5 (22,500), 252.5 (15,250), 239.5 (7250), 228 (4000), and 213.5 (57,250) nm, ν_{max} (CCl $_4$) 3030 (CH=CH), 2235 (C=C), and 1745 (ester CO) cm^{-1} , ν_{max} (CS $_2$) 945 (trans-CH=CH) cm^{-1} , τ (CCl $_4$) 8.85–7.90 (m, $[\text{CH}_2]_6\cdot\text{CH}_2\cdot\text{CO}_2\text{Me}$), 8.18 (d, J 6.8 Hz, $\text{CH}_3\cdot\text{CH}=\text{CH}$), 7.78 (t, J 7 Hz, $\text{CH}_2\cdot\text{CH}_2\cdot\text{CO}_2\text{CH}_3$), 6.98 (d, J 5.5 Hz, $\text{C}\equiv\text{C}\cdot\text{CH}_2\cdot\text{CH}=\text{CH}$), 6.40 (s, $\text{CO}_2\cdot\text{CH}_3$), 4.58 (m, $\text{CH}_2\cdot\text{CH}=\text{CH}\cdot\text{CH}_2$), 4.48 (d, J 15.7 Hz, trans- $\text{CH}_3\cdot\text{CH}=\text{CH}$), and 3.80 (dq, J 15.7 and 6.8 Hz, trans- $\text{CH}_3\cdot\text{CH}=\text{CH}$), m/e 286 (M^+ , 3%), 157 (27), 143 (63), 129 (88), 128 (100), 115 (60), 91 (41), 87 (21), and 79 (48).

Methyl 18-Hydroxyoctadeca-cis-9,trans-16-diene-12,14-diyynoate (XIII).—trans-Pent-2-en-4-yn-1-ol 19 (30 mg, 0.37 mmol) in MeOH (6 ml) containing $\text{NH}_2\text{OH}\cdot\text{HCl}$ (35 mg), CuCl (3 mg), and EtNH $_2$ (0.14 ml) was coupled with the iodo-ester (X) (105 mg, 0.302 mmol) in MeOH (4 ml). Repeated p.l.c. of the Et $_2$ O extract (R_F 0.35 in petrol–Et $_2$ O, 1 : 1; R_F 0.2 in CH_2Cl_2 , 3 elutions; R_F 0.35 in CHCl_3) gave the liquid hydroxy-ester (XIII) (46 mg, 48%), b.p. $160\text{--}170^\circ$ (block) at 10^{-5} mmHg (Found: C, 75.3; H, 8.75. $\text{C}_{19}\text{H}_{26}\text{O}_3$ requires C, 75.5; H, 8.7%), λ_{max} (EtOH) 283 (ϵ 15,750), 266 (19,500), 252 (13,500), 239 (4500), and 227.5 (3000) nm, ν_{max} (CCl $_4$) 3620 (OH free), 3490 (OH bonded), 3010 (CH=CH), 2240 (C=C), 1745 (ester CO), 1650 (CH=CH), and 950 (trans-CH=CH) cm^{-1} , τ (CDCl $_3$) 8.13br (OH), 7.8–8.9 (m, $\text{CH}=\text{CH}\cdot[\text{CH}_2]_6\cdot\text{CH}_2$), 7.68 (t, J 7 Hz, $\text{CH}_2\cdot\text{CH}_2\cdot\text{CO}_2$

Me), 6.94 (d, J 6 Hz, $\text{CH}=\text{CH}\cdot\text{CH}_2\cdot\text{C}\equiv\text{C}$), 6.33 (s, $\text{CO}_2\cdot\text{CH}_3$), 5.77 (dd, J 5.5 and 2 Hz, $\text{CH}=\text{CH}\cdot\text{CH}_2\cdot\text{OH}$), 4.53 (m, cis- $\text{CH}_2\cdot\text{CH}=\text{CH}\cdot\text{CH}_2$), 4.19 (dm, J 16 and ca. 1 Hz, trans- $\text{CH}=\text{CH}\cdot\text{CH}_2\cdot\text{OH}$), and 3.59 (dt, J 16 and 5.5 Hz, trans- $\text{CH}=\text{CH}\cdot\text{CH}_2\cdot\text{OH}$), m/e 302 (M^+ , 1%), 284 (2.8), 171 (24), 152 (64), 149 (24), 124 (20), 111 (37), 97 (34), 83 (57), and 74 (100).

Methyl 18-Hydroxyoctadec-cis-9-ene-12,14,16-triynoate (XIV).—Penta-2,4-diyne-1-ol 18 (52 mg, 0.64 mmol) in MeOH (7 ml)–Me $_2\text{N}\cdot\text{CHO}$ (0.2 ml) containing CuCl (6 mg), $\text{NH}_2\text{OH}\cdot\text{HCl}$ (60 mg), and EtNH $_2$ (0.3 ml) and the iodo-ester (X) (160 mg, 0.46 mmol) in MeOH (6 ml) were coupled. P.l.c. of the Et $_2$ O extract (petrol–Et $_2$ O, 1 : 1; 2 elutions) gave the liquid hydroxy-ester (XIV) (102 mg, R_F 0.5, plates (from Et $_2$ O–hexane) (72 mg, 52%), m.p. 43° (Found: C, 76.2; H, 8.0. $\text{C}_{19}\text{H}_{24}\text{O}_3$ requires C, 76.0; H, 8.05%), λ_{max} (EtOH) 213 (ϵ 141,000) nm, ν_{max} (CCl $_4$) 3660 (OH free), 3478 (OH bonded), 3020 (CH=CH), 2220 and 2100 (C=C), and 1745 (ester CO) cm^{-1} , ν_{max} (CS $_2$) 725 (cis-CH=CH) cm^{-1} , τ (CCl $_4$) 8.2–8.9 (m, $\text{CH}_2\cdot[\text{CH}_2]_5\cdot\text{CH}_2$), 7.55–8.2 (m, $\text{CH}_2\cdot[\text{CH}_2]_5\cdot\text{CH}_2$), 7.23br (OH), 6.97 (d, J 6 Hz, $\text{C}\equiv\text{C}\cdot\text{CH}_2\cdot\text{CH}=\text{CH}$), 6.35 (s, $\text{CO}_2\cdot\text{CH}_3$), 5.75 (s, $\text{CH}_2\cdot\text{OH}$), and 4.3–4.8 (m, cis- $\text{CH}_2\cdot\text{CH}=\text{CH}\cdot\text{CH}_2$), m/e 300 (M^+ , 5%), 282 (15), 167 (70), 153 (67), 141 (45), 129 (52), 128 (100), and 127 (55).

[18- ^{14}C]Methyl 18-Hydroxyoctadec-cis-9-ene-12,14,16-triynoate, [18- ^{14}C]- (XIV).—[1- ^{14}C]Penta-2,4-diyne-1-ol (245 μCi , 380 $\mu\text{Ci mmol}^{-1}$) was converted into the [18- ^{14}C]hydroxy-ester [18- ^{14}C]- (XIV) (91 μCi ; 380 $\mu\text{Ci mmol}^{-1}$) as described above.

Methyl 16,16-Diethoxyhexadec-cis-9-ene-,12,14-diyynoate (XVIII).—3,3-Diethoxypropyne 12 (185 mg, 1.45 mmol) in MeOH (12 ml) containing EtNH $_2$ (2 ml), $\text{NH}_2\text{OH}\cdot\text{HCl}$ (120 mg), and CuCl (8 mg) was coupled with the iodo-ester (X) (420 mg, 1.2 mmol) in MeOH (8 ml). Repeated p.l.c. of the Et $_2$ O extract (R_F 0.5; petrol–Et $_2$ O, 19 : 1; 2 elutions) gave the liquid acetal ester (XVIII) (243 mg, 58%), ν_{max} (CCl $_4$) 3020 (CH=CH), 2280 and 2180 (C=C), and 1750 (ester CO) cm^{-1} , ν_{max} (CS $_2$) 725 (cis-CH=CH) cm^{-1} , τ (CCl $_4$) 8.82 [6H, t, J 7 Hz, $(\text{CH}_3\cdot\text{CH}_2\cdot\text{O})_2$], 8.2–8.9 (10H, m, $\text{CH}_2\cdot[\text{CH}_2]_5\cdot\text{CH}_2$), 7.8–8.2 (2H, m, $\text{CH}=\text{CH}\cdot\text{CH}_2\cdot\text{CH}_2$), 7.79 (2H, t, J 7 Hz, $\text{CH}_2\cdot\text{CH}_2\cdot\text{CO}_2\text{Me}$), 6.92 (2H, d, J 7 Hz, $\text{C}\equiv\text{C}\cdot\text{CH}_2\cdot\text{CH}=\text{CH}$), 6.42 (3H, s, $\text{CO}_2\cdot\text{CH}_3$), 6.44 [4H, m, $(\text{CH}_3\cdot\text{CH}_2\cdot\text{O})_2$], 4.86 [1H, s, (EtO) $_2\text{CH}$], and 4.59 (2H, m, $\text{CH}_2\cdot\text{CH}=\text{CH}\cdot\text{CH}_2$), m/e 348 (M^+ , 10%), 303 (98), 302 (73), 215 (35), 159 (45), 145 (38), 131 (72), 117 (53), 115 (50), 103 (71), and 91 (100).

Methyl 15-Formylpentadec-cis-9-ene-12,14-diyynoate (XXI).—The acetal ester (XVIII) (348 mg, 1 mmol) was kept in Me $_2\text{CO}$ (10 ml)–HCl (conc., 1 ml) for 0.5 h. H $_2$ O (20 ml)–NaHCO $_3$ addition (pH ca. 8), ether extraction, and p.l.c. (R_F 0.35; petrol–Et $_2$ O, 19 : 1) gave the liquid aldehyde ester (XXI) (249 mg, 90%), λ_{max} (EtOH) 288 (ϵ 5750), 272 (6925), 257 (4575), 244 (2475), and 232 (1825) nm, ν_{max} (CCl $_4$) 3020 (CH=CH), 2730 (CHO), 2230 and 2130 (C=C), 1745 (ester CO), and 1665 (aldehyde CO) cm^{-1} , ν_{max} (CS $_2$) 740 (cis-CH=CH) cm^{-1} , τ (CCl $_4$) 7.8–8.9 (12H, m, $\text{CH}=\text{CH}\cdot[\text{CH}_2]_6\cdot\text{CH}_2$), 7.78 (2H, t, J 7 Hz, $\text{CH}_2\cdot\text{CH}_2\cdot\text{CO}_2\text{Me}$), 6.89 (2H, d, J 6 Hz, $\text{CH}=\text{CH}\cdot\text{CH}_2\cdot\text{C}\equiv\text{C}$), 6.4 (3H, s, $\text{CO}_2\cdot\text{CH}_3$), 4.3–4.8 (2H, m, $\text{CH}_2\cdot\text{CH}=\text{CH}\cdot\text{CH}_2$), and 0.88 (1H, s, CHO), m/e 274 (7%), 215 (32), 214 (36), 157 (62), 145 (78), 85 (18), 157 (62), 145 (78), 131 (98), 117 (98), 103 (86), 91 (78), and 77 (100).

[9- ^{14}C]Methyl 15-Formylpentadec-cis-9-ene-12,14-diyynoate, [9- ^{14}C]- (XXI).—3,3-Diethoxypropyne (5.5 mg, 0.0425 mmol) and the [9- ^{14}C]iodo-ester [9- ^{14}C]- (X) (100 μCi ; 11.3

24 J. L. H. Allan and M. C. Whiting, *J. Chem. Soc.*, 1953, 3314.

mg; 3.07 $\mu\text{Ci mmol}^{-1}$) gave the [9- ^{14}C]acetal ester [9- ^{14}C]-(XVIII) [38.6 μCi ; 39% label conversion; iodo-ester (29.3 μCi) was recovered, increasing thus the label yield to 55%]. This (10 μCi) was converted into the aldehyde ester [9- ^{14}C]-(XXI) (9.1 μCi ; 3.07 mCi mmol $^{-1}$; 91%).

Dimethyl Octadeca-trans-2,cis-9-diene-4,6-diynedioate (XV) and *Dimethyl Octadeca-cis-2,cis-9-diene-4,6-diynedioate* (XVI).—(a) The aldehyde ester (XXI) (137 mg, 0.5 mmol) in CH_2Cl_2 (6 ml) was added dropwise to the phosphorane (XXII) (184 mg, 0.55 mmol) stirred rapidly in CH_2Cl_2 (6 ml) at -10° . After 0.5 h at -10° the mixture was allowed to warm to 20° over 0.5 h. Transfer into Et_2O (10 ml), filtration, and p.l.c. (petrol- Et_2O , 2:1; 2 elutions) gave bands A (R_F 0.55) and B (R_F 0.4). On rechromatography (same solvent system), band A gave the liquid *trans-cis-dimethyl ester* (XV) (98 mg), plates (from petrol at -70°), m.p. ca. 18° (Found: C, 73.0; H, 7.8. $\text{C}_{20}\text{H}_{26}\text{O}_4$ requires C, 72.7; H, 7.9%), λ_{max} (EtOH) 304.5 (ϵ 19,250), 286.5 (19,500), 271 (10,500), 257 inf (5150), 223 (35,000), and 215 (28,750) nm, ν_{max} (CCl_4) 3025 ($\text{CH}=\text{CH}$), 2218 and 2120 ($\text{C}=\text{C}$), 1745 (nonconj. ester CO), 1730 (conj. ester CO), 1617 ($\text{CH}=\text{CH}$), and 957 (*trans*- $\text{CH}=\text{CH}$) cm^{-1} , ν_{max} (CS_2) 715 (*cis*- $\text{CH}=\text{CH}$) cm^{-1} , τ (CCl_4) 8.23—8.87 (m, CH_2 - $[\text{CH}_2]_5$ - CH_2 - CO_2Me), 7.95 (m, $\text{CH}=\text{CH}\cdot\text{CH}_2\cdot\text{CH}_2$), 7.78 (t, J 7 Hz, $\text{CH}_2\cdot\text{CH}_2\cdot\text{CO}_2\text{Me}$), 6.92 (d, J 6 Hz, $\text{C}=\text{C}\cdot\text{CH}_2\cdot\text{CH}=\text{CH}$), 6.4 (s, $\text{CO}_2\cdot\text{CH}_3$), 6.27 (s, $\text{CH}=\text{CH}\cdot\text{CO}_2\cdot\text{CH}_3$), 4.31—4.77 (m, *cis*- $\text{CH}_2\cdot\text{CH}=\text{CH}\cdot\text{CH}_2$), 3.75 (d, J 17 Hz, *trans*- $\text{CH}=\text{CH}\cdot\text{CO}_2\text{Me}$), and 3.26 (d, J 17 Hz, *trans*- $\text{CH}=\text{CH}\cdot\text{CO}_2\text{Me}$), m/e 330 (M^+ , 13%), 299 (35), 289 (100), 201 (16), 188 (15), 187 (55), 155 (50), 129 (26), and 97 (18). Band B gave the liquid *cis-cis-dimethyl ester* (XVI) (24 mg) (plates from petrol at -70° , m.p. below 0°), λ_{max} (EtOH) 307 (ϵ 14,000), 289 (15,000), 274.5 (9250), 225 (29,000), and 216.5 (25,000) nm, ν_{max} (CCl_4) 3025 ($\text{CH}=\text{CH}$), 2216 and 2120 ($\text{C}=\text{C}$), 1740—1720 (nonconj. and conj. ester CO), and 1608 ($\text{CH}=\text{CH}$) cm^{-1} , ν_{max} (CS_2) 805 (conj. *cis*- $\text{CH}=\text{CH}$) and 720 (nonconj. *cis*- $\text{CH}=\text{CH}$) cm^{-1} , τ (CCl_4) 8.26—8.87 (10H, m, CH_2 - $[\text{CH}_2]_5$ - CH_2), 7.94 (2H, m, $\text{CH}=\text{CH}\cdot\text{CH}_2\cdot\text{CH}_2$), 7.78 (2H, m, $\text{CH}_2\cdot\text{CH}_2\cdot\text{CO}_2\text{Me}$), 6.91 (2H, d, J 5.4 Hz, $\text{C}=\text{C}\cdot\text{CH}_2\cdot\text{CH}=\text{CH}$), 6.4 (3H, s, $\text{CH}_2\cdot\text{CO}_2\cdot\text{CH}_3$), 6.27 (3H, s, $\text{CH}=\text{CH}\cdot\text{CO}_2\cdot\text{CH}_3$), 4.41—4.71 (2H, m, *cis*- $\text{CH}_2\cdot\text{CH}=\text{CH}\cdot\text{CH}_2$), and 3.9 (2H, s, *cis*- $\text{CH}=\text{CH}\cdot\text{CO}_2\text{Me}$), m/e 330 (M^+ , 15%), 299 (55), 200 (25), 187 (100), 175 (10), 155 (30), 125 (26), and 97 (55). Combined yield of the two isomers 75%; ratio of *cis,trans* to *cis,cis* was 4:1:1.

(b) Prop-2-ynal (30 mg, 0.56 mmol) in CH_2Cl_2 (4 ml) was treated with the phosphorane (XXII) (150 mg, 0.44 mmol) in CH_2Cl_2 (4 ml). The mixture was added to CuCl (6 mg), $\text{NH}_2\cdot\text{OH}\cdot\text{HCl}$ (100 mg), and EtNH_2 (0.4 ml) stirred in MeOH (8 ml), and to this was added dropwise the iodo-ester (X) (150 mg, 0.44 mmol) in MeOH (15 ml). Usual work-up and p.l.c. (see above) gave the slightly contaminated *trans,cis*-diester (XV) (40 mg) (n.m.r. indicated the presence of a second ester which could not be removed by p.l.c. in several solvent systems), and the *cis,cis*-diester (XVI) (24 mg). Combined yield of the two isomers was 43%; the ratio of *cis,trans* to *cis,cis* was 1.7:1.

[2- ^3H] *Dimethyl Octadeca-trans-2,cis-9-diene-4,6-diynedioate*, [2- ^3H]-(XV), and [2- ^3H] *Dimethyl Octadeca-cis-2,cis-9-diene-4,6-diynedioate*, [2- ^3H]-(XVI).—[2- ^3H] Phosphorane (XXII) (318 μCi ; 5.3 mCi mmol $^{-1}$; 0.06 mmol) and the aldehyde (XXI) (19.2 mg, 0.07 mmol) gave the [2- ^3H]-

trans,cis-diester [2- ^3H]-(XV) (190 μCi ; 5.3 mCi mmol $^{-1}$) and the [2- ^3H]-*cis,cis*-diester [2- ^3H]-(XVI) (40.3 μCi ; 5.3 mCi mmol $^{-1}$). Combined tritium yield was 74%.

[2- ^{14}C] *Dimethyl Octadeca-trans-2,cis-9-diene-4,6-diynedioate*, [2- ^{14}C]-(XV), and [2- ^{14}C] *Dimethyl Octadeca-cis-2,cis-9-diene-4,6-diynedioate*, [2- ^{14}C]-(XVI).—[2- ^{14}C] Phosphorane (XXII) (164.4 μCi ; 1.37 mCi mmol $^{-1}$, 0.12 mmol) and the aldehyde (XXI) (32.9 mg, 0.12 mmol) gave the [2- ^{14}C]-*trans,cis*-diester [2- ^{14}C]-(XV) (111.4 μCi ; 1.37 mCi mmol $^{-1}$) and the [2- ^{14}C]-*cis,cis*-diester [2- ^{14}C]-(XVI) (25.7 μCi ; 1.37 mCi mmol $^{-1}$). Combined ^{14}C yield was 83%.

Dimethyl Octadeca-cis-9-ene-2,4,6-triynedioate (XVII).—Methyl penta-2,4-diyne 25 (55 mg, 0.51 mmol) in MeOH (8 ml) containing CuCl (8 mg), $\text{NH}_2\text{OH}\cdot\text{HCl}$ (75 mg), and EtNH_2 (0.25 ml) and the iodo-ester (X) (139.6 mg, 0.37 mmol) in MeOH (5 ml) were coupled. P.l.c. of the Et_2O extract (petrol- Et_2O , 9:1; 4 elutions) yielded the liquid diester (XVII) (52.5 mg, 43%), R_F 0.4, needles (from petrol at -70°), m.p. ca. 0° (M^+ , 328.1674. $\text{C}_{20}\text{H}_{24}\text{O}_4$ requires M , 328.1674), λ_{max} (EtOH) 328.5 (ϵ 3800), 307.5 (5700), 288.5 (4300), 272 (1900), 257.5 (1100), 227.5 (115,000), 218.5 (102,000), and 210 inf (75,000) nm, ν_{max} (CCl_4) 3030 ($\text{CH}=\text{CH}$), 2205 and 2120 ($\text{C}=\text{C}$), and 1745—1720 (nonconj. and conj. ester CO) cm^{-1} , τ (CCl_4) 7.9—8.8 (m, $[\text{CH}_2]_6\cdot\text{CH}_2\cdot\text{CO}_2\text{Me}$), 7.77 (t, J 7 Hz, $\text{CH}_2\cdot\text{CO}_2\text{Me}$), 6.92 (d, J 5 Hz, $\text{C}=\text{C}\cdot\text{CH}_2\cdot\text{CH}=\text{CH}$), 6.40 (s, $\text{CH}_2\cdot\text{CO}_2\cdot\text{CH}_3$), 6.25 (s, $\text{C}=\text{C}\cdot\text{CO}_2\cdot\text{CH}_3$), and 4.6 (m, $\text{CH}=\text{CH}$).

Methyl 15-Carbamoylpentadec-cis-9-ene-12,14-diyneate (XIX).—The iodo-ester (X) (100 mg, 0.29 mmol) in MeOH (3 ml) was added to CuCl (30 mg), $\text{NH}_2\cdot\text{OH}\cdot\text{HCl}$ (15 mg), and EtNH_2 (1 ml) stirred in MeOH (1 ml)— $\text{Me}_2\text{N}\cdot\text{CHO}$ (1 ml) under N_2 , and then, after 1 min, propiolamide 26 (50 mg, 0.72 mmol) in Et_2O (25 ml) was added dropwise over 15 min to the vigorously stirred mixture. Usual work-up, isolation with Et_2O , p.l.c. (Et_2O ; R_F 0.5), and crystallisation (CS_2) gave plates of the *amide ester* (XIX) (20 mg, 24%), m.p. 56 — 58° (Found: C, 70.6; H, 8.1; N, 4.7. $\text{C}_{17}\text{H}_{23}\text{NO}_3$ requires C, 70.6; H, 8.0; N, 4.8%), λ_{max} (EtOH) 274 (ϵ 3850), 259 (5850), 245 (4950), 232 (5150), and 221 inf (6900) nm, ν_{max} (CCl_4) 3520, 3480, and 3390 (NH free), 3330 and 3170 (NH bonded), 3020 ($\text{CH}=\text{CH}$), 2230 and 2150 ($\text{C}=\text{C}$), 1745 (ester CO), and 1680 (amide CO) cm^{-1} , ν_{max} (CS_2) 735 (*cis*- $\text{CH}=\text{CH}$) cm^{-1} , τ (CS_2) 8.2—8.9 (m, CH_2 - $[\text{CH}_2]_5\cdot\text{CH}_2$), 7.8—8.2 (m, $\text{CH}=\text{CH}\cdot\text{CH}_2\cdot\text{CH}_2$), 7.89 (t, J 7 Hz, $\text{CH}_2\cdot\text{CH}_2\cdot\text{CO}_2\text{Me}$), 6.95 (d, J 7 Hz, $\text{C}=\text{C}\cdot\text{CH}_2\cdot\text{CH}=\text{CH}$), 6.43 (s, $\text{CO}_2\cdot\text{CH}_3$), 4.3—4.9 (m, $\text{CH}_2\cdot\text{CH}=\text{CH}\cdot\text{CH}_2$), and 4.0 br and 3.2 br (NH_2), m/e 289 (M^+ , 7%), 272 (28), 147 (58), 146 (48), 129 (100), 117 (46), 115 (45), 103 (42), 91 (47), and 78 (84).

[9- ^{14}C] *Methyl 15-Carbamoylpentadec-cis-9-ene-12,14-diyneate*, [9- ^{14}C]-(XIX).—[9- ^{14}C] Iodo-ester [9- ^{14}C]-(X) (100 μCi ; 3.07 mCi mmol $^{-1}$, 0.033 mmol) and propiolamide (7.5 mg, 0.108 mmol) gave, by the above procedure, the [9- ^{14}C]amide [9- ^{14}C]-(XIX) (12.6 μCi ; 3.07 mCi mmol $^{-1}$). Unchanged [9- ^{14}C]iodo-ester [9- ^{14}C]-(X) (68 μCi) was recovered during the p.l.c. purification.

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