532. *The Preparation of* 1-O-*Alk*-1′-*enyl Ethers of Glycerol*

By Jill Cunningham and Roy Gigg

1-*O*-Prop-1′-enylglycerol and 1-*O*-prop-1′-enyl-2,3-*O*-isopropylideneglycerol were prepared by isomerisation of the corresponding 1-*O*-allyl ethers with potassium t-butoxide in dimethyl sulphoxide at 100°. Under the same conditions, 1-*O*-heptadec-2′-enyl-2,3-*O*-isopropylideneglycerol was cleaved to a mixture of conjugated heptadecadienes. 1-*O*-Hept-1′-enylglycerol 2,3-carbonate was synthesised by the thermal decomposition of heptanal di-(glycerol 1,2-carbonate) acetal, and by the action of triethylamine on 1-*O*-(1-chloroheptyl)glycerol 2,3-carbonate which was prepared from the acetal by the action of acetyl chloride. Alkaline hydrolysis of the 1-*O*-hept-1′-enylglycerol 2,3-carbonate, which was a mixture of *cis*- and *trans*-isomers, gave 1-*O*-hept-1′-enylglycerol. 1-*O*-Prop-1′-enylgycerol was converted into 1-*O*-prop-1′-enyl-2,3-epoxypropane.

The naturally occurring phospholipids known as the plasmalogens [1] are phosphorylated derivatives of 2-*O*-acyl-1-*O*-alk-1′-enylglycerol (in which the double bond of the enol ether has the *cis* configuration [2]), whereas the "normal" phospholipids are phosphorylated derivatives of 1,2-di-*O*-acylglycerol. The mixture of plasmalogens and "normal" phospholipids occurring in natural lipid extracts is not easily separated,[3] and pure plasmalogens are not therefore readily available for biological studies. Since the enol ether structure present in the plasmalogens suggests considerably higher chemical and biological reactivity for these compounds than for the "normal" phospholipids, synthetic plasmalogens would be valuable in promoting further biological studies.

Although many syntheses of the "normal" phospholipids have been reported,[4] no synthetic route to the plasmalogens is yet available. The initial step in a synthesis of the plasmalogens involves the preparation of 1-*O*-alk-1′-enyl ethers of glycerol, and new methods for the preparation of these compounds are described in this Paper. A previous preparation [5] of 1-*O*-alk-1′-enyl ethers of glycerol by the fission of 1,2-*O*-(2-bromoalkylidene)glycerols with sodium in ether produces compounds which "are not entirely pure" and which have the double bond in the *trans* configuration. 2-*O*-Alk-1′-enyl ethers of glycerol are probable contaminants of the product. A further route to the 1-*O*-alkenyl ethers through acetylenic intermediates, which would allow control over the configuration of the double bond, has also been investigated.[6] The Russian workers [6] prepared 1-*O*-hept-1′-enyl-2,3-*O*-isopropylideneglycerol by partial reduction of the product obtained from the condensation of the sodio-derivative of 1,2-*O*-isopropylideneglycerol with 1-bromohept-1-yne. However, since the enol ether and the 2,3-*O*-isopropylidene group have the same order of acid lability,[7] and since 1-*O*-alk-1′-enyl ethers of glycerol are rapidly cyclised to 1,2-*O*-alkylideneglycerols in the presence of acids, this does not seem to be a useful route for the preparation of 1-*O*-alk-1′-enyl ethers of glycerol.

We recently reported [7] the preparation of 1-*O*-prop-1′-enyl-2,3-*O*-isopropylideneglycerol (II) and 1-*O*-prop-1′-enylglycerol (XII) by the base catalysed rearrangement of the corresponding allyl ethers (I) and (XI). The rearrangement proceeds readily in the presence

[1] O. W. Thiele, *Z. klin. Chem.*, 1964, **2**, 33; E. Klenk and H. Debuch, *Progr. Chem. Fats and Lipids*, 1963, **6**, 1; M. M. Rapport and W. T. Norton, *Ann. Rev. Biochem.*, 1962, **31**, 103.

[2] W. T. Norton, E. L. Gottfried, and M. M. Rapport, *J. Lipid Res.*, 1962, **3**, 456; H. R. Warner and W. E. M. Lands, *J. Amer. Chem. Soc.*, 1963, **85**, 60.

[3] E. L. Gottfried and M. M. Rapport, *J. Biol. Chem.*, 1962, **237**, 329; O. Renkonen, *Acta Chem. Scand.*, 1963, **17**, 634; G. B. Ansell and S. Spanner, *J. Neurochem.*, 1963, **10**, 941.

[4] P. E. Verkade, *Bull. Soc. chim. France*, 1963, 1993; E. Baer, *Progr. Chem. Fats and Lipids*, 1963, **6**, 31.

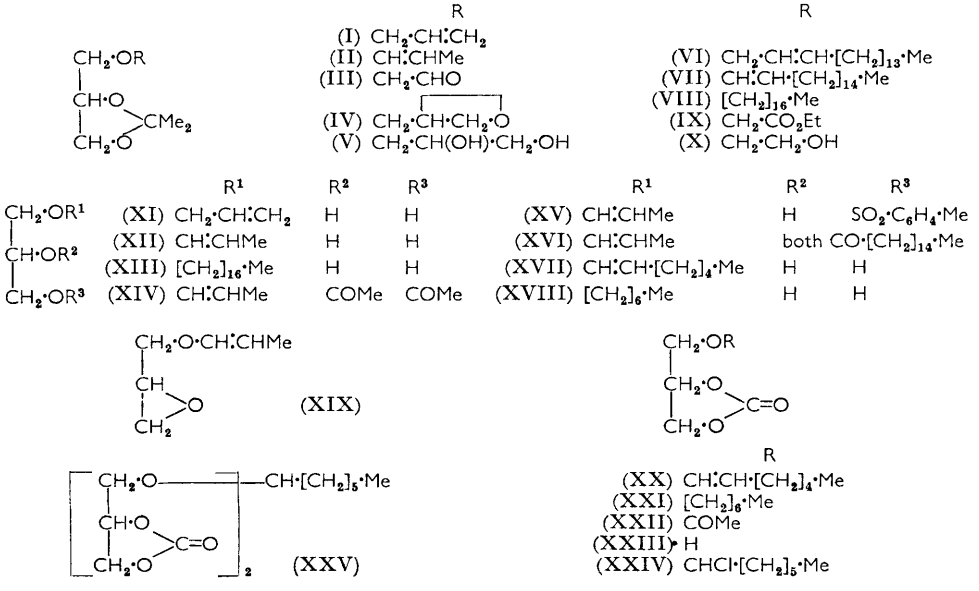
[5] C. Piantadosi, A. F. Hirsch, C. L. Yarbro, and C. E. Anderson, *J. Org. Chem.*, 1963, **28**, 2425.

[6] M. V. Berezovskaya, I. K. Sarycheva, N. A. Preobrazhenskii, *Zhur. obshchei Khim.*, 1964, **34**, 543.

[7] J. Cunningham, R. Gigg, and C. D. Warren, *Tetrahedron Letters*, 1964, 1191.

of potassium t-butoxide in dimethyl sulphoxide at 100°, and the preparations of these compounds are recorded here in detail. The double bond formed in this type of rearrangement is reported [8] to have the *cis* configuration. The presence of the enol ether on the 1-position of glycerol in this preparation of 1-*O*-prop-1′-enylglycerol was confirmed by catalytic reduction to 1-*O*-propylglycerol which was completely cleaved by sodium metaperiodate. On treatment with acid catalysts in anhydrous solvents, the 1-*O*-prop-1′-enylglycerol (XII) was rapidly converted into a mixture of 1,2-*O*- and 1,3-*O*-propylideneglycerols; the explosive nature of cyclisations of this type had previously been observed with hydroxyethyl vinyl ether [9] and the reaction also occurs readily with the deacylated natural plasmalogens.[10] 1-*O*-Prop-1′-enylglycerol (XII) was converted into 1-*O*-prop-1′-enyl-2,3-epoxypropane (XIX) by a base catalysed elimination of toluene-*p*-sulphonic acid from 1-*O*-prop-1′-enyl-3-*O*-toluene-*p*-sulphonylglycerol (XV). 1-*O*-Alk-1′-enyl-2,3-epoxypropanes are also potential intermediates for the synthesis of plasmalogens since epoxides can be opened by phosphate anions [11] to give phosphoric acid esters of the corresponding glycols.

Since the rearrangement of the allyl ether proceeded so readily in 1-*O*-allyl-2,3-*O*-isopropylideneglycerol (I), the action of base on the γ-substituted allyl ether (VI) was



investigated to see if long chain 1-*O*-alk-1′-enyl ethers of glycerol could be prepared by this method. 1-*O*-Heptadec-2′-enyl-2,3-*O*-isopropylideneglycerol (VI) was synthesised by a Wittig reaction [12] between the phosphorane derived from pentadecyltriphenylphosphonium bromide and 1-*O*-formylmethyl-2,3-*O*-isopropylideneglycerol (III); the aldehyde (III) was prepared by ozonolysis of the allyl ether (I) or by oxidation of 1-*O*-(2,3-dihydroxypropyl)-2,3-*O*-isopropylideneglycerol (V) with sodium metaperiodate. The glycol (V) was prepared by alkaline hydrolysis of 1-*O*-(2,3-epoxypropyl)-2,3-*O*-isopropylideneglycerol (IV) which was obtained by the action of 1-chloro-2,3-epoxypropane on the sodio-derivative of 1,2-*O*-isopropylideneglycerol. Attempts to prepare the aldehyde

[8] (*a*) T. J. Prosser, *J. Amer. Chem. Soc.*, 1961, **83**, 1701; (*b*) C. C. Price and W. H. Snyder, *ibid.*, p. 1773.
[9] H. S. Hill and L. M. Pidgeon, *J. Amer. Chem. Soc.*, 1928, **50**, 2718.
[10] J. B. Davenport and R. M. C. Dawson, *Biochem. J.*, 1962, **84**, 490; R. Pietruszko and G. M. Gray, *Biochim. Biophys. Acta*, 1962, **56**, 232.
[11] D. M. Brown, *Adv. Org. Chem.*, 1963, **3**, 75.

(III) by oxidation of the toluene-*p*-sulphonate of the corresponding alcohol (X) in dimethyl sulphoxide were unsuccessful. The unsaturated ether (VI) which was probably a mixture of *cis*- and *trans*-isomers [12] was characterised by hydrogenation to the corresponding saturated ether (VIII) which gave 1-*O*-heptadecylglycerol (XIII) on hydrolysis with dilute acid. The aldehyde (III) was characterised by reduction with lithium aluminium hydride to the corresponding alcohol (X) which was converted into the 1-naphthylurethane derivative.

When 1-*O*-heptadec-2′-enyl-2,3-*O*-isopropylideneglycerol (VI) was treated with potassium t-butoxide in dimethyl sulphoxide at 100° for 1 hr., the product had the properties of an unsaturated hydrocarbon rather than those expected for the required alk-1′-enyl ether (VII). The elemental analyses and ultraviolet absorption spectrum indicated a mixture of conjugated heptadecadienes, and on catalytic hydrogenation two molecules of hydrogen were absorbed and the product had the correct melting point for heptadecane. Gas chromatography and comparison [13] of the retention time of the product with the retention times of hexadecane and octadecane on the same column confirmed that the saturated hydrocarbon was heptadecane. The formation of dienes by this method has not previously been reported.

In considering further routes for the preparation of 1-*O*-alk-1′-enyl ethers of glycerol it seemed desirable to protect the 1- and 2-positions of glycerol by groups which could be removed under alkaline conditions. 1,2-Di-*O*-acyl derivatives of glycerol are not suitable since they are readily isomerised to 1,3-di-*O*-acyl derivatives under acidic conditions,[14] and we therefore investigated the use of the recently characterised [15] glycerol 1,2-carbonate (XXIII). Cyclic carbonates show considerable stability to acids but are readily hydrolysed under basic conditions.[16] When heptanal and glycerol 1,2-carbonate were heated in benzene in the presence of toluene-*p*-sulphonic acid, with the removal of water by azeotropic distillation, heptanal di(glycerol 1,2-carbonate) acetal (XXV) was obtained. Thermal decomposition of the acetal (XXV) at 210—220° and distillation of the products gave a mixture of glycerol 1,2-carbonate and 1-*O*-hept-1′-enylglycerol 2,3-carbonate (XX). The mixture was readily separated by distribution between water and ether, and the hept-1′-enyl ether (XX) was obtained in good yield. The ether (XX) was completely hydrolysed by dilute acid to heptanal and glycerol 1,2-carbonate, and on catalytic hydrogenation gave 1-*O*-heptylglycerol 2,3-carbonate (XXI) which was readily hydrolysed to 1-*O*-heptylglycerol (XVIII) by dilute alkali. The 1-*O*-heptylglycerol was completely oxidised by sodium metaperiodate, thus confirming the position of the ether linkage in 1-*O*-hept-1′-enylglycerol 2,3-carbonate. However, thin-layer chromatography of the analytically pure product (XX) showed the presence of two compounds with similar R_F values, and it is assumed therefore, since the presence of other isomers has been ruled out, that both *cis*- and *trans*-isomers are present. Alkaline hydrolysis of 1-*O*-hept-1′-enylglycerol 2,3-carbonate gave 1-*O*-hept-1′-enylglycerol (XVII). The acetal (XXV) was also converted into a mixture of 1-*O*-(1-chloroheptyl)glycerol 2,3-carbonate (XXIV) and 1-*O*-acetylglycerol 2,3-carbonate (XXII) by heating with acetyl chloride. The conversion of acetals into chloro-ethers by this procedure has been described previously.[17] The mixed product was treated with anhydrous triethylamine to eliminate hydrogen chloride from the chloro-ether, and this was followed by hydrolysis with aqueous sodium hydroxide solution which removed the cyclic carbonate esters. The products, which consisted of glycerol and 1-*O*-hept-1′-enylglycerol, were readily separated and the alkenyl ether was obtained in good overall yield.

[12] S. Trippett, *Quart. Rev.*, 1963, **17**, 406.
[13] J. F. Smith, *Chem. and Ind.*, 1960, 1024.
[14] D. T. Jackson and C. G. King, *J. Amer. Chem. Soc.*, 1933, **55**, 678.
[15] J. Cunningham and R. Gigg, *J.*, 1965, 1553.
[16] L. Hough, J. E. Priddle, and R. S. Theobald, *Adv. Carbohydrate Chem.*, 1960, **15**, 91.
[17] H. W. Post, *J. Org. Chem.*, 1936, **1**, 231; O. Grummitt and J. A. Stearns, *J. Amer. Chem. Soc.*, 1955, **77**, 3136.

Experimental

All the glycerol derivatives described are in the racemic form. The light petroleum had b. p. 40—60° unless otherwise stated. Thin-layer chromatography was carried out on microscope slides coated with silica gel G (Merck). For the detection of unsaturated compounds the plates were first sprayed with a 1% (w/v) solution of potassium permanganate in a 2% (w/v) aqueous solution of sodium carbonate. The unsaturated compounds were revealed immediately as yellow spots on a purple background. The plates were then resprayed with aqueous sulphuric acid (50% v/v) and heated at 200° for the detection of other compounds.

1-O-*Allyl*-2,3-O-*isopropylideneglycerol* (I).—1,2-*O*-Isopropylideneglycerol [18] (100 g.) was added slowly with stirring to a mixture of sodium hydride (20 g.), allyl bromide (110 g.), and dry benzene (250 ml.) at 50°. When the addition was complete, the mixture was heated under reflux for 2 hr. After cooling, methanol was added to destroy the excess sodium hydride, and the benzene solution was washed with water and dried ($MgSO_4$). Removal of the benzene and distillation of the residue gave the product (I) (110 g.), b. p. 97°/35 mm. (lit.,[19] 87°/22 mm.) (Found: C, 62·6; H, 9·6. Calc. for $C_9H_{16}O_3$: C, 62·8; H, 9·4%).

1-O-*Prop*-1′-*enyl*-2,3-O-*isopropylideneglycerol* (II).—A solution of 1-*O*-allyl-2,3-*O*-isopropylideneglycerol (5 g.) and dry potassium t-butoxide [8a,20] (3·3 g.) in dry dimethyl sulphoxide [21] (50 ml.) was stirred at 100° for 15 min. Thin-layer chromatography (ether–petroleum 1 : 4 as mobile phase) showed that conversion of the allyl ether (R_F 0·45) into the prop-1′-enyl ether (R_F 0·6) was complete. After cooling, the mixture was diluted with water (50 ml.) and extracted with petroleum, dried (K_2CO_3), the solvent evaporated, and the residue distilled, to give the *product* (3 g.), b. p. 44°/0·8 mm., $\nu_{max.}$ 1670 cm.$^{-1}$ (O·CH:CH) (Found: C, 63·1; H, 9·6. $C_9H_{16}O_3$ requires C, 62·8; H, 9·4%).

2,3-*Di*-O-*acetyl*-1-O-*prop*-1′-*enylglycerol* (XIV).—1-*O*-Allylglycerol [19] (26·4 g.), dry potassium t-butoxide (67·3 g.), and dry dimethyl sulphoxide (200 ml.) were stirred under dry nitrogen for 1 hr. at 100°. After this time, thin-layer chromatography (ether as the mobile phase) showed complete conversion of the starting material (R_F 0·23) into the prop-1-enyl ether (R_F 0·4). Water (10 ml.) and solid carbon dioxide were added, the mixture was diluted with chloroform, and the precipitated potassium carbonate filtered off. The solution was distilled under reduced pressure and 1-*O*-prop-1′-enylglycerol (23 g.), b. p. 96°/1·5 mm., was collected. It was contaminated with dimethyl sulphoxide and was converted into the diacetate for purification. Acetic anhydride (12·5 g.) was added slowly to a cooled solution of crude 1-*O*-prop-1′-enylglycerol (6·8 g.) in dry pyridine (20 ml.) and the solution was then kept at 50° for 90 min. Water was added to decompose the excess acetic anhydride and the solution was extracted with ether (2 × 150 ml.). The ether extract was washed carefully with dilute hydrochloric acid without allowing the washings to become acidic and this was followed by a thorough washing with sodium hydrogen carbonate solution. The extract was dried and after removal of the ether the residue was distilled to give the *product* (8·3 g.), b. p. 80—85°/1 mm., $\nu_{max.}$ 1730 (C=O) and 1665 cm.$^{-1}$ (O·CH:CH), n_D^{22} 1·4423 (Found: C, 55·0; H, 7·4. $C_{10}H_{16}O_5$ requires C, 55·5; H, 7·5%).

1-O-*Prop*-1′-*enylglycerol* (XII).—2,3-Di-*O*-acetyl-1-*O*-prop-1′-enylglycerol (8 g.) in a solution of potassium hydroxide in aqueous methanol (100 ml.; N) was heated under reflux for 2 hr. Solid carbon dioxide was added to destroy the excess potassium hydroxide and the solution was evaporated to dryness and the residue extracted with chloroform. The chloroform solution was dried over potassium carbonate, and distillation gave the *product* (4·2 g.), b. p. 80°/1 mm., $\nu_{max.}$ 1665 cm.$^{-1}$ (O·CH:CH) (Found: C, 54·1; H, 8·85. $C_6H_{12}O_3$ requires C, 54·5; H, 9·15%). The *bisphenylurethane derivative* was prepared from 1-*O*-prop-1′-enylglycerol (0·5 g.) and phenyl isocyanate (0·95 g.) in dry pyridine (2 ml.) at room temperature for 12 hr. The solution was poured into dry petroleum and the solid which separated was recrystallised from benzene–petroleum to give needles, m. p. 111° (Found: C, 65·0; H, 6·0; N, 7·6. $C_{20}H_{22}N_2O_5$ requires C, 64·9; H, 6·0; N, 7·6%).

1-*O*-Prop-1′-enylglycerol (0·5 g.) and potassium carbonate (0·1 g.) in ethanol (25 ml.) were treated with hydrogen at atmospheric pressure in the presence of platinum oxide until uptake

[18] E. Fischer and E. Pfähler, *Ber.*, 1920, **53**, 1606.
[19] R. M. Evans and L. N. Owen, *J.*, 1949, 244.
[20] W. S. Johnson and G. H. Daub, *Org. Reactions*, 1951, **6**, 1.
[21] G. G. Price and M. C. Whiting, *Chem. and Ind.*, 1963, 775.

was complete. The solution was filtered, the solvent evaporated, the residual 1-*O*-propylglycerol dissolved in water (15 ml.), and sodium metaperiodate (0·95 g.) added with stirring. After 30 min. at room temperature, thin-layer chromatography (ether as mobile phase) showed complete cleavage of the 1-*O*-propylglycerol (R_F 0·3) to a product (R_F 0·75) which was not further investigated.

2,3-*Di*-O-*palmitoyl*-1-O-*prop*-1′-*enylglycerol* (XVI).—A solution of palmitoyl chloride (8·9 g.) in chloroform (10 ml.) was added slowly with stirring to a solution of 1-*O*-prop-1′-enylglycerol (2·1 g.) in pyridine (10 g.) at 0°, and the mixture was kept at room temperature for 12 hr. Chloroform (50 ml.) was added and the solution was washed with water, N-sulphuric acid (70 ml.), and saturated aqueous sodium hydrogen carbonate solution. The chloroform solution was dried, and after evaporation of the solvent the oily product was chromatographed on neutral alumina. Elution with petroleum removed some impurity and elution with petroleum–ether (9 : 1) gave the *product*, needles, m. p. 39—41° (from petroleum), $\nu_{max.}$ 1725 (C=O) and 1665 cm.$^{-1}$ (O·CH:CH) (Found: C, 74·7; H, 11·8. $C_{38}H_{72}O_5$ requires C, 75·0; H, 11·9%).

1,2- *and* 1,3-O-*Propylideneglycerols*.—(*a*) Glycerol (9 g.), propionaldehyde (5·6 g.), and toluene-*p*-sulphonic acid (100 mg.) were shaken together for 30 min. Potassium carbonate was added and the mixture was diluted with ether and filtered. Removal of the solvent and distillation of the residue gave a mixture of 1,2- and 1,3-*O*-propylideneglycerols (8·8 g.), b. p. 70—75°/3 mm. (lit.,[22] 70—72°/3 mm.). Thin-layer chromatography (ether–petroleum 3 : 1 as mobile phase) showed the two isomers with R_F values of 0·5 and 0·6 (Found: C, 54·0; H, 9·2. Calc. for $C_6H_{12}O_3$: C, 54·5; H, 9·2%).

(*b*) 1-*O*-prop-1′-enylglycerol (100 mg.) and toluene-*p*-sulphonic acid (10 mg.) in dry chloroform (5 ml.) were kept at room temperature for 15 min. After this time thin-layer chromatography (as above) showed only the presence of the two propylideneglycerols.

1-O-*Prop*-1′-*enyl*-3-O-*toluene*-p-*sulphonylglycerol* (XV).—A solution of toluene-*p*-sulphonyl chloride (23·5 g.) in dry chloroform (50 ml.) was added during 2 hr. to a solution of 1-*O*-prop-1′-enylglycerol (18 g.) in dry pyridine (30 g.) at 0°, and the mixture was kept for 12 hr. at 0°. Water (10 ml.) was added slowly, keeping the temperature below 5°, and the mixture was diluted with chloroform (100 ml.) and water (100 ml.). The chloroform solution was washed carefully as described in the previous preparations of acyl derivatives, and dried ($MgSO_4$). Evaporation of the chloroform gave crude 1-*O*-prop-1′-enyl-3-*O*-toluene-*p*-sulphonylglycerol (26 g.) as an oil. Thin-layer chromatography (ether–petroleum 1 : 1 as mobile phase) showed the monotoluene-*p*-sulphonate (R_F 0·3) and some ditoluene-*p*-sulphonate (R_F 0·5).

1-O-*Prop*-1′-*enyl*-2,3-*epoxypropane* (XIX).—The crude monotoluene-*p*-sulphonate (XV) (26 g.) was added to a cooled solution of sodium methoxide (5 g.) in dry methanol (50 ml.). After 1 hr. at room temperature, water (100 ml.) and solid carbon dioxide were added, and the solution was extracted with petroleum (b. p. <45°; 3 × 150 ml.). The petroleum solution was dried, and the solvent evaporated, and distillation of the residue gave the *product* (4·3 g., 28% yield from 1-*O*-prop-1′-enylglycerol), b. p. 56°/15 mm., $\nu_{max.}$ 1665 cm.$^{-1}$ (O·CH:CH) (Found: C, 63·2; H, 9·0. $C_6H_{10}O_2$ requires C, 63·1; H, 8·8%).

1-O-(2,3-*Epoxypropyl*)-2,3-O-*isopropylideneglycerol* (IV).—1,2-*O*-Isopropylideneglycerol (13·2 g.) was added slowly with stirring to a mixture of sodium hydride (4·8 g.; 50% dispersion in oil) in dry tetrahydrofuran (250 ml.). When the initial vigorous reaction had subsided the mixture was heated under reflux for 2 hr. 1-Chloro-2,3-epoxypropane (18·5 g.) was added and the solution heated under reflux for 6 hr. After removal of the solvent the residue was diluted with water and extracted with ether. The ether solution was dried, the solvent removed, and the residue distilled, to give the *product* (9·4 g.), b. p. 136—140°/18 mm., n_D^{22} 1·4420 (Found: C, 57·4; H, 8·5. $C_9H_{16}O_4$ requires C, 57·4; H, 8·5%).

1-O-(2,3-*dihydroxypropyl*)-2,3-O-*isopropylideneglycerol* (V).—A solution of 1-*O*-(2,3-epoxypropyl)-2,3-*O*-isopropylideneglycerol (5 g.) in aqueous sodium hydroxide solution (60 ml.; N) and dioxan (60 ml.) was heated under reflux for 2 hr. Solid carbon dioxide was added and the solution was evaporated to dryness. The residue was extracted with chloroform and the solution dried (K_2CO_3). Removal of the solvent and distillation gave the glycol (V) (4·4 g.), b. p. 140°/1 mm. (lit.,[23] 147—148°/4 mm.), n_D^{22} 1·4590 (Found: C, 52·5; H, 8·8. Calc. for $C_9H_{18}O_5$: C, 52·4; H, 8·8%).

[22] S. M. Trister and H. Hibbert, *Canad. J. Res.*, 1936, **14***B*, 415.
[23] H. P. Kaufmann and N. Foerster, *Fette u. Seifen*, 1960, **62**, 796.

1-O-*Formylmethyl*-2,3-O-*isopropylideneglycerol* (III).—(*a*) A stream of dry ozonised oxygen was bubbled through a solution of 1-*O*-allyl-2,3-*O*-isopropylideneglycerol (10 g.) in dry ethyl acetate (200 ml.) at −30° until a blue colour developed (6 hr.). Excess ozone and oxygen were removed by passing dry nitrogen through the solution which was then treated with hydrogen at 0° and atmospheric pressure in the presence of Lindlar's catalyst [24] (1 g.) until uptake was complete. Removal of the catalyst and the solvent, and distillation in a nitrogen atmosphere, gave the *product* (6·6 g.), b. p. 76—80°/1 mm., $\nu_{max.}$ 1735 cm.$^{-1}$ (C=O).

(*b*) Finely powdered sodium metaperiodate (5 g.) was added slowly with stirring to a cooled solution of 1-*O*-(2,3-dihydroxypropyl)-2,3-*O*-isopropylideneglycerol (5 g.) in water (25 ml.). After the addition was complete the mixture was stirred at room temperature for 30 min. The solution was saturated with potassium chloride, extracted with chloroform, dried, and the solvent removed. Distillation of the residue in a nitrogen atmosphere gave 1-*O*-formylmethyl-2,3-*O*-isopropylideneglycerol (2·5 g.), b. p. 108°/9 mm.

1-*O*-Formylmethyl-2,3-*O*-isopropylideneglycerol (1 g.) was added slowly to a mixture of lithium aluminium hydride (0·5 g.) and dry ether (25 ml.) and the solution was refluxed for 1 hr. Ethyl acetate was added to decompose the excess hydride, and water was then added slowly with stirring until the inorganic material was in the form of a white powder. The solution was filtered and dried (K_2CO_3), the solvent removed, and the residue distilled, to give 1-*O*-(2-hydroxyethyl)-2,3-*O*-isopropylideneglycerol, b. p. 92°/0·8 mm. The 1-naphthylurethane derivative had m. p. and mixed m. p. 97—98° with the derivative described below.

1-O-*Carboxymethyl*-2,3-O-*isopropylideneglycerol Ethyl Ester* (IX).—1,2-*O*-Isopropylideneglycerol (13·2 g.) in dry benzene (20 ml.) was added slowly to a stirred mixture of sodium hydride (2·4 g.), ethyl bromoacetate (16·7 g.), and dry benzene (100 ml.). After the initial reaction had subsided, the mixture was heated under reflux for 2 hr., cooled, and washed with water. The benzene solution was dried and the solvent removed. Distillation of the residue gave the *ester* (IX) (10·6 g.), b. p. 100°/1·5 mm., n_D^{22} 1·4342 (Found: C, 54·8; H, 8·1. $C_{10}H_{18}O_5$ requires C, 55·0; H, 8·3%).

1-O-(2-*Hydroxyethyl*)-2,3-O-*isopropylideneglycerol* (X).—The ester (IX) (10 g.) in dry ether (30 ml.) was added slowly with stirring to a solution of lithium aluminium hydride (2 g.) in dry ether (100 ml.). After the addition was complete, the solution was refluxed for 2 hr. Ethyl acetate was added to decompose the excess hydride, and then water was added slowly with stirring until the inorganic material was in the form of a fine, white, powdery precipitate. The solution was filtered, dried (K_2CO_3), and the ether removed. Distillation of the residue gave the alcohol (X) (6·5 g.), b. p. 90°/0·7 mm., n_D^{22} 1·4420 (Found: C, 54·1; H, 9·3. Calc. for $C_8H_{16}O_4$: C, 54·5; H, 9·15%, lit.,[25]).

The 1-*naphthylurethane derivative*, recrystallised from cyclohexane, had m. p. 96—98° (Found: C, 66·3; H, 6·7; N, 4·1. $C_{19}H_{23}NO_5$ requires C, 66·1; H, 6·7; N, 4·05%).

Pentadecyltriphenylphosphonium Bromide.—Pentadecyl bromide (60 g.), which was prepared from palmitic acid (L. Light and Co.; "98% by g.l.c.") by the Hunsdiecker reaction,[26] and triphenylphosphine (54 g.) were heated together at 140° for 5 hr. The mixture was cooled and dissolved in the minimum quantity of acetone, ether was added, and the product (102 g.), which crystallised on standing, was filtered and washed with ether. Recrystallisation from benzene–ether gave the *product* as plates, m. p. 92° (Found: C, 71·3; H, 8·3; Br, 14·1; P, 5·4. $C_{33}H_{46}BrP$ requires C, 71·6; H, 8·4; Br, 14·4; P, 5·6%).

1-O-*Heptadec*-2'-*enyl*-2,3-O-*isopropylideneglycerol* (VI).—A solution of phenyl-lithium (2·9 g.) in dry ether (50 ml.) was added to pentadecyltriphenylphosphonium bromide (19 g.) in dry tetrahydrofuran (100 ml.), and the solution was stirred and heated under reflux in a dry, oxygen-free, nitrogen atmosphere for 15 min. Freshly prepared 1-*O*-formylmethyl-2,3-*O*-isopropylideneglycerol (6 g.) was added to the solution, refluxing was continued for 6 hr., the solvent was removed by evaporation, and water (100 ml.) was added to the residue. The mixture was extracted with petroleum and the extracted material was chromatographed on silica gel. Elution with ether–petroleum (1 : 3) gave the *product* (2·6 g.), b. p. 170°/0·03 mm., n_D^{22} 1·4572 (Found: C, 74·7; H, 11·7. $C_{23}H_{44}O_3$ requires C, 75·0; H, 12·0%).

1-O-*Heptadecylglycerol* (XIII).—1-*O*-Heptadec-2'-enyl-2,3-*O*-isopropylideneglycerol

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[25] M. S. Kharasch, U.S.P. 2,428,805/1947 (*Chem. Abs.*, 1948, **42**, 618).
[26] L. Ahlquist, C. Asselineau, J. Asselineau, S. Ställberg-Stenhagen, and E. Stenhagen, *Arkiv Kemi*, 1959, **13**, 543.

(600 mg.) in ethanol (20 ml.) was treated with hydrogen at atmospheric pressure in the presence of platinum until uptake was complete (70 ml. consumed). After filtration and removal of the solvent, the product was dissolved in ethanol (10 ml.) and 3N-hydrochloric acid (2 ml.), and the solution refluxed for 1 hr., neutralised with N-sodium hydroxide, and evaporated to dryness. The residue was extracted with ether and the solution dried. Evaporation of the ether and recrystallisation from cyclohexane gave the *product* (450 mg.) as plates, m. p. 66—68° (Found: C, 72·6; H, 12·7. $C_{20}H_{42}O_3$ requires C, 72·7; H, 12·8%).

Fission of 1-O-*Heptadec-2′-enyl*-2,3-O-*isopropylideneglycerol to Heptadecadienes*.—The ether (VI) (1 g.) and dry potassium t-butoxide (400 mg.) in dry dimethyl sulphoxide (10 ml.) were stirred at 100° in an atmosphere of dry nitrogen for 1 hr. After this time, thin-layer chromatography (petroleum–ether 3 : 1 as the mobile phase) showed a trace of starting material (R_F 0·7) and a product (R_F 1·0). Water (10 ml.) and solid carbon dioxide were added to the cooled solution which was then extracted with petroleum. The extract was washed with water and dried, and evaporation of the solvent and chromatography of the product on silica gel gave a mixture of heptadecadienes (480 mg.) as an oil (Found: C, 86·7; H, 13·5. Calc. for $C_{17}H_{32}$: C, 86·4; H, 13·6%), $\lambda_{max.}$ (in hexane) 225 and 230 mμ. The heptadecadiene mixture (326 mg.), in ethyl acetate (25 ml.), was treated with hydrogen at atmospheric pressure in the presence of platinum until uptake was complete (66 ml., 2·1 mol.). After filtration, the solvent was evaporated to give heptadecane (330 mg.), m. p. 22° (Found: C, 84·8; H, 14·9. Calc. for $C_{17}H_{36}$: C, 84·9; H, 15·1%). The hydrocarbon and two standards were analysed on a Perkin-Elmer 800 Gas Chromatogram using a column (6 ft. × 1/8 in.) of Chromosorb W containing 15% Apiezon L, at 180°. The retention times for hexadecane, octadecane, and the heptadecane prepared above were 9·34, 22·24, and 14·92 min., respectively.

Heptanal Di(glycerol 1,2-*carbonate) Acetal* (XXV).—A mixture of glycerol 1,2-carbonate [15] (30 g.), heptanal (15 g.), toluene-*p*-sulphonic acid (50 mg.), and dry benzene (75 ml.) was heated under reflux for 3 hr. with vigorous stirring in an atmosphere of dry nitrogen, and the azeotropically distilled water (2 ml., 85%) was collected in a trap. The cooled solution was washed with aqueous sodium hydrogen carbonate solution and saturated potassium chloride solution and dried ($MgSO_4$). After evaporation of the benzene, the oily residue was extracted with petroleum (5 × 50 ml.) to remove impurities. The product (24 g., 54%) was investigated by thin-layer chromatography (ethyl acetate as mobile phase) which showed the main product (R_F 0·6) together with a small amount of impurity (R_F 0·98). For analysis, a portion was chromatographed on silica gel and, after elution of the impurity with ether, elution with ethyl acetate gave the pure *product*, $\nu_{max.}$ 1790 cm.$^{-1}$ (C=O) (Found: C, 54·3; H, 7·3. $C_{15}H_{24}O_8$ requires C, 54·2; H, 7·3%).

1-O-*Hept*-1′-*enylglycerol* 2,3-*Carbonate* (XX).—Heptanal di(glycerol 1,2-carbonate) acetal (16 g.) was heated under a high vacuum at a bath temperature of 210—220°, and the material distilling at 125—150°/0·05 mm. was collected. Only a small residue remained in the distillation flask. The homogeneous distillate was diluted with ether (50 ml.), and the ether layer was washed with saturated sodium hydrogen carbonate solution and dried ($MgSO_4$). Removal of the ether gave an oil (8 g.) which was redistilled to give the *product*, b. p. 120°/0·03 mm. $\nu_{max.}$ 1790 (C=O) and 1665 cm.$^{-1}$ (O·CH:CH). Thin-layer chromatography (ether as the mobile phase) showed two products, with R_F values of 0·65 and 0·75, and a small amount of impurity (R_F 1·0) which was removed by chromatography on silica gel (Found: C, 61·8; H, 8·2. $C_{11}H_{18}O_4$ requires C, 61·7; H, 8·5%). The ether (XX) (200 mg.) was heated at 80° in glacial acetic acid (3 ml.) and water (1 ml.) for 1 hr. After this time, thin-layer chromatography (ether–petroleum 2 : 1 as mobile phase) showed the presence of glycerol 1,2-carbonate (R_F 0·1) and heptanal (R_F 0·98) and the absence of starting material (R_F 0·35—0·6).

1-O-*Heptylglycerol* 2,3-*Carbonate* (XXI).—1-*O*-Hept-1′-enylglycerol 2,3-carbonate (1·2 g.) and sodium hydrogen carbonate (25 mg.) in ethanol (25 ml.) were treated with hydrogen at atmospheric pressure in the presence of platinum until uptake was complete (130 ml. consumed). After filtration, glacial acetic acid (2 ml.) was added, and the solvent was removed by evaporation under reduced pressure. The residue was extracted with ether, and the extract was washed with sodium hydrogen carbonate solution and dried. Removal of the solvent and distillation gave the *product*, b. p. 130°/0·04 mm. (Found: C, 60·9; H, 9·0. $C_{11}H_{20}O_4$ requires C, 61·1; H, 9·3%).

1-O-*Heptylglycerol* (XVIII).—1-*O*-Heptylglycerol 2,3-carbonate (800 mg.) and sodium hydroxide (1 g.) in ethanol (10 ml.) and water (10 ml.) were heated on a steam-bath for 15 min.

Solid carbon dioxide was added to the cooled mixture which was then evaporated to dryness. The residue was extracted with chloroform, the extract dried, and the solvent removed by evaporation under reduced pressure. Distillation of the residue gave 1-*O*-heptylglycerol, b. p. 120—122°/0·5 mm., n_D^{22} 1·4495 (Found: C, 63·5; H, 11·7. Calc. for $C_{10}H_{22}O_3$: C, 63·1; H, 11·65%) (lit.,[27] b. p. 124—126°/0·5 mm., n_D^{20} 1·4492). Powdered sodium metaperiodate (300 mg.) was added with stirring to a solution of 1-*O*-heptylglycerol (200 mg.) in water (6 ml.) and ethanol (4 ml.). After 15 min., thin-layer chromatography (ether as mobile phase) showed that the oxidation of the starting material (R_F 0·4) to a product (R_F 0·9) was complete, thus ruling out the presence of 2-*O*-heptylglycerol in the product.

1-O-*Hept*-1′-*enylglycerol* (XVII).—(*a*) A solution of 1-*O*-hept-1′-enylglycerol 2,3-carbonate (5 g.) and sodium hydroxide (3 g.) in methanol (60 ml.) and water (40 ml.) was heated on a steam-bath for 15 min. After cooling, solid carbon dioxide was added and the mixture was evaporated to dryness. The residue was extracted with ether and the extract dried (K_2CO_3). Removal of the solvent by evaporation, and distillation of the residue (with a small amount of potassium carbonate in the distillation flask), gave the *product* (4 g.), b. p. 99°/0·03 mm., $\nu_{max.}$ 1665 cm.$^{-1}$ (O·CH:CH) (Found: C, 63·7; H, 10·8. $C_{10}H_{20}O_3$ requires C, 63·8; H, 10·7%).

(*b*) A solution of heptanal di(glycerol 1,2-carbonate) acetal (9 g.) in acetyl chloride (10 ml.) was heated under reflux for 2 hr. The excess acetyl chloride was removed by distillation under reduced pressure, and dry triethylamine (5 ml.) was added to the residue. After warming at 80° for 15 min. the semi-solid mass was diluted with dry ether (100 ml.) and the crystalline triethylamine hydrochloride was removed by filtration. The ether and excess triethylamine were removed by distillation under reduced pressure, and thin-layer chromatography (ether as mobile phase) showed the presence of 1-*O*-hept-1′-enylglycerol 2,3-carbonate (R_F 0·6 and 0·7) and 1-*O*-acetylglycerol 2,3-carbonate (R_F 0·3). The product was added to a solution of sodium hydroxide (6 g.) in ethanol (60 ml.) and water (40 ml.) and heated on a steam-bath for 15 min. After cooling, solid carbon dioxide was added, and 1-*O*-hept-1′-enylglycerol (2·2 g., 43%), b. p. 105°/0·05 mm., was isolated as described above.

1-O-*Acetylglycerol* 2,3-*Carbonate*.—Glycerol 1,2-carbonate (5 g.), pyridine (10 ml.), and acetic anhydride (5 g.) were heated on a steam-bath for 15 min. Chloroform (50 ml.) was added, and the solution was washed with saturated potassium chloride solution, dilute hydrochloric acid, and sodium hydrogen carbonate solution, and dried. Removal of the chloroform by evaporation and distillation of the residue gave the *product* (5 g.), b. p. 131°/0·5 mm., n_D^{22} 1·4446 (Found: C, 45·3; H, 5·1. $C_6H_8O_5$ requires C, 45·0; H, 5·0%).

National Institute for Medical Research,
Mill Hill, London N.W.7.

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