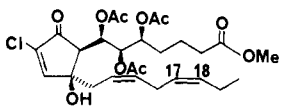
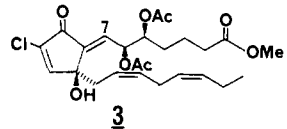


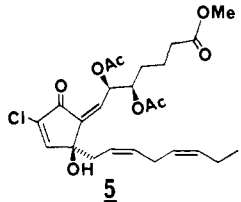
1

2 17,18-dihydro-1



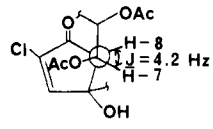
3

4 17,18-dihydro-3



5

6 17,18-dihydro-5



a

Desorption–chemical ionization MS[13] revealed molecular ions and the presence of chlorine, which was confirmed by combustion analysis. The 17,18-dihydro relationship of **1** and **2** and of **3** and **4** is evident from ^{1}H and ^{13}C NMR data and from their formulas, each pair differing by two mass units. The structure of **1**, $C_{27}H_{37}ClO_{10}$, was deduced as follows: Three acetates (δ 171.3, 170.5, 170.4, 2.11, 2.08, 2.00, all singlets; 1740 cm^{-1}) and one methyl ester (δ 173.8, 3.65) account for eight oxygens and four of nine unsaturations. An α,β-enone (228 nm, ϵ 7900; δ 196.0 s, 136.1 s, 158.1 d, 7.26 s) and a 3° hydroxyl (3500 cm^{-1}; δ 77.2 s) complete the oxygen functions and leave three unsaturations. Two of these are *Z* olefins (δ 134.6, 132.9, 126.0, 121.5, all doublets; δ 5.30, 5.61, J = 10.8 Hz, 5.24, 5.41 J = 10.6 Hz) and the last must be a ring for lack of additional low-field NMR signals.

Extensive decoupling experiments at 500 MHz fully documented all protons from C-2 to C-8 and C-13 to C-20 and hence both side chains. A 3° hydroxyl at C-12 was supported by the nonequivalence of the C-13 ^{1}H NMR signals (δ 2.53, 2.45) and their only coupling to H-14 (δ 5.30, J = 7.0 Hz), thereby unequivocally placing chlorine at C-10.

Punaglandin 1 (**1**) loses HOAc when treated with pyridine[14] affording a 3:1 mixture of (*Z*)-7,8-punaglandin 3 (**5**)[12] and **3**. The predominant *Z* isomer has an $H_{6,7}$ coupling constant of 7.7 Hz vs. 9.1 Hz for the *E* isomer. This assignment is further confirmed by comparing the chemical shifts of H-6 (6.02 ppm) and H-7 (6.35 ppm) in the *E* isomer **3** with those of H-6 (6.32 ppm) and H-7 (6.08 ppm) in the *Z* isomer **5**. The downfield shift of H-6 and the upfield shift of H-7 when going from *E* to *Z* is caused by the anisotropy of the C-9 carbonyl and is analogous to observations in the claviridenone series.[15] Under the same reaction conditions, **2** is transformed into (*Z*)-7,8-punaglandin 4 (**6**)[12] and its *E* isomer, also in a ratio of 3:1. These reactions show that all four punaglandins belong to the same stereochemical series. The relative stereochemistry of the five centers was deduced as follows. The trans relationship of the two side chains was proven by irradiating H_2-13 at ~2.5 ppm and observing a strong NOE of the H-8 signal at 2.75 ppm. The three acetates at C-5, C-6, and C-7 must have all-threo configuration since $J_{5,6} = J_{6,7}$ = 5.3 Hz.[16] Finally, H-7 must be gauche to H-8 (J = 4.2 Hz), as the less favorable *Z* isomer can only predominate, as it does in the HOAc elimination, if H-8 and AcO-7 are anti to each other, as in *a*. If one assumes that the punaglandins have the same stereochemistry as other marine eicosanoids,[17,18] our structures also represent the correct absolute stereochemistry.

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Supplementary Material Available: Full physical data and ^{1}H NMR spectra of compounds **1** and **6** (10 pages). Ordering information is given on any current masthead page.

(13) We thank Professor K. Nakanishi (Columbia) for these determinations.

(14) 3 days, room temperature. Product isolated by addition of C_6H_6, distillation, freeze drying, and chromatography over a SiO_2-filled pipet, eluted with petroleum ether/EtOAc, 8:2.

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Nucleophilic Addition of Azide Ion to Benzene Oxide: A Reinvestigation

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The reaction of benzene oxide (**1**) with sodium azide in H_2O at room temperature affords *trans*-6-azidocyclohexa-2,4-dien-1-ol (**2**) as the major product.[1] The 220-MHz ^{1}H NMR spectrum of **2** indicated the presence of a minor amount of 4-azidocyclohexa-2,5-dien-1-ol (**3**) for which stereochemistry was not assigned.[2] The reaction of **1**-*3,6*-$^2H_2$ with N_3^- gave the 1,2-azido alcohol as a mixture of deuterium-labeled isomers **2**-*2,5*-$^2H_2$ and **2**-*3,6*-$^2H_2$ in addition to **3**-*2,5*-$^2H_2$, and it was concluded that both trans-1,2 and trans-1,6 addition of N_3^- to **1** occurs to form **2**.[1]

Recent observations of facile (room temperature) [3,3]-sigmatropic rearrangements (Claisen rearrangements) involving

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(2) Dienol **3** shows absorptions at δ 6.32 and 6.26 (H_2, H_6 or H_3, H_5), 4.52 (H_1), and 4.04 (H_4). The absorption reported previously at 4.78 ppm apparently was due to the hydroxyl proton; the absorption for H_4 at 4.04 ppm was obscured by the absorption for H_6 of **2** at 4.09 ppm and the absorption of H_2, H_6 or H_3, H_5 was obscured by the absorption for H_3 of **2** at 6.04 ppm in the 220-MHz spectrum.

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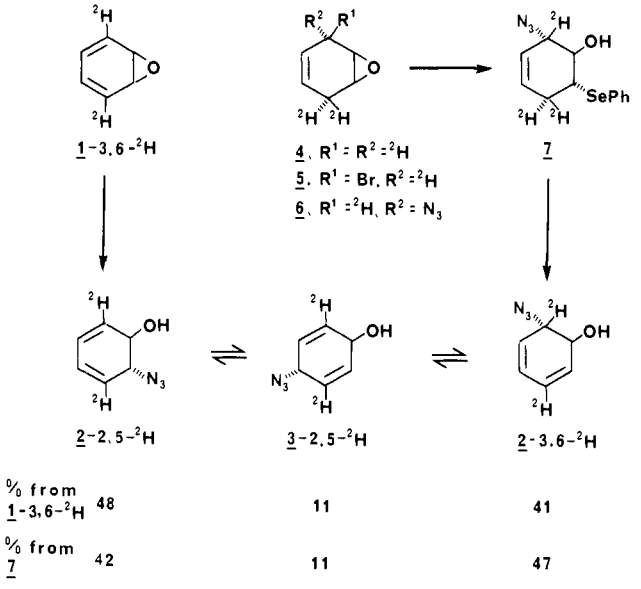
Scheme I

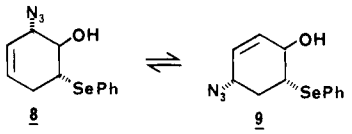


cyclohexadienyl systems[3] have led us to question whether 1,4 or 1,6 addition of N_3^- to **1** does, in fact, occur. An alternative explanation for the results observed with **1**-*3,6*-$^2H_2$ would be to assume only trans-1,2 addition of N_3^- to afford **2**-*2,5*-$^2H_2$ which undergoes rapid thermal equilibration with **3**-*2,5*-$^2H_2$ and **2**-*3,6*-$^2H_2$ by consecutive [3,3]-sigmatropic rearrangements (or 1,3 shifts). The rearrangement of allyl azides is well documented,[4] including examples that occur at 25 °C.[4a,b]

Reaction of **1**-*3,6*-$^2H_2$ with NaN_3 in H_2O at room temperature followed by workup and chromatography (silica gel plate, 2:1 hexane/ethyl acetate, R_f 0.32) gave **2**-*2,5*-$^2H_2$, **3**-*2,5*-$^2H_2$,[5] and **2**-*3,6*-$^2H_2$ in the relative amounts indicated in Scheme I.[6] The ratio did not change on standing at room temperature. Attempts to monitor the course of the reaction in ^2H_2O were not successful due to interference by ^2HOH absorption. Consequently, we decided to develop a reaction sequence that would provide **2**-*3,6*-$^2H_2$ as the sole isomeric product.

Bromide **5** was prepared from **4**[1] by the same procedure described for the undeuterated material.[7,8] Displacement of bromide **5** with N_3^- (1 h, room temperature) afforded **6** (83%) which reacted with PhSeLi in THF (1 h, room temperature) to provide **7** (53%). Oxidation of **7** with $(n\text{-Bu})_4N^+IO_4^-$ in MeOH gave the selenoxide which underwent selenoxide elimination at room temperature (6 h). Workup and chromatography (as above) gave **2**-*2,5*-$^2H_2$, **3**-*2,5*-$^2H_2$, and **2**-*3,6*-$^2H_2$ in the relative amounts indicated in Scheme I. The ratio did not change on standing at room temperature. These results establish the rapid thermal equilibrium among the three isomeric products at room temperature.[9] Within experimental error the product ratios from addition of N_3^- to **1**-*3,6*-$^2H_2$ and from selenoxide elimination from **7** are identical, and, as expected, **2**-*2,5*-$^2H_2$ and **2**-*3,6*-$^2H_2$ are present in equal amounts at equilibrium.

Furthermore, heating of azide **8**,[10] at 120 °C in dimethylformamide for 10 h gave an equilibrium mixture of **8** (72%) and **9** (28%). The two isomers were easily separated by flash chromatography[11] on silica gel (4:1 hexane/ethyl acetate). Selenoxide elimination from **9** at room temperature (1.5 h) gave the same equilibrium mixture of **2** (88%) and **3** (12%) as that obtained from addition of N_3^- to **1** (87% **2** and 13% **3**).[12]



Due to the rapid thermal equilibrium among **2**-*2,5*-$^2H_2$, **3**-*2,5*-$^2H_2$, and **2**-*3,6*-$^2H_2$, it is not possible to address the question of 1,2 vs. 1,4 vs. 1,6 addition of N_3^- to **1** on the basis of available data. Since PhS^- and MeO^- undergo nucleophilic addition to **1** solely by 1,2 addition,[1] it is reasonable to assume that addition of N_3^- to **1** occurs only by the 1,2 addition.

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Supplementary Material Available: Spectra and physical data for **5**-**9** (2 pages). Ordering information is given on any current masthead page.

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(6) Product ratios were determined by integration of the 250-MHz ^1H NMR spectrum in $CDCl_3$. Chemical shift data for **3** are given in ref 2; chemical shift data for **2** are given in ref 1.
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(8) The sequence **4** → **7** and subsequent selenoxide elimination was first developed with undeuterated material.
(9) The possibility of a [1,5] shift of the azido group cannot be eliminated.
(10) Azide **8** was prepared from unlabeled starting material by the same procedure for preparation of **7**.
(11) Still, W. C.; Kahn, M.; Mitra, A. *J. Org. Chem.* **1978**, *43*, 2923-2925.
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Crystal Structure of *meso*-Tetratolylporphyrin: Implications for the Solid-State ^{15}N CPMAS NMR

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There has been considerable interest in the N-H tautomerism of free-base porphyrins and chlorins, which has been interpreted in terms of Scheme I.[2-14] The recent observation of tautomerism

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