mer)[26] for one hour. The solution was allowed to warm to room temperature. The next day a small sample was negative to potassium iodide–starch solution, hence the reaction product was diluted with 300 ml. of Skellysolve B and worked up by the usual washing and crystallization procedure. There was obtained 7.35 g. (91.8% yield) of bisnoraldehyde, $[\alpha]_D$ +81.4° (chf.), 8.37% titratable acid, 4 ± 2% dienone, and 85 ± 3% purity by infrared analysis.

Stannous Chloride Decomposition of Ozonolysis Mixture.—The cold ozonolysis mixture was poured onto 20 g. of anhydrous stannous chloride, 8 ml. of concentrated hydrochloric acid was added with stirring, and the mixture was quickly warmed to 25°, stirred for 4.5 hours and allowed to stand overnight. To the orange-brown mixture was then added 300 ml. of Skellysolve C and 250 ml. of water. It was stirred for 5 minutes and then transferred to a separatory funnel. The organic phase was separated and washed again with 150 ml. of water, three times with cold 5% sodium hydroxide at 5°, and then with water to neutrality, each wash being backwashed with a single solution of 125 ml. of methylene chloride and 250 ml. of Skellysolve C. The combined organic phase was dried over anhydrous sodium sulfate and concentrated at reduced pressure (temperature between 40–50°) to 50 ml. volume. The product crystallized from the mixture overnight. The product was collected on a filter and dried at room temperature at 5–10 cm. pressure over concentrated sulfuric acid. There was obtained 6.65 g. (85.2% of theory), $[\alpha]_D$ +87.1° (chf.), 98.1% pure by infrared assay, 0.51% acid by titration and 2% dienone by infrared assay.

KALAMAZOO, MICHIGAN

(26) J. F. Walker, "Formaldehyde," Reinhold Publ. Corp., New York, N. Y., 1953, p. 30.

[CONTRIBUTION FROM THE INSTITUTE OF APPLIED MICROBIOLOGY, UNIVERSITY OF TOKYO]

Steroid Studies. VI.[1] Studies on the Constitution of Sargasterol

BY KYOSUKE TSUDA, RYOICHI HAYATSU,[2] YUKICHI KISHIDA[2] AND SABURO AKAGI[2]

RECEIVED JUNE 27, 1957

Fucosterol was isolated from brown algae with the exception of *Sargassum ringgoldianum* Harvey which yielded sargasterol (I), which was shown to have two double bonds in the 5,6- and 24,28-positions. Upon Oppenauer oxidation compound I yielded sargastadienone (II) and upon ozonolysis the acetate Ib gave 20-iso-24-ketocholesteryl acetate (VIII). Our results indicate that I is C_{20}-isofucosterol: Wolff–Kishner reduction of VIII gave 20-isocholesterol (IX). The treatment of II with N-bromosuccinimide and subsequent dehydrobromination gave the trienone III from which 3-keto-Δ^4-20-iso-bisnorcholen-22-al (IV) was obtained by ozonolysis. The dienones of sargasterol and fucosterol (XI and XVIII, respectively) yielded the same trienone XIII which upon ozonolysis gave progesterone.

Fucosterol which was isolated from *Fucus vesiculosus* by Heilbron, *et al.*[3], is the only well-characterized sterol obtained from brown algae (*Phaeophyceae*). We have extracted sterols from *Phaeophyceae* growing in the seas off Japan; the yields of crude sterols are given in Table I.

TABLE I

Algae	Crude oil from dry algae, %	Unsaponifiable matter from crude oil, %	Crude sterol from unsap. matter, %
A. *Sargassum ring-goldianum* Harvey[a]	1.86–2.95[e]	22.8–30.0[e]	32.2–63.0[e]
B. *Eisenta bicyclis* (Kjellman) Setchell[a]	0.65	20.4	56.6
C. *Cystophyllum hakodatense* Yendo[b]	0.50	24.8	40.6
D. *Fucus evanescens* Agardh[c]	3.6	14.0	40.8
E. *Pelvetia wrightii* (Harvey) Yendo[c,d]	3.0	12.5	54.3
F. *Costaria costata* (Turner) Sanders[b]	2.3	7.7	12.7

[a] From Aburatsubo Bay (May). [b] From Atsukeshi in Hokkaido (June). [c] From Fuyushima in Hokkaido (June). [d] K. Shirahama, *J. Agricul. Chem. Soc. Jap.*, **11**, 980 (1936); **12**, 521 (1937). [e] T. Kaneda and S. Ishii, *Bull. Jap. Soc. Scient. Fisheries*, **15**, 608 (1950); T. Kaneda, *ibid.*, **17**, 20 (1952).

The sterols obtained from B–F were identified as fucosterol, since upon Oppenauer oxidation they yielded fucostadienone[4] and upon ozonolysis they gave 24-ketocholesterol[5-7] and acetaldehyde.

Since the sterol from A yielded a stadienone (II) and a 24-keto-steryl acetate (VIII) which were not identical with the corresponding fucosterol derivatives (m.p. and α_D), it was named sargasterol (I) and its structure investigated.

Perbenzoic acid oxidation and bromination of sargasterol showed the presence of two double bonds; the differences in rotation between the sterol and its derivatives, and its oxidation to a conjugated ketone showed the presence of a 5,6-double bond. That the second double bond in sargasterol is located in the side chain between carbon atoms 24 and 28 was shown by the ozonolysis fragments. Sargasteryl acetate (Ib) was readily reduced with platinum oxide in ethyl acetate to 5,6-dihydrosteryl acetate (V)[8] and with palladium black in ethyl acetate to 24,28-dihydrosteryl acetate (VI). Both dihydrosteryl acetates (V and VI) were reduced to the same stanyl acetate (VII) in an acid medium with platinum oxide. Although this stanyl acetate (VII) seemed to be pure reduction gives rise to a new asymmetric center.

(1) Preceding paper, THIS JOURNAL, **78**, 4107 (1956).

(2) Takamine Research Laboratory, Sankyo Co., Ltd., Shinagawa, Tokyo, Japan.

(3) I. M. Heilbron, R. F. Phipers and H. R. Wright, *Nature*, **133**, 419 (1934); *J. Chem. Soc.*, 1572 (1934); D. H. Coffey, I. M. Heilbron, F. S. Spring and H. R. Wright, *J. Chem. Soc.*, 1205 (1935); I. M. Heilbron, E. G. Parry and R. F. Phipers, *Biochem. J.*, **29**, 1376 (1935); D. H. Coffey, I. M. Heilbron and F. S. Spring, *J. Chem. Soc.*, 738 (1936); P. W. Carter, I. M. Heilbron and B. Lythgoe, *Proc. Roy. Soc. (London)*, **B128**, 82 (1939).

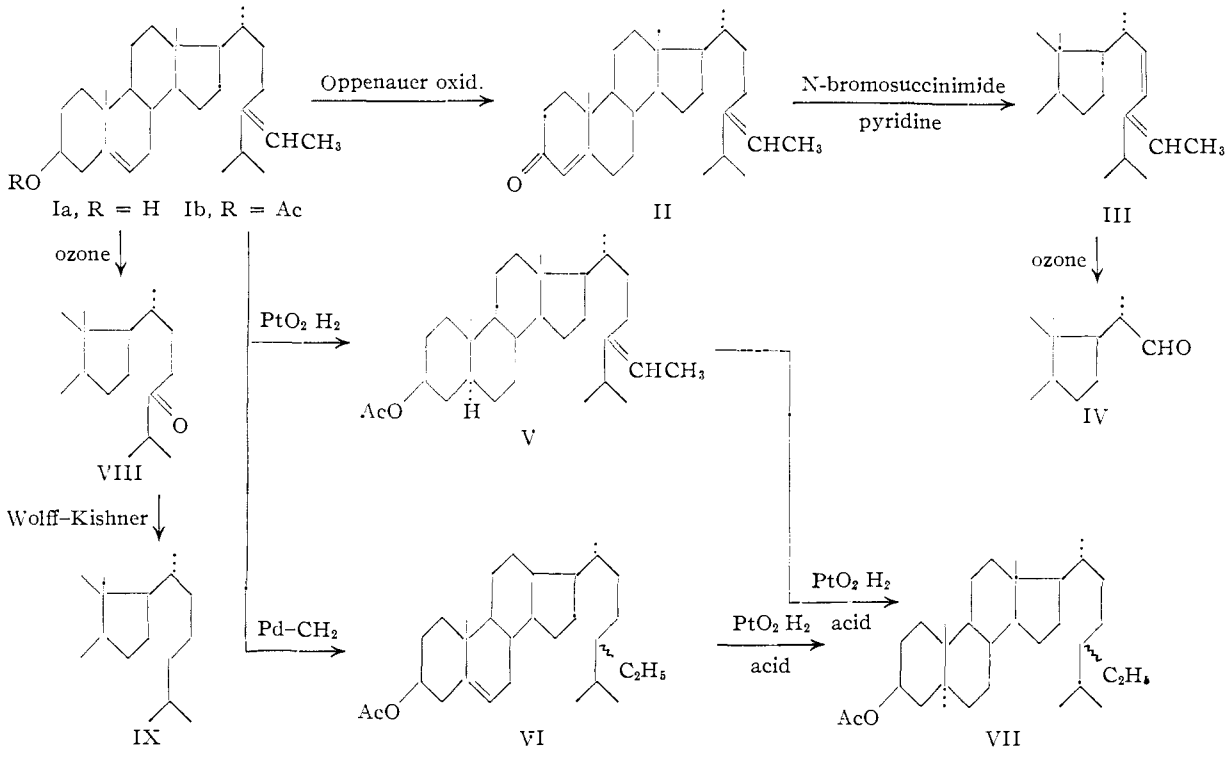
(4) E. R. H. Jones, P. A. Wilkinson and R. H. Kerlogue, *J. Chem. Soc.*, 391 (1942).

(5) H. B. MacPhillamy, THIS JOURNAL, **64**, 1732 (1942).

(6) B. Riegel and I. A. Kaye, *ibid.*, **66**, 723 (1944).

(7) D. H. Hey, J. Honeyman and W. J. Peal, *J. Chem. Soc.*, 2881 (1950).

(8) The referee suggested that the fact that the reduction of Ib with platinum attacks selectively the 5,6-double bond rather than the more reactive double bond of the side chain is an abnormal phenomenon. The observed Δ-value in going from Ib to the V is +154. This is in disagreement with the accepted value of about +300. However, the infrared spectrum of V has maxima (823 and 820 cm.$^{-1}$) corresponding to the $\Delta^{24(28)}$ (all the compounds of $\Delta^{24(28)}$-fuco and sarga series have one or two maxima in the region 824–819 cm.$^{-1}$) and has no absorption bands of Δ^5 (840 and 800 cm.$^{-1}$). The above problem is under study.



Wolff–Kishner reduction of the 24-ketosteryl acetate (VIII) gave an isomer of cholesterol (IX) ($C_{27}H_{46}O$, m.p. 155°, α_D −43.0°) which was considered to be C_{20}-isocholesterol. Unfortunately C_{20}-isocholesterol has not been reported in the literature and its synthesis in this Laboratory was not successful.[9]

Treatment of sargastadienone (II) with N-bromosuccinimide and subsequent dehydrobromination of the product yielded III which has a diene system in the side chain.

Ozonolysis of III gave an aldehyde IV ($C_{22}H_{32}O_2$, m.p. 139–140°, α_D +102.9°) which was identical in its physical constants and infrared absorption with 3-keto-Δ^4-20-iso-bisnorcholen-22-al, prepared from stigmastadienone.[10] Therefore, sargasterol can differ from fucosterol only in the configuration of the C_{20}-methyl.

Treatment of the stadienones of sargasterol and fucosterol (II and XVI, respectively) with a mixture of concentrated hydrochloric acid and acetic acid gave the 24-chlorides (X and XVII). Dehydrochlorination of 24-chlorosargastenone (X) with various reagents yielded three products in a variable yield. The structures of these products, $\Delta^{4,24(28)}$ (II), $\Delta^{4,23}$ (XI) and $\Delta^{4,24}$ (XII) were established by identification of the ozonolysis fragments: acetaldehyde, ethyl isopropyl ketone and acetone, respectively. Other 24-chlorides of the sargasterol and fucosterol[11] series were dehydrochlorinated in the same manner; see Table II, Experimental section.

The dienones XI and XVIII, which were prepared by the dehydrochlorination, respectively, of 24-chlorosargastenone and 24-chlorofucostenone, were converted to the same trienone (XIII) by the method of Meystre–Miescher[12]; ozonolysis of XIII gave progesterone. Pregnenolone and allopregnenolone were obtained from sargasteryl acetate and 5,6-dihydrosargasteryl acetate, respectively, by the procedure described above.

$\Delta^{5,23(24)}$-Fucostadienyl benzoate,[13] obtained by dehydrochlorination of 24-chlorofucosteryl benzoate, was isomerized to fucosteryl benzoate ($\Delta^{24(28)}$) with a platinum catalyst in ethyl acetate under nitrogen; the reverse reaction did not proceed.[14] From these results we conclude that sargasterol is probably C_{20}-isofucosterol.

Bergmann, *et al.*,[15] have reported that both haliclonasterol and palysterol are C_{20}-isosterols on the basis of molecular rotation data. The differences in molecular rotation between the C_{20}-iso series (sargasterol (M_D −195) and C_{20}-isocholesterol (M_D −168)) and the normal series (fucosterol (M_D −168) and cholesterol (M_D −151)) are −27 and −17, respectively. Although the values are somewhat different from those recorded,[16] the fact that differences are both negative lends support to our conclusion.

(9) Further study will be reported shortly.

(10) M. E. Herr and F. W. Heyl, THIS JOURNAL, **74**, 3627 (1952).

(11) D. H. Hey, J. Honeyman and W. J. Peal, *J. Chem. Soc.*, 4836 (1952).

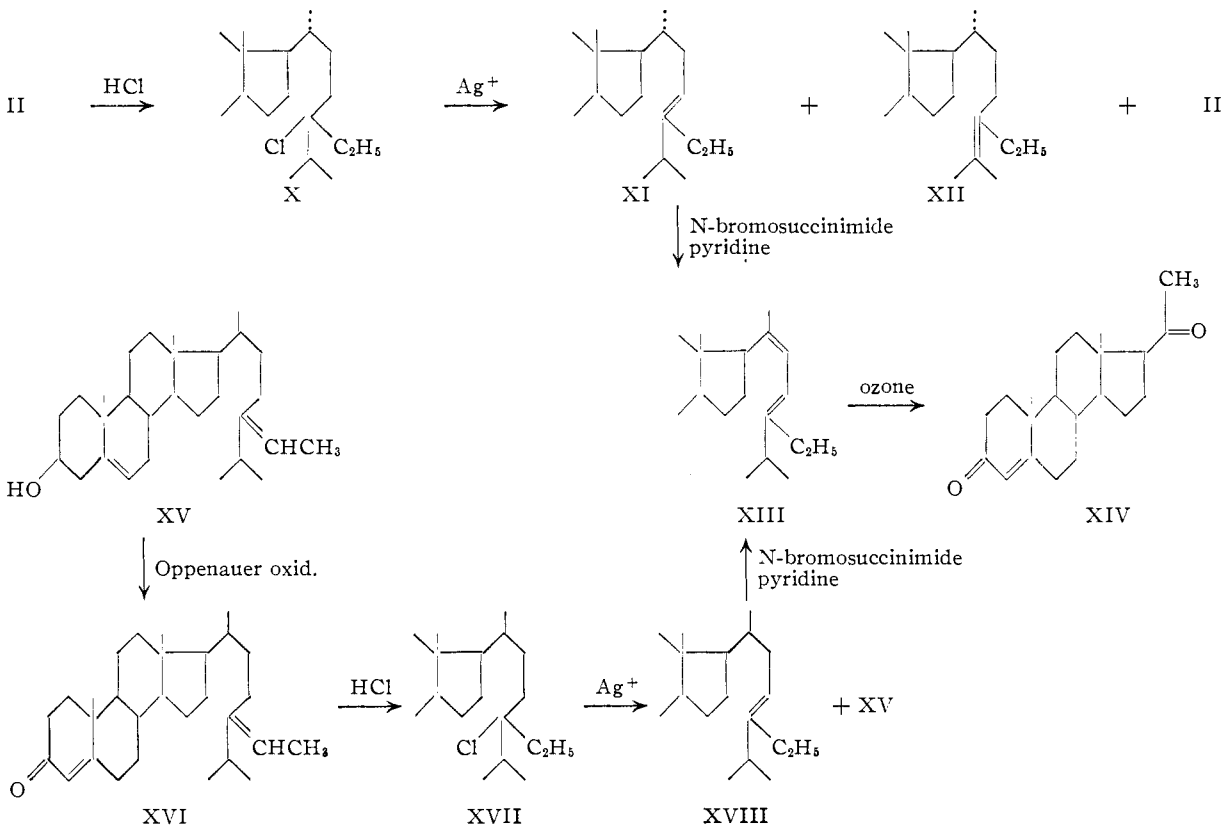
(12) C. Meystre, H. Frey, A. Wettstein and K. Miescher, *Helv. Chim. Acta*, **27**, 1815 (1944).

(13) The location of the side chain double bond of the $\Delta^{5,23}$-fucostadienyl benzoate could not be determined unequivocally by the ozonolysis. A maximum in the infrared spectrum of this compound is located at 827 cm.$^{-1}$ which differs from that of fucosteryl benzoate (823 cm.$^{-1}$). Δ^{24}-Compounds have no absorption maxima near 820 cm.$^{-1}$. See also Table II.

(14) H. Wieland, F. Rath and H. Hesse, *Ann.*, **548**, 34 (1941).

(15) W. Bergmann, R. J. Feeney and A. N. Swift, *J. Org. Chem.*, **16**, 1337 (1951).

(16) L. F. Fieser and Mary Fieser, "Natural Products Related to Phenanthrene," Reinhold Publ. Corp., New York, N. Y., 1949, p. 204.



Experimental[17]

Extraction of Crude Sterols.—Finely powdered dry algae was kept in ether for two weeks or extracted three times with boiling benzene for 3–4 hours with stirring. The oil obtained after evaporation of the solvent was saponified with methanolic alkali (3–4%), and the unsaponifiable material was extracted seven times with benzene. The solvent was evaporated and the unsaponifiable material dissolved in hot methanol under reflux. A crude sterol deposited from the methanol solution on cooling.

Purification of Sargasterol.—Crude sargasterol (50 g.) was heated with pyridine and acetic anhydride for 6 hours at 100°. The resulting acetate was purified by repeated recrystallization from ethyl acetate–alcohol and chromatography; yield 22.8 g., m.p. 130–132°. It was saponified with alcoholic potassium carbonate to give the sterol, which was recrystallized from alcohol; yield 17 g., m.p. 129–131°. Sargasteryl benzoate, obtained from the sterol in the usual way, was crystallized from ethyl acetate; yield 7.6 g., m.p. 114–115°, α_D −22.5° (*c* 1.4).

Anal. Calcd. for $C_{36}H_{52}O_2$: C, 83.72; H, 10.07. Found: C, 83.57; H, 10.10.

Pure sterol and acetate were obtained from the benzoate; sterol, m.p. 132–133.5°, α_D −47.5° (*c* 1.3).

Anal. Calcd. for $C_{29}H_{48}O$: C, 84.40; H, 11.72. Found: C, 84.19; H, 11.63.

Steryl acetate, m.p. 138–139°, α_D −52.9° (*c* 1.3).

Anal. Calcd. for $C_{31}H_{50}O_2$: C, 81.88; H, 11.08. Found: C, 82.20; H, 10.76.

The sterol (m.p. 129–131°) was also purified *via* the *p*-phenylazobenzoyl ester which was chromatographed[18,19] and then saponified. The sterols and their derivatives were obtained from the other algae in a similar manner.

Sterols, m.p.'s 120–126°, α_D −37.6 to −41.4° (*c* 1.1 to 1.4); steryl acetates, m.p.'s 118–122°, α_D −41.4 to −43.6° (*c* 1.0 to 1.4); steryl benzoates, m.p.'s 116–122°, α_D −19.7 to −20.9° (*c* 1.0 to 1.3).

Stadienones.—A mixture of 5 g. of sargasterol, 30 ml. of freshly distilled cyclohexanone and 150 ml. of dry toluene was distilled until the moisture had been azeotropically removed. A solution of 4 g. of aluminum isopropoxide in 50 ml. of dry toluene was added, and the mixture was refluxed for 1 hour and then cooled. About 40 ml. of a saturated aqueous solution of Rochelle salt was added and the volatile solvents were removed by steam distillation under reduced pressure. The oily residue was crystallized from acetone–methanol and chromatographed. Elution with benzene yielded a residue, which was crystallized from methyl alcohol–acetone as colorless needles of sargastadienone (II); yield 4.2 g., m.p. 109–111.5°, α_D +84.7° (*c* 1.3); λ_{max}^{alc} 240 mμ (ε 16,700), ν_{max} 1692 and 1625 cm.$^{-1}$ in Nujol.

Anal. Calcd. for $C_{29}H_{46}O$: C, 84.81; H, 11.29. Found: C, 84.67; H, 11.07.

The 2,4-dinitrophenylhydrazone of sargastadienone (II) melted at 208–210°, $\lambda_{max}^{CHCl_3}$ 391 mμ.

Anal. Calcd. for $C_{35}H_{50}O_4N_4$: N, 9.48. Found: N, 9.51.

Fucostadienone[4] was obtained from the other sterols in the same way; m.p. 95–96.5°, α_D +74.4 to +78.5° (*c* 1.1 to 1.3); ν_{max} 1680 and 1623 cm.$^{-1}$ in Nujol.

Ozonolysis of Sargasteryl Acetate (Ib). A. Acetaldehyde 2,4-Dinitrophenylhydrazone.—Compound Ib (1.5 g.), suspended in 70 ml. of glacial acetic acid, was ozonized for 50 minutes. The reaction mixture was diluted with water to 150 ml. and distilled. The 2,4-dinitrophenylhydrazone, prepared from the first 40 ml. of the distillate, was identified as that of acetaldehyde by mixed m.p. and infrared spectrum.

B. 20-Iso-24-ketocholesteryl Acetate (VIII).—The clear solution, resulting from the ozonolysis of 1.5 g. of Ib, was treated with 1.7 g. of zinc powder at room temperature. Water was added and the reaction mixture was extracted several times with ether. The extract was washed with aqueous alkali, dried and the solvent removed. The residue was chromatographed, crystallized from methyl alcohol and

(17) All melting points were corrected and the optical rotations were measured in chloroform at 25°. Alumina columns were used for chromatography; PEB, a 1:1 mixture of petroleum ether (b.p. 40–60°) and benzene was used as the solvent and developer. Exceptions are indicated in the text.

(18) The column contained Celite and silicic acid (1:1). The latter was the analytical grade specially prepared for chromatography by the method of Ramsey and Patterson, Mallinckrodt Chemical Works.

(19) D. R. Idler, W. W. Nicksic, D. R. Johnson, V. W. Meloche, H. A. Schuette and C. A. Baumann, THIS JOURNAL, **75**, 1712 (1953).

chromatographed again; m.p. 115–117°, yield 300 mg., α_D −25.0° (*c* 1.0), ν_{max} 1734 and 1617 cm.$^{-1}$ (in Nujol).

Anal. Calcd. for $C_{29}H_{46}O_3$: C, 78.68; H, 10.47. Found: C, 78.39; H, 10.40.

24-Ketocholesteryl acetate[5-7] was prepared in the same way from the other steryl acetates (B–F). The ketone from B melted at 129°, α_D −41.0° (*c* 1.0). Mixtures of these ketones showed no depression of the melting point with the exception of a mixture containing the ketone derived from A.

The 2,4-dinitrophenylhydrazones of the ketones prepared from B–F melted at 170–171°; that from A at 215–218°.

Anal. Calcd. for $C_{35}H_{50}N_4O_6$ (A): N, 9.00. Found: N, 9.27.

Wolff-Kishner Reduction of Ketones.—A mixture of 1.0 g. of the ketone VIII, 1.7 g. of sodium metal, 80 ml. of absolute alcohol and 5 ml. of 85% hydrazine hydrate was heated in a sealed tube at 200° for 14 hours. The reaction mixture was poured into 10% acetic acid and extracted with ether. The ethereal extract was washed with aqueous sodium carbonate and with water, dried and the ether removed. The residue, which was purified by chromatography, crystallization from alcohol and repeated recrystallization from hexane, yielded an isomer of cholesterol; yield 270 mg., m.p. 154–155°, α_D −43.0° (*c* 0.9).

Anal. Calcd. for $C_{27}H_{46}O$: C, 83.87; H, 11.99. Found: C, 84.13; H, 11.72.

The acetate of this sterol was recrystallized from alcohol; m.p. 123–124°, α_D −47.9° (*c* 1.3).

Anal. Calcd. for $C_{29}H_{48}O_2$: C, 81.37; H, 11.21. Found: C, 81.00; H, 11.50.

The benzoate melted at 164–165°; α_D −19.2° (*c* 1.4).

24-Ketocholesteryl acetate from *Fucus* (D), upon reduction as described above, yielded cholesterol; m.p. and mixed m.p. with an authentic sample 147–148°.

Perbenzoic Acid Titration.—In 48 hours, 320 mg. of sargasterol absorbed the equivalent of 2.62 mg. of oxygen, corresponding to 2.11 double bonds.

Bromine Titration.—Sargasterol (1 g.) in dry chloroform was treated with a solution of bromine in chloroform at 0° until a permanent color was obtained. The tetrabromide thus produced melted at 118°.

Anal. Calcd. for $C_{29}H_{48}OBr_4$: Br, 43.71. Found: Br, 43.18.

Hydrogenation of Sargasteryl Acetate (Ib).—(A) When solution of 10 g. of Ib in 300 ml. of ethyl acetate was shaken with 200 mg. of platinum oxide and hydrogen, one mole of hydrogen was absorbed in 1.5 hours. After filtration, the solvent was removed under reduced pressure to give a colorless solid which soon crystallized. Three recrystallizations from ethyl acetate–alcohol gave colorless needles of 5,6-dihydrosargasteryl acetate (V), m.p. 128–129°, α_D −18.7° (*c* 2.6), yield 7.7 g.; 5,6-dihydrosargasterol, m.p. 138–139°, α_D −13.0 (*c* 2.3).

Anal. Calcd. for $C_{31}H_{52}O_2$: C, 81.52; H, 11.48. Found: C, 81.40; H, 11.20.

(B) Compound Ib (12 g.) in 300 ml. of ethyl acetate was hydrogenated with a palladium black catalyst. The reaction mixture, treated essentially as described above, yielded 24,28-dihydrosargasteryl acetate (VI), m.p. 141–143°, α_D −48.0° (*c* 1.3), yield 4.2 g.; 24,28-dihydrosargasterol, m.p. 138–139°, α_D −44.6° (*c* 1.4).

Anal. Calcd. for $C_{31}H_{52}O_2$: C, 81.52; H, 11.48. Found: C, 81.16; H, 11.19.

Hydrogenation of V and VI in Acidic Medium.—When solution of 3 g. of V in 90 ml. of ethyl acetate–glacial acetic acid (1:1) was shaken with platinum oxide under hydrogen, 1.2 moles of hydrogen was absorbed in 3 hours. Five recrystallizations from ethyl acetate–alcohol gave colorless plates of sargastanyl acetate (VII), m.p. 122–124°, α_D +2.0° (*c* 1.40).

Anal. Calcd. for $C_{31}H_{54}O_2$: C, 81.16; H, 11.87. Found: C, 80.88; H, 11.62.

VI was also hydrogenated by the above procedure to yield VII, m.p. 123–124.5°, which gave no depression in m.p. on admixture with VII prepared from V. The stanol, obtained by saponification of VII, melted at 131–132°, α_D +6.5° (*c* 2.32).

Anal. Calcd. for $C_{29}H_{52}O$: C, 83.58; H, 12.58. Found: C, 83.16; H, 12.49.

$\Delta^{4,22,24,(28)}$-Sargastatrien-3-one (III) from II.—To a solution of 5.8 g. of II in 50 ml. of carbon tetrachloride was added 2.8 g. of N-bromosuccinimide; the mixture was irradiated with a 375 watt infrared lamp and refluxed with exclusion of moisture for 15 minutes. After filtration, the solvent was removed under reduced pressure below 40°, to yield a reddish-brown oily residue (6.1 g.) which was dissolved in 22 ml. of diethylaniline and refluxed for 25 minutes. The cooled mixture was poured into cold dilute hydrochloric acid and extracted with ether. The ether layer was washed consecutively with 10% hydrochloric acid and water, dried, and the solvent was removed under reduced pressure. The residue was adsorbed on an alumina column which was developed with PEB (1:3). Further development with benzene afforded an oil which upon repeated crystallization from acetone–alcohol yielded III; yield 1.3 g., m.p. 106–107°, λ_{max}^{alc} 236–239 mμ (ε 16,800).

Anal. Calcd. for $C_{29}H_{44}O$: C, 85.23; H, 10.85. Found: C, 85.80; H, 10.48.

Ozonolysis of III.—A cold solution of 1.2 g. of III in 50 ml. of chloroform and 1 ml. of pyridine was ozonized for 30 minutes. The 4 g. of zinc dust and 30 ml. of glacial acetic acid were added with stirring which was continued for 1.5 hours at 10–15°. The zinc dust was removed and the solvent was reduced under diminished pressure below 30°. The acetic acid solution was poured into water and extracted with ether. After removal of an acid fraction with aqueous potassium carbonate (3%), evaporation of the extract gave a colorless oil which was crystallized from isopropyl alcohol. Repeated recrystallization from petroleum ether gave 3-keto-Δ^4-20-isobisnorcholen-22-al (IV); yield 0.25 g., m.p. 137.5–139°, α_D +102° (*c* 1.4). It was identical with an authentic sample described by Herr, *et al.*[9]

Anal. Calcd. for $C_{22}H_{32}O_2$: C, 80.44; H, 9.83. Found: C, 80.12; H, 9.57.

Preparation of 24-Chloro Derivatives.—The following procedure is typical. A solution of sargasteryl acetate (7 g.) in acetic acid (700 ml.) containing concentrated hydrochloric acid (30 ml.) was kept overnight at room temperature. The reaction mixture was poured into water and extracted with ether. Evaporation of the washed and dried extract yielded a residue which after repeated recrystallization from methanol gave 24-chlorosargasteryl acetate as colorless microcrystals, m.p. 103.5–105°.

Anal. Calcd. for $C_{31}H_{51}O_2Cl$: C, 75.84; H, 10.39; Cl, 7.1. Found: C, 75.48; H, 10.27; Cl, 6.73.

5,6-Dihydrosargasteryl acetate (V) yielded 24-chloro-5,6-dihydrosargasteryl acetate, m.p. 117–119°.

Anal. Calcd. for $C_{31}H_{53}O_2Cl$: C, 75.53; H, 10.76; Cl, 7.20. Found: C, 75.26; H, 10.69; Cl, 7.00.

Sargastadienone (II) gave 24-chlorosargastenone (X), m.p. 104–108°.

Anal. Calcd. for $C_{29}H_{47}OCl$: C, 77.93; H, 10.52; Cl, 7.95. Found: C, 77.98; H, 10.30; Cl, 7.49.

Fucosteryl acetate yielded 24-chlorofucosteryl acetate, m.p. 116.5–118°.

Anal. Calcd. for $C_{31}H_{51}O_2Cl$: C, 75.84; H, 10.39; Cl, 7.1. Found: C, 75.51, H, 10.69; Cl, 6.70.

Fucosteryl benzoate gave 24-chlorofucosteryl benzoate, m.p. 144–145°.

Anal. Calcd. for $C_{36}H_{53}O_2Cl$: C, 78.19; H, 9.59; Cl, 6.44. Found: C, 78.58; H, 9.90; Cl, 6.80.

Fucostadienone (XVI) gave 24-chlorofucostenone (XVII); white powder, m.p. 80–92°.

Anal. Calcd. for $C_{29}H_{47}OCl$: C, 77.93; H, 10.52; Cl, 7.95. Found: C, 78.24; H, 10.80; Cl, 7.01.

Dehydrochlorination of the 24-Chlorides.—(A) To a solution of 5 g. of X in 80 ml. of ligroin–benzene (5:1) was added 3.5 g. of silver *p*-toluenesulfonate and the mixture was heated on a steam-bath for 3 hours. After filtration, the solvent was removed *in vacuo* and the residue chromatographed; the eluate was collected in 40-ml. portions. The oily residue from fractions 3–5 was crystallized from acetone–methanol as colorless needles of XI, m.p. 121–122.5°, λ_{max}^{alc} 241 mμ (ε 17,000).

Anal. Calcd. for $C_{29}H_{46}O$: C, 84.81; H, 11.29. Found: C, 84.76; H, 11.40.

Fractions 7–9 afforded a colorless oil which was crystallized three times from acetone–methanol. This product (m.p. 109–110°) was identified as II by mixed melting point and infrared spectrum. Evaporation of the mother liquor gave crystals of XII which were recrystallized from alcohol; m.p. 139–140°.

Anal. Calcd. for $C_{29}H_{46}O$: C, 84.81; H, 11.29. Found: C, 84.44; H, 11.08.

(B) A solution of 2 g. of X in 30 ml. of pyridine (or diethylaniline) was refluxed for 30 minutes. The cooled solution was poured into water and extracted with ether. The ethereal solution was washed, dried, and evaporated. Recrystallization of the residue gave sargastadienone (II), m.p. 109–110°.

(C) A solution of 2 g. of X in 25 ml. of acetic anhydride was refluxed for 12 hours, the cooled solution was poured into ice-water and extracted with ether. The extract was washed with 5% alkali solution and then with water, and dried. Removal of the solvent under reduced pressure gave a brownish oily residue, which was chromatographed; the eluate was collected in 40-ml. portions. Fractions 4–5 gave colorless needles of XI, m.p. 121–122°, yield 260 mg.; II (m.p. 110–111.5°) was obtained from fractions 7–9.

These methods were used for the dehydrochlorination of the other 24-chloro compounds; the results are summarized in Table II.

TABLE II

DEHYDROCHLORINATION OF 24-CHLORO DERIVATIVES

24-Chloro compound	Yield, %, from method A $\Delta^{24(28)}$	A Δ^{23}	A Δ^{24}	B Δ^{24}	B $\Delta^{24(28)}$	B Δ^{23}	C Δ^{24}	C $\Delta^{24(28)}$	C Δ^{23}	C Δ^{24}
-5,6-Dihydrosargasteryl acetate	20	60[a]	0	50		30[a]	0	40	20[a]	0
-Sargasteryl acetate	25	60[b]	5[c]	50		24[b]	0	45	20[b]	0
-Sargastenone (X)	8	64	4	40		?	0	15	4	0
-Fucosteryl benzoate	10	70[d]	0	65		11[d]	0	40	7[d]	0
-Fucosteryl acetate	?	?	?	55		7[e]	0	..	..	..
-Fucostenone (XVII)	15	60[f]	..	..		..	..	..	..	..

[a] M.p. 136–138°, α_D −12.0° (*c* 1.3). [b] M.p. 112–114°, α_D −45.3° (*c* 2.3). [c] M.p. 102–103°, α_D −40.5° (*c* 1.1). [d] M.p. 128–130°, α_D −10.6° (*c* 1.4). [e] M.p. 101–109° (amorphous solid). [f] M.p. 110–111.5°, α_D +86.3° (*c* 2.3).

Ozonolysis of Δ^{23}- and Δ^{24}-Steroids.—Compound XI (Δ^{23}) in acetic acid was ozonized for 20 minutes at 8–10°. The reaction mixture was treated with water and distilled. Ethyl isopropyl ketone was isolated from the distillate as the *p*-nitrophenylhydrazone; m.p. and mixed m.p. 89–90.5°. Under the conditions described above, XII (Δ^{24}) gave acetone which was identified as the 2,4-dinitrophenylhydrazone, m.p. 124.5–126°. The other Δ^{23}- and Δ^{24}-compounds were also identified in this way.

Isomerization of $\Delta^{5,23}$-Fucostadienyl Benzoate.—A solution of 1 g. of the dienyl benzoate dissolved in 35 ml. of ethyl acetate was shaken with platinum (made from platinum oxide and hydrogen) under nitrogen for 7 hours. After filtration, the solution was distilled under reduced pressure to give a white solid, which was crystallized from ethyl acetate; m.p. 114–115°, yield 680 mg. The infrared spectrum and mixed melting point showed this sample to be identical with fucosteryl benzoate.

$\Delta^{4,20,(22),23}$-Fucostatrien-3-one (XIII) from XI.—Compound XI (3 g.) was treated with N-bromosuccinimide and the product worked up in essentially the manner described for the conversion of II to III. Microcrystals of XIII were obtained; m.p. 96–97°, yield 1.7 g., λ_{max}^{alc} 241–243 mμ (ε 17,900).

Anal. Calcd. for $C_{29}H_{44}O$: C, 85.23; H, 10.85. Found: C, 85.60; H, 10.69.

The 2,4-dinitrophenylhydrazone of XIII melted at 205° dec.

Progesterone (XIV) by Ozonolysis of XIII.—Compound XIII (1 g.) was treated as described for the ozonolysis of III. The yellow residue, resulting from distillation of the solvent, was crystallized repeatedly from methanol to give progesterone (m.p. 127.5–128.5°, yield 590 mg.) which was identified by a mixed melting point determination.

$\Delta^{4,23}$-Fucostadien-3-one (XVIII) and $\Delta^{4,20,(22),23}$-Fucostatrien-3-one (XIII) from XVII.—Compounds XVIII and XIII were prepared by the method described for the sargasterol derivatives, XI and XIII; XIII (m.p. 96.5–98°) showed no depression in m.p. on admixture with an authentic specimen; XVIII, m.p. 110–111.5°, yield 60%.

Anal. Calcd. for $C_{29}H_{46}O$: C, 84.81; H, 11.29. Found: C, 84.87; H, 11.46.

Acknowledgment.—The authors wish to thank Prof. Y. Yamada and Dr. Y. Nakamura of Hokkaido University for their suggestion concerning the collection and identification of the algae. The authors are also indebted to Prof. T. Uchida, Dr. M. Yamada and Mr. K. Hamano of Hokkaido University, Prof. I. Tomiyama and Mr. G. Deguchi of Tokyo University, and Drs. H. Higashi, S. Sudo and T. Kaneda of the Tokai Fishery Research Institute for their kind help in collecting the algae. A sample of fucosterol was supplied by Dr. J. Honeyman of King's College, University of London. The microanalyses were made by Miss C. Furukawa and Miss H. Otsuka.

HONGO, BUNKYO-KU, TOKYO, JAPAN