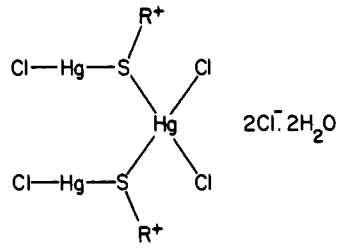
Finally the ν(CO) frequency in **2** (1672 cm^{-1}) is intermediate between values in free carboxylic acids and carboxylate anions.

Our structural and synthetic results for **1** and **2** allow a reassessment of previous literature data on Hg^{+2}-L-cysteine complexation. Under neutral or slightly acid conditions the most stable complex is **2.** Since the chloride in **2** is ionic, it is likely that structurally similar compounds with different anions would be obtainable from other Hg^{+2} salts. Complex **2** appears to be identical with a compound obtained via different routes by Neville and Drakenberg.[15] Moreover, facile removal of HCl from **2** without change in mercury coordination would seem possible to generate $Hg[SCH_2CH(NH_3)COO]_2$, which is the usual formula assumed for "mercury cysteinate".[1]

The observation of strong sulfur bridging in **1** and ionic halide in **2** provides a ready explanation for the existence of mercury complexes with the unusual stoichiometries Hg_2L_2·, Hg_3L_2·, Hg_2L_2HCl·, $Hg_3L_2Cl_2$·, and $Hg_3L_2Cl_6{\cdot}2H_2O$[16] which have been suggested either in solution[17] or the solid state.[18] Thus a likely formulation for $Hg_3L_2Cl_6{\cdot}2H_2O$ is **3** with two



3

sulfur bridges, a tetrahedral mercury atom as in **1,** two two-coordinate mercury atoms, chloride ion, and water of crystallization as in **2.** A single bridging sulfur ligand, one terminal sulfur bonded amino acid, and two bicoordinate mercury atoms can likewise be expected for Hg_2L_2HCl. We also note that the much higher affinity of thioneine for Hg^{2+} than $MeHg^{+4}$ may be explicable on the basis that at least two sulfur sites are available for strong binding to the same metal ion in thioneine (cf. **1** and **2**). Methylmercury appears to have only a very weak residual Lewis acidity when coordinated linearly to one sulfhydryl site.[19] The polarity of complexes such as **2** contrasts sharply with the essentially nonpolar $MeHg^{+}$-L-cysteine complex,[19] a fact of obvious relevance to membrane permeabilities and biotransport mechanisms.[4] Furthermore, the association of chloride ion with the polar bis(amino acid)mercury unit in **2** and the coordination of chloride to mercury in **1** may explain the significantly different distributions[20] of inorganic and methylmercury between red blood cells and plasma in whole blood. The high Cl^- concentrations in plasma suggest a role for this ion in the distribution of Hg^{2+} in the body.

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(9) All intensity data were collected on a General Electric XRD-6 Datex automated diffractometer operating at 298K in the θ–2θ scan mode with a scan rate of 2° min^{-1} for 1 and 1° min^{-1} for **2** and with a scan width determined by the equation $\Delta\theta = \pm(0.9 \pm 0.43 \tan\theta)$.
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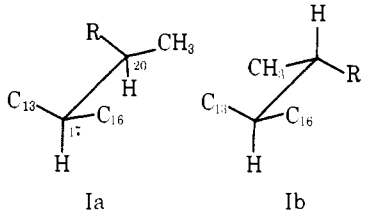
Further Arguments on the Stereochemistry of Sterols at C-20

Sir:

A number of recent communications concern C-20 conformation in sterols.[1-5] Nes[1-3] suggests a solution to this important problem based on (1) comparison of chemical shift differences for cholesterol and isocholesterol with those for analogous stereoisomeric $\Delta^{17(20)}$ olefins, (2) assumption of similar stereochemistry in the saturated and unsaturated analogues, and (3) conclusions regarding the ground-state populations of rapidly equilibrating conformers based on the stereochemistry of products derived from them. We wish to present evidence that (1) the olefin is not a valid model for NMR analysis of the saturated system, (2) the C-17–C-20 rotational barrier may be quite small and there still be the observed NMR differences, and (3) arguments on ground-stage populations of conformers such as those presented are thermodynamically unsound.

Nes[1] has concluded from molecular models that cholesterol, which has the 20*R* configuration, should be most stable in either conformation Ia or Ib, with Ib preferable. The reasons for



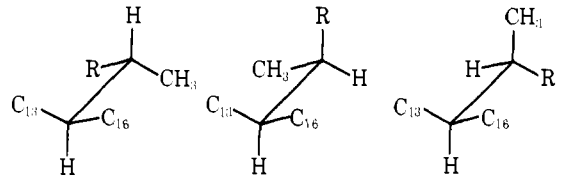
Ia Ib

R = isohexyl

seriously considering Ia are somewhat puzzling since it is eclipsed and has maximized hindrance between the largest substituents. Conformation Ib would, indeed, appear to be the best of the staggered rotamers.

In the case of 20-isocholesterol (20*S*), it is less clear-cut

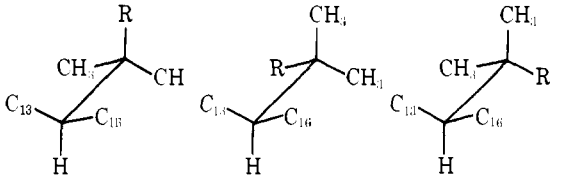
which staggered conformation, IIa, IIb, or IIc, is most stable. Thus, although IIa places the 20-H skew to the two largest



IIa IIb IIc

R = isohexyl

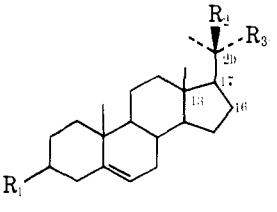
groups on CH17, it also introduces a skew interaction between isohexyl and quaternary C-13, not present in IIc. Nes,[1] nevertheless, concludes that IIa is predominant and cites as evidence the ^{1}H NMR doublet due to 21-methyl which is at δ 0.91 ppm (from Me_4Si) in cholesterol but at 0.81 in 20-isocholesterol. Analogy is drawn between the 0.10-ppm upfield shift observed in these two epimers and the similar upfield shift for the *E* and *Z* isomers of $\Delta^{17(20)}$ olefins. It is argued that, when 21-methyl is toward C-13, its ^{1}H NMR is downfield from that in isomers in which it is toward C-16. The fallacy in using the olefin as a model can be seen from the ^{1}H NMR data on 20-methylcholesteryl systems. With two methyls now on C-20, conformational analysis of the system becomes unambiguous; IIIc, which places the sterically most demanding isohexyl



IIIa IIIb IIIc

R = isohexyl

group on C-20 skew to the two smallest groups on C-17, is clearly favored. It follows that the 21- and 28-methyls must be oriented as shown in IIIc, and yet they show singlets at 0.91–0.95 and 0.83–0.86 ppm! The ~0.10-ppm difference is thus not due to a conformational similarity to (*Z*)- and (*E*)-17(20)-dehydrocholesterol, but rather to the different magnetic environments each methyl is in owing to the adjacent chiral C-17. Even though isohexyl is larger than methyl, the barrier to rotation may be insufficient to freeze conformation. Indeed, it is found that, when the C-17 side chain is replaced by *tert*-butyl, it shows only a single sharp peak which broadens on cooling but gives no indication of splitting or even a shoulder down to −110 °C so that the barrier to rotation must be quite small. The *tert*-butyl compound, IVd, was synthesized by



	R_1	R_2	R_3	
IVa	OTHP	H	CHO	
IVb	OTHP	Me	CHO	mixture
	OTHP	CHO	Me	
IVc	OTHP	Me	Me	
IVd	OH	Me	Me	

potassium *tert*-butoxide catalyzed methylation of aldehyde IVa[6] with excess methyl iodide in *tert*-butyl alcohol–tetrahydrofuran to give IVb, mp 158–160 °C, which was reduced by Huang-Minlon modification of Wolff–Kishner reduction to give IVc, mp 163–165 °C, which on acid hydrolysis (HCl in THF) gave in 28% overall yield IVd, mp 174–176 °C, NMR δ 0.95 (s, 9, *tert*-butyl). Satisfactory elemental and spectral analyses of all new compounds were obtained.

The single resonance for *tert*-butyl in IVd shows that even a quaternary carbon at C-20 does not necessarily lead to conformational freezing of the C-17–C-20 bond. In support of his arguments for conformational freezing, Nes[2] cited Kohen's report[7] that there is sufficient barrier to rotation about C-17–C-20 to give rise to optical isomers in a molecule in which C-20 bears two methyls. However, full x-ray analysis[4] of Kohen's alleged C-20 epimeric pair shows them to be skeletal isomers.

A final word should be said about the dangers inherent in drawing conclusions about the population of ground-state conformers from the ratio of products which appear to be specifically derived from the different rotamers. As was pointed out by Hammett[8] long ago, the ratio of such products is independent of the equilibrium constant among ground-state conformers if conformational equilibration is rapid compared to the rate of reaction of the conformers. Thus, it is not valid to conclude that "approximately equal amounts of two conformers should exist at equilibrium which in turn would lead to approximately equal amounts of the *Z* and *E* products" as has been suggested for C-20 carbocations deprotonating to $\Delta^{17(20)}$-dehydrocholesterol.[3] Nor is it valid to conclude that the formation of both cholesterol and 20-isocholesterol by reduction of the $\Delta^{20(22)}$ double bond demonstrates the presence of two rotational isomers about C-17–C-20.[1]

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Synthesis and Characterization of the Dimolybdate Ion, $Mo_2O_7^{2-}$

Sir:

Although the dichromate ion, $Cr_2O_7^{2-}$, is a well-characterized species,[1] its molybdenum analogue has never been reported. Dichromate is formed as the predominent product upon stoichiometric acidification of aqueous CrO_4^{2-}, but acidification of aqueous M_2MoO_4 (M = Na, K, NH_4) at 25 °C fails to generate measurable concentrations of dimolybdate.[2] Instead, the heptamolybdate ion, $Mo_7O_{24}^{6-}$, is produced (eq I). Compounds $M_2Mo_2O_7$ (M = K, Na, NH_4, and Ag) have been isolated from aqueous solution and anhydrous melts, but their structures are polymeric and do not contain discrete $Mo_2O_7^{2-}$ ions.[3] We report here the synthesis and structure of the dimolybdate ion as a tetrabutylammonium salt, and demonstrate that its stability relative to $Mo_7O_{24}^{6-}$ and MoO_4^{2-} (see eq 1) is determined by counterion interactions.