These experiments allow revision of the C_{13} and C_{12} acid structures derived from magnamycin to VIII and IX and thus postulation of the magnamycin structure as II. The expected magnamycinaldehyde proton triplet could not be observed, even with variations in solvent polarity, using deuterated benzene, chloroform, or dimethyl sulfoxide as solvents and a temperature range of -30 to $80°$.[16] However, conversion of tetrahydromagnamycin to an oxime showed the elusive splitting as the expected triplet at δ 6.8, $J = 5$ c.p.s.

A nuclear magnetic resonance spectrum of the spiramycins at 100 Mc. showed a separation of 16 c.p.s. for the two aldehyde signals, clearly ruling out a spin–spin splitting doublet. Direct evidence for two stereoisomeric aldehyde functions attached to an epimerizable center was found in the change of a 31:69% to 34:66% ratio of signals of a sample dissolved in acetic acid and then treated with sodium bicarbonate.

Acknowledgment. We wish to thank Dr. Emil Schlittler and Dr. W. I. Taylor, Ciba, Summit, N. J., for a gift of the spiramycins and valuable discussions, Dr. Hans Grisebach, University of Freiburg, for a procedure for the oxidation of carimbose, Dr. Klaus Biemann, Massachusetts Institute of Technology, for spectral data, and Mr. Grant Warner of our group for nuclear magnetic resonance spectra and Dr. Ross Pitcher of Varian Associates for a 100-Mc. spectrum.

(16) G. J. Karabatsos and N. Hsi, *J. Am. Chem. Soc.*, **87**, 2864 (1965).
(17) Alfred P. Sloan Foundation Fellow.
(18) National Defense Education Act Predoctoral Fellow.

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The Structure of Magnamycin

Sir:

Extensive degradative studies led us to propose structure I for the macrolide antibiotic magnamycin *a* in 1957.[1,2] We now wish to record new observations which require that the magnamycin structure be revised to II.[3]

Our previous deductions about the C-1–C-11 system of magnamycin were based in large part upon the degradation of the macrolide, through oxidation, followed by vigorous base treatment, to an $\alpha,\beta,\gamma,\delta$-doubly unsaturated γ-methoxy acid $C_{13}H_{18}O_7$, which was readily hydrolyzed to the corresponding α,β-unsaturated γ-keto acid $C_{12}H_{16}O_7$. Either acid was further oxidized to an *optically active* acid $C_8H_{12}O_6$, m.p. 99–100°, whose
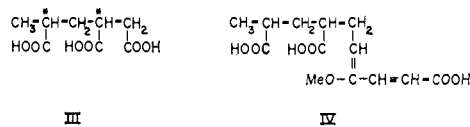
(1) R. B. Woodward, *Angew. Chem.*, **69**, 50 (1957); *Festschr. Arthur Stoll*, 524 (1957).
(2) In the interim the stereochemistry of the sugar components, mycarose and mycaminose, has been completely elucidated. Mycarose: D. M. Lemal, P. D. Pacht, and R. B. Woodward, *Tetrahedron*, **18**, 1275 (1962); F. Korte, U. Claussen, and K. Göhrring, *ibid.*, **18**, 1257 (1962); W. Hofheinz, H. Grisebach, and H. Friebolin, *ibid.*, **18**, 1265 (1962); H. Grisebach, W. Hofheinz, and N. Doerr, *Chem. Ber.*, **96**, 1823 (1963). Mycaminose: A. B. Foster, T. D. Inch, J. Lehmann, M. Stacey, and J. M. Webber, *J. Chem. Soc.*, 2116 (1962); A. C. Richardson, *ibid.*, 2758 (1962); W. Hofheinz and H. Grisebach, *Z. Naturforsch.*, **17b**, 355 (1962).
(3) Professor Martin Kuehne [Vermont] has kindly informed us privately that he has reached a similar conclusion, and concurrent publication has been arranged [M. E. Kuehne and B. W. Benson, *J. Am. Chem. Soc.*, **87**, 4660 (1965)].
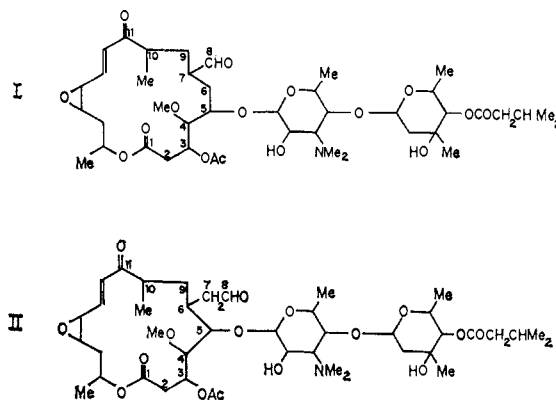

trimethyl ester was converted by sodium methoxide to a mixture of diastereomers, from which, after hydrolysis, there was obtained a *racemic* acid $C_8H_{12}O_6$, m.p. 154–155°, identical with a sample of 2-methyl-4-carboxyadipic acid (III) prepared by synthesis. Con-

version of the $-COCH{=}CHCOOH$ chain of the C_{12} acid to $-CH_2CH_3$ led to a dibasic acid which gave an anhydride (*not* a succinic anhydride) *rather than a cyclopentanone* on treatment with acetic anhydride under pyrolytic conditions; consequently, the C_{13} acid was formulated as IV, and the C_{12} acid as the corresponding ketone.

We were led to re-examine these results when Srinivasan and Gilner[4] reported that, while the trimethyl ester of a synthetic 2-methyl-4-carboxyadipic acid (III) was readily cyclized by sodium in refluxing benzene to the cyclic β-keto ester (V), the ester of the C_8 acid from
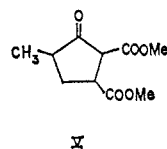

magnamycin was unchanged under the same conditions. Since these observations brought the structural assignment of the C_8 acid from natural sources into question, we have repeated the degradation and subjected the resulting racemic acid to renewed rigorous scrutiny, in comparison with new samples of synthetic material prepared by our earlier method[1] and by an alternative synthesis[5]; melting points, mixture melting points, and detailed infrared and mass spectrometric studies, buttressed by nuclear magnetic resonance, infrared, mass spectrometric, and vapor chromatographic studies on the corresponding esters, leave no doubt whatsoever that the materials from all three sources are identical and that the racemic acid $C_8H_{12}O_6$ from magnamycin is one of the diastereomers of structure III. On the other hand, we have confirmed the observation

(4) D. Gilner, Ph.D. Dissertation, Columbia University, New York, N. Y., 1963; private communication from Dr. P. R. Srinivasan.
(5) E. Hope and W. H. Perkin, Jr., *J. Chem. Soc.*, **99**, 776 (1911).

that the ester of the optically active acid from degradation does *not* undergo Dieckmann cyclization under conditions which bring about ready conversion of the racemic ester to V. This striking contrast can only be rationalized on the basis that the optically active $C_8H_{12}O_6$ acid initially obtained by degradation is diastereomeric with that resulting from subsequent base-catalyzed equilibration of the corresponding ester, followed by hydrolysis; indeed, consideration of steric factors in the transition states for Dieckmann cyclizations of the diastereomers VI (R = Me) and VII (R

VI   VII
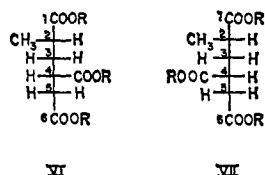
= Me) strongly suggests that serious crowding may impede the formation of a cyclopentanone from VI (R = Me). These considerations permit the tentative assignment of the $2S,4S$ configuration (VI, R = H) to the optically active acid derived from magnamycin by degradation, and the $2S,4R$ ($2R,4S$) configuration (VII, R = H) to the acid obtained from VI by isomerization and by synthesis.

The facts set down above clearly provided occasion for concern with respect to our conclusion *vis-à-vis* the relationship of the C_8 acid, now confirmed as III, and the C_{13} acid IV, based as this conclusion was on our failure to observe cyclopentanone formation from an acid which might be formulated as VI ($-CH_2CH_2CH_3$ in place of COOR at C-4), and therefore fall in a class, one member of which had now been shown to be very resistant to cyclization. Obviously the alternative (VIII) deserved renewed consideration as the structure

VIII
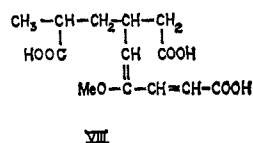
of the C_{13} acid. Examination of the nuclear magnetic resonance spectrum (60 Mc., CCl_4 solution) of the trimethyl ester [b.p. 115–120° (10^{-5} mm.); λ_{max} 263 mμ (ϵ 24,300). *Anal.* Calcd.: C, 58.52; H, 7.37; OMe, 37.80. Found: C, 58.65; H, 7.42; OMe, 37.51] of the C_{13} acid revealed at once that structure VIII is correct; sharp bands are present at 420, 405, 359, 344, 312, and 302 c.p.s. downfield from the tetramethylsilane reference band. All these bands are clearly associated with olefinic protons, and the lower field symmetrical quartet must be assigned to the α and β hydrogens of the *trans* $-CH=CH-$ system. Consequently, the remaining *doublet* arises from the hydrogen of the $-CH=C(OMe)-$ group, *which must be adjacent to a methine grouping, as in VIII, and not to a methylene grouping, as in IV*.

The change (IV → VIII) in the structure of the C_{13} acid requires only that the C-9–C-7 bond in the previously proposed structure (I) for magnamycin be replaced by a C-9–C-6 bond, as in II; none of the other elements of the original structural argument is affected by the required modification in the structure of the degradation product. It is of much interest that

the new structure suggests the introduction of a succinic acid unit into the main chain of the macrolide nucleus at C-6 → C-5, in place of the more common acetic acid or propionic acid unit, in the biogenesis of magnamycin, particularly in the light of the observed effective incorporation of succinic acid.[6,7]

(6) H. Achenbach and H. Grisebach, *Z. Naturforsch.*, **19b**, 561 (1964).
(7) We are indebted to the National Institutes of Health for generous support of this work.

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The Reactions of Carbon Atoms with Saturated Hydrocarbons

Sir:

We have reported[1-3] our studies on the reactions of carbon atoms with olefinic substrates. We now report on the extension of these studies to include reactions with saturated hydrocarbons.

The reaction system used was as described earlier[4]; reactions occur in condensed phase at liquid nitrogen temperature. Analysis was done by vapor phase chromatography, products being identified by isolation and comparison of their infrared and mass spectra with those of known materials.

The reaction of carbon atoms with 2-methylpropane yields two products which have added a carbon atom, 1,1-dimethylcyclopropane and 2-methylbutane.

38% (relative yields)   62%
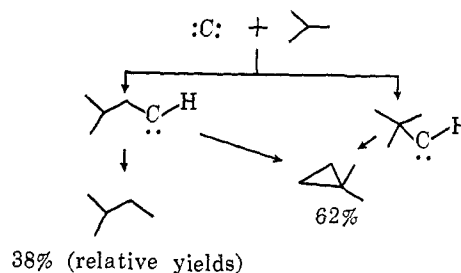
The initial reaction is postulated to be insertion on either the tertiary or a primary carbon–hydrogen bond, giving the intermediate free carbenes shown. Either carbene can undergo intramolecular insertion to give the 1,1-dimethylcyclopropane. The isobutylcarbene can abstract hydrogens from the surrounding 2-methylpropane ($\sim$1000-fold molar excess over carbon atoms and molecules) to produce 2-methylbutane. Isomeric octanes resulting from coupling of radicals thus produced were isolated. *Neither 2-methylpropene nor acetylene was formed.*

The reaction of carbon atoms with cyclopropane gave as the major product methylenecyclopropane (65%). This can be described as resulting from initial insertion on a carbon–hydrogen bond followed by hydrogen migration. Evidence is not available to define a mechanism for the formation of the hydrogenated products.

(1) P. S. Skell and R. R. Engel, *J. Am. Chem. Soc.*, **87**, 1135 (1965).
(2) P. S. Skell and R. R. Engel, *ibid.*, **87**, 1135 (1965).
(3) P. S. Skell and R. R. Engel, *ibid.*, **87**, 2493 (1965).
(4) P. S. Skell, L. D. Wescott, Jr., J-P. Golstein, and R. R. Engel, *ibid.*, **87**, 2829 (1965).