benzophenone.[14] The mixture was heated on the steam-bath for an additional 30 minutes, then it was cooled and hydrolyzed with an aqueous solution of ammonium chloride. The ether solution was separated from the aqueous solution, and the aqueous solution was extracted with fresh ether. Evaporation of the ether from the combined organic material afforded an oil. This was mixed with 200 cc. of water plus 50 cc. of concentrated sulfuric acid and then heated under reflux for one hour. Solid 1-phenyl-1-*p*-ethoxyphenylethylene was filtered from the cooled solution and crystallized from ethanol. There was obtained 168 g. (0.75 mole, 93%) of the olefin, m.p. 78.8–79.4°. Since the reported[15] m.p. is 71°, the material was analyzed.

Anal. Calcd. for $C_{16}H_{16}O$: C, 85.68; H, 7.19. Found: C, 85.83; H, 7.41.

Schmidt Reaction of 1-Phenyl-1-*p*-ethoxyphenylethylene.—The reaction was carried out as described above for 1-phenyl-1-*p*-anisylethylene, 50.0 g. (0.223 mole) of 1-phenyl-1-*p*-ethoxyphenylethylene being employed. A total of 20.98 g. of mixed ketones was obtained by distillation, a major portion distilling at 83–107° (13 mm.) and the remainder at 111–170° (16 mm.). The infrared method of analysis was identical with that described above. The ratio T 840 cm.$^{-1}$/T 689 cm.$^{-1}$ equalled 3.48 for the ketone fraction, and this corresponds to a molar ratio of acetophenone to *p*-ethoxyacetophenone of 6.2.

Infrared Calibration Curve with Known Mixtures of Acetophenone and *p*-Ethoxyacetophenone.—*p*-Ethoxyacetophenone was prepared by the procedure of Hartough and Kosak.[16] Chloroform solutions were prepared containing about 9 weight % of the mixed ketones, and the infrared spectra were measured in a 0.05-mm. cell. Following are the values of the ratio T 840 cm.$^{-1}$/T 689 cm.$^{-1}$, followed in each case by the weight % of acetophenone in the corresponding binary mixture: 1.33, 52.3%; 2.38, 68.8%; 3.35, 80.9%; 4.93, 89.8%.

(14) W. E. Bachmann and J. W. Ferguson, THIS JOURNAL, **56**, 2081 (1934).

(15) G. Busignies, *Compt. rend.*, **151**, 515 (1910).

(16) H. D. Hartough and A. I. Kosak, U. S. Patent 2,475,564, July 5, 1949.

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COMMUNICATIONS TO THE EDITOR

TOTAL SYNTHESIS OF THE ANTIBIOTIC PUROMYCIN[1]

Sir:

The structure of puromycin has been elucidated as 6-dimethylamino-9-(3′-*p*-methoxy-L-phenylalanylamino-3′-deoxy-β-D-ribofuranosyl)-purine.[2] Recently the conversion of the antibiotic to the highly biologically active 6-dimethylamino-9-(3′-amino-3′-deoxy-β-D-ribofuranosyl)-purine (I) and the resynthesis of the antibiotic from I were described.[1] This communication outlines the synthesis of I from D-xylose, thus completing a total synthesis of the antibiotic.

Reaction of crude methyl D-xylofuranoside[3] with acetone in the presence of copper sulfate and 0.002 *N* sulfuric acid afforded a readily separable mixture of 41% (based on D-xylose) of methyl 3,5-O-isopropylidene-α-D-xylofuranoside, b.p. 85° (0.1 mm.), $[\alpha]^{24}D$ +17.6° ($CHCl_3$) and the β-anomer, b.p. 108° (0.1 mm.), $[\alpha]^{24}D$ −64° ($CHCl_3$) in 31% yield.[4] Found: (α), C, 53.1; H, 8.06; (β), C, 52.3; H, 7.93. Each anomer was then used separately in the synthesis until the O-methyl was removed. 2-O-Mesylation, deacetonation in 70% acetic acid, and oxide formation with sodium methoxide gave methyl 2,3-anhydro-D-lyxofuranoside: α-anomer (74% yield), m.p. 80–82°, $[\alpha]^{26}D$ + 67° (H_2O); β-anomer (71%), m.p. 74–75°, $[\alpha]^{25}D$ −102° (H_2O).[5] Found: (α), C, 48.9; H, 6.90; (β), C, 49.5; H, 7.07. Ring-opening of the anhydro sugar with ammonia at 100° occurred with Walden inversion to give methyl 3-amino-3-deoxy-D-arabinofuranoside, isolated as the crystalline N-isopropylidene derivative[6]: α-anomer (54%), m.p. 157–159°, $[\alpha]^{26}D$ +98° (H_2O); β-anomer (47%), m.p. 155–157°, $[\alpha]^{25}D$ −96° (H_2O). Found: (α), C, 53.1; H, 7.96; N, 7.12; (β), C, 52.9; H, 8.69; N, 7.05. Acetylation in water with acetic anhydride formed methyl 3-acetamino-3-deoxy-D-arabinofuranoside: α-anomer (90%), m.p. 115–116°, $[\alpha]^{24}D$ +102° (H_2O); β-anomer (98%), m.p. 155°, $[\alpha]^{24}D$ −119° (H_2O). Found: (α), C, 47.2; H, 7.30; N, 6.88; (β), C, 47.2; H, 7.56; N, 6.41. Mesyl chloride in pyridine gave methyl 2,5-di-O-mesyl-3-acetamino-3-deoxy-D-arabinofuranoside: α-anomer (84%), m.p. 125–126°, $[\alpha]^{28}D$ +104° (Pyr.); β-anomer (84%), m.p. 169–170°, $[\alpha]^{25}D$ −88° (Pyr.). Found: (β), C, 33.6; H, 5.36; N, 3.93; (β), C, 33.5; H, 5.48; N, 3.89. Treatment with sodium acetate in boiling 95% Methyl Cellosolve caused displacement of the 2-mesylate by the neighboring 3-acetamino group with Walden inversion via an oxazoline[7] and the 5-mesylate by acetate. Isolation of the product by acetylation afforded methyl 2,5-di-O-acetyl-3-acetamino-3-deoxy-D-ribofurano-

(1) This communication is derived from papers VIII and IX of the series Puromycin, Synthetic Studies; for paper VII, *cf.* B. R. Baker, J. P. Joseph and J. H. Williams, THIS JOURNAL, **76**, 2838 (1954).

(2) (a) C. W. Waller, P. W. Fryth, B. L. Hutchings and J. H. Williams, THIS JOURNAL, **75**, 2025 (1953); (b) N. Y. Meeting-in-miniature, Feb., 1954.

(3) P. A. Levene, A. L. Raymond and R. T. Dillon, *J. Biol. Chem.*, **95**, 699 (1932).

(4) E. E. Percival and R. Zobrist. *J. Chem. Soc.*, 4306 (1952), have reported for this preparation, b.p. 110° (0.1 mm.) and $[\alpha]D$ −26°, indicating a mixture of 54% α-anomer and 46% β-anomer.

(5) E. E. Percival and R. Zobrist, *J. Chem. Soc.*, 564 (1953), deacetonated crystalline methyl 2-O-tosyl-3,5-O-isopropylidene-β-D-xylofuranoside with 1% methanolic hydrogen chloride which caused extensive anomerization. Oxide formation afforded them 23% of methyl 2,3-anhydro-α-D-lyxofuranoside, m.p. 81°, $[\alpha]D$ +57° (H_2O).

(6) Hydrolysis of either anomer gave 3-amino-3-deoxy-D-arabinose hydrochloride, m.p. 159° dec., $[\alpha]^{24}D$ −112°. This gave a negative ninhydrin test in 3% alkali and is isomeric to the other possible oxide ring-opening product, 2-amino-2-deoxy-D-xylose hydrochloride, described by M. L. Wolfrom and K. Anno, THIS JOURNAL, **75**, 1038 (1953).

(7) B. R. Baker and R. E. Schaub, *J. Org. Chem.*, **19**, 646 (1954).

side (II): α-anomer (98%), m.p. 90–91°, $[\alpha]^{23}D$ +135° ($CHCl_3$); β-anomer (94%), m.p. 98–99°, $[\alpha]^{24}D$ +35° ($CHCl_3$). Found: (α), C, 49.5; H, 6.80; N, 5.07; (β), C, 49.7; H, 6.56; N, 4.69. Hydrolysis of II with 1% hydrochloric acid gave authentic 3-amino-3-deoxy-D-ribose hydrochloride.[7]

O-Deacetylation of either anomer of II, O-benzoylation and removal of the O-methyl group with hydrogen bromide in acetic acid[8] gave 48% of 2,5-di-O-benzoyl-3-acetamino-3-deoxy-α-D-ribofuranose, m.p. 153–154°, $[\alpha]^{25}D$ +108° (Pyr.). Found: C, 63.2; H, 5.89; N, 3.41. Acetylation with acetic anhydride–pyridine at 100° gave 98% of an anomeric mixture (III) of 1-O-acetyl-2,5-di-O-benzoyl-acetamino-3-deoxy-D-ribofuranosides, from which one anomer was obtained crystalline, m.p. 152–154°, $[\alpha]^{25}D$ +63° (pyr.). Found: C, 62.2; H, 5.31; N, 3.46.

Addition of titanium tetrachloride to a mixture of III, the chloromercury derivative[9] of 2-methylmercapto-6-dimethylaminopurine[10] and ethylene dichloride followed by a 20-hour reflux afforded a crude nucleoside. Raney nickel desulfurization and O-debenzoylation with methanolic sodium methoxide gave 6-dimethylamino-9-(3′-acetamino-3′-deoxy-β-D-ribofuranosyl)-purine (23% from III), m.p. 187–188°, which was identical in all respects with the N-acetyl derivative of I. Found: C, 49.8; H, 5.93; N, 25.2. Removal of the N-acetyl group with barium hydroxide gave 80% of I.

(8) H. G. Fletcher, Jr., THIS JOURNAL, **75**, 2624 (1953).

(9) B. R. Baker, J. P. Joseph and J. H. Williams, Paper IV of this series, *J. Org. Chem.*, in press.

(10) B. R. Baker, J. P. Joseph and R. E. Schaub, THIS JOURNAL, **75**, 2624 (1953).

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RECEIVED JUNE 30, 1954

THE STRUCTURE OF COLLAGEN

Sir:

A structure[1] has been deduced for that part of the collagen molecule which is responsible for the observed X-ray diffractions.[2–4] This structure is in agreement with all experimental facts known to the writer.

The sequence of residues is given by the formula $(RR'R'')_n$, where R″ represents a residue which is usually proline or hydroxyproline and R and R′ denote other types. The 3-residue group, RR′R″, has the bond structure indicated within the rectangle in the figure (in which R′ and R″ have been taken as glycine and hydroxyproline residues, respectively). The chain is coiled in a left-handed helix. The coördinates in the table have been computed, assuming: (1) 30 residues per 3 turns[4] and per 28.6 Å.; (2) Pauling–Corey bond angles and lengths in the polypeptide chain; (3) rectilinear N–H · · · O hydrogen bonds, of equal length; (4) planar C–CO–NH–C groups; (5) dimensions in the hydroxyproline ring like those in hydroxyproline itself.[5]

(1) This structure was described briefly at the Pasadena Conference on the Structure of Proteins, Sept. 22, 1953.

(2) R. S. Bear, "Advances in Protein Chemistry," **7**, 69 (1952).

(3) C. Cohen and R. S. Bear, THIS JOURNAL, **75**, 2783 (1953).

(4) J. T. Edsall, *Science*, **119**, 302 (1954).

TABLE I

COÖRDINATES*

	x	y	
C_1	4.04	0.00	0.00
C_2	3.13	1.23	0.00
C_3	3.88	1.34	2.39
C_4	2.87	0.74	3.38
C_5	2.34	3.09	3.85
C_6	1.19	3.64	3.00
C_7	5.38	0.33	0.66
C_8	1.93	1.36	5.47
C_9	2.42	2.57	6.25
C_{10}	2.34	3.69	5.26
N_1	3.41	−1.12	0.72
N_2	3.16	1.87	1.21
N_3	2.17	1.64	4.04
O_1	2.46	1.57	−0.92
O_2	2.64	−0.48	3.37
O_3	1.39	4.00	1.83
O_4	3.82	2.36	6.64
$O_{1(3)}$	2.91	−0.18	7.66
H_1	3.13	−0.89	1.68
H_2	3.89	−0.29	−1.05
H_3	2.52	2.64	1.44
H_4	4.59	0.59	2.07
H_5	4.41	2.21	2.88
H_6	3.30	3.28	3.35
H_7	2.50	0.47	5.77
H_8	0.85	1.23	5.64
H_9	1.74	2.77	7.09
H_{10}	3.22	4.35	5.37
H_{11}	1.42	4.26	5.42
H_{12}	3.52	1.53	6.97

*Referred to a left-handed rectangular coördinate system, in Å.

The computed (not assumed) NHO hydrogen bond length is 2.83 Å. The hydroxyl oxygen of the hydroxyproline residue is 2.9 Å. from a car-

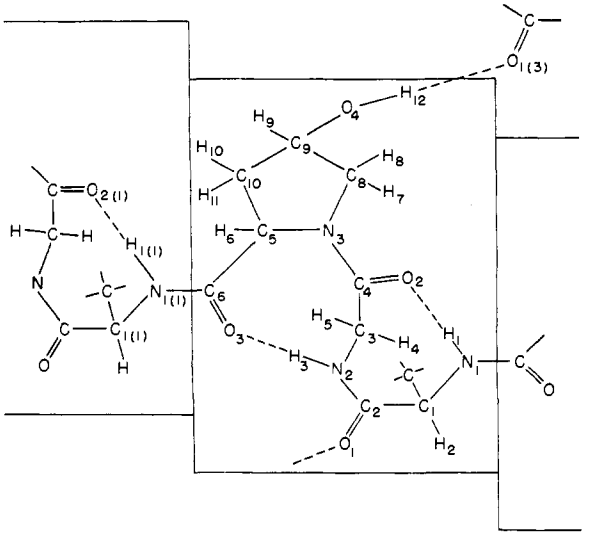

Fig. 1.—The bond structure in the proposed model for Collagen.

(5) J. Donohue and K. N. Trueblood, *Acta Cryst.*, **5**, 419 (1952).