Anal. Calcd for $C_{14}H_{19}N_5O_5S_2$: C, 41.9; H, 4.77; N, 17.4; S, 16.0. Found: C, 41.8; H, 5.05; N, 17.1; S, 15.8.

Thin layer chromatography using *n*-propanol–ethyl acetate–water (12:8:1) as the developing solvent showed one spot with R_f 0.72.

Subsequent methylsulfonations on **6b** gave yields of 62% of product, mp 196–204°.

9-(2-*O*-Methylsulfonyl-4-thio-β-D-xylofuranosyl)adenine (8).—A solution of 0.45 g (1.12 mmoles) of **7** in 18 ml of 80% aqueous acetic acid was heated on a steam bath for 1 hr then was evaporated to dryness *in vacuo*. The residue was dissolved in hot absolute ethanol and evaporated to dryness to give 0.44 g of yellow foam.

Crystallization from absolute ethanol gave 0.22 g (54%) of white crystals: mp 168–172°; $[\alpha]^{21}D$ −17° (*c* 0.98, methanol).

Anal. Calcd for $C_{11}H_{15}N_5O_5S_2$: C, 36.6; H, 4.18; N, 19.4; S, 17.7. Found: C, 36.4; H, 4.23; N, 19.6; S, 17.8.

9-(2,3-Anhydro-4-thio-β-D-lyxofuranosyl)adenine (9).—A solution of 380 mg (1.05 mmoles) of crude **8** in 8 ml of methanol and 75 mg (1.4 mmoles) of sodium methoxide was heated at reflux for 12 min. The solution was cooled to room temperature and neutralized with IRC-50 (H) then was evaporated to dryness *in vacuo* to give 470 mg of crude product. Trituration of the residue with water gave 170 mg (62%) of white solid which was homogeneous on thin layer chromatography using chloroform–methanol (4:1). The analytical sample was obtained by two recrystallizations from 80% aqueous acetone and had mp 220–229° dec, $[\alpha]^{21}D$ +7° (*c* 0.96, 2-methoxyethanol).

Anal. Calcd for $C_{10}H_{11}N_5O_2S$: C, 45.3; H, 4.18; N, 26.4; S, 12.1. Found: C, 45.4; H, 4.19; N, 26.4; S, 12.4.

9-(4-Thio-β-D-arabinofuranosyl)adenine (10).—A mixture of 0.17 g (0.65 mmole) of 9-(2,3-anhydro-4-thio-β-D-lyxofuranosyl)-adenine (**9**) and 0.16 mg (1.97 mmoles) of anhydrous sodium acetate in 10 ml of 95% aqueous DMF was heated at reflux with stirring for 8 hr, then was evaporated to dryness *in vacuo*. The residue was triturated with several portions of DMF to remove the relatively insoluble sodium acetate. The DMF solution was evaporated to dryness *in vacuo* to give 0.22 g of crude residue which contained two major components with R_f values 0.21 and 0.30 on thin layer chromatography using chloroform–methanol (4:1). The two components were resolved by ion exchange chromatography using 40 g of Dowex 1 (OH). Washing the column with water, then with methanol–water (1:1) eluted small quantities of by-products. Elution with methanol–water (3:2) gave two uv absorbing fractions. The first, which contained 22 mg was 9-(4-thio-β-D-xylofuranosyl)adenine (**5b**) contaminated with a small amount of material which had an R_f value (0.57) identical with that of starting epoxide **9** on tlc using chloroform–methanol (4:1).

The arabinoside **10** was contained in the second fraction, which weighed 97 mg (53% yield) and was homogeneous on tlc (R_f 0.23) using chloroform–methanol (4:1). It crystallized upon trituration with water. The analytical sample was obtained by recrystallization from water and had mp 135–142° and $[\alpha]^{21}D$ −8° (*c* 0.5, water); ultraviolet bands were at $\lambda_{max}^{pH\ 1}$ 259 mμ (ε 14,800) and $\lambda_{max}^{pH\ 7,\ 13}$ 260 mμ (ε 15,400).

Anal. Calcd for $C_{10}H_{13}N_5O_3S \cdot H_2O$: C, 39.9; H, 5.02; N, 23.3; S, 10.6. Found: C, 40.2; H, 5.06; N, 23.3; S, 10.9.

Registry No.—**2**, 15076-96-7; **4**, 15076-97-8; **5a**, 15023-72-0; **5b**, 15023-73-1; **6a**, 15023-74-2; **6b**, 7687-51-6; **7**, 15023-78-6; **8**, 15023-76-4; **9**, 15026-14-9; **10**, 15023-77-5.

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Indole and 4-Aminoindole Nucleosides

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The synthesis of 1-(β-D-ribopyranosyl) and 1-(β-D-ribofuranosyl)indole is described. Reaction of indoline with 1,2,3,4-tetra-*O*-acetyl-β-D-ribopyranose and with 1-*O*-acetyl-2,3,5-tri-*O*-benzoyl-β-D-ribofuranose produced the related 1-(β-D-ribosyl)indolines which were oxidized to the corresponding indoles with 2,3-dichloro-5,6-dicyanobenzoquinone. Removal of the acyl blocking groups with methanolic sodium methoxide led to the desired 1-(β-D-ribosyl)indoles. Application of essentially the same reaction scheme to 4-benzamidoindoline and 1-*O*-acetyl-2,3,5-tri-*O*-benzoylribofuranose led to 4-amino-1-(β-D-ribofuranosyl)indole, the 1,3,7-trideaza analog of adenosine. A method for the synthesis of the required 4-benzamidoindoline from 4-aminoindole is described. Some attempts to treat sugar derivatives directly with indoles are described as well as some trials toward alternative syntheses of 4-aminoindole. Through a combination of nmrs measurements, periodate oxidations, and ORD determinations, the assignment of the β anomeric configuration to all of the glycosyl indoles was substantiated.

During the past ten years a veritable flood of adenosine analogs, showing a variety of biological activities, has been obtained by synthesis or from natural sources.[1] It is striking that what might, in one sense, be described as the simplest adenosine analog, 4-amino-1-(β-D-ribofuranosyl)indole (**12**, 1,3,7-trideazaadenosine), has not been reported. The lack of a requirement for a full complement of purine ring nitrogen heteroatoms for biological activity as exemplified by the antibiotic tubercidin, as well as the variety of biological effects shown by variously substituted indoles, encouraged us to undertake the synthesis of **12**.

Examination of the literature revealed that the synthesis of 1-glucopyranosylindole (**3**) reported by Suranov and Preobrazhenskaya[2] was the only prior example of a 1-glycosyl indole. The synthetic approach used by these workers involved reaction of 1,2,3,4,6-penta-*O*-acetyl-D-glucopyranose with 2 moles of indoline. The intermediate 1-(2,3,4,6-tetra-*O*-acetyl-β-D-glucopyranosyl)indoline (**1**) was separated from 1-acetylindoline and oxidized with tetrachloro-*p*-benzoquinone to produce the glucosyl indole **2** which was deblocked to give **3**.

In order to have on hand a supply of 1-(β-D-glucopyranosyl)indole (**3**) for confirmation of the β configurational assignment,[2] as well as for configurational comparisons with the ribofuranosyl derivative **12** which we planned to prepare, the synthesis of **3** was repeated following the published directions. As the yield of the indole from the oxidation of the intermediate indo-

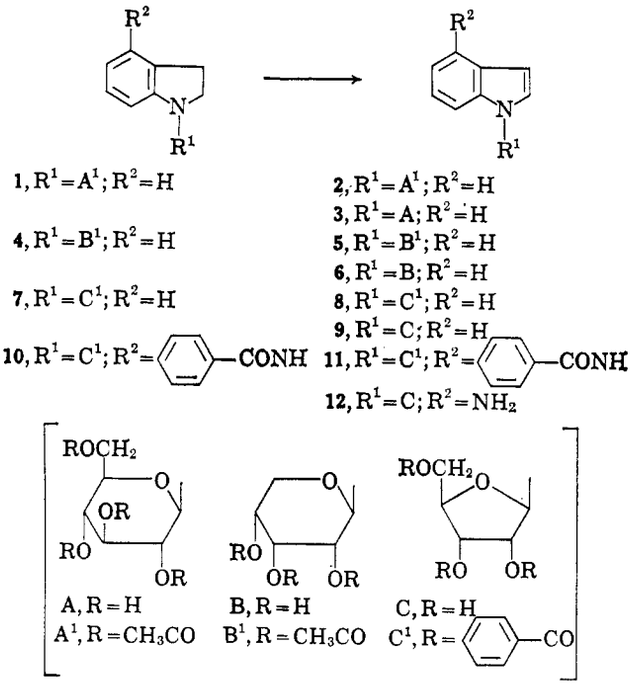
(1) Many of these are to be found in reviews by (a) J. A. Montgomery and H. J. Thomas, *Advan. Carbohydrate Chem.*, **17**, 301 (1962); (b) J. J. Fox, K. A. Watanabe, and A. Block, in "Progress in Nucleic Acid Research and Molecular Biology," J. N. Davidson and W. E. Cohn, Ed., Academic Press Inc., New York, N. Y., 1966, p 251.

(2) N. N. Suranov and M. N. Preobrazhenskaya, *Zh. Obshch. Khim.*, **31**, 2839 (1961).

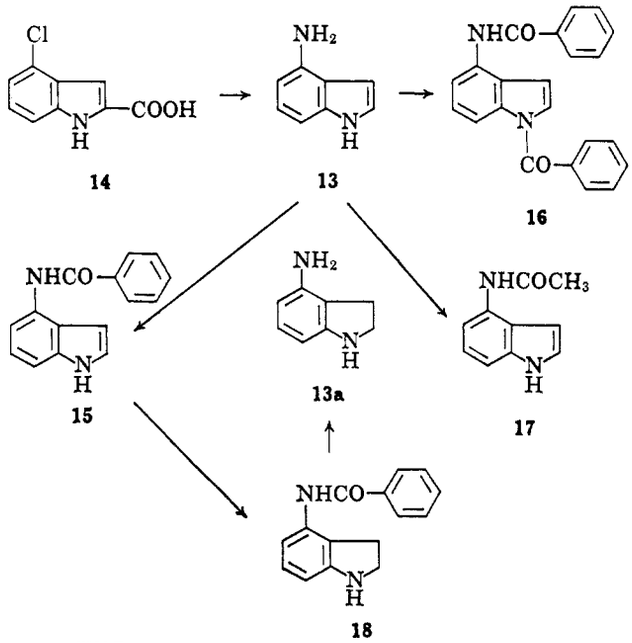
line was rather low, we substituted 2,3-dichloro-5,6-dicyanobenzoquinone as the oxidant for the chloranil used by the earlier workers. A remarkable improvement of yield from 30 to 90% was obtained. About this time, a second publication by Suranov and Preobrazhenskaya[3] became available, wherein they also noted the superiority of 2,3-dichloro-5,6-dicyanobenzoquinone over chloroanil in the oxidation of 1-(2,3,4,6-tetra-*O*-benzyl-β-D-glucopyranosyl)indoline to the corresponding indole.

Before proceeding with the synthesis of **12**, it was decided to study the reaction of indoline with poly-*O*-acyl pentoses both in the pyranose and furanose forms. Whereas the reaction of indoline with pentaacetyl-α-D-glucopyranose occurred at room temperature and produced a good yield (90%) of 1-(2,3,4,6-tetra-*O*-acetyl-β-D-glucopyranosyl)indoline (**1**) in 8 hr, the reaction with tetra-*O*-acetyl-β-D-ribopyranose required 48 hr and the yield (53%) of 1-(2,3,4-tri-*O*-acetyl-β-D-ribopyranosyl)indoline (**4**) was considerably lower. In the reaction of indoline with 1-*O*-acetyl-2,3,5-tri-*O*-benzoyl-β-D-ribofuranose, none of the desired 1-(2,3,5-tri-*O*-benzoyl-β-D-ribofuranosyl)indoline (**7**) was produced at room temperature, even after several days. Heating the reaction mixture at 80° for 6.5 hr was required to obtain **7** in 45% yield. The course of all of the above glycosylation reactions was followed by tlc on silica gel in mixtures of benzene and ethyl acetate. In all cases the production of 1-acetylindoline formed from the 1-O-deacylation of the poly-*O*-acyl sugar was completed rapidly indicating that the difference in rate of product formation with the various acylated sugars was not a function of the rate of aminolysis of the 1-acyl moiety.[4]

The 1-glycosylindolines (**1**, **4**, and **7**) were all oxidized with 2,3-dichloro-5,6-dicyano-1,4-benzoquinone in boiling xylene to produce 1-(2,3,4,6-tetra-*O*-acetyl-β-D-glucopyranosyl)indole (**2**), 1-(2,3,4-tri-*O*-acetyl-β-D-ribopyranosyl)indole (**5**), and 1-(2,3,5-tri-*O*-benzoyl-β-D-ribofuranosyl)indole (**8**) in over 80% yield. The acyl blocking groups in **2**, **5**, and **8** were removed catalytically with sodium methoxide in methanol giving 1-(β-D-glucopyranosyl)indole (**3**), 1-(β-D-ribopyranosyl)indole (**6**), and 1-(β-D-ribofuranosyl)indole[4a] (**9**).

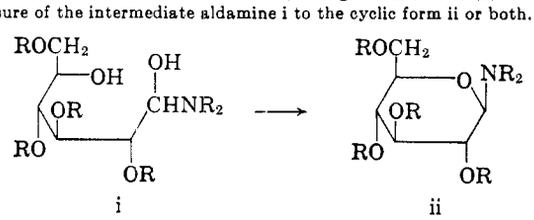


After determining that a modification of the procedure of Suranov and Preobrazheskaya[2] was applicable to the glycosylation of indoline with poly-*O*-acyl pentopyranoses and pentofuranoses, it was decided to proceed with the synthesis of 4-amino-1-(β-D-ribofuranosyl)-indole (**12**). This required a source of 4-aminoindoline (**13a**). The synthesis of 4-aminoindole (**13**) had been reported earlier[5] by a method[6] which started with the isomeric mixture of 2-nitro-6-bromotoluene and 2-nitro-4-bromotoluene and used in the penultimate step the ammonative decarboxylation of 4-bromoindole-2-carboxylic acid which was obtained after an isomer separation at an earlier stage. The synthesis of 4-chloroindole-2-carboxylic acid (**14**) from the single isomer 2-nitro-6-chlorotoluene had been reported previously,[7] but its usefulness in ammonative



(3) M. N. Preobrazhenskaya and N. N. Suranov, *Zh. Obshch. Khim.*, **35**, 893 (1965).

(4) Although a generally acceptable mechanism for the formation of glycosylamines has not been documented, if one assumes reaction of the amine with the open chain (aldehyde) sugar then the variation in rate might be a function of (a) the amount of aldehyde sugar available or (b) the rate of reclosure of the intermediate aldamine i to the cyclic form ii or both.



Based on stereochemical considerations only, the rate of reclosure of the glucopyranosyl derivative to a chair conformation (*C1*) with all bulky substituents equatorial should be faster than the ribopyranosyl derivative which closes to a *C1* form with one axial substituent. The ribofuranose would be expected to be the slowest because of the vicinal 2,3 eclipsing interaction in the five-membered cyclic product. This reasoning, however, does not explain the yet slower rate of reaction of 1-*O*-acetyl-2,3,5-tri-*O*-benzoyl-β-D-ribofuranose with 4-benzamidoindoline.

(4a) M. N. Preobrazhenskaya, M. M. Vigdorchik, and N. N. Suvorov, *Tetrahedron*, **23**, 4653 (1967), have recently described a synthesis of this compound (**9**) by a related method. Their reported rotation differs significantly from ours.

(5) H. Pleninger, *Chem. Ber.*, **88**, 370 (1955).

(6) J. A. Barltrop and D. A. H. Taylor, *J. Chem. Soc.*, 3399 (1954).

(7) F. C. Uhle, *J. Am. Chem. Soc.*, **71**, 761 (1949).

decarboxylation reaction to produce 4-aminoindole was unknown. However, as the required 2-nitro-6-chlorotoluene was commercially available as a single isomer, it was decided to proceed with the synthesis *via* 4-chloroindole-2-carboxylic acid (**14**). When **14** was heated at 270°[8] with concentrated ammonium hydroxide and a small amount of cuprous chloride, a 60% yield of 4-aminoindole (**13**) was obtained.[9] 4-Aminoindole is rather easily oxidized in air and, for further preparative purposes, the crude product from the ammonia reaction was purified after first being converted into 4-benzamidoindole (**15**) by fusion with benzoic anhydride at 150° followed by crystallization of the product by the slow addition of ethanol to the melt at 100°. Surprisingly, when **13** was treated with benzoyl chloride in hot pyridine, the product, which again was cystallized from hot ethanol, was not **15** but 4-benzamido-1-benzoylindole (**16**). On the other hand, treatment of **13** in pyridine with acetic anhydride at room temperature led to the isolation of 4-acetamidoindole (**17**). The isolation of **17** was complicated by its ready solubility in the dilute hydrochloric acid used to remove pyridine from the reaction products.

The conversion of 4-benzamidoindole (**15**) into the required 4-benzamidoindoline (**18**) by hydrogenation in presence of Ni(R) in dioxane was complicated by the fact that the temperature (125°) necessary for reduction of the 2,3 double bond is close to that (150°) at which overreduction to the octahydroindole occurs.[10a] However, at 125° some of the starting material remains unreduced and the yield of the desired produce **18**, obtained by chromatography, was never more than 60%. The reaction of **18** with 1-*O*-acetyl-2,3,5-tri-*O*-benzoyl-β-D-ribose in ethanol containing a small amount of acetic acid was much slower than was the reaction of unsubstituted indoline with the same sugar derivative. Heating at the reflux temperature for 72 hr was required for maximum conversion to 4-benzamido-1-(2,3,5-tri-*O*-benzoyl-β-D-ribosyl)indoline (**10**), whereas the reaction of indoline with 1-*O*-acetyl-2,3,5-tri-*O*-benzoyl-β-D-ribofuranose was complete in 6.5 hr under similar reaction conditions. The yield (29%) of **10** was also lower. 1-Acetyl-4-benzamidoindoline (62%), formed by aminolysis of the 1-*O*-acetyl-2,3,5-tri-*O*-benzoyl-β-D-ribofuranose, was isolated from among the reaction products in addition to 3 g (36%) of unreacted poly-*O*-acyl sugar and a small amount of unchanged starting 4-benzamidoindoline (**18**). Oxidation of the indoline **10** with 2,3-dichloro-5,6-dicyanobenzoquinone gave only 28% of the desired 4-benzamido-1-(2,3,5-tri-*O*-benzoyl-β-D-ribosyl)indole (**11**) as a crystalline solid.

The removal of the benzoyl blocking groups from **11**, which was expected to be routine, presented unforeseen difficulties. When the indole **11** was refluxed with methanolic sodium methoxide, the *O*-benzoyl groups of the sugar moiety were rapidly removed but the benzamido group at the 4 position was virtually untouched. This result was completely unexpected in view of the easy cleavage of the 6-benzamido group of blocked purine nucleosides with catalytic amounts of sodium methoxide in boiling methanol. A study of conditions required for the cleavage of the benzoyl group from 4-benzamidoindole (**15**) was undertaken. No cleavage was detected after boiling a methanol solution of **15** with excess sodium methoxide for 48 hr. A similar result obtained when a *t*-butyl alcohol solution of **15** was refluxed for 96 hr with excess potassium *t*-butoxide. When 4-benzamidoindole was refluxed with methanol and a 20-fold molar excess of 2 *N* aqueous sodium hydroxide for 72 hr most of the amide group in **15** was hydrolyzed to 4-aminoindole. The same reaction, when carried out in a sealed tube at 130° for 16 hr, gave complete conversion to **13**. When this procedure was applied to the deblocking of 4-benzamido-1-(2,3,5-tri-*O*-benzoyl-β-D-ribosyl)indole (**11**), the large amount of sodium salts introduced in working up the reaction mixture interfered with the isolation of the product **12**. The desired 4-amino-1-(β-D-ribofuranosyl)indole (**12**) was eventually obtained in 40% yield by heating the intermediate **11** in water with a large excess of $Ba(OH)_2$ in a sealed tube at 130° for 16 hr. The insolubility of barium hydroxide expedited its removal from the reaction products. The product **12** resisted cystallization but was obtained as an analytically pure glass by column chromatography.

Because the over-all yield of 4-amino-1-(β-D-ribofuranosyl)indole (**12**) was rather poor by the above route, some attempts were made to find a method for the direct glycosylation of indole which would eliminate the conversion to indoline and reconversion to indole—steps, which at least in the case of 4-aminoindole, were rather tedious and resulted in low product yields. Indole, as its sodio derivative, can be N-alkylated with alkyl halides. For example, when indole in dimethylformamide was treated with NaH followed by *p*-chlorobenzyl chloride, a 99% yield of isolated, crystalline 1-β-chlorobenzylindole (**19**) was obtained.[10b] When the same reaction was tried with sodio indole and 2,3,5-tri-*O*-benzoyl-D-ribosyl chloride (**20**), a complex mixture was obtained. One-half of the indole was recovered unchanged and none of the desired 1-(D-ribofuranosyl)-indole could be isolated from the mixture of products that remained.

(8) Pleninger[5] reported a 60% conversion of 4-*bromo*indole-2-carboxylic acid into 4-aminoindole by heating with ammonium hydroxide and Cu_2Cl_2 at 220°. At this temperature, we obtained a quantitative recovery of unchanged starting material **14**.

(9) It might be noted that S. M. Parmerter, A. G. Cook, and W. B. Dixon, *J. Am. Chem. Soc.*, **80**, 4621 (1958), have reported a synthesis of 4-nitroindole, from ethyl pyruvate-*m*-nitrophenylhydrazine *via* a Fischer cyclization with polyphosphoric acid followed by alkaline hydrolysis and CuO-catalyzed decarboxylation of the resultant ethyl 4-nitroindole-2-carboxylate. Reduction of the nitro group in 4-nitroindole would complete a second route to 4-aminoindole. The yield of ethyl 4-nitroindole-2-carboxylate reported by Parmerter and coworkers from the Fischer cyclization was, however, only 19%, which represents a lower potential over-all yield of 4-aminoindole than the present method. Toward an improved synthesis of 4-nitroindole, we attempted the synthesis of 2,6-dinitrophenylpyruvic acid (iii) from a base-catalyzed condensation of the symetrically constituted 2,6-dinitrotoluene and diethyl oxalate. The desired product (iii), which we planned to cyclize to 4-nitroindole-2-carboxylic acid following Uhle's procedure[7] for the cyclization of 2-chloro-4-nitrophenylpyruvic acid, could not, however, be isolated from the reaction mixture.

Another potential and more direct route to 4-aminoindole was investigated. Reduction of 2,6-dinitrotoluene gave 2,6-diaminotoluene which when heated with formic acid yielded 2,6-diformamidotoluene. However, when the 2,6-diformamidotoluene was subjected to the conditions of a Madalung cyclization (*i.e.*, heating with $NaNH_2$ in *N*,*N*-diethylaniline) none of the expected 4-formamidoindole could be isolated from the reaction products.

(10) (a) Similarly, F. E. Ring, *J. Chem. Soc.*, 277 (1945), reported that hydrogenation of indole in ethanol at 100–110° at a maximum hydrogen pressure of 1500 psig in the presence of Ni(R) gave indoline, whereas reduction to octahydroindole accompanied by N-ethylation occurred at 150–160°. In dioxane solution the N-alkylation is avoided but the temperature required for indoline formation was higher (150–160°) and overreduction occurred at 200°. (b) B. Cardillo, G. Casnati, A. Pochini, and A. Ricca, *Tetrahedron*, **23**, 3771 (1967), have recently reported that alkylation of indole sodium salt with alkyl halides in tetrahydrofuran gives mixtures of 1, 1,3, 3, and 3,3 alkylated products, whereas when dimethylformamide is the solvent, only 1-alkyl indoles are produced.

Mercury derivatives of purines have been very useful in the synthesis of purine nucleosides through reaction with glycosyl halides.[11] Indole itself did not give a homogeneous mercury derivative when treated with $HgCl_2$ and sodium hydroxide in aqueous ethanol. The insoluble precipitates obtained varied in composition and the yields were not reproducible. In a reaction of one of these products with 2,3,5-tri-*O*-benzoyl-D-ribofuranosyl chloride (**20**) none of the desired product could be isolated. 4-Benzamidoindole in reaction with $HgCl_2$ gave a more satisfactory chloromercury derivative (**22**). However, when it reacted with the glycosyl halide (**20**), about 80% of 4-benzamidoindole was recovered unchanged. The fusion of poly-*O*-acyl sugars with various purines has been used successfully for the synthesis of purine nucleosides.[12] A similar reaction between 4-benzamidoindole and 1-*O*-acetyl-2,3,5-tri-*O*-benzoyl-D-ribofuranose did not produce any isolatable glycosyl indole.

Configurational Assignments.—Suranov and Preobrazhenshaya[2] assigned the β-anomeric configuration to their product, 1-(β-D-glucopyranosyl)indole (**3**) on the basis of (1) the "*trans*" rule, (2) the thermodynamic preference for the equatorial conformation of the indoline moiety which obtains in the β configuration whereas the aglucone in the α anomer is axial, and (3) the magnitude of the specific rotation of the product. The failure of the "*trans*" rule in nonheavy-metal condensations of nitrogenous aglucones with sugar derivatives has been well documented[13] in the case of the Hilbert–Johnson reaction. Point 2 ignores the so-called "anomeric effect"[14] which would predict greater thermodynamic stability for the α (C-1 indolinyl, axial) configuration. We have determined that the nmr spectrum of 1-β-D-glucopyranosyl)indole (**3**) obtained by the method of Suranov and Preobrazhenshaya and the magnitude of the spin–spin coupling constant ($J_{1',2'}$ = 8.5 cps) of the anomeric proton (τ 4.51 ppm) confirms the vicinal diaxial relationship of the C-1′ and C-2′ protons and hence the β configuration.

A similar measurement on 1-(β-D-ribopyranosyl)indole (**6**) indicates that it is also of the β configuration. However, the magnitude of the coupling constant (6.0 cps) of the C-1′ and C-2′ protons of 1-(β-D-ribofuranosyl)indole (**9**) is such that an anomeric configurational assignment cannot be made on this basis. In order to establish the β configuration of **9**, it was oxidized with sodium metaperiodate, and the optical rotation of the periodate oxidation solution was found to be identical (after adjusting for differences in molecular weight) with that obtained for the periodate oxidation product of 1-(β-D-glucopyranosyl)indole (**3**).[15] Identical optical rotations could only result if **9**, like **3**, was of the β configuration. As in the case of the unsubstituted ribosyl indole **9**, nmr measurements were not useful in determining the anomeric configuration of 4-amino-1(β-D-ribofuranosyl)indole. However, it seems entirely reasonable to assume that the same anomer would be produced in the reaction of 1-*O*-acetyl-2,3,5-tri-*O*-benzoyl-β-D-ribofuranose with 4-benzamidoindoline that was obtained with indoline. Additional information concerning the anomeric configuration of **12** was obtained from ORD measurements. Because of several overlapping ultraviolet absorption bands, the ORD curves of **3**, **6**, and **9** show multiple, but poorly resolved, Cotton effects in the range of 300 to 250 mμ. However, all of these curves show an over-all increase in negative rotation with decreasing wavelength in the range of 400 to 230 mμ. A similar, but better resolved, ORD curve was obtained for **12** and, as the β configurations of **3**, **6**, and **9** were determined independently, it indicates that **12** is also of the β configuration. From the limited data obtained from these four compounds, it appears that indole nucleosides may conform in general to the proposals advanced[16] for correlation of the ORD of purine nucleosides with their anomeric configuration.

Experimental Section[17]

1-(β-D-Glucopyranosyl)indole (3).—A solution of 4.5 g (10 mmoles) of 1-(2,3,4,6-tetra-*O*-acetyl-β-D-glucopyranosyl)indoline (**1**)[2] in 120 ml of dry xylene was treated with 2.27 g (10 mmoles) of 2,3-dichloro-5,6-dicyano-1,4-benzoquinone and refluxed for 2.5 hr. The reaction mixture was filtered and concentrated to 60 ml and cooled. The crystalline solid (4.3 g, mp 149.5–152°) was removed and recrystallized from 150 ml of ethanol. The yield of analytically pure 1-(2,3,4,6-tetra-*O*-acetyl-β-D-glucopyranosyl)indole, having properties identical with those reported previously,[2] was 4.1 g (91%). The product was deacetylated in methanolic sodium methoxide as previously described[2] giving a 75% yield of (**3**) as an analytically pure glass: R_f 0.8, tlc on cellulose in water; $[\alpha]_D$ −28°, $[\alpha]_{578}$ −32° (*c* 3.5, H_2O); [φ] (λ, mμ), −700° (400), −800° (350), −1000° (300), −4500° (250), −8000° (230) (fine structure between 300 and 350 mμ) (*c* 0.0042 H_2O); $\lambda_{max}^{H_2O}$ mμ (ε × 10^{-3}), 218 (33), 264 (6.0), 277 (4.9), 280 shoulder (4.6), 288 (3.0); nmr (D_2O) gave signals at τ 4.51 (doublet, C-1′ proton, $J_{1',2'}$ = 8.5 cps), 2.61 (doublet, C-2 proton), and 3.38 ppm (doublet, C-3 proton, $J_{2,3}$ = 3.0 cps).

1-(2,3,4-Tri-*O*-acetyl-β-D-ribopyranosyl)indoline (4).—A solution of 40 g (0.12 mole) of 1,2,3,4-tetra-*O*-acetyl-β-D-ribopyranose in 700 ml of hot ethanol was cooled to 40° and treated with 28 g (0.24 mole) of freshly distilled indoline and 36 ml of acetic acid. The solution was stirred at 25° while the course of the reaction was followed by tlc on silica gel in benzene–ethyl acetate (4:1). After 2 days the solution was concentrated to about 300 ml and the product (24.9 g) crystallized. A second crop (4 g) was obtained from the filtrate by crystallization followed by chromatography on silica gel in benzene–ethyl acetate (9:1). Recrystallization of the combined crops from ethanol gave 24.3 g (53%) of 1-(2,3,4-tri-*O*-acetyl-β-D-ribopyranosyl)indoline (**4**): mp 151–153°; $[\alpha]_D$ +76°, $[\alpha]_{578}$ +80° (*c* 1, $CHCl_3$); R_f 0.48, tlc on silica gel in benzene–ethyl acetate (4:1); λ_{max}^{Nujol} 5.70 and 5.79 μ (ester); λ_{max}^{EtOH} mμ (ε × 10^{-3}), 297.5 (2.47), 246 (10.9).

(11) J. Davoll and B. A. Lowy, *J. Am. Chem. Soc.*, **73**, 1650 (1951).

(12) T. Shimidate, Y. Ishido, and T. Sato, *Nippon Kagaku Zasshi*, **82**, 938 (1961).

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(15) The uptake of periodate was about 1 mole more than that calculated for the sugar moiety. This is in keeping with the known reactivity of periodate with indoles at the 2,3 position. See L. J. Dolby and D. L. Booth, *J. Am. Chem. Soc.*, **88**, 1049 (1966).

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(17) Microanalyses were performed by Mr. R. N. Boos and his associates, and ultraviolet spectral measurements were done by Mr. E. A. MacMullin and his associates. The nmr spectra were determined by Dr. B. Arison on a Varian Associates Model A-60 spectrometer. All melting points were taken on a micro hot stage and are corrected. Tlc was done on plates of silica gel G, aluminum oxide G, and MN cellulose powder. With sugar derivatives, zones were made visible by spraying the plates with a solution of 100 mg of 1,3-dihydroxynaphthalene in 50 ml of ethanol containing 2.5 ml of H_3PO_4 and warming them on the steam cone until the colors developed. For the indoles the zones were observed after spraying with a dilute solution of $KMnO_4$ in water. Unless noted otherwise all concentrations were carried out in a rotary evaporator at reduced pressure. Fritted-glass Büchner funnels of medium porosity were used for column chromatographic separations, wherein the silica gel (J. T. Baker, 100–200 mesh) packing had a height to diameter ratio of about 1:1.

Anal. Calcd for $C_{19}H_{23}NO_7$: C, 60.47; H, 6.14; N, 3.71. Found: C, 60.77; H, 6.06; N, 3.69.

1-(2,3,4-Tri-*O*-acetyl-β-D-ribopyranosyl)indole (5).—A solution of 12 g (32 mmoles) of **4** in 300 ml of dry xylene was treated with 7.9 g (35 mmoles) of 2,3-dichloro-5,6-dicyano-1,4-benzoquinone. The mixture was heated at the reflux temperature while the course of the reaction was followed by tlc on silica gel in benzene–ethyl acetate (4:1). The mixture was heated for 2.5 hr although there was little indication of change in composition after 15 min. The hot mixture was filtered and the filtrate was concentrated to about 150 ml. After being kept at 5° for several hours, the crystalline product (11 g, mp 161–165°) was removed. Two recrystallizations from 200 ml of ethanol gave 9.4 g (79%) of 1-(2,3,4-tri-*O*-acetyl-β-D-ribopyranosyl)indole (**5**): mp 169–171°; R_f 0.70, tlc on silica gel in benzene–ethyl acetate (4:1); $[\alpha]_D$ +40°, $[\alpha]_{578}$ +43° (*c* 1, $CHCl_3$); λ_{max}^{EtOH} mμ (ε × 10^{-3}), 288 (2.88), 276 (5.40), 264 (7.24), 220 (41.5).

Anal. Calcd for $C_{19}H_{21}NO_7$: C, 60.79; H, 5.64; N, 3.73. Found: C, 60.86; H, 5.60; N, 4.02.

1-(β-D-Ribopyranosyl)indole (6).—A suspension of 6 g (16 mmoles) of **5** in 100 ml of dry methanol was treated with a solution prepared from 0.37 g of sodium and 150 ml of dry methanol. The solution was refluxed for 1 hr although no appreciable change in the ultraviolet absorption spectrum was noted after 20 min. The solution was concentrated and the residue was dissolved in a mixture of 40 ml of methanol and 10 ml of ether. Carbon dioxide was passed through the cooled solution for 1 hr and the precipitated $NaHCO_3$ (1.2 g) was removed by filtration. The filtrate was concentrated and the residue (4.0 g) was dissolved in 100 ml of water and extracted with five 100-ml portions of methylene chloride. A third, oily phase which separated during the first extraction disappeared as the extractions were continued. The combined methylene chloride layers were washed with water and dried. Concentration of the solution gave 1.5 g (38%) of 1-(β-D-ribopyranosyl)indole (**6**) as a glass: $[\alpha]_D$ −20°, $[\alpha]_{578}$ −21° (*c* 1, CH_2Cl_2); $[\phi]$ (λ, mμ), −500° (400), −600° (350), −1000° (300), −1800° (250), −2000° (230) (fine structure between 300 and 250 mμ) (*c* 0.0049, H_2O); R_f 0.84, tlc on cellulose in water; $\lambda_{max}^{H_2O}$ mμ (ε × 10^{-3}), 286 infl (3.06), 276 infl (5.15), 265 (6.30), 218 (31.9); nmr (D_2O) signals appeared at τ 4.33 ppm (doublet, C-1′ proton, $J_{1',2'}$ = 9.0 cps).

Anal. Calcd for $C_{13}H_{15}NO_4$: C, 62.64; H, 6.07; N, 5.62. Found: C, 62.40; H, 6.30; N, 5.33.

Further extractions of the water layer from above with six 100-ml portions of methylene chloride gave an additional 1.2 g (68% total yield) of **6**.

1-(2,3,5-Tri-*O*-benzoyl-β-b-ribofuranosyl)indoline (7).—A solution of 6 g (11.8 mmoles) of 1-*O*-acetyl-2,3,5-tri-*O*-benzoyl-β-D-ribofuranose in 60 ml of warm ethanol was refluxed with 4.2 g (35.6 mmoles) of indoline and 4.2 ml of acetic acid. The reaction was followed by tlc on silica gel in benzene–ethyl acetate (19:1). After 6.5 hr, the reaction was judged to be complete and the ethanol was removed. The residue in 125 ml of chloroform was washed with two 50-ml portions of 10% $NaHCO_3$ and two 50-ml portions of water, and concentration of the dried solution gave 11 g of residual oil. The oil was chromatographed on 220 g of silica gel using benzene–ethyl acetate (19:1) as the eluant. Fractions containing mostly product (R_f 0.48, tlc) were combined and gave 3.9 g of an oil. After treatment, in ethanol, with a small amount of decolorizing carbon, the solvent was removed and the residual oil (3.4 g) was rechromatographed on 85 g of silica gel using benzene as the eluent. This process removed some minor impurities and gave 3.0 g (45%) of 1-(2,3,5-tri-*O*-benzoyl-β-D-ribofuranosyl)indoline as a glass: $[\alpha]_D$ −26°, $[\alpha]_{578}$ −27° (*c* 6, $CHCl_3$); λ_{max}^{EtOH} mμ (ε × 10^{-3}), 292.5 (2.8), 282 (4.3), 275 (4.4), 231 (41.6).

Anal. Calcd for $C_{34}H_{29}NO_7$: C, 72.45; H, 5.19; N, 2.49. Found: C, 72.32; H, 5.38; N, 2.60.

1-(2,3,5-Tri-*O*-benzoyl-β-D-ribofuranosyl)indole (8).—A solution of 2.8 g (5 mmoles) of **7** in 90 ml of dry xylene was treated with 1.14 g (5 mmoles) of 2,3-dichloro-5,6-dicyanobenzoquinone. The deep red mixture was refluxed. Periodically samples of the reaction mixture were examined by tlc on silica in benzene–ethyl acetate (19:1). The spray reagent[17] produced a gray-blue color with the starting material whereas the product gave an orange color. Although the R_f of the product (0.53) was very close to that of the starting material (0.48), the difference in color allowed the course of the reaction to be followed. After 5 hr, the reaction mixture was cooled and filtered, and the filtrate was concentrated. The residual oil (3 g) was chromatographed on 75 g of silica gel in benzene–ethyl acetate (19:1). Concentration of the fractions containing product gave 2.2 g (78%) of 1-(2,3,5-tri-*O*-benzoyl-β-D-ribofuranosyl)indole as a glass: $[\alpha]_D$ −57°, $[\alpha]_{578}$ −60° (*c* 1, $CHCl_3$); λ_{max}^{EtOH} mμ (ε × 10^{-3}), 289 (3.8), 266 (9.8), 222.5 (55.8).

Anal. Calcd for $C_{34}H_{27}NO_7$: C, 72.72; H, 4.85; N, 2.49. Found: C, 72.71; H, 4.99; N, 2.97.

1-(β-D-Ribofuranosyl)indole[4a] (9).—A suspension of 650 mg (1.5 mmoles) of 1-(2,3,5-tri-*O*-benzoyl-β-D-ribofuranosyl)indole in 10 ml of dry methanol was treated with a solution from 28 mg (1.2 mmole) of sodium in 15 ml of methanol and the mixture was refluxed for 1 hr. Periodic examination of the ultraviolet absorption spectrum of samples of the reaction mixture indicated that the methanolysis was practically complete after 5 min. The methanol was concentrated and 25 ml of ether and 10 ml of water was added to the residue. Carbon dioxide was bubbled through the mixture for 1 hr after which the aqueous phase was pH 7. The ether layer was removed and the aqueous layer was extracted with three 10-ml portions of ether. The ether extracts were concentrated and the product (200 mg, 70%; mp 140–145°) crystallized. Recrystallization from water gave analytically pure 1-(β-D-ribofuranosyl)indole: mp 143–145°; $[\alpha]_D$ −94°, $[\alpha]_{578}$ −99° (*c* 1, H_2O); $[\phi]$ (λ, mμ), −630° (400), −960° (350), −1860° (300), −3920° (250) (fine structure between 300 and 250 mμ) (*c* 0.0064, H_2O); $\lambda_{max}^{H_2O}$ mμ (ε × 10^{-3}), 287.5 (3.3), 276 (5.3), 264 (6.4), 218 (32.7); tlc on silica in methanol, R_f 0.77; on cellulose in methanol, R_f 0.72; nmr (D_2O) signals appeared at τ 3.98 (doublet, C-1′ proton, $J_{1',2'}$ = 5.0 cps).

Anal. Calcd for $C_{13}H_{15}NO_4$: C, 62.64; H, 6.07; N, 5.62. Found: C, 62.73; H, 6.03; N, 5.63.

4-Aminoindole (13).—A mixture of 35 g (0.179 mole) of 4-chloroindole-2-carboxylic acid (**14**),[7] 600 ml of concentrated NH_4OH, and 3 g of Cu_2Cl_2 was heated at 270° in a pressure vessel for 4 hr. The reaction mixture was cooled and extracted with four 300-ml portions of ether. Concentration of the dried ($MgSO_4$) ether solution gave a residue (25 g) of very dark-colored product, mp 103–109°. This was combined with similar material obtained from a reaction using 32 g (0.164 mole) of 4-chloroindole-2-carboxylic acid and recrystallized from 300 ml of benzene. 4-Aminoindole (mp 104–107°, 28.4 g, 63%) suitable for use in the next step was obtained. Sublimation of a 420-mg sample gave 360 mg of purified **13**: mp 105–107°; λ_{max}^{EtOH} mμ (ε × 10^{-3}), 272.5 (9.93), 223 (33.6).

Anal. Calcd for $C_8H_8N_2$: C, 72.70; H, 6.10; N, 21.20. Found: C, 72.57; H, 5.90; N, 21.17.

4-Benzamidoindole (15).—A mixture of 28 g (0.21 mole) of **13** and 69.6 g (0.42 mole) of benzoic anhydride was heated to 150° for 15 min. A clear melt was obtained at approximately 140°. The melt was cooled to about 100° and 250 ml of ethanol was carefully added and the solution was refluxed for 15 min. After the solution was cooled in an ice bath several hours, 32 g of 4-benzamidoindole, mp 194.5–196°, was obtained. A second crop (5 g), contaminated with benzoic acid, was obtained from the filtrate after concentration to 100 ml. This material was leached with hot chloroform to remove the benzoic acid and gave an additional 3 g (total yield 70%) of **15**.

For analysis, a 1-g sample was recrystallized from 15 ml of ethanol and gave 900 mg of pure 4-benzamidoindole: mp 195–196°; λ_{max}^{EtOH} mμ (ε × 10^{-3}), 297.5 (8.8), 218 (40.6); λ_{max}^{Nujol} −3.0 (NH), 6.1 μ (CONH); R_f 0.59, tlc on silica gel in chloroform–ethyl acetate (7:3).

Anal. Calcd for $C_{15}H_{12}N_2O$: C, 76.25; H, 5.12; N, 11.86. Found: C, 76.00; H, 5.04; N, 11.83.

4-Benzamido-1-benzoylindole (16).—A solution of 0.5 g (3.8 mmoles) of **13** in 5 ml of pyridine was treated with 0.83 ml (7.6 mmoles) of benzoyl chloride and refluxed for 15 min. The solution was concentrated and chloroform, water, and ice were added to the residue. The chloroform layer was separated and washed with dilute HCl, dilute $NaHCO_3$, and water. The chloroform was removed and the residue was refluxed with ethanol for 10 min. Concentration of the ethanol solution to 25 ml gave 500 mg (40%) of 4-benzamido-1-benzoylindole: mp 220–225°; λ_{max}^{Nujol} 2.95 (NH) and 5.98 μ (CONH). For analysis a sample was recrystallized from ethanol.

Anal. Calcd for $C_{22}H_{16}N_2O_2$: C, 77.63; H, 4.74; N, 8.23. Found: C, 77.45; H, 4.85; N, 8.34.

4-Acetamidoindole (17).—A solution of 250 mg (1.9 mmoles) of **13** in 2 ml of pyridine was treated with 300 mg (3 mmoles) of acetic anhydride. After being stirred at room temperature for 30 min, the reaction mixture was poured into 5 ml of ice water

and the aqueous solution was extracted with four 5-ml portions of ether. The ether extracts were washed with dilute HCl, dilute $NaHCO_3$, and water. Concentration of the ether layer yielded a residue of only 100 mg of **17**. The HCl washes from above were made alkaline with NH_4OH solution and extracted with ether. Concentration of the ether extracts gave an additional 200 mg (total 90%) of crude **17**. Recrystallization from ethanol for analysis gave pure 4-acetamidoindole: mp 154–156°; λ_{max}^{Nujol} 3.1 (NH) and 6.15 μ (CONH); R_f 0.71, tlc on silica gel in ethyl acetate.

Anal. Calcd for $C_{10}H_{10}N_2O$: C, 68.95; H, 5.79; N, 16.08. Found: C, 68.13; H, 5.74; N, 16.60.

4-Benzamidoindoline (18).—A mixture of 15 g (0.063 mole) of 4-benzamidoindole (**15**), 15 g of Raney nickel (washed with dioxane), and 300 ml of dioxane was heated to 125° and shaken with hydrogen at 1500–2000 psig for 1 hr. The catalyst was removed and examination of the filtrate by tlc, on silica gel in chloroform–ethyl acetate (7:3), indicated that the reduction was not complete. Another 15 g of Raney nickel was added and the mixture was shaken as before for an additional hour. The catalyst was removed, the residue was dissolved in acetone, and 125 g of silica gel was added. The solvent was concentrated and the residue (a dry powder) was added to the top of 1000 g of silica gel and chromatographed in chloroform–ethyl acetate (7:3). Elution of the column gave fractions containing 2.8 g of 4-benzamidoindole, then fractions containing 9 g (60%) of 4-benzamidoindoline (**18**), mp 147–157°. Recrystallization of a 1-g sample of **18** from 35 ml of benzene gave 0.9 g of analytically pure 4-benzamidoindoline: mp 157–160°; λ_{max}^{Nujol} 3.03 (NH) and 6.03 μ (CONH); λ_{max}^{EtOH} mμ ($\epsilon \times 10^{-3}$), 237.5 shoulder (13.1); R_f 0.35, tlc on silica in chloroform–ethyl acetate (7:3).

Anal. Calcd for $C_{15}H_{14}N_2O$: C, 75.60; H, 5.92; N, 11.76. Found: C, 75.68; H, 5.80; N, 11.62.

1-(2,3,5-Tri-*O*-benzoyl-β-D-ribofuranosyl)-4-benzamidoindoline (10).—A solution of 8 g (33 mmoles) of 4-benzamidondoline (**18**) and 8.3 g (16.5 mmoles) of 1-*O*-acetyl-2,3,5-tri-*O*-benzoyl-β-D-ribofuranose in 340 ml of ethanol at 80° was treated with 0.8 ml of acetic acid and the mixture was refluxed for 3 days. Tlc on silica in benzene–ethyl acetate (4:1) indicated that no further change in the composition of the reaction products occurred after 3 days. The solution was concentrated to about 100 ml and the solid (6.9 g) which precipitated was removed. Chromatography of this solid gave 3 g of unreacted 1-*O*-acetyl-2,3,5-tri-*O*-benzoyl-β-D-ribofuranose and 3 g of 1-acetyl-4-benzamidoindoline, mp 187–188°.

Anal. Calcd for $C_{17}H_{16}N_2O_2$: C, 72.84; H, 5.75; N, 9.99. Found: C, 72.47; H, 5.32; N, 9.94.

The ethanol filtrate obtained after removal of the 6.9 g of solid was concentrated and the semisolid residue was dissolved in ethyl acetate and 100 g of silica gel was added. Concentration of this mixture gave, after complete removal of solvent, a dry powder which was added to the top of 1000 g of silica gel. Elution with benzene–ethyl acetate (4:1) gave fractions which contained 1 g of 1-*O*-acetyl-2,3,5-tri-*O*-benzoyl-β-D-ribofuranose, followed by fractions which yielded 5.4 g of semisolid **10**. Crystallization of this material from ether gave 3.2 g (29%) of 1-(2,3,5-tri-*O*-benzoyl-β-D-ribofuranosyl)-4-benzamidoindoline (**10**): mp 163–165°; λ_{max}^{Nujol} 2.99 (NH), 5.78 (COOR), and 6.0 μ (CONH); λ_{max}^{EtOH} mμ ($\epsilon \times 10^{-3}$), 231 (56.0); $[\alpha]_D$ −68°, $[\alpha]_{578}$ −72° (*c* 1, $CHCl_3$); R_f 0.59, tlc on silica in benzene–ethyl acetate (4:1).

Anal. Calcd for $C_{41}H_{34}N_2O_8$: C, 72.13; H, 5.02; N, 4.10. Found: C, 71.99; H, 4.91; N, 4.31.

1-(2,3,5-Tri-*O*-benzoyl-β-D-ribofuranosyl)-4-benzamidoindole (11).—A solution of 3 g (4.4 mmoles) of 1-(2,3,5-tri-*O*-benzoyl-β-D-ribofuranosyl-4-benzamidoindoline in 90 ml of dry xylene at 90° was cooled to 25° and treated with 1 g (4.4 mmoles) of 2,3-dichloro-5,6-dicyano-1,4-benzoquinone. The mixture became dark red, but after heating to reflux the color changed to light brown while a brown solid precipitated from solution. The course of the reaction was followed by tlc on silica gel in benzene–ethyl acetate (4:1) and no further change was noted after 1.5 hr. The reaction mixture was cooled to room temperature and the dark brown solid was removed. The filtrate was concentrated and the residue was chromatographed on 100 g of silica gel in benzene–ethyl acetate (4:1). Fractions containing the desired product were pooled and concentrated. The residue (2.1 g) was crystallized from 20 ml of benzene and 850 mg (28%) of product (mp 161–165°) was obtained. Recrystallization from ethyl acetate–petroleum ether gave 700 mg of 1-(2,3,5-tri-*O*-benzoyl-β-D-ribofuranosyl)-4-benzamidoindole (**11**): mp 163–165°; $[\alpha]_D$ −112°, $[\alpha]_{578}$ −118° (*c* 1, $CHCl_3$); λ_{max}^{Nujol} 2.95 (NH), 5.78 (COOR), 6.01 μ (CONH); λ_{max}^{EtOH} mμ ($\epsilon \times 10^{-3}$), 295 shoulder (10.9), 283 (12.5), 277.5 shoulder (12.0), 226 (64.6); R_f 0.60, tlc on silica in benzene–ethyl acetate (4:1).

Anal. Calcd for $C_{41}H_{32}N_2O_8$: C, 72.34; H, 4.74; N, 4.11. Found: C, 72.14; H, 4.65; N, 4.25.

1-(β-D-Ribofuranosyl)-4-aminoindole (12).—A suspension of 600 mg (0.88 mmole) of **11** in 60 ml of water and 19.2 g of $Ba(OH)_2 \cdot 8H_2O$ was heated and shaken in a pressure vessel[18] for 16 hr at 130°. The reaction was cooled and the precipitated $Ba(OH)_2$ was removed by filtration and the filtrate was concentrated to a small volume. The insoluble salts were removed and the filtrate was concentrated to dryness. The residue was leached with several portions of 2-propanol. Concentration of the 2-propanol gave a residue (131 mg) which contained the product. By leaching the insoluble salts above in a similar manner with 2-propanol an additional 78 mg of crude product was obtained. The combined product was chromatographed in ethyl acetate on 11 g of silica gel. Combination of those fractions containing only the desired product and concentration of the solvent gave a residue (93 mg, 40%) of 1-(β-D-ribofuranosyl)-4-aminoindole as an amorphous solid. For analysis, a sample was dried at 60° and reduced pressure to constant weight: tlc on cellulose in water showed only one zone, R_f 0.8; $[\alpha]_D$ −46°, $[\alpha]_{578}$ −49° (*c* 1, MeOH); $[\phi]$ (λ, mμ), −520° (400), −1800° (307) tr, −1250° (290) pk, −1760° (277) tr, −740° (261) pk, −1390° (250) (*c* 0.005, H_2O); $\lambda_{max}^{H_2O}$ mμ ($\epsilon \times 10^{-3}$) (pH 1), 219 (35.8), 268 (7.0), 275 (6.7), 286 infl (4.8); (pH 7), 210 infl (22.4), 223 (31.3), 269 (8.0), 293 (5.8), 297 shoulder (5.7); (pH 13), 224 (30.2), 270 (7.8), 293 shoulder (6.1), 297 (6.1); an nmr (D_2O) signal was observed at τ 3.98 ppm (doublet, C-1′ proton, $J_{1',2'}$ = 5.5 cps).

Anal. Calcd for $C_{13}H_{16}N_2O_4$: C, 59.08; H, 6.10; N, 10.60. Found: C, 59.57; H, 6.14; N, 10.47.

Periodate Titrations. A.—A solution of 50 mg (0.179 mmole) of 1-(β-D-glucopyranosyl)indole (**3**) in 1 ml of water was treated with 6 ml of 0.197 *N* $NaIO_4$ solution. The optical rotation of the solution was constant after 30 min: $[\alpha]_D$ −73° (*c* 0.714), $[\alpha]_M$ −20,400°. A 1-ml aliquot of the solution was added to 10 ml of saturated $NaHCO_3$ and 6.08 ml of 0.382 *N* $NaAsO_2$ and 2 ml of 20% KI solution were added. Titration with 0.0918 *N* I_2 solution revealed that the oxidation of **3** required 2.8[15] equiv of periodate.

B.—A solution of 25 mg (0.1 mmole) of 1-β-D-ribofuranosylindole (**9**) in 1.5 ml of water was treated with 1.5 ml of 0.197 *N* $NaIO_4$. The optical rotation became constant after a few minutes, $[\alpha]_D$ −98° (*c* 0.832). One-half of the solution was treated with 0.1 ml of water containing 2.3 mg (0.05 mmole) of formic acid: $[\alpha]_D$ −82° (*c* 0.777), $[\alpha]_M$ −20,500°. Titration of the rotation solution as above revealed that 1.8 equiv[15] of $NaIO_4$ was required in the oxidation.

Registry No.—**3**, 5059-37-0; **4**, 4613-26-7; **5**, 4627-31-0; **6**, 7660-91-5; **7**, 15040-72-9; **8**, 15040-73-0; **9**, 15040-74-1; **10**, 15040-75-2; **11**, 15040-76-3; **12**, 15040-77-4; **13**, 5192-23-4; **15**, 5192-24-5; **16**, 15040-80-9; **17**, 15040-81-0; **18**, 15040-82-1; 1-acetyl-4-benzamidoindoline, 15156-51-1.

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(18) A polyethylene liner was used.