[Chem. Pharm. Bull. 34(1) 15—23 (1986)]

Synthesis of 2′-Deoxy-8,2′-ethanoadenosine and 3′-Deoxy-8,3′-ethanoadenosine (Nucleosides and Nucleotides. LXIV[1])

HIROYUKI USUI and TOHRU UEDA*

Faculty of Pharmaceutical Sciences, Hokkaido University, Kita-12, Nishi-6, Kita-ku, Sapporo 060, Japan

(Received May 1, 1985)

2′-Deoxy-8,2′-ethanoadenosine and its 3′-isomer were synthesized from 2′- and 3′-keto-adenosine derivatives. Treatment of 3′,5′-*O*-(tetraisopropyldisiloxane-1,3-diyl)-2′-ketoadenosine with ethoxycarbonylmethylenetriphenylphosphorane gave the 2′-ethoxycarbonylmethylene derivative, which was reduced to the 2′-hydroxyethyl derivative. This compound was converted to the 2′-iodoethyl-N^6,N^6-dibenzoyladenosine, which was cyclized by treatment with tri-*n*-butyltin hydride, then deprotected to furnish 2′-deoxy-8,2′-ethanoadenosine. Photocyclization of a 2′-phenylthioethyl derivative also gave the ethano-cycloadenosine. 3′-Deoxy-8,3′-ethanoadenosine was prepared from 2′,5′-di-*O*-(*tert*-butyldimethylsilyl)-3′-ketoadenosine *via* 2′,5′-di-*O*-acetyl-3′-deoxy-3′-phenylthio-ethyladenosine by photocyclization. The circular dichroism spectral features of these cyclo-adenosines are presented.

Keywords——*C*-cycloadenosine; 2′-deoxy-8,2′-ethanoadenosine; 3′-deoxy-8,3′-ethanoadenosine; nucleosides conformation; Wittig reaction; photoreaction; NMR; CD

We are currently interested in the synthesis of carbon-bridged cyclonucleosides and their phosphates as model compounds of fixed conformations of nucleosides and nucleotides. Among the purine nucleosides, we have synthesized 8,5′-cyclo derivatives of adenosine, inosine and guanosine.[2] More recently, we have developed methods for the synthesis of 6,5′(and 2′)-methano- and ethano-cyclouridines.[3] In order to obtain information on the interaction of purine nucleosides or nucleotides with the enzymes utilizing them, purine cyclonucleosides in which the glycosyl torsion angles are fixed at particular values are required. This paper describes the synthesis of 2′-deoxy-8,2′-ethanoadenosine and its 8,3′-cyclo isomer. A preliminary account of this work has appeared.[4]

In the synthesis of 2′-deoxy-6,2′-ethanouridine,[3b] we used 2′-deoxy-2′-hydroxy-ethyluridine, which was prepared from a 2′-ketouridine, for the 6,2′-bridging. This route may also be adaptable for the present purpose.

Treatment of 3′,5′-*O*-(tetraisopropyldisiloxane-1,3-diyl)adenosine (**1**)[5]with acetic anhydride and dimethylsulfoxide (DMSO) gave the 2′-keto derivative (**2**), which was condensed with ethoxycarbonylmethylenetriphenylphosphrane to afford the 2′-ethoxycarbonylmethyl-ideneadenosine (**3**) in an amorphous form in a yield of 74% from **1**. The signal due to the H-1′ proton in the nuclear magnetic resonance (NMR) spectrum of **3** appeared as a triplet, which may be due to long-range coupling with the protons at the 3′ position and at the 2′-methylene group with the same coupling constants ($J=1.7$ Hz). Although the configuration at the 2′-exomethylene carbon remains undetermined, there seemed to be only one isomer of **3**. Treatment of **3** with sodium borohydride in ethanol afforded the 2′-ethoxycarbonylmethyl derivative (**4**) in 42% yield along with the 2′-hydroxyethyl (**5**) and 2′-hydroxyethylidene (**6**) derivatives. Compound **4** was further converted to **5** by treatment with lithium aluminum hydride in tetrahydrofuran (THF). The structure of **4** was confirmed on the basis of the spectroscopic data. The *S*-configuration at C-2′ of **4** is assumed, since the hydride attack on **3**

should occur from the alpha side, as in the case of 2′-ethoxycarbonylmethyluridine.[3b] Compound **5** was treated with methanesulfonyl chloride (MsCl) at low temperature and the product was benzoylated to give the N^6,N^6-dibenzoyl derivative. This N^6-protection seemed to be critical in order to preclude cyclonucleoside formation between N-3 and the mesyloxy function at the 2′-position in the next step.

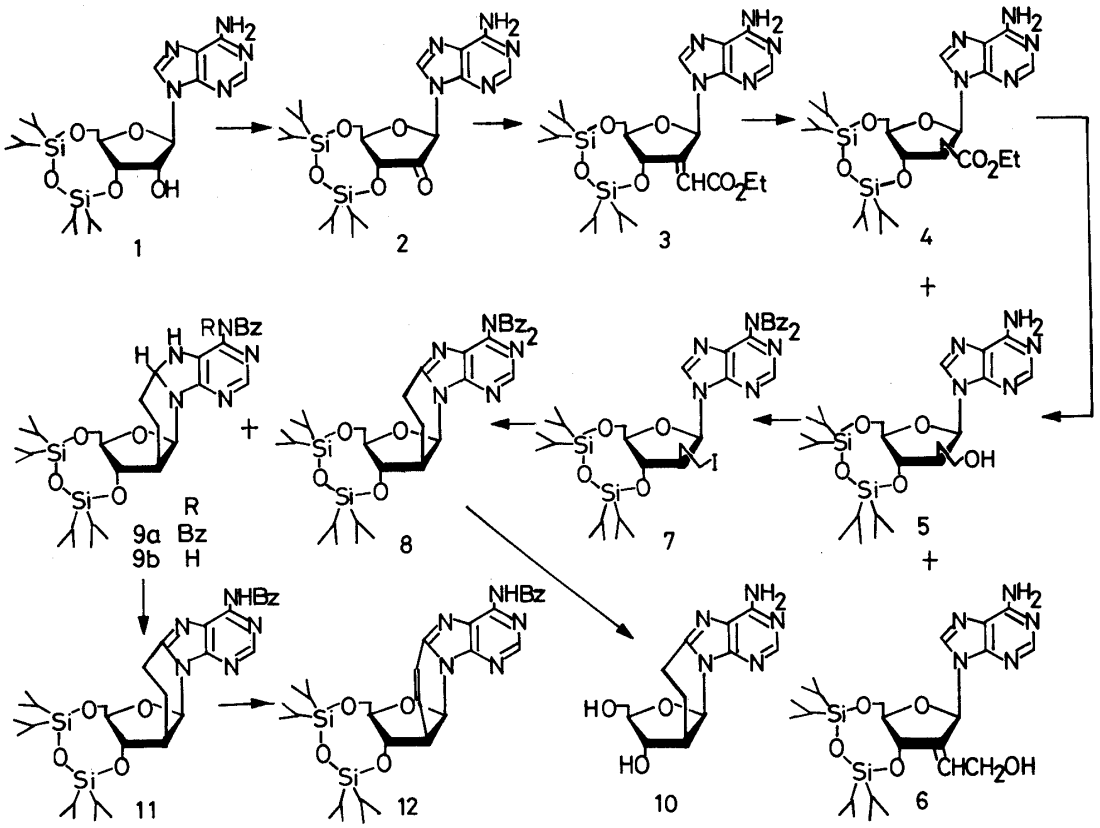

Chart 1

The compound was then treated with lithium iodide in 2-butanone to furnish the 2′-iodoethyl derivative (**7**) as a foam. The dropwise addition of a mixture of tri-*n*-butyltin hydride and azobisisobutyronitrile (AIBN) to a benzene solution of **7** under reflux resulted in cyclization to afford the 8,2′-ethanoadenosine (**8**), which was isolated in a yield of 36% as crystals. The 7,8-dihydro derivative (**9a**) of **8** was also formed, and its identity was confirmed as the N^6-monobenzoate (**9b**). The structure of **8** was confirmed by NMR measurement (the proton at H-8 had disappeared). Deprotection of **8** with ammonia followed by tetra-*n*-butylammonium fluoride furnished 2′-deoxy-8,2′-ethanoadenosine (**10**) as crystals. The structure of **10** was fully confirmed by elemental and instrumental analyses, including an X-ray diffraction analysis.[6] Dehydrogenation of **9b** by treatment with Pd–carbon in refluxing toluene gave the N^6-monobenzoate (**11**) of **8** in good yield. Oxidation of **9b** with dichlorodicyanobenzoquinone (DDQ) also gave **11** along with by-products, one of which was assumed to be the 8,2′-etheno derivative (**12**). In fact, compound **12** was produced by dehydrogenation of **11** with DDQ.

Since radical attack to form the carbon bridge from C-8 of adenosines by the use of the butyltin hydride always produced the 7,8-dihydroadenosines, as shown in the synthesis of 5′-deoxy-8,5′-cycloadenosine,[7] photochemical radical generation from the phenylthioalkyl group in the sugar portion[2a] seemed to be more promising. Compound **5** was mesylated and the product was treated with potassium thiophenoxide to give the 2′-phenylthioethyl

derivative (**13**, Chart 2) as an amorphous form. Compound **13** was irradiated with a low-pressure Hg lamp in the presence of trimethyl phosphite.[2a] The product was isolated in 60% yield in a crystalline form and the structure was assigned as **14**. In this reaction, formation of the 7,8-dihydro derivative was not observed. Desilylation of **14** gave **10** in good yield. Therefore it appears that bridge formation in purine nucleosides is best achieved by photolysis.

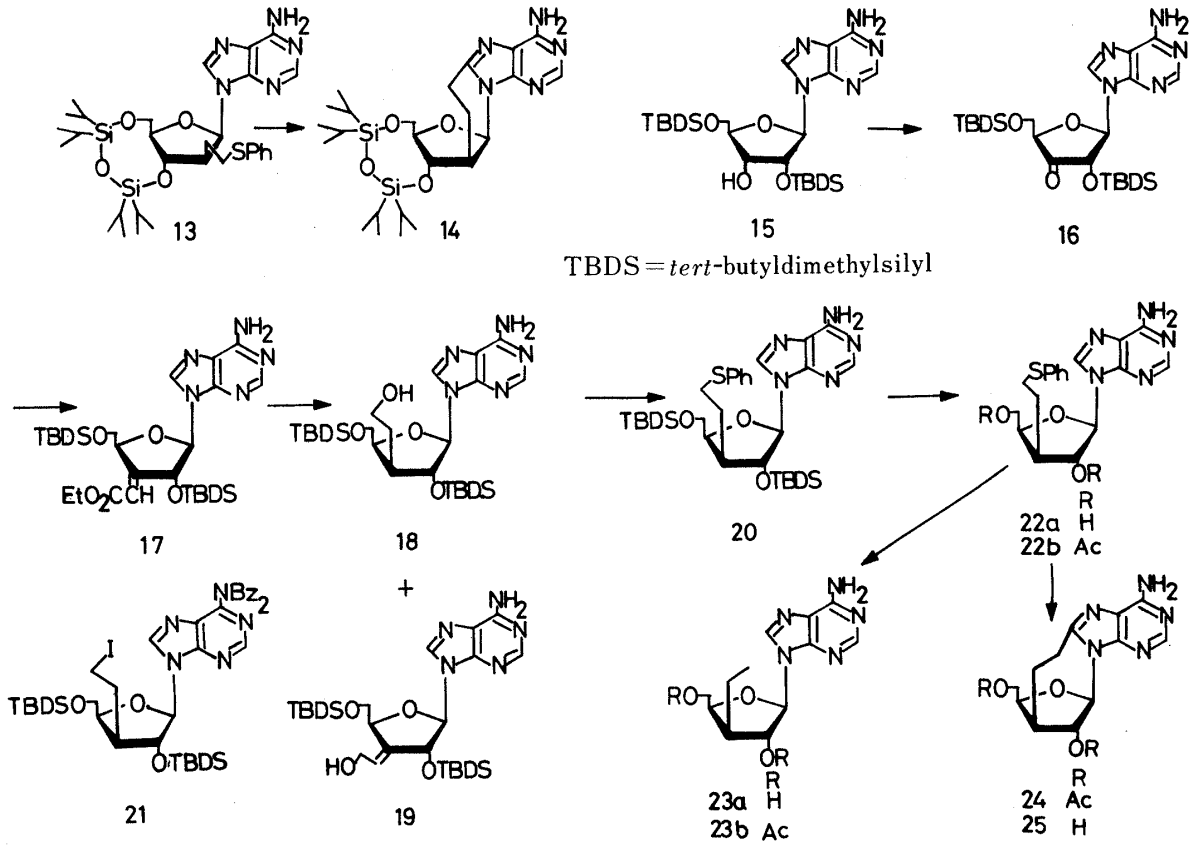

Chart 2

Synthesis of the 8,3′-ethano-cyclo derivative was next undertaken. Treatment of 2′,5′-di-*O*-(*tert*-butyldimethylsilyl)adenosine (**15**)[8] with acetic anhydride and DMSO afforded the 3′-ketoadenosine (**16**) in a yield of 40%. A recently reported method[9] of oxidation of **15** with chromic trioxide–pyridine was not satisfactory for the large-scale preparation of **16** in our hands. Compound **16** was condensed with ethoxycarbonylmethylenetriphenylphosphorane in THF to afford the 3′-ethoxycarbonylmethylideneadenosine (**17**) in high yield. The structure of **17** was deduced by NMR analysis, which showed that there was a single product, although the configuration at the 2′-exomethylene group of **17** was uncertain. Treatment of **17** with an excess of sodium borohydride in ethanol gave a mixture of the 3′(*S*)-hydroxyethyl derivative (**18**) and the 3′-hydroxyethylidene derivative (**19**) in a ratio of 4:1. Although the initial formation of the 3′-ethoxycarbonylmethyl derivative was observed as an intermediate of the conversion of **17** to **18**, separation was not attempted and further reduction to **18** was performed.

The *S*-configuration of the 3′-position of **18** was deduced from the NMR spectrum. The coupling constant of H-2′ and H-3′ was large ($J = 9.3$ Hz), which is possible only in the *trans* orientation of both protons. A mixture of **18** and **19** was treated with mesyl chloride, then with potassium *tert*-butoxide and thiophenol, and the product was separated to give the 3′-phenylthioethyl derivative (**20**). Photoirradiation of **20**, however, did not give the cyclo

derivative and the starting material was recovered. The 3′-iodoethyl derivative (**21**), obtained by the mesylation of **18** and further benzoylation and replacement of the product with lithium iodide, was also found to be unreative under the conditions used for radical cyclization by treatment with the butyltin hydride and AIBN. Although the inertness of **20** and **21** is unexpected, the hindrance due to the bulkiness of the silyl functions is presumably responsible.

Therefore, **20** was de-silylated in the usual manner to give 3′-deoxy-3′-phenylthioethyladenosine (**22a**). Photo-irradiation of **22a** for 2 h gave a product which was separated by preparative thin layer chromatography (PTLC). The NMR spectrum of the product (**23**) showed methyl protons at δ 0.99 (triplet) and the H-8 proton was also detected (δ 8.35, singlet). Therefore, the product **23** was not the cyclo compound but merely the reduced product, 3′-deoxy-3′(*S*)-ethyladenosine. The free hydroxyl groups in **22a** may be the hydrogen source for the photo-reduction. Then, compound **22a** was acetylated to give **22b**, which was photoirradiated in acetonitrile at room temperature. Two products could be separated on PTLC and the faster-migrating product (**23b**, 36%) was confirmed to be the diacetate of **23a** on the basis of NMR measurement. The slower migrating product (**24**, 16%) was confirmed to be the expected product, 2′,5′-di-*O*-acetyl-3′-deoxy-8,3′-ethanoadenosine, based on NMR and mass spectral analyses. Irradiation of **22b** in acetonitrile at reflux temperature improved the yield of **24** to 40%. Deacetylation of **24** by using triethylamine in methanol afforded 3′-deoxy-8,3′-ethanoadenosine (**25**) in a crystalline form. Since the quantity of the final product was very small, the crystals of **25** were stored for the X-ray diffraction analysis.

The circular dichroism (CD) spectrum of **10** showed the presence of a weak positive band at 255 nm. The glycosyl torsion angle of **10** determined by the X-ray analysis was 104°, showing the *exo*-puckering of the 8,2′-ethano bridge. This is in contrast with the result for 2′-deoxy-6,2′-ethanouridine,[10] whose puckering of the ethano bridge was in the *endo* mode.

Although the shape of the crystals of **25** was not suitable for X-ray diffraction analysis, and therefore the glycosyl torsion angle of **25** was not directly determined, the CD spectra of **25** showed a negative band at 255 nm, which suggests the glycosyl torsion angle to be close to 50°. From the coupling constant of H-3′ and the adjacent methylene protons of **25** and examination of molecular models of two possible conformers, the 8,3′-ethano bridge is assumed to be in an *endo*-puckering mode, which is consistent with the conformation expected from the CD spectrum. 5′-Deoxy-8,5′-cycloadenosine exhibits a strongly negative CD spectrum,[2b] and it can be stated that anti-fixed adenosines having a glycosyl torsion angle of up to 50° show a negative band in the major absorption region.

For further investigations on the correlation of CD spectral sign and magnitude with glycosyl torsion angles, synthesis of 8,2′-methanoadenosines would be crucial, and this will be the subject of a forthcoming paper.[11]

Experimental

All melting points were determined on a Yanagimoto MP-3 micromelting point apparatus and are uncorrected. Ultraviolet (UV) spectra were measured with a Shimadzu UV-240 or 260 spectrophotometer. NMR spectra were taken on a JEOL JNM-FX 100FT or 200FT spectrometer with tetramethylsilane (TMS) as an internal standard. Chemical shifts are expressed in ppm (δ), and signals are described as s (singlet), d (doublet), t (triplet), q (quartet), m (multiplet) or br (broad). Mass spectra (MS) were taken on a JEOL D-300 spectrometer. CD spectra were recorded on a JEOL J-40 or J-500A spectropolarimeter at room temperature. The photoreaction was carried out in an apparatus with an Eikosha PIL-60 60W low-pressure Hg vapor lamp (quartz filter) in an argon atmosphere. The starting nucleoside, adenosine, was from Yamasa Shoyu Co. Silica gel used for column chromatography or PTLC was Wako gel C-200.

3′,5′-*O*-(Tetraisopropyldisiloxane-1,3-diyl)-2′-ethoxycarbonylmethylideneadenosine (3)——a) Compound **1**[5] at room temperature, the reaction mixture was partitioned between AcOEt (300 ml) and saturated $NaHCO_3$–H_2O

(200 ml). The aqueous layer was extracted with AcOEt (150 ml) and the extract was combined with the organic layer. The combined organic layer was washed four times with saturated $NaHCO_3$ solution, and filtered through a Whatman 1PS filter paper. The filtrate was concentrated *in vacuo*, and the residue was applied to a column of silica gel (350 g). The eluate with $CHCl_3$–AcOEt (1 : 1 to 3 : 7) was evaporated *in vacuo* to leave 9.61 g (54%) of **2**. This was used for the following reaction without purification. Compound **2** (4.37 g) and ethoxycarbonylmethylenetriphenylphosphorane (3.29 g, 1.1 eq) were dissolved in CH_2Cl_2 (80 ml) and the solution was stirred at room temperature for 30 h. After evaporation of the solvent, the residue was taken up in AcOEt–*n*-hexane, the separated crystals of triphenylphosphine oxide being filtered off, and the filtrate was concentrated. The residue was dissolved in $CHCl_3$ and applied to a column of silica gel (100 g). The eluate with 1.5% MeOH–$CHCl_3$ was concentrated to leave **3** (3.69 g, 74%) as a foam. MS *m/z*: 577 (M^+), 534 $(M-\text{iso-Pr})^+$. NMR ($CDCl_3$): 8.20 (1H, s, H-8), 7.96 (1H, s, H-2), 7.03 (1H, t, H-1′, $J_{1',6'}=J_{1',3'}=1.7$ Hz), 6.15—6.02 (2H, m, H-6′, H-3′), 5.55 (2H, br s, H-N^6), 4.18—3.95 (4H, m, H-5′a, b, $OC\underline{H}_2CH_3$), 3.80 (1H, m, H-4′), 1.25—1.07 (31H, m, iso-Pr, $OCH_2C\underline{H}_3$).

b) DMSO (1.35 ml in 7 ml of CH_2Cl_2) was added dropwise to a solution of $(COCl)_2$ in CH_2Cl_2 (0.8 ml in 40 ml) at −60—−70 °C. After 30 min, **1** (3.10 g) in CH_2Cl_2–THF (7 ml each) was added over a period of 30 min. Et_3N (3.7 ml) was then added, and the mixture was allowed to warm to room temperature, and stirred for 1.5 h. Then, $CHCl_3$ (10 ml) and H_2O (40 ml) were added, the aqueous layer was neutralized by addition of 1 N HCl, and the organic layer was separated, then washed with H_2O and filtered through a Whatman 1PS filter paper. The filtrate was concentrated to one half of its initial volume, ethoxycarbonylmethylenetriphenylphosphorane (2.12 g) was added, and the whole was stirred at room temperature for 1.5 h. After work-up as described above, **3** (1.87 g, 53%) was obtained as a foam. The physical constants were similar to those described above.

3′,5′-*O*-(Tetraisopropyldisiloxane-1,3-diyl)-2′-deoxy-2′(*S*)-ethoxycarbonylmethyladenosine (4)——Compound **3** (3.47 g) was dissolved in EtOH (80 ml), and $NaBH_4$ (1.5 g, every 90 min) was added to the stirred solution. After 6 h, the solution was neutralized by addition of 50% AcOH. After removal of the insoluble material by filtration, the filtrate was partitioned between AcOEt and H_2O. The organic layer was separated and dried over Na_2SO_4, then the solvent was evaporated off. The residue was applied to a silica gel column (100 g). The eluate with 1.5% MeOH–$CHCl_3$ was concentrated to leave **4** (1.48 g, 42%) as a colorless foam. From the 3% eluate, a mixture of **5** and **6** (0.8 g, 25%) was obtained. MS *m/z*: 579 (M^+), 536 $(M-\text{iso-Pr})^+$. NMR ($CDCl_3$): 8.24 (1H, s, H-8), 7.95 (1H, s, H-2), 6.40 (1H, d, H-1′, $J_{1',2'}=7.3$ Hz), 5.93 (2H, br s, H-N^6), 4.95 (1H, dd, H-3′, $J_{2',3'}=10.3$ Hz, $J_{3',4'}=8.1$ Hz), 4.29 (1H, dd, H-5′a, $J_{4',5'a}=5.4$ Hz, $J_{5'a,b}=12.7$ Hz), 4.09—3.88 (4H, m, H-4′, H-5′b, $OC\underline{H}_2CH_3$), 3.29 (1H, m, H-2′), 2.62 (1H, dd, H-6′a, $J_{2',6'a}=4.2$ Hz, $J_{6'a,b}=17.6$ Hz), 2.03 (1H, dd, H-6′b, $J_{2',6'b}=11.5$ Hz), 1.30—1.04 (31H, m, iso-Pr, $OCH_2C\underline{H}_3$).

3′,5′-*O*-(Tetraisopropyldisiloxane-1,3-diyl)-2′-deoxy-2′(*S*)-(2-hydroxyethyl)adenosine (5)——Compound **4** (0.60 g) was dissolved in THF (5 ml), and $LiAlH_4$ (118 mg, in 3 ml of THF) was added. The reaction mixture was stirred for 20 min, then $NaSO_4 \cdot 10H_2O$ was added under ice cooling to decompose excess hydride. The insoluble material was filtered off, the filtrate and washings with THF were combined, and the whole was concentrated. The residue was partitioned between AcOEt and H_2O, and the organic layer was concentrated. The residue was crystallized from acetone to give 261 mg (47%) of **5**, mp 182—184 °C. MS *m/z*: 537 (M^+), 494 $(M-\text{iso-Pr})^+$. NMR ($CDCl_3+D_2O$): 8.45 (1H, s, H-8), 8.29 (1H, s, H-2), 6.48 (1H, d, H-1′, $J_{1',2'}=6.1$ Hz), 4.40 (1H, d, H-3′, $J_{3',4'}=8.5$ Hz), 4.28 (1H, d, H-5′a, $J_{5'a,b}=8.8$ Hz), 4.11 (1H, dd, H-5′b, $J_{4',5'b}=2.5$ Hz), 3.89—3.39 (3H, m, H-4′, 7′a, b), 2.85 (1H, m, H-2′), 1.75 (1H, m, H-6′a), 1.32—0.93 (29H, m, H-6′b, iso-Pr). *Anal.* Calcd for $C_{24}H_{41}N_5O_5Si_2$: C, 53.60; H, 8.06; N, 13.02. Found: C, 53.45; H, 8.02; N, 13.12.

N^6,N^6-Dibenzoyl-3′,5′-*O*-(tetraisopropyldisiloxane-1,3-diyl)-2′-deoxy-2′-(*S*)-(2-iodoethyl)adenosine (7)——Compound **5** (1.25 g) in pyridine (20 ml) was treated with MsCl (230 μl, 1.3 eq) for 4 h under stirring at 0 °C. BzCl (0.81 ml) was added, and the mixture was stirred overnight at 0 °C, then concentrated *in vacuo* to half of its initial volume. Saturated $NaHCO_3$–H_2O (50 ml) was added dropwise under stirring, and the whole was extracted with $CHCl_3$. The organic layer was filtered through a Whatman 1PS filter paper, and the filtrate was concentrated. The residue was applied to a column of silica gel (50 g). The eluate with 4% AcOEt–$CHCl_3$ was concentrated to leave 1.21 g of the 2′-mesyloxyethyl derivative. The product was taken up in 2-butanone (20 ml), LiI (390 mg) was added to the solution, and the mixture was refluxed for 40 min, then allowed to cool. The precipitate was filtered off, the filtrate was concentrated, and the residue was partitioned between AcOEt–0.1 M $Na_2S_2O_3$. The organic layer was filtered through a Whatman 1PS filter paper, and the filtrate was concentrated. The residue was applied to a column of silica gel (30 g). The eluate with 1% AcOEt–$CHCl_3$ was concentrated to leave 0.74 g (37%) of **7** as a foam. MS *m/z*: 727 $(M-HI)^+$. NMR ($CDCl_3$): 8.65 (1H, s, H-2), 8.35 (1H, s, H-8), 7.88—7.78 (4H, m, H-*o*-Bz), 7.48—7.24 (6H, m, H-*m*-,*p*-Bz), 6.44 (1H, d, H-1′, $J_{1',2'}=7.1$ Hz), 4.54 (1H, dd, H-3′), 4.10—3.85 (3H, m, H-4′, 5′a, b), 3.15 (2H, m, H-7′a, b), 2.88 (1H, m, H-2′), 1.88 (1H, m, H-6′a), 1.51—1.04 (29H, H-6′b, iso-Pr). UV λ_{max}^{MeOH} nm: 250, 269 (shoulder).

N^6,N^6-Dibenzoyl-3′,5′-*O*-(tetraisopropyldisiloxane-1,3-diyl)-2′-deoxy-8,2′-ethanoadenosine (8)——Compound **7** (2.45 g) was dissolved in benzene (70 ml). The solution was refluxed under Ar, and a mixture of AIBN (470 mg) and *n*-Bu_3SnH (1.51 ml) in benzene (9 ml) was added dropwise to the refluxing solution over a period of 30 min through an injector syringe. A mixture of AIBN (470 mg) and *n*-Bu_3SnH (2 ml) in benzene (10 ml) was further added over a period of 40 min. After 1 h, the solvent was removed *in vacuo* and the residue was partitioned between acetonitrile and

n-hexane. The acetonitrile layer was collected, the solvent was removed *in vacuo*, and the residue was crystallized from EtOH to give 0.55 g (27%) of **8**. From the mother liquor, additional **8** (134 mg, 9%) was obtained after chromatographic separation (see the procedure for **9b**), mp 184—186 °C. UV λ_{max}^{MeOH} nm (ε): 278 (19400), 249 (23900). MS *m/z*: 727 (M^+), 699 ($M-C_2H_4$)$^+$, 684 ($M-$iso-Pr)$^+$. NMR ($CDCl_3$): 8.63 (1H, s, H-2), 7.87—7.31 (10H, m, Bz), 6.31 (1H, d, H-1′, $J_{1',2'}=6.8$ Hz), 4.37 (1H, t, H-3′, $J_{2',3'}=J_{3',4'}=5.9$ Hz), 4.12—3.98 (2H, m, H-5′a, b), 3.78 (1H, m, H-4′), 3.09 (2H, t, H-7′a,b), 2.85 (1H, m, H-2′), 2.10 (2H, m, H-6′a, b), 1.11—0.92 (28H, m, iso-Pr). *Anal.* Calcd for $C_{38}H_{49}N_5O_6Si_2 \cdot 1/2$ EtOH: C, 62.37; H, 6.98; N, 9.32. Found: C, 62.25; H, 6.90; N, 9.36.

N^6-Benzoyl-3′,5′-*O*-(tetraisopropyldisiloxane-1,3-diyl)-2′-deoxy-7,8-dihydro-8,2′-ethanoadenosine (9b)——The mother liquor of the above reaction, after separation of **8**, was concentrated and the residue was applied to a column of silica gel (90 g). The eluate with 0.5% EtOH–$CHCl_3$ was concentrated and the residue was dissolved in dioxane (15 ml). After addition of conc. NH_4OH (15 ml), the solution was kept overnight at room temperature. The solvent was removed *in vacuo* and the residue was applied to a silica gel column (30 g). The eluate with 0.5% MeOH–$CHCl_3$ was concentrated and the residue was dissolved in a small volume of MeOH. On cooling, **9b** (0.48 g, 27%) separated as an amorphous solid. UV λ_{max}^{MeOH} nm: 330, 279, $\lambda_{max}^{H_2O\,(pH\,1)}$ nm: 352. MS *m/z*: 625 (M^+). NMR ($CDCl_3$): 9.26 (1H, br s, H-N^6), 7.95—7.85 (2H, m, H-*o*-Bz), 7.85 (1H, s, H-2), 7.57—7.39 (3H, m, H-*m*-,*p*-Bz), 5.96 (1H, d, H-1′, $J_{1',2'}=$ 4.6 Hz), 5.64—5.37 (2H, m, H-N^7, H-8), 4.23—3.67 (4H, m, H-3′, 4′, 5′a, b), 2.28—1.88 (3H, m, H-2′, H-7′a, b), 1.71—1.33 (2H, m, H-6′a, b), 1.25—0.87 (28H, m, iso-Pr). From the eluate of the column with 1% MeOH–$CHCl_3$ **8** (134 mg, 9%) was obtained.

2′-Deoxy-8,2′-ethanoadenosine (10)——Compound **8** (300 mg) was suspended in a mixture of dioxane (6 ml) and conc. NH_4OH (4 ml), and the suspension was stirred overnight at room temperature. The solvent was removed *in vacuo* and the residue was partitioned between AcOEt and H_2O. The organic layer was filtered through a Whatman 1PS filter paper, and the filtrate was concentrated. The residue was taken up in THF (3 ml), *n*-Bu_4NF (1 M in THF, 0.4 ml) was added, and the solution was stirred for 1 h at room temperature. The solvent was removed *in vacuo* and the residue was partitioned between $CHCl_3$ and H_2O. The aqueous layer was separated and concentrated, and the residue was dissolved in EtOH, and subjected to PTLC (4 plates). After development with $CHCl_3$–MeOH (4 : 1), the appropriate band was extracted with $CHCl_3$–EtOH (1 : 1). The solvent was evaporated off to give crude **10** (64 mg, 54%) as a powder. A part of **10** was crystallized from iso-PrOH–H_2O. mp 229—230 °C. UV $\lambda_{max}^{H_2O}$ nm (ε): 262 (16600), 207 (20980), $\lambda_{min}^{H_2O}$ nm (ε): 226 (2480). CD in H_2O [θ] (nm): +3200 (253). NMR (dried sample in D_2O, TMS as an external standard): 7.87 (1H, s, H-2), 5.90 (1H, d, H-1′, $J_{1',2'}=6.4$ Hz), 3.99 (1H, t, H-3′, $J_{2',3'}=5.9$ Hz, $J_{3',4'}=$ 5.4 Hz), 3.84 (1H, m, H-4′), 3.56 (1H, dd, H-5′a, $J_{4',5'a}=2.9$ Hz, $J_{5'a,b}=12.7$ Hz), 3.40 (1H, dd, H-5′b, $J_{4',5'b}=5.4$ Hz), 2.78 (2H, m, H-7′a, b), 2.62 (1H, m, H-2′), 1.89 (2H, m, H-6′a, b). *Anal.* Calcd for $C_{12}H_{15}N_5O_3 \cdot 1/3$ iso-PrOH: C, 52.52; H, 5.99; N, 23.55. Found: C, 52.54; H, 6.23; N, 23.52.

N^6-Benzoyl-3′,5′-*O*-(tetraisopropyldisiloxane-1,3-diyl)-2′-deoxy-8,2′-ethanoadenosine (11)——a) A mixture of **9b** (30 mg) and Pd–carbon (5%, 15 mg) in 3 ml of toluene was refluxed for 7 h, further Pd–carbon (15 mg) was added and refluxing was continued for 2 d. The Pd–carbon was filtered off and the filtrate was concentrated to leave 25 mg (83%) of **11** as a powder.

b) A mixture of **9b** (94 mg) and DDQ (37 mg) in 2 ml of CH_2Cl_2 was stirred at room temperature for 30 min. The precipitate was filtered off and the filtrate was washed with $NaHCO_3$–H_2O. The solvent was removed *in vacuo* and the residue was dissolved in a small volume of $CHCl_3$, and subjected to PTLC (2 plates). After development with $CHCl_3$–AcOEt (2 : 1), the main band was extracted with $CHCl_3$–EtOH (3 : 2). The solvent was evaporated off to leave 76 mg (80%) of **11**. UV λ_{max}^{MeOH} nm: 283, 230, $\lambda_{max}^{H_2O(pH\,1.0)}$ nm: 287, 250. MS *m/z*: 623 (M^+). NMR ($CDCl_3$): 8.91 (1H, br s, H-N^6), 8.79 (1H, s, H-2), 8.05—7.97 (2H, m, H-*o*-Bz), 7.61—7.44 (3H, m, H-*m*-,*p*-Bz), 6.33 (1H, d, $J_{1',2'}=$ 6.8 Hz), 4.39 (1H, t, H-3′), 4.17—3.64 (3H, m, H-4′, 5′a, b), 3.14 (2H, t, H-7′a, b), 2.88 (1H, m, H-2′), 2.13 (2H, m, H-6′a, b), 1.25—1.02 (28H, m, iso-Pr). Compound **11** was converted to **10** by treatment similar to that described in the previous section.

N^6-Benzoyl-3′,5′-*O*-(tetraisopropyldisiloxane-1,3-diyl)-2′-deoxy-8,2′-ethenoadenosine (12)——A mixture of **11** (72 mg) and DDQ (26 mg, 1 eq) in 2 ml of benzene was heated at 50 °C for 30 min, then at reflux for 30 min.The solvent was removed *in vacuo* and the residue was partitioned between CH_2Cl_2 and $NaHCO_3$–H_2O. The organic layer was separated and the solvent was evaporated off. The residue was subjected to PTLC. After development with $CHCl_3$–AcOEt (2 : 1), the band at higher *Rf* value was extracted with $CHCl_3$–EtOH (3 : 2). The solvent was evaporated off to leave 3 mg (4%) of **12**. From the band at lower *Rf* value, a fluorescent compound (11 mg) was obtained. UV λ_{max}^{MeOH} nm: 317 (shoulder), 308, 300 (shoulder), 244, $\lambda_{max}^{H_2O(pH\,1.0)}$ nm: 322 (shoulder), 314, 246, $\lambda_{max}^{H_2O(pH\,11)}$ nm: 325, 246. MS *m/z*: 621 (M^+). NMR ($CDCl_3$): 8.93 (1H, br s, H-N^6), 8.81 (1H, s, H-2), 8.05—7.98 (2H, m, H-*o*-Bz), 7.61—7.50 (3H, m, H-*m*-,*p*-Bz), 6.78 (1H, dd, H-7′, $J_{6',7'}=10.3$ Hz, $J_{2',7'}=1.5$ Hz), 6.54 (1H, dd, H-6′, $J_{2',6'}=3.4$ Hz), 6.51 (1H, d, H-1′, $J_{1',2'}=7.3$ Hz), 4.45 (1H, t, H-3′), 4.15—3.69 (3H, m, H-4′, 5′a, b), 3.49 (1H, m, H-2′), 1.25—1.01 (28H, m, iso-Pr).

3′,5′-*O*-(Tetraisopropyldisiloxane-1,3-diyl)-2′-deoxy-2′(*S*)-(2-phenylthioethyl)adenosine (13)——Compound **5** (1.07 g) was dissolved in pyridine (15 ml), MsCl (0.18 ml, 1.2 eq) was added under cooling, and the mixture was stirred for 2 h. The solvent was removed *in vacuo* and the residue was partitioned between AcOEt (20 ml) and H_2O (15 ml). The organic layer was washed with 1 N HCl, saturated $NaHCO_3$–H_2O, and then NaCl–H_2O, and filtered through a

Whatman 1PS filter paper. The filtrate was concentrated and the residue was dissolved in dimethylformamide (DMF) (25 ml). PhSH (0.31 ml) and *tert*-BuOK (337 mg) were added and the mixture was stirred for 2.5 h at room temperature, then neutralized by addition of 1 N HCl. The solvent was removed and the residue was taken up in AcOEt (30 ml) and H_2O (20 ml). The organic layer was separated, the solvent was removed, and the residue was applied to a column of silica gel (50 g). The eluate with 2% MeOH–$CHCl_3$ was concentrated to leave **13** (966 mg, 77%) as a foam. UV λ_{max}^{MeOH} nm: 257.5, $\lambda_{max}^{H_2O(pH\,1)}$ nm: 258. MS *m/z*: 629 (M^+), 586 ($M-$iso-Pr)$^+$. NMR ($CDCl_3$): 8.28 (1H, s, H-8), 8.11 (1H, s, H-2), 6.40 (1H, d, H-1′, $J_{1',2'}=7.3$ Hz), 5.74 (2H, br s, H-N^6), 4.54 (1H, dd, H-3′, $J_{3',4'}=8.3$ Hz, $J_{2',3'}=10.3$ Hz), 4.28 (1H, dd, H-5′a, $J_{4',5'}=2.4$ Hz, $J_{5'a,b}=13.3$ Hz), 3.94 (1H, dd, H-5′b, $J_{4',5'b}=2.9$ Hz), 3.85 (1H, m, H-4′), 3.03—2.91 (3H, m, H-2′, 7′a, b), 1.76 (2H, m, H-6′a, b), 1.15—1.10 (28H, m, iso-Pr).

3′,5′-*O*-(Tetraisopropyldisiloxane-1,3-diyl)-2′-deoxy-8,2′-ethanoadenosine (14)——A mixture of **13** (300 mg) and trimethyl phosphite (1 ml) in acetonitrile (300 ml) was flushed with Ar for 30 min, then irradiated with a 60W low-pressure Hg lamp for 2 h. This reaction was run three times and the combined solution was concentrated *in vacuo*. The residue was dissolved in $CHCl_3$ and applied to a column of silica gel (50 g). The eluate with 2% MeOH–$CHCl_3$ was concentrated to leave **14** (397 mg, 60%) as a foam. A portion was crystallized from MeOH to give pure **14**, mp 199—200 °C. UV λ_{max}^{MeOH} nm (ε): 261.8 (17000). MS *m/z*: 519 (M^+), 476 ($M-$iso-Pr)$^+$. NMR ($CDCl_3$): 8.37 (1H, s, H-2), 6.26 (1H, d, H-1′, $J_{1',2'}=6.6$ Hz), 5.63 (2H, br s, H-N^6), 4.37 (1H, dd, H-3′), 4.06 (2H, m, H-5′a, b), 3.75 (1H, m, H-4′), 3.04 (2H, t, H-7′a, b), 2.82 (1H, m, H-2′), 2.08 (2H, m, H-6′a, b), 1.12—1.04 (28H, m, iso-Pr). *Anal.* Calcd for $C_{24}H_{41}N_5O_4Si_2$: C, 55.46; H, 7.95; N, 13.47. Found: C, 55.32; H, 8.08; N, 13.34.

Treatment of **14** with *n*-Bu_4NF in THF and work-up as described above for the preparation of **10** gave **10**, which was identical with an authentic sample.

2′,5′-Di-*O*-*tert*-butyldimethylsilyl-3′-ketoadenosine (16)——A mixture of **15**[8] (11.2 g) and Ac_2O (11.3 ml) in DMSO (90 ml) was stirred for 13.5 h at room temperature. The whole was partitioned between AcOEt and saturated $NaHCO_3$–H_2O, and the organic layer was separated, washed with $NaHCO_3$–H_2O 4 times, and filtered through a Whatman 1 PS filter paper. The filtrate was concentrated *in vacuo* to leave **16** (4.52 g, 40%) as colorless crystals. MS *m/z*: 478 ($M-$Me)$^+$, 436 ($M-$*tert*-Bu)$^+$. NMR ($CDCl_3$): 8.37 (1H, s, H-8), 8.15 (1H, s, H-2), 6.14 (1H, d, H-1′, $J_{1',2'}=8.3$ Hz), 5.74 (2H, br s, H-N^6), 4.94 (1H, d, H-2′), 4.31 (1H, m, H-4′), 4.13 (1H, dd, H-5′a), 3.83 (1H, dd, H-5′b), 0.92, 0.73 (9H each, m, *tert*-Bu), 0.11, 0.07 (3H each, s, Me), 0.00, −0.19 (3H each, s, Me). *Anal.* Calcd for $C_{22}H_{39}N_5O_4Si_2$: C, 53.52; H, 7.96; N, 14.18. Found: C, 53.26; H, 7.92; N, 14.08.

2′,5′-Di-*O*-*tert*-butyldimethylsilyl-3′-ethoxycarbonylmethylideneadenosine (17)——A mixture of **16** (1.24 g) and ethoxycarbonylmethylenetriphenylphosphorane (1.31 g, 1.5 eq) in THF (30 ml) was refluxed for 5 h. The solvent was removed *in vacuo* and the residue was taken up in AcOEt–*n*-hexane. The precipitate was removed, the filtrate was concentrated, and the residue was applied to a column of silica gel (60 g). The eluate with $CHCl_3$–AcOEt (3 : 1) was concentrated to leave **17** (1.28 g, 90%) as a syrup. MS *m/z*: 563 (M^+), 548 ($M-$Me)$^+$, 506 ($M-$*tert*-Bu)$^+$. NMR ($CDCl_3$): 8.35 (1H, s, H-8), 8.31 (1H, s, H-2), 6.00—5.92 (2H, m, H-1′,6′), 5.72 (2H, br s, H-N^6), 5.44 (1H, m, H-4′), 5.19 (1H, m, H-2′), 4.33—4.12 (3H, m, H-5′a, OCH_2CH_3), 3.98 (1H, dd, H-5′b), 1.33 (3H, t, OCH_2CH_3), 0.93, 0.78 (9H each, s, *tert*-Bu), 0.00, 0.07, −0.10, −0.53 (3H each, s, Me).

2′,5′-Di-*O*-*tert*-butyldimethylsilyl-3′-deoxy-3′(*S*)-(2-hydroxyethyl)adenosine (18)——Compound **17** (3.16 g) was dissolved in EtOH (100 ml), $NaBH_4$ (2.0 g) was added, and the mixture was stirred for 20 h at room temperature. Further $NaBH_4$ (1.1 g) was added and the whole was stirred for 25 h, then neutralized by the addition of 50% AcOH. The solvent was evaporated off, and the residue was partitioned between AcOEt (100 ml) and H_2O (100 ml). The organic layer was washed once with H_2O and dried through a Whatman 1 PS filter paper. The solvent was removed and the residue was applied to a column of silica gel (100 g). The eluate with 2—4% MeOH–$CHCl_3$ was concentrated to leave **18** (2.26 g, containing **19** as a 4 : 1 mixture, 77%) as a foam. MS *m/z*: 508 ($M-$Me)$^+$, 466 ($M-$*tert*-Bu)$^+$. NMR ($CDCl_3+D_2O$): 8.33 (1H, s, H-8), 8.21 (1H, s, H-2), 5.87 (1H, d, H-1′, $J_{1',2'}=6.4$ Hz), 4.81 (1H, dd, H-2′, $J_{2',3'}=9.3$ Hz), 4.45 (1H, m, H-4′), 4.18—3.69 (4H, m, H-5′a, b, 7′a, b, $J_{4,5'a}=4.2$ Hz, $J_{4',5'b}=2.4$ Hz), 2.63 (1H, m, H-3′), 1.90 (2H, m, H-6′a, b), 0.98, 0.77 (9H each, s, *tert*-Bu), 0.17, 0.16, −0.07, −0.55 (3H each, s, Me).

2′,5′-Di-*O*-*tert*-butyldimethylsilyl-3′-deoxy-3′-(2-hydroxyethylidene)adenosine (19)——A portion of the above mixture was subjected to PTLC ($CHCl_3$–MeOH, 10 : 1) and **19** was separated as a homogenous foam. MS *m/z*: 506 ($M-$Me)$^+$, 464 ($M-$*tert*-Bu)$^+$. NMR ($CDCl_3+D_2O$): 8.32 (1H, s, H-8), 8.06 (1H, s, H-2), 5.88 (1H, m, H-6′), 5.71 (1H, d, H-1′, $J_{1',2'}=7.3$ Hz), 5.42 (1H, m, H-2′), 5.08 (1H, m, H-4′), 4.31 (2H, d, H-7′a, b), 4.08 (1H, dd, H-5′a), 3.82 (1H, dd, H-5′b, $J_{4',5'b}=3.9$ Hz), 0.94, 0.77 (9H each, s, *tert*-Bu), 0.13, 0.12, −0.11, −0.51 (3H each, s, Me). Compound **19** was also obtained by treatment of **17** with $LiAlH_4$.

2′,5′-Di-*O*-*tert*-butyldimethylsilyl-3′-deoxy-3′(*S*)-(2-phenylthioethyl)adenosine (20)——A mixture of **18** and **19** (2.26 g) in pyridine (20 ml) was treated with MsCl (0.4 ml, 1.2 eq) for 1 h at room temperature. A small volume of MeOH–H_2O was added, the solvent was evaporated off, and the residue was partitioned between AcOEt and H_2O. The organic layer was separated and concentrated, and the residue was dissolved in DMF (60 ml). PhSH (0.58 ml) and *tert*-BuOK (580 mg) were added, and the mixture was stirred at room temperature for 220 min, then neutralized by addition of 1 N HCl. The solvent was removed and the residue was partitioned between AcOEt and H_2O. The organic layer was concentrated and the residue was applied to a column of silica gel (100 g). The eluate with 2% MeOH–$CHCl_3$ was concentrated to leave **20** (1.46 g, 55%) as a foam. UV λ_{max}^{MeOH} nm: 260, $\lambda_{max}^{H_2O(pH\,1.0)}$ nm: 258. MS *m/z*:

615 (M^+), 600 $(M-Me)^+$, 558 $(M-tert\text{-}Bu)^+$, 506 $(M-SPh)^+$. NMR ($CDCl_3$): 8.34 (1H, s, H-8), 8.19 (1H, s, H-2), 7.35—7.16 (5H, m, SPh), 5.89 (1H, d, H-1′, $J_{1',2'}=6.3$ Hz), 5.67 (2H, br s, H-N^6), 4.68 (1H, dd, H-2′, $J_{2',3'}=9.0$ Hz), 4.37 (1H, m, H-4′), 3.90 (1H, dd, H-5′a, $J_{5'a,b}=11.8$ Hz, $J_{4',5'a}=3.4$ Hz), 3.72 (1H, dd, H-5′b, $J_{4',5'b}=2.7$ Hz), 3.00 (2H, t, H-7′a, b), 2.66 (1H, m, H-3′), 1.92 (2H, q, H-6′a, b), 0.95, 0.71 (9H each, s, *tert*-Bu), 0.13, 0.11, −0.17, −0.58 (3H each, s, Me).

N^6,N^6-Dibenzoyl-2′,5′-di-*O*-*tert*-butyldimethylsilyl-3′-deoxy-3′-(*S*)-(2-iodoethyl)adenosine (21)——A mixture of **18** and **19** (4:1, 1.07 g) in pyridine (10 ml) was treated with MsCl (0.19 ml, 1.2 eq) at room temperature for 1 h. Pyridine (5 ml) and BzCl (0.71 ml) were added and the whole was stirred for 3 h. The solvent was evaporated off and the residue was partitioned between AcOEt (150 ml) and H_2O saturated with $NaHCO_3$ (70 ml). The organic layer was separated and the solvent was evaporated off. The residue was applied to a column of silica gel (40 g) and the eluate with $CHCl_3$ was concentrated to leave the 2′-mesyloxy compound. This was taken up in 2-butanone (15 ml) and heated with LiI (257 mg) at reflux for 30 min. After work-up as described in the synthesis of **7**, **21** (579 mg, 42%) was obtained as a foam. UV λ_{max}^{MeOH} nm: 267 (shoulder), 251. MS *m/z*: 784 (M^+). NMR ($CDCl_3$): 8.65 (1H, s, H-2), 8.34 (1H, s, H-8), 7.90—7.80 (4H, m, H-*o*-Bz), 7.55—7.23 (6H, m, H-*m*-, *p*-Bz), 5.93 (1H, d, H-1′, $J_{1',2'}=6.3$ Hz), 4.73 (1H, dd, H-2′, $J_{2',3'}=8.8$ Hz), 4.33 (1H, m, H-4′), 3.98 (1H, dd, H-5′a, $J_{4',5'a}=3.9$ Hz, $J_{5'a,b}=11.7$ Hz), 3.77 (1H, dd, H-5′b, $J_{4',5'b}=2.9$ Hz), 3.25 (2H, t, H-7′a, b), 2.65 (1H, m, H-3′), 2.17 (2H, m, H-6′a, b), 0.95, 0.75 (9H each, s, *tert*-Bu), 0.14 (3+3H, s, Me), −0.07, −0.66 (3H each, s, Me).

3′-Deoxy-3′(*S*)-(2-phenylthioethyl)adenosine (22a)——Compound **20** (685 mg) was dissolved in THF (20 ml) and *n*-Bu_4NF (1 M in THF, 2 ml) was added. The mixture was stirred for 4 h, the solvent was removed *in vacuo*, and the residue was applied to a silica gel column (25 g). The eluate with 4—6% MeOH–$CHCl_3$ was concentrated to give **22a** (357 mg, 83%) as a powder. UV λ_{max}^{MeOH} nm: 257. MS *m/z*: 387 (M^+), 369 $(M-H_2O)^+$, 257 $(M-CH_2O)^+$. NMR (DMSO-d_6 + D_2O): 8.34 (1H, s, H-8), 8.13 (1H, s, H-2), 7.35—7.18 (5H, m, SPh), 5.69 (1H, d, H-1′, $J_{1',2'}=7.1$ Hz), 4.59 (1H, dd, H-2′, $J_{2',3'}=10.0$ Hz), 4.25 (1H, m, H-4′), 3.57 (2H, m, H-5′a, b, overlapped with HDO), 3.12 (2H, m, H-7′a, b), 2.53 (1H, m, H-3′, overlapped with DMSO), 2.02 (2H, m, H-6′a, b).

2′,5′-Di-*O*-acetyl-3′-deoxy-3′(*S*)-(2-phenylthioethyl)adenosine (22b)——Compound **22a**, obtained from 387 mg of **20** by the procedure described above, was dissolved in pyridine (3 ml) and Ac_2O (0.3 ml) was added. The mixture was stirred overnight at room temperature, then a small volume of MeOH was added, and the solvent was evaporated off. The residue was partitioned between AcOEt and H_2O saturated with $NaHCO_3$, and the organic layer was separated. The solvent was removed *in vacuo* and the residue was applied to a column of silica gel (30 g). The eluate with 3% EtOH–$CHCl_3$ was concentrated to leave **22b** (244 mg, 82%) as a foam. UV λ_{max}^{MeOH} nm: 257.2. MS *m/z*: 471 (M^+). NMR ($CDCl_3$): 8.30 (1H, s, H-8), 7.95 (1H, s, H-2), 7.36—7.18 (5H, m, SPh), 6.00 (1H, d, H-1′, $J_{1',2'}=5.1$ Hz), 5.88 (1H, dd, H-2′, $J_{2',3'}=11.4$ Hz), 5.73 (2H, br s, H-N^6), 4.53 (1H, m, H-4′), 4.28 (2H, d, H-5′a, b), 3.10—2.81 (3H, m, H-3′, 7′a, b), 2.06, 2.04 (3H each, s, Ac), 2.06—1.81 (2H, m, H-6′a, b).

3′-Deoxy-3′(*S*)-ethyladenosine (23a)——A mixture of **22a** (100 mg) and trimethyl phosphite (0.5 ml) in acetonitrile (150 ml) was irradiated with a 60W Hg lamp for 2 h under Ar bubbling. The solvent was removed *in vacuo* and the residue was subjected to PTLC (3 sheets, $CHCl_3$–MeOH, 8:1). The appropriate band was extracted with $CHCl_3$–EtOH (1:1) and the solvent was evaporated off to leave **23a** (47 mg, 65%) as a powder. UV λ_{max}^{MeOH} nm: 260. MS *m/z*: 279 (M^+). NMR (DMSO-d_6 + D_2O): 8.35 (1H, s, H-8), 8.14 (1H, s, H-2), 5.68 (1H, d, H-1′, $J_{1',2'}=7.1$ Hz), 4.54 (1H, dd, H-2′, $J_{2',3'}=9.8$ Hz), 4.23 (1H, m, H-4′), 3.63 (2H, m, H-5′a, b), 2.27 (1H, m, H-3′), 1.68 (2H, m, H-6′a, b), 0.99 (3H, t, Me).

2′,5′-Di-*O*-acetyl-3′-deoxy-8,3′-ethanoadenosine (24)——a) A mixture of **22b** (240 mg) and trimethyl phosphite (1.5 ml) in acetonitrile (300 ml) was irradiated with a 60W Hg lamp for 1.5 h in an oil bath at 85 °C. The solvent was removed *in vacuo* and the residue was applied to a column of silica gel (15 g). The eluate with 3—5% EtOH–$CHCl_3$ was concentrated and the residue was then subjected to PTLC ($CHCl_3$–MeOH, 10:1). The appropriate band was extracted with $CHCl_3$–EtOH (1:1) and the extract was concentrated to leave **24** (74 mg, 40%). A part of **24** was crystallized from EtOH to give a pure sample, mp 229—231 °C. UV $\lambda_{max}^{H_2O}$ nm (ε): 262.5 (16700). CD [θ] (nm): −14300 (255), 0 (244). MS *m/z*: 361 (M^+). NMR ($CDCl_3$): 8.33 (1H, s, H-2), 6.43 (1H, s, H-1′), 4.80—4.50 (3H, m, H-4′, 5′a, b), 3.24 (2H, m, H-7′a, b), 2.63 (1H, m, H-3′), 2.14, 2.13 (3H each, s, Ac), 2.23—2.13 (2H, m, H-6′a, b). The signal for EtOH appeared at 4.9 (q) and 1.25 (t), and the molar ratio was determined to be 1/4. *Anal.* Calcd for $C_{16}H_{19}N_5O_6 \cdot 1/4$ EtOH: C, 53.15; H, 5.54; N, 18.78. Found: C, 53.07; H, 5.43; N, 19.03.

b) Compound **22b** (100 mg) in 150 ml of acetonitrile was irradiated with a 60W Hg lamp in the presence of trimethyl phosphite for 2.5 h at room temperature. After evaporation of the solvent, the residue was applied to a column of silica gel (10 g). From the last half of the eluate with 3—5% MeOH–$CHCl_3$, **24** (12 mg, 16%) was obtained. From the first half of the eluate, **23b** (28 mg, 36%) was isolated along with a mixture of the two (20 mg).

3′-Deoxy-8,3′-ethanoadenosine (25)——Compound **24** (23 mg) was dissolved in a mixture of MeOH (1.5 ml) and Et_3N (0.2 ml) and the solution was heated under reflux for 5 h. The solvent was evaporated and the residue was subjected to PTLC ($CHCl_3$–MeOH, 6:1). The main band was extracted with $CHCl_3$–EtOH (3:2) and the solvent was evaporated off. The residue was crystallized from EtOH to give **25** (4 mg, 22%), mp 294—296 °C. UV $\lambda_{max}^{H_2O}$ nm: 262.7. CD [θ] (nm): −14000 (255), 0 (219), assuming the ε of **25** to be 16700. MS *m/z*: 277 (M^+). NMR (D_2O): 7.91 (1H, s, H-2), 5.94 (1H, s, H-1′), 4.47 (1H, m, H-4′), 4.00 (1H, s, H-2′), 3.93—3.80 (2H, m, H-5′a, b), 2.93 (2H, m, H-

7′a, b), 2.42 (1H, m, H-3′), 1.98 (1H, m, H-6′a), 1.76 (1H, m, H-6′b).

Acknowledgement This work was supported in part by a Grant-in-Aid for Scientific Research from the Ministry of Education, Science and Culture, Japan. The instrumental analyses were performed by the staff of the Center of Instrumental Analysis, Hokkaido University, to whom our thanks are due.

References and Notes

1) Part LXIII: J. Boryski and T. Ueda, *Nucleosides & Nucleotides*, **4**, 595 (1985).
2) *a*) A. Matsuda, K. Muneyama, T. Nishida, T. Sato, and T. Ueda, *Nucleic Acids Res.*, **3**, 3349 (1976); *b*) A. Matsuda, M. Tezuka, and T. Ueda, *Tetrahedron*, **34**, 2449 (1978); *c*) A. Matsuda, M. Tezuka, K. Niizuma, E. Sugiyama, and T. Ueda, *ibid.*, **34**, 2633 (1978); *d*) A. Matsuda, K. Niizuma, and T. Ueda, *Chem. Pharm. Bull.*, **28**, 876 (1980); *e*) A. Matsuda and T. Ueda, *Nippon Kagaku Kaishi*, **1981**, 845.
3) *a*) T. Ueda, H. Usui, S. Shuto, and H. Inoue, *Chem. Pharm. Bull.*, **32**, 3410 (1984); *b*) T. Ueda, S. Shuto, M. Satoh, and H. Inoue, *Nucleosides & Nucleotides*, **4**, 401 (1985); *c*) T. Sano, H. Inoue, and T. Ueda, *Chem. Pharm. Bull.*, **33**, 1856 (1985); *d*) *Idem, ibid.*, **33**, 1856 (1985); *e*) T. Sano, S. Shuto, H. Inoue, and T. Ueda, *ibid.*, **33**, 3617 (1985).
4) *a*) H. Usui and T. Ueda, *Nucleic Acids Res. Symposium Series*, **No. 15**, 61 (1984); *b*) *Idem*, Abstracts Papers 104th Meeting of Pharmaceutical Society of Japan, Kanazawa, April 1985, p. 305.
5) W. T. Markiewicz, *J. Chem. Res.* (*M*), **1979**, 181; *idem, J. Chem. Res.* (*S*), **1979**, 24.
6) Y. Yamagata, K. Tomita, and T. Ueda, unpublished results (1984).
7) K. N. V. Duong, A. Gaudemer, M. D. Johnson, R. Quillivic, and J. Zylber, *Tetrahedron Lett.*, **1975**, 2997.
8) *a*) K. K. Ogilvie, S. L. Beaucage, A. L. Schifman, N. Y. Theriault, and K. L. Sadana, *Can. J. Chem.*, **56**, 2768 (1978); *b*) G. H. Hakimelahi, Z. A. Proba, and K. K. Ogilvie, *ibid.*, **60**, 1106 (1982).
9) F. Hansske, D. Madej, and M. J. Robins, *Tetrahedron*, **40**, 125 (1984).
10) Y. Yamagata, K. Tomita, S. Shuto, and T. Ueda, unpublished results (1983).
11) *a*) Synthesis of 2′-deoxy-8,2′-methanoadenosine has been reported: A. Matsuda, Y. Fujisawa, M. Yamanaka, H. Tanaka, T. Miyasaka, and T. Ueda, *Tetrahedron*, **41**, 6013 (1985); *b*) 8,2′-Methanoadenosine has also been prepared: see ref. 4*b*.