PREPARATION OF SUBSTITUTED (±)-5*t*-HYDROXYMETHYL-3*t*-AMINOCYCLOPENTANE-1*r*,2*c*-DIOL DERIVATIVES RELATED TO CARBOCYCLIC RIBONUCLEOSIDE ANALOGUES* **

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Catalytic hydrogenation of ethyl cyclopentane-2,3-dione-1,4-dicarboxylate (*III*) followed by reaction with 2,2-dimethoxypropane afforded ethyl 2,3-O-isopropylidene-2*t*,3*t*-dihydroxycyclopentane-1*r*,4*c*-dicarboxylate (*IV*) and its 1*r*,4*t*-isomer *V*. By the action of lithium aluminium hydride, compound *IV* was converted into 1,2-O-isopropylidene-3*t*,5*t*-bis(hydroxymethyl)cyclopentane-1*r*,2*c*-diol (*VII*) which with benzoyl cyanide yielded a mixture of (±)-1,2-O-isopropylidene-3*t*-hydroxymethyl-5*t*-benzoyloxymethylcyclopentane-1*r*,2*c*-diol (*X*) and the dibenzoyl derivative *VIII*. The sodium periodate oxidation of compound *X* in the presence of Ru^{4+} afforded (±)-2,3-O-isopropylidene-5*c*-benzoyloxymethyl-2*t*,3*t*-dihydroxycyclopentane-1*r*-carboxylic acid (*XI*) which was converted to the corresponding azide by the successive treatment with ethyl chloroformate and lithium azide or by reaction with diphenylphosphoryl azide. Thermal rearrangement of the compound *XI* azide in the presence of 2,2,2-trichloroethanol afforded (±)-1,2-O-isopropylidene-5*t*-benzoyloxymethyl-3*t*-(2,2,2-trichloroethoxycarbonyl)amino-1*r*,2*c*-cyclopentanediol (*XII*). On treatment with zinc in methanol, compound *XII* was converted into the free amino derivative *XIII* from which the N-acetyl derivative *XIV* was prepared. Compound *V* was analogously converted to the 3*c*,5*t*-isomer of compound *VII* and then to the 3′,5′-di-O-benzoyl derivative *XVI*. Partial debenzoylation of compound *XVI* afforded the monobenzoyl derivatives *XVII* and *XVIII* which were converted to the N-acetyl derivatives *XXIII* and *XXVI*, isomeric with compound *XIV*.

In the group of nucleoside analogues with a modified sugar moiety, attention has been particularly paid to derivatives with potential virostatic and cancerostatic effects such as arabinosides of cytosine and adenine as well as their derivatives. Of interest are also compounds, the sugar aldofuranoside moiety of which is replaced by the corresponding isosteric cyclopentane derivative. In this connection it is worthy of mention the isolation of a carbocyclic (*cf.*[4]) adenosine (*II*) analogue, namely, aristeromycin (*I*) as an antibiotic produced by the strain *Streptomyces citricolor*[2] and active on some fungi. The structure and absolute configuration of the antibiotic *I* as deter-

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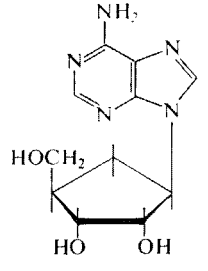
mined by X-ray analysis[3] indicated a close relationship to the naturally occurring adenosine (*II*).

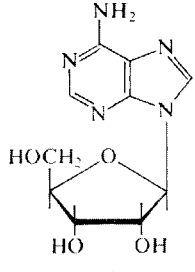
Synthetic investigations in this field concentrate on the preparation of a suitably substituted cyclopentane derivative containing hydroxylic functions at positions corresponding to positions 2′ and 3′ of the original ribofuranoside moiety of the nucleoside, a hydroxymethyl group at the appropriate position 4′, and such a substituent at position 1′ which would make possible introduction or formation of a heterocyclic base. The mutual orientation of these groups must be identical with the stereochemistry of the sugar moiety of ribonucleosides.

The first approach to the synthesis of such a cyclopentane derivative consisted in a multistep route starting from norbornadiene and including successive hydroxylation and partial degradation of the ring with the formation of two isomeric derivatives of 2,3-dihydroxycyclopentane-1,4-dicarboxylic acid, one of which was converted in additional several steps to the corresponding partially protected cyclopentylamine derivative[4] as the key intermediate of further syntheses[4-7]. The practical applicability of this procedure in the synthesis of compounds of the type *I* is somewhat limited by a great number of synthetic steps, low yield of the final product (8–10%), and difficult accessibility of the starting material. In the present paper, we wish to report an alternative route for the synthesis of the cyclopentylamine type intermediate as a valuable key substance in the preparation of racemic carbocyclic ribonucleoside analogues.

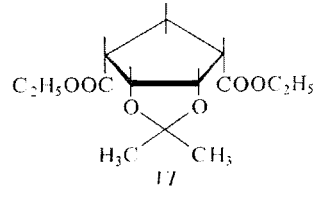
As the starting material there was used diethyl 2,3-cyclopentanedione-1,4-dicarboxylate (*III*), readily accessible by the Dieckmann condensation of diethyl oxalate



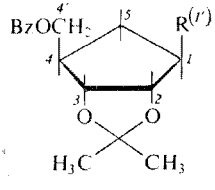
I



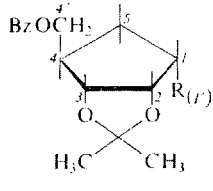
II



III



Type A



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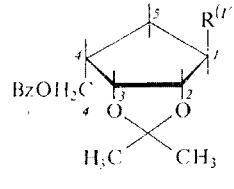


Type C

and diethyl glutarate[8,9]. Catalytic hydrogenation of compound *III* in ethanol or dioxane over platinum catalyst or in the presence of Raney nickel[10] affords a mixture of stereoisomeric diethyl 2,3-dihydroxycyclopentane-1,4-dicarboxylates. The isomers containing the 2,3-*cis*-diol system are separated by treating this crude mixture with 2,2-dimethoxypropane in the presence of acidic catalysts; the resulting 2,3-O-isopropylidene derivatives can be distilled under diminished pressure and form the predominating portion of products obtained from the hydrogenation mixture. Diethyl 2,3-O-isopropylidene-2*t*,3*t*-dihydroxycyclopentane-1*r*,4*c*-dicarboxylate (*IV*) is obtained in a high yield by crystallisation from light petroleum while the noncrystalline liquid 1*r*,4*t*-isomer *V* remains in the mother liquor[14]. Elemental analyses and mass spectra of compounds *IV* and *V* are in accord with expectations. The ^{1}H-NMR spectra exhibit proton signals of typical functions present in the molecule (isopropylidene, ethoxycarbonyl) as well as the corresponding overall number of the cyclopentane ring protons; the assignment of signals failed even with the use of shift reagents. Nevertheless, the character of the spectrum confirms the symmetrical structure of the solid isomer *IV* and the only possible asymmetrical structure *V* for the liquid isomer. The alternative symmetrical all-*cis* structure *VI* in the case of the solid isomer may be excluded on the basis of evidence given below.

Compound *IV* is thus formed from the diketone *III* as the main reaction product possessing a structure suitable for subsequent synthetic steps. The lithium aluminium hydride reduction of compound *IV* yielded a symmetrical tetrol derivative, namely, 1,2-O-isopropylidene-3*t*,5*t*-bis(hydroxymethyl)cyclopentane-1*r*,2*c*-diol (*VII*). The ^{1}H-NMR spectrum of compound *VII* again corresponded to a symmetrical molecule but the analysis of coupling constants was not possible. Not even the 3',5'-di-O-benzoyl derivative *VIII* (obtained from compound *VII* on treatment with benzoyl chloride in pyridine or, better, by the action of benzoyl cyanide in acetonitrile[11]) is not useful for confirmation of the structure by ^{1}H-NMR spectra. The IR spectrum of compound *VII* indicates the presence of two hydroxylic functions, one of which is attached to the other one (remaining free) by an intramolecular hydrogen bonding. This type of hydrogen bonding differs from bondings between a primary hydroxylic function and oxygen atom of a dioxolane ring; such bondings were measured with numerous compounds of an unequivocal *cis*-configuration between the hydroxymethyl group and the dioxolane ring, belonging to the isomer *V* series (*vide infra*, compounds *XVII* and *XVIII*; Table I). Consequently, the configuration between the hydroxymethyl group and the *cis*-diol system of compound *IV* is *trans* and the structure *VI* is out of the question.

In a further step of the synthesis, one of the hydroxymethyl groups of compound *VII* had to be converted to an amine function which would make possible formation of the required heterocyclic base. It was therefore necessary to protect the other hydroxymethyl group of compound *VII* at position 2 (or 5). Thus, tritylation afforded a mixture of monotrityl and ditrityl derivatives of compound *VII* which was easy

C2H5OOC
COOC2H5
H3C
CH3
I
II
III
HOCH2
CH2OH
VII
ROCH2
CH2OR'
IXa, R = trityl, R' = H
IXb, R = R' = trityl
BzOCH2
CH2OBz
VIII
BzOCH2
CH2OH
X
BzOCH2
N3
BzOCH2
COOH
XI
BzOCH2
NHR
XII, R = Cl3CCH2OCO
XIII, R = H
XIV, R = CH3CO
Bz = benzoyl group

SCHEME 1

to separate but the resulting products *IXa* and *IXb* did not possess suitable properties. On the other hand, the monobenzoyl derivative *X* proved more advantageous. Compound *X* was prepared by a partial benzoylation of compound *VII* with benzoyl cyanide in acetonitrile. Alcohols react with this agent in the presence of a basic catalyst very rapidly[11]; addition of a solution containing one equivalent of the agent to a dilute solution of compound *VII* containing the catalyst results in a preferential formation of the monobenzoyl derivative *X* accompanied by a minor subsequent reaction affording a lesser amount of the dibenzoate *VIII* (identical with the perbenzoylation of compound *VII*). The products *VIII* and *X* may be readily separated by fractional crystallisation[12]. An alternative route to the preparation of the monobenzoyl derivative *X* and, simultaneously, utilisation of the by-product *VIII* consists in partial debenzoylation of the dibenzoate *VIII* with an equimolecular amount of sodium hydroxide in aqueous ethanol or dioxane. However, this alternative route is not as advantageous as the direct benzoylation of compound *VII* with benzoyl cyanide (Scheme 1).

The thus-obtained (±)-1,2-O-isopropylidene-3*t*-benzoyloxymethyl-5*t*-hydroxymethylcyclopentane-1*r*,2*c*-diol (*X*) was oxidised with sodium periodate in aqueous acetone and in the presence of ruthenium catalyst to afford (±)-2,3-O-isopropylidene-4*c*-benzoyloxymethyl-2*t*,3*t*-dihydroxycyclopentane-1*r*-carboxylic acid (*XI*) in a high yield. The acid *XI* (characterised by elemental analysis, IR spectrum, and ^{1}H-NMR spectrum) was obtained in sufficient purity and did not require to be isolated for further purposes[13] (Scheme 1).

The use of the Hofmann degradation for conversion of the carboxylic function into the amino group (as reported in the paper mentioned above[4]) did not prove suitable in the present instance. Two modern modifications of the Curtius acyl azide rearrangement have been therefore applied, namely, a direct treatment of the carboxylic acid *XI* either with diphenylphosphoryl azide[14], or, better, with ethyl chloroformate and an inorganic azide[15]. Both methods afford a quantitative yield of the corresponding azide which might be isolated in crystalline state; owing to the instability of the azide (spontaneous rearrangement even at room temperature) it is advisable to perform the rearrangement *in situ* by heating in an inert solvent (evolution of nitrogen at 70°C) to obtain the corresponding isocyanate which reacts with 2,2,2-trichloroethanol with the formation of the required compound *XII* (*cf.*[13]; Scheme 1).

The resulting (±)-1,2-O-isopropylidene-5*t*-benzoyloxymethyl-3*t*-(2,2,2-trichloroethoxycarbonyl)aminocyclopentane-1*r*,2*c*-diol (*XII*) may serve in the role of the starting cyclopentylamine derivative for the synthesis of carbocyclic analogues of ribonucleosides. Thus, compound *XII* contains properly situated and orientated groups (two secondary hydroxylic functions and one hydroxymethyl function) protected by two types (acidolabile and alkalilabile type) of blocking groups which may be selectively removed in further synthetic steps. Furthermore, compound *XII* contains a properly orientated amino group protected with a trichloroethoxycarbonyl

TABLE I

Infrared Spectra (in CCl_4, $c = 2\%$) (in cm^{-1})

Compound (type)	R	ν(c=o)	ν(c—o)	δs(CH_3)	ν(OH) free	ν(OH) bound	free ν(NH)	ν amide I / ν amide II	Additional bands
VIII (*A*)	$CH_2OCOC_6H_5$	1 724	1 272	1 372 1 381	—	—	—	—	1 018, 1 027
X (*A*)	CH_2OH	1 724	1 273	1 373 1 381	3 637	3 560[a]	—	—	1 012, 1 027
XI (*A*)	COOH	1 749[b] 1 716	1 277	1 375 1 383	3 535[c]	—	—	—	1 017, 1 027
XII (*A*)	$NHCOOCH_2CCl_3$	1 725 1 744[d]	1 272	1 374 1 382	—	—	3 445	1 745 1 507	1 014, 1 027
XIV (*A*)	$NHCOCH_3$	1 724	1 273	1 373 1 381	—	—	3 450	1 686 1 505	1 013, 1 027
XVI (*B*)	$CH_2OCOC_6H_5$	1 725	1 270	1 373 1 381	—	—	—	—	1 013, 1 027, 1 052
XVII (*B*)	CH_2OH	1 725	1 271	1 373 1 381	3 638	3 562[a,e]	—	—	1 017, 1 027, 1 053

XX (*B*)	COOH	1 749[b,f] 1 716	1 275	1 376 1 384	2 980	—	—	—	1 017, 1 027, 1 058
XXIV (*B*)	$NHCOOCH_2CCl_3$	1 727 1 746[d]	1 273	1 376 1 383	—	—	3 444	1 746 1 509	1 014, 1 027, 1 052
XXVI (*B*)	$NHCOCH_3$	1 726	1 270	1 373 1 381	—	—	3 449	1 687 1 505	1 014, 1 027, 1 051
XVIII (*C*)	CH_2OH	1 723	1 275	1 373 1 381	3 645 3 638 3 610	—	—	—	1 020, 1 027, 1 040 1 050
XIX (*C*)	COOH	1 716 1 745[b,g]	1 281	1 376 1 384	2 980[h]	—	—	—	1 018, 1 027, 1 042, 1 060
XXI (*C*)	$NHCOOCH_2CCl_3$	1 725 1 749[d]	1 277	1 375 1 383	—	—	3 447[i]	1 505	1 017, 1 027, 1 051
XXIII (*C*)	$NHCOCH_3$	1 724	1 286	1 372 1 381	—	—	3 452[j]	1 653 1 555	1 008, 1 027, 1 059

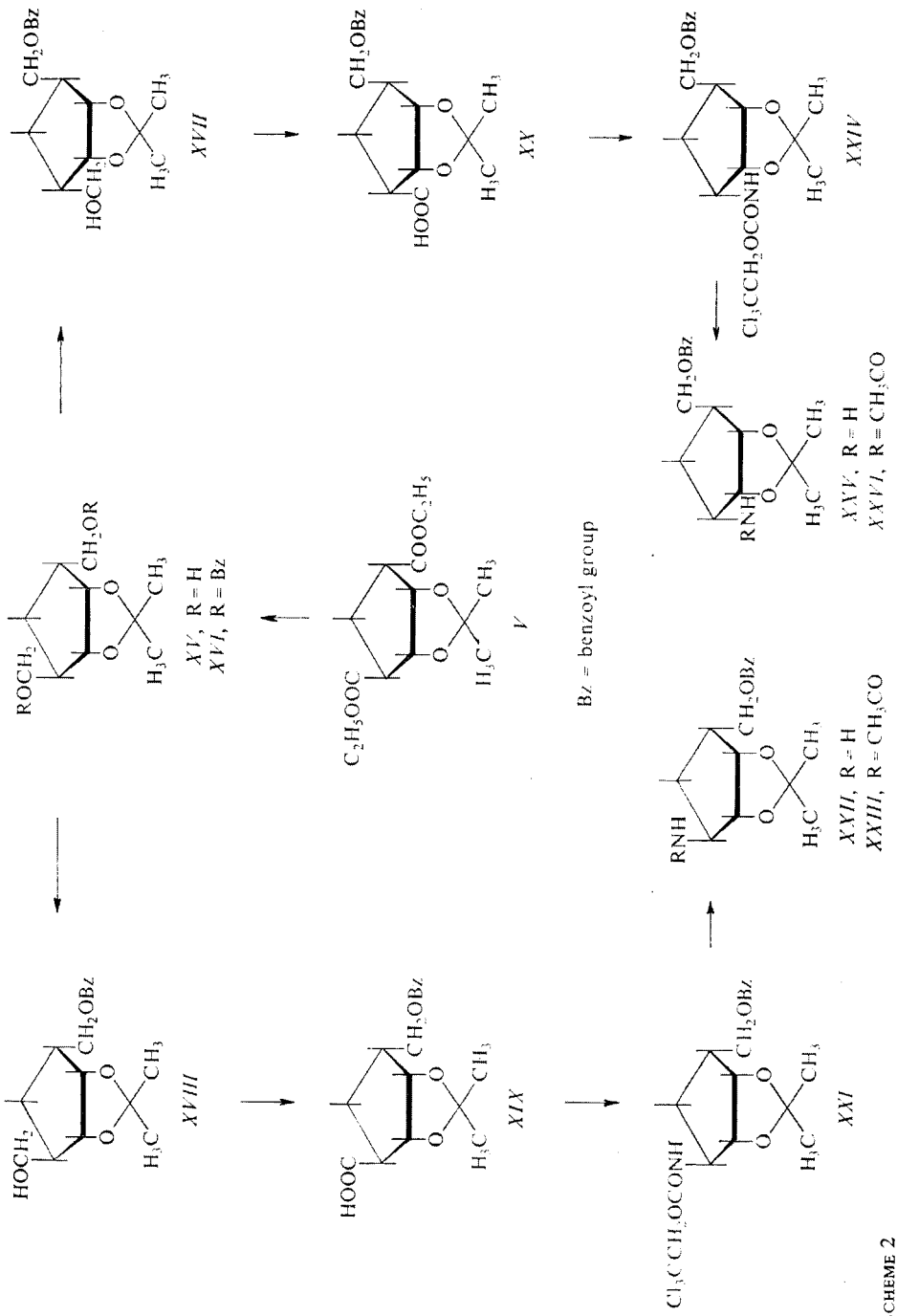
[a] Intramolecular hydrogen bonding; [b] ν(C=O) carboxyl (monomer); [c] monomer; [d] ν(C=O) carbonate; [e] bound to C—O—C linkage; [f] ν(C=O) carboxyl 1714 cm^{-1}, 1719 cm^{-1} (dimer); [g] ν(C=O) carboxyl 1710 cm^{-1} (dimer); [h] ν(OH) carboxyl 3526 cm^{-1} (monomer), 2630 cm^{-1} (dimer); [i] ν(NH) bound 3355 cm^{-1} (dimer); [j] ν(NH) bound 3300 cm^{-1} (dimer).

residue which may be selectively removed by the action of zinc in methanol without affecting the protecting groups of the hydroxylic functions. Compound *XII* is stable when stored. It represents a versatile key intermediate for further synthetic purposes; the corresponding derivative *XIII* is easily generated from compound *XII* and may be used *in situ* (*cf.*[16]).

The structure of compound *XII* follows from analysis, mass spectrum, IR spectrum, and conversion to the amino derivative *XIII* which was characterised in the form of the N-acetyl derivative *XIV* exhibiting the expected analytical values as well as ^{1}H-NMR, IR, and mass spectral data. As shown by the spectral evidence, conversion of the carboxylic acid *XI* to the urethan *XII via* the Curtius reaction was not accompanied by any configurational change on the $C_{(1)}$ carbon atom. The substituent configuration at positions 1–4 of the cyclopentane ring in the amino derivative *XIII* and the N-acetyl derivative *XIV* is identical with that of the starting material *IV*.

An analogous reaction sequence as that one leading to the amino derivative *XII* from the isomer *IV* has been also applied to the isomer *V* (Scheme 2). The lithium aluminium hydride reduction of the diester *V* afforded the tetrol *XV* (not characterised) which was directly converted by benzoylation into the dibenzoyl derivative *XVI*, isomeric with compound *VIII*. The structure *XVI* was confirmed by elemental analysis as well as *IR* and ^{1}H-NMR spectra which are in accord with expectations but at variance with those of the symmetrical isomer *VIII* (Table I and II). The partial debenzoylation of compound *XVI* afforded a mixture of the isomeric monobenzoates *XVII* and *XVIII* as expected (the isomer *XVIII* predominated). The isomers *XVII* and *XVIII* are also formed (along with some dibenzoate *XVI*) on benzoylation of the tetrol *XV* with one equivalent of benzoyl cyanide in acetonitrile (in this case, compound *XVII* predominated). These findings are in accordance with the easier steric accessibility of the hydroxylic function when *trans* with respect to the dioxolane in the compound *XV* towards the benzoylating agent (in the case of benzoylation) or the greater stability of the ester function in *cis*-configuration with respect to the dioxolane system of compound *XVI* (in the case of the partial hydrolysis). The structure of the stereoisomer *XVIII* was unequivocally inferred from the ^{1}H-NMR spectrum by analysis of the particular proton signals and $H_{1,5}$ or $H_{2,4}$ coupling constant magnitudes. Signals of methylene groups at positions 3 and 5 were differentiated by comparison of the spectra before and after the conversion of the free hydroxylic function attached to one of these groups into the corresponding trichloroacetate. The structure of the other isomer *XVII* was confirmed as the only possible. Also the IR spectra of compounds *XVII* and *XVIII* are in accordance with the structures proposed. Thus, compound *XVII* exhibits an intramolecular hydrogen bonding between the primary hydroxylic function at position 3′ and the oxygen atom of the dioxolane ring at position 2 while the formation of such a bonding is not possible in compound *XVIII*, the 5′-hydroxylic function of which is therefore exclusively free.

The sodium periodate oxidation of the two isomeric monobenzoates *XVII* and


XVII
XX
XXIV
XV, R = H
XVI, R = Bz
V
XXV, R = H
XXVI, R = CH3CO
XVIII
XIX
XXI
XXVII, R = H
XXVIII, R = CH3CO
Bz = benzoyl group

SCHEME 2

TABLE II

^{1}H-NMR-Spectra (in deuteriochloroform; δ values in p.p.m., J in Hz)

Compound (type)	R	H_1	H_2	H_3
VII (*A*)	[a]	1·90	4·64 m ($J \leq 1{\cdot}0$, $J = 4{\cdot}0$)	
VIII (*A*)	$CH_2OCOC_6H_5$	2·20 m	4·68 m	
X (*A*)	CH_2OH	1·45—2·40 m	4·63 m	
XI (*A*)	COOH	2·70 m	4·87 t $J_{1,2} = J_{2,3} = 5{\cdot}5$	4·67 t $J_{2,3} = 5{\cdot}5$ $J_{3,4} = 5{\cdot}0$
XII (*A*)	$NHCOOCH_2CCl_3$ [b]	3·90 br	4·55—4·70 m	
XVI (*B*)	$CH_2OCOC_6H_5$	2·55 m	4·74 t $J_{1,2} = 5{\cdot}0$ $J_{2,3} = 5{\cdot}5$	4·67 $J_{2,3} = 5{\cdot}5$ $J_{3,4} \leq 1$
XVII (*B*)	CH_2OH	2·25 m	4·70 m	4·55 m
XX (*B*)	COOH	2·50—3·10 m	4·05—4·90 m	
XXIV (*B*)	$NHCOOCH_2CCl_3$ [b]	3·90 br	4·55—4·70 m	
XVIII (*C*)	CH_2OH	2·27 brd $J_{1,2} \leq 1{\cdot}0$ $J_{1,5} \leq 2{\cdot}0$ $J_{1,5'} = 7{\cdot}0$	4·54 d $J_{2,3} = 5{\cdot}5$ $J_{1,2} \leq 1{\cdot}0$	4·46 t $J_{3,4} = J_{3,2} = 5{\cdot}5$
XIX (*C*)	COOH [e]	3·01 brd $J_{1,2} \leq 1{\cdot}0$ $J_{1,5} \sim 2{\cdot}0$ $J_{1,5'} = 7{\cdot}0$	4·93 d $J_{1,2} \leq 1{\cdot}0$ $J_{3,2} = 5{\cdot}5$	4·72 brt $J_{3,4} = 5{\cdot}0$ $J_{2,3} = 5{\cdot}5$
XXI (*C*)	$NHCOOCH_2CCl_3$ [b]	3·89 m	4·53 d $J_{2,3} = 5{\cdot}5$ $J_{1,2} \leq 1{\cdot}0$	4·72 t $J_{3,4} = 5{\cdot}2$ $J_{3,2} = 5{\cdot}5$

[a] *Cf.* Scheme 1; [b] CH_2CCl_3: 4·72 (s, 2 H); [c] 4·40 after addition of trichloroacetyl isocyanate; [d] 4·16 after addition of trichloroacetyl isocyanate; [e] COOH: 10·65 (brs, 1 M).

TABLE II

H_4	$H_{1'}$	$H_{4'}$	$C(CH_3)_2$	$2\ H_5$	OH	NH
1·90 m	3·74 m (J = 6·0)		1·25 s 1·39 s	1·50 m	2·72 s	—
2·20 m	4·46 (2 × dd) $J_{1,1'} = J_{4,4'} = 6·5$; $J_{1,1''} = J_{4,4''} = 7·5$; $J_{gem} = 11$		1·30 s 1·44 s	1·45—2·05 m	—	—
1·45—2·40 m	3·75 brd	4·40 brd	1·21 s 1·36 s	1·45—2·40 m	2·36 s	—
2·17 m	—	4·43 (2 × dd) $J_{4,4'} = 6·5$ $J_{4,4''} = 8·0$ $J_{gem} = 11·0$	1·30 s 1·42 s	1·70—2·20 m	—	—
2·20 br	—	4·41 m	1·33 s 1·48 s	1·45—2·10 m	—	5·85 brd $J_{NH,H_1} = 8·0$
2·55 m	4·46 (2 dd) $J_{1,1'} = 7·5$ $J_{1,1''} = 6·5$ $J_{gem} = 11·0$	4·21 d J = 7·5	1·31 s 1·48 s	1·60—2·20 m	—	—
2·55 m	3·80 (2 dd)[c] $J_{1,1'} = 5·0$ $J_{1,1''} = 6·0$ $J_{gem} = 11·0$	4·19 d J = 7·5	1·30 s 1·47 s	1·45—2·15 m	2·42 s	—
2·0—2·40 m	—	4·05—4·90 m	1·23 s 1·34 s	1·50—2·0 m	—	—
2·10 br	—	4·40 m	1·32 s 1·49 s	1·45—2·10 m	—	6·08 d ($J_{NH,H_1} = 8$)
2·45 m	3·50 d[d] (J = 7·5)	4·42 (2 dd) $J_{4,4'} = 7·5$ $J_{4,4''} = 6·5$ $J_{gem} = 11·0$	1·30 s 1·45 s	1·50—2·05 m $J_{4,5} = 7·0 = J_{1,5'}$ $J_{5,5'} \leqq 2·0$ $J_{4,5''} = 12·5$ $J_{gem} = 12·5$	2·55 s	—
2·50 m	—	4·43 (2 dd) $J_{4,4'} = 7·5$ $J_{4,4''} = 6·5$ $J_{gem} = 11·0$	1·31 s 1·45 s	1·75—2·25 m $J_{4,5} = 6·5$ $J_{1,5} \sim 2·0$ $J_{4,5'} = 12·5$ $J_{1,5'} = 7·0$ $J_{gem} = 12·5$		
2·70 m	—	4·40 (2 dd) $J_{4,4'} = 8·0$ $J_{4,4''} = 7·5$ $J_{gem} = 11·0$		1·87 m $J_{1,5} = 4·0$	$J_{4,5} = 10$	—

XVIII in the presence of ruthenium afforded the corresponding carboxylic acids *XIX* and *XX* which were treated with ethyl chloroformate and sodium azide and the resulting intermediary azides subjected to thermal rearrangement in the presence of 2,2,2-trichloroethanol with the formation of the corresponding 2,2,2-trichloroethoxycarbonyl derivatives of (±)-1,2-O-isopropylidene-3*c*-benzoyloxymethyl-5*t*-aminocyclopentane-1*r*,2*c*-diol (*XXI*) and (±)-1,2-O-isopropylidene-3*t*-benzoyloxymethyl-5*c*-aminocyclopentane-1*r*,2*c*-diol (*XXIV*). By the action of zinc in methanol, compounds *XXI* and *XXIV* were converted to the corresponding amines *XXII* and *XXV* from which the N-acetyl derivatives *XXIII* and *XXVI* were directly prepared on treatment with acetic anhydride.

The following conclusions may be drawn from comparison of the ^{1}H-NMR spectra shown by the thus-prepared triads of isomeric asymmetrically substituted derivatives of type *A*–*C* (Table I). Character and configuration of substituents at positions 1 and 4 of the cyclopentane ring does not markedly affect the chemical shift magnitude of the CH_2 group at position 5 or of the geminal methyl groups of the dioxolane ring. Also the chemical shift difference of these methyl group signals (Δ = 0·12–0·17) could be hardly used in order to determine the orientation of substituents at positions 1 and 4 in contrast to the nucleoside derivatives[17]. Signals of H_1 and H_4 protons mainly form multiplets which are difficult to analyse. On the other hand, in some type *B* and *C* compounds, the H_2 and H_3 proton signals may be analysed and used for configurational predictions since coupling constants of *trans* orientated protons equal 1 whereas with *cis*-orientated protons this value varies from 5·0 to 5·5 Hz.The sole analysable derivative of type *A*, the carboxylic acid *XI* does not obey this rule; unfortunately, there is no information on the effect of a carboxyl group on conformation of the cyclopentane ring (ring-puckering).

The IR spectra of the above prepared compounds exhibit some common features characteristic of the typical structure of all the three types of compounds, such as ν(C=O) at 1723–1725 cm^{-1} (at 1716 cm^{-1} with carboxylic acids *XI*, *XIX*, and *XX*), the ester ν(C—O) at 1270–1280 cm^{-1}, $\delta_{C(CH_3)_2}$ at 1373–1376 cm^{-1} and 1381–1383 cm^{-1} and further bands in the fingerprint region. All the three carboxylic acids *XI*, *XIX*, and *XX* display an intensive band in the 3000 cm^{-1} region and ν(C=O) bands at 1749 cm^{-1} (monomers) and 1710–1716 cm^{-1} (dimers). The urethans *XII*, *XXI*, and *XXIV* show the presence of ν(C=O) carbonate at 1740 to 1750 cm^{-1}, ν(N=H) free at about 3445 cm^{-1}, and δ_{NH} at about 1505 cm^{-1}.

Only the steric arrangement of compound *XXI* (type C) makes possible the formation of intermolecular associates characterised by ν(N—H) bound at 3355 cm^{-1}. The formation of intramolecular hydrogen bondings in the case of derivatives with a primary alcoholic group as indication of their configuration has been discussed above. The most characteristic band in the 1050–1053 cm^{-1} region (or at 1058 to 1060 cm^{-1} with carboxylic acids) is present in all compounds with *trans*-orientated substituents at positions 1 and 4 (*i.e.* in all compounds of type *B* and *C*) and absent

in compounds of type *A*. Moreover, compounds of the general structure *C* exhibit an additional band at 1040 cm^{-1}. Both these fingerprint region bands are obviously attributable to the stretching vibration of the C—O bond and possess a different intensity when compared with the benzoate value 1027 cm^{-1} as internal standard.

The substituted cyclopentylamine derivatives shown in the present paper serve as suitable starting compounds in the synthesis of purine and pyrimidine carbocyclic ribonucleoside analogues. Isosters of β-ribonucleosides are obtained from compound *XIII*, isosters of α-ribonucleosides from compound *XXV*, and analogues of α-lyxofuranosides from compound *XXII*.

EXPERIMENTAL

Melting points were taken on a heated microscope stage (Kofler block) and are uncorrected. Unless stated otherwise, solutions were taken down at 35°C/15 Torr on a rotatory evaporator. Substances and analytical samples were dried over phosphorus pentoxide at 25°C/0·1 Torr. Thin-layer chromatography was performed on ready-for-use Silufol UV_{235} (Kavalier Glassworks, Votice, Czechoslovakia) silica gel sheets in chloroform; preparative runs were carried out on 45 × 16 × 0·3 cm loose layers of fluorescent indicator containing macroporous silica gel (produced by Service Laboratories of this Institute). Column chromatography was performed on the Pitra macrop oroussilica gel (product of Service Laboratories; particle size, 30—60 micron); fraction volume, 30 ml. The ^{1}H-NMR spectra were measured on a Varian 100 apparatus in deuteriochloroform (hexamethyldisiloxane as internal standard; chemical shift values δ, in p.p.m.; coupling constant values, in Hz). The IR spectra were recorded on a double-beam UR-10 spectrophotometer in chloroform or tetrachloromethane.

Diethyl Cyclopentane-2,3-dione-1,4-dicarboxylate[8] (*III*)

Ethanolic sodium ethoxide (prepared from 260 g *i.e.* 11·3 gramatom of sodium and 2400 ml of 99% ethanol) is diluted with benzene (1000 ml), treated dropwise under stirring over 2 h with a mixture of diethyl glutarate (988 g; 5·24 mol), diethyl oxalate (768 g), and benzene (200 ml) and distilled to afford 2000—2500 ml of a distillate, b.p. 68—78°C. The residue is diluted with benzene (800 ml) and the whole refluxed under stirring for 3 h. The mixture is cooled down and diluted with 4000 ml of ether. The thus-obtained salt is collected with suction, washed with ether (2000 ml), and added into a stirred mixture of ice-cold water (4000 ml) and conc. sulfuric acid (320 ml). The whole mixture is stirred in an ice-bath for 30 min, the solid collected with suction, washed with water until neutral, and crystallised from ethanol (1500 ml) to afford 900—920 g (71—72·5%) of the ester *III*, m.p. 115°C (reported[8], m.p. 115°C). Mass spectrum: (*m*/*e*): 242 (M^+), 227 (M—15), 212 (M—30).

Ethyl 2,3-O-Isopropylidene-2*t*,3*t*-dihydroxycyclopentane-1*r*,4*c*-dicarboxylate (*IV*) and -1*r*,4*t*--dicarboxylate (*V*)

A) A solution of compound *III* (48·4 g; 0·2 mol) in dioxane (800 ml) is hydrogenated over platinum dioxide (3 g) at room temperature and ordinary pressure up to the hydrogen uptake of 9000 ml (for 2 days). The suspension is filtered through Celite and the filtrate evaporated under diminished pressure. The residue is stirred with a mixture of acetone (100 ml), 2,2-dimethoxypropane (50 g; 0·5 mol), and conc. sulfuric acid until a solution is obtained. The solution is

kept at room temperature overnight, neutralised with triethylamine, and evaporated under diminished pressure. The residue is taken up into ether (200 ml), the solution washed with three 50 ml portions of water, dried over anhydrous magnesium sulfate, and evaporated. Distillation of the residue yielded 21 g (37%) of a fraction, b.p. 130–131°C/0·3 Torr, which was diluted with light petroleum (200 ml) and kept at 0°C overnight to deposit 10 g (18%) of the isomer *IV*, m.p. 61–62°C. For $C_{14}H_{22}O_6$ (286·3) calculated: 58·73% C, 7·75% H; found: 57·75% C, 7·80% H. Mass spectrum (*m/e*): 286 (M^+), 285 (M–1), 271 (M–CH_3), 241 (M–CH_3-acetone).

The mother liquor remaining after isolation of compound *IV* was evaporated under diminished pressure and the residue rectified to afford 10 g (18%) of the isomer *V*, b.p. 130°C/0·3 Torr, containing less than 2% of the isomer *IV*. For $C_{14}H_{22}O_6$ (286·3) calculated: 58·73% C, 7·75% H; found: 58·62% C, 7·72% H. Mass spectrum (*m/e*): 286 (M^+), 285 (M–1), 271 (M–CH_3), 241 (M-CH_3-acetone).

B) A mixture of compound *III* (250 g; 1·06 mol), dioxane (3000 ml), and Raney nickel W 8 (50 g) was stirred in an autoclave at 60°C and hydrogen pressure of 80 atm for 2 days, filtered through Celite, and the filtrate evaporated under diminished pressure. To the residue there was added acetone (200 ml), 2,2-dimethoxypropane (200 ml), and 6 M hydrogen chloride in dimethylformamide to an acidic reaction on a moistened pH-paper (15 ml). The whole mixture was kept at room temperature overnight, neutralised with triethylamine, evaporated under diminished pressure, and the residue taken up into ether (500 ml). The ethereal solution was washed with two 50 ml portions of water, dried over anhydrous magnesium sulfate, filtered, the filtrate evaporated, and the residue distilled to afford 158·5 g (52·5%) of a fraction, b.p. 165–170°C/0·5 Torr. Crystallisation from light petroleum (300 ml) yielded 106 g (37·3%) of compound *IV*, m.p. 61–62°C. Rectification of the mother liquor afforded 49 g (16%) of compound *V*. As shown by gas chromatography, the isomers *IV* and *V* were identical with the corresponding specimens obtained by procedure *A*.

1,2-O-Isopropylidene-3*t*,5*t*-bis(hydroxymethyl)cyclopentane-1*r*,2*c*-diol (*VII*)

To a stirred suspension of lithium aluminium hydride (29 g; 0·76 mol) in ether (600 ml) there was added dropwise under ice-cooling over 30 min a solution of compound *IV* (143 g; 0·5 mol) in ether (400 ml) and the mixture stirred at 40°C for 2 h. Ethyl acetate (200 ml), water (90 ml), and 4M sodium hydroxide (90 ml) were then successively dropped over 30 min into the mixture. The resulting suspension was filtered and the solid on the filter washed with ether (200 ml) and chloroform (two 400 ml portions). The filtrate and washings were combined, dried over anhydrous magnesium sulfate for 30 min, and evaporated under diminished pressure. The residue was triturated with light petroleum (800 ml) to deposit a solid which was collected with suction, washed with light petroleum (200 ml), and dried under diminished pressure. Yield, 90–94 g (89–93%) of the diol *VII*, m.p. 82–83°C. For $C_{10}H_{18}O_4$ (202·2) calculated: 59·39% C, 8·97% H; found: 59·51% C, 8·99% H.

1,2-O-Isopropylidene-3*t*,5*t*-bis(benzoyloxymethyl)cyclopentane-1*r*,2*c*-diol (*VIII*)

To a solution of compound *VII* (34 g; 0·17 mol) in pyridine (150 ml) there was added dropwise under stirring and ice-cooling over 10 min benzoyl chloride (57 g; 0·4 mol), the mixture kept at 0°C overnight, diluted with ethanol (20 ml), poured onto ice (500 g), and extracted with three 200 ml portions of chloroform. The extracts were combined, dried over anhydrous magnesium sulfate, and evaporated under diminished pressure. The residue was crystallised from ethanol (200 ml), collected with suction, washed on the filter with ethanol (100 ml), and dried under

diminished pressure. Yield, 65 g (93%) of compound *VIII*, m.p. 126—127°C. For $C_{24}H_{26}O_6$ (410·4) calculated: 70·21% C, 6·38% H; found: 70·30% C, 6·42% H. R_F value: 0·82.

(±)-1,2-O-Isopropylidene-3*t*-benzoyloxymethyl-5*t*-hydroxymethylcyclopentane-1*r*,2*c*-diol (*X*)

A) To a solution containing compound *VII* (181·8 g; 0·9 mol), triethylamine (25 ml), and acetonitrile (1 500 ml) there was added dropwise under stirring over 90 min a solution of benzoyl cyanide (131 g; 1·0 mol) in acetonitrile (500 ml) and the whole mixture was stirred 1 h without cooling to deposit a crystalline solid which was collected with suction, washed with ethanol (100 ml), the filtrate and washings combined and evaporated under diminished pressure. The residue was crystallised from ethanol (500 ml), collected with suction, washed with ethanol (100 ml), and dried under diminished pressure. The two crops were combined to afford 136 g (37%) of compound *VIII*, m.p. 126—127°C, undepressed on admixture with an authentic specimen.

The mother liquor remaining after the crystallisation of compound *VIII* was concentrated under diminished pressure almost to dryness, the concentrate triturated with light petroleum (1 000 ml), and the whole kept at −5°C to −10°C for 24 h to deposit a solid which was collected with suction, washed with ice-cold light petroleum (200 ml), and dried under diminished pressure. Yield, 132 g (48%) of compound *X*, m.p. 116°C; R_F 0·35. For $C_{17}H_{22}O_5$ (306·4) calculated: 66·63% C, 7·23% H; found: 66·17% C, 7·07% H.

B) To a solution of compound *VIII* (41 g; 0·1 mol) in 90% aqueous dioxane (500 ml) there was added a solution of sodium hydroxide (4 g; 0·1 mol) in water (20 ml) and the resulting mixture stirred without cooling, the pH value being occasionally checked with the use of a moistened pH-paper. At pH 7·5—8·0, the mixture was evaporated under diminished pressure and the residue distributed between chloroform (500 ml) and water (100 ml). The chloroform layer was washed with two 100 ml portions of water, dried over anhydrous magnesium sulfate, filtered, and the filtrate evaporated under diminished pressure. The residue was dissolved in ethanol (50 ml), the solution diluted with light petroleum (300 ml), and the mixture kept at −5°C overnight to deposit a solid which was collected with suction, washed with light petroleum (100 ml), and dried under diminished pressure. Yield, 18·0 g (59%) of the chromatographically homogeneous compound *X*, m.p. 116°C, identical with the specimen obtained by procedure *A*.

C) Compound *VIII* (27 g; 0·066 mol) in 1 000 ml of 70% aqueous ethanol preheated to 50°C was treated with a solution of sodium hydroxide (2·7 g; 0·066 mol) in water (100 ml), the mixture stirred until neutral (moistened pH-paper), and processed according to procedure *B*. Yield, 8·5 g (42%) of chromatographically homogeneous compound *X*, m.p. 116°C.

(±)-2,3-O-Isopropylidene-4*c*-benzoyloxymethyl-2*t*,3*t*-dihydroxycyclopenta ne-1*r*-carboxylic Acid (*XI*)

To a solution containing (±)-1,2-0-isopropylidene -3*t*-benzoyloxymethyl-5*t*-hydroxymethylcyclopentane-1*r*,2*c*-diol (*X*; 61·2 g; 0·2 mol), crystalline sodium periodate (65 g), and 70% aqueous acetone (1 000 ml), there was added an aqueous solution of ruthenium hydroxytrichloride (content, 20 mg of ruthenium), the whole mixture stirred without cooling for 2·5 h, filtered with suction, and the material on the filter washed with acetone (500 ml). The filtrate and washings were combined, evaporated almost to dryness, the residue diluted with chloroform (2000 ml), and the aqueous layer separated. The chloroform layer was dried over anhydrous magnesium sulfate, filtered, and the filtrate evaporated under diminished pressure. The crystalline residue may be directly used in the preparation of compound *XII* or recrystallised from ethanol (400 ml) by the addition of light petroleum (1000 ml). The product was collected and washed with light petroleum (200 ml). Yield (after drying under diminished pressure), 59 g (92%) of compound *XI*, m.p.

190—192°C. For $C_{17}H_{20}O_6$ (320·3) calculated 63·74% C, 6·29% H; found: 63·87% H, 6·41% H. R_F value: 0·60.

(±)-1,2-O-Isopropylidene-3*t*-benzoyloxymethyl-5*t*-(2,2,2-trichloroethoxycarbonyl)amino-cyclopentane-1*r*,2*c*-diol (*XII*)

A) To an ice-cooled suspension of compound *XI* (64 g; 0·2 mol) in acetone (800 ml) there was added under stirring triethylamine (300 ml) and then ethyl chloroformate (28 ml). The mixture was stirred at 0°C for 30 min, treated with saturated aqueous lithium azide (16·5 g) or sodium azide (22 g), stirred at 0°C for additional 2 h, and concentrated at 30°C/15 Torr to the volume of about 200 ml. The concentrate was taken up into chloroform (1 000 ml), the chloroform solution washed with two 200 ml portions of water, dried over anhydrous magnesium sulfate, and evaporated at 30°C/15 Torr almost to dryness. Toluene (300 ml) was added to the residue and the mixture gradually heated under reflux condenser under exclusion of atmospheric moisture (calcium chloride tube). The spontaneous evolution of nitrogen began at about 70°C and ceased after about 20 min at 90°C. The mixture was then maintained at 90°C for 30 min, treated with 2,2,2-trichloroethanol (50 ml), and the heating at 90°C was continued for 2 h. The mixture was kept at room temperature overnight and evaporated first at 40°C/15 Torr and then at 40°C/0·1 Torr. Recrystallisation of the residue from ethanol (400 ml) afforded 72 g (80%) of compound *XII*, m.p. 156—157°C. For $C_{19}H_{20}Cl_3NO_5$ (448·7) calculated: 50·85% C, 4·49% H, 23·70% Cl, 3·12% N; found: 50·67% C, 5·18% H, 23·53% Cl, 2·97% N. R_F value: 0·70.

B) A mixture of compound *XI* (4·48 g; 14 mmol), diphenylphosphoryl azide[14] (4·2 g), benzene (40 ml), and triethylamine (1·5 g; 2·1 ml; 15 mmol) was stirred at room temperature for 30 min and then refluxed for 30 min under exclusion of atmospheric moisture. 2,2,2-Trichloroethanol (2·6 g; 1·7 ml; 17·4 mmol) was added and the reflux continued for 3 h. The benzene was evaporated under diminished pressure, the residue taken up into ethyl acetate (100 ml), the organic solution washed with two 50 ml portions of water, dried over anhydrous magnesium sulfate, evaporated under diminished pressure, and the residue crystallised from ethanol. Yield, 2·8 g (44·5%) of compound *XII*, m.p. 156—157°C, undepressed on admixture with the specimen prepared by procedure *A*.

1,2-O-Isopropylidene-3*t*,5*c*-bis(benzoyloxymethyl)cyclopentane-1*r*,2*c*-diol (*XVI*)

To a stirred suspension of lithium aluminium hydride (20·5 g) in ether (500 ml) there was added dropwise under ice-cooling over 30 min a solution of compound *V* (49 g; 0·17 mol) in ether (200 ml). The mixture was refluxed with stirring for 2 h under exclusion of atmospheric moisture, cooled down with ice, and treated dropwise with ethyl acetate (90 ml), then water (45 ml), and finally 4M sodium hydroxide (45 ml). The suspension was filtered through Celite and the material on the filter washed with ether (200 ml) and hot chloroform (200 ml). The filtrate and washings were combined, dried over anhydrous magnesium sulfate, filtered with suction, and the filtrate evaporated under diminished pressure. The residual crude *XV* (34 g; 98%) was dissolved in pyridine (150 ml) and the solution treated dropwise under stirring and ice-cooling with benzoyl chloride (56·2 g; 46·5 ml; 0·4 mol). The mixture was kept at room temperature overnight, treated with ethanol (20 ml), kept for 1 h, poured onto ice (500 g), and extracted with three 200 ml portions of chloroform. The extract was washed with three 100 ml portions of water, dried over anhydrous magnesium sulfate, and evaporated under diminished pressure. Crystallisation of the residue from ethanol (200 ml) afforded 50·0 g (72%) of compound *XVI*, m.p. 130—131°C; R_F 0·82. For $C_{24}H_{26}O_6$ (410·4) calculated: 70·21% C, 6·38% H; found: 70·49% C, 6·38% H.

(±)-1,2-O-Isopropylidene-3*t*-benzoyloxymethyl-5*c*-hydroxymethylcyclopentane-1*r*,2*c*-diol (*XVII*) and (±)-1,2-O-Isopropylidene-3*c*-benzoyloxymethyl-5*t*-hydroxymethylcyclopentane-1*r*,2*c*-diol (*XVIII*)

A) On partial hydrolysis of compound XVI. To a stirred suspension of compound *XVI* (74 g; 0·18 mol) in methanol (500 ml) there was added successively at 60°C a solution of sodium hydroxide (7·2 g; 0·18 mol) in water (250 ml) and then dioxane (250 ml). The mixture was stirred at 60°C until the starting compound disappeared (as shown by thin-layer chromatography; 2 h), the neutral solution concentrated under diminished pressure to the volume of about 200 ml, the concentrate diluted with water (200 ml), and extracted with three 200 ml portions of chloroform. The extract was washed with two 100 ml portions of water, dried over anhydrous magnesium sulfate, and evaporated under diminished pressure. The residue was chromatographed on silica gel (150 g) in chloroform under standard conditions. The fractions containing compound *XVII* (R_F 0·4) and *XVIII* (R_F 0·27) were taken down under diminished pressure and the residues crystallised from appropriate solvents. Yield, 5·65 g (10%) of compound *XVII*, m.p. 96—97°C (ethanol–light petroleum). For $C_{17}H_{22}O_5$ (306·4) calculated: 66·63% C, 7·23% H; found: 66·96% C, 7·27% H. The other residue yielded 11·5 g (21%) of compound *XVIII*, m.p. 88°C (cyclohexane); R_F 0·27. For $C_{17}H_{22}O_5$ (306·4) calculated: 66·63% C, 7·23% H; found: 66·77% C, 7·09% H.

B) On partial benzoylation of compound XV. The crude residue of compound *XV* (see the preparation of compound *XVI*) was dissolved (70·8 g; 0·35 mol) in acetonitrile (1 000 ml) and triethylamine (10 ml) and the whole treated dropwise under stirring over 2 h with a solution of benzoyl cyanide (65·5 g; 0·5 mol) in acetonitrile (250 ml). The stirring was continued for 30 min, the mixture cooled down, filtered with suction, and the material on the filter washed with acetonitrile. The filtrate and washings were combined, evaporated under diminished pressure, and the residue was crystallised from ethanol (200 ml) to deposit an additional crop of the dibenzoate *XVI* which was combined with the first crop and dried under diminished pressure. Overall yield, 74 g (51·5%) of the pure dibenzoate *XVI*, m.p. 130—131°C.

The ethanolic mother liquor remaining after the crystallisation of compound *XVI* was taken down under diminished pressure and the residue chromatographed on a column of silica gel (200 g) in chloroform–tetrachloromethane (1 : 1) under standard conditions. Work-up of the fraction containing compound *XVII* and crystallisation of the residue from a mixture of ethanol and light petroleum yielded 18 g (16%) of compound *XVII*, m.p. 95—97°C, undepressed on admixture with the specimen obtained by procedure *A*; R_F value, 0·40.

Elution with chloroform, evaporation of the eluate, and crystallisation of the residue from cyclohexane yielded 1·5 g (1·4%) of compound *XVIII*, m.p. 88°C; R_F 0·27.

(±)-2,3-O-Isopropylidene-5*t*-benzoyloxymethyl-2*t*,3*t*-dihydroxycyclopentane-1*r*-carboxylic Acid (*XIX*)

To a solution containing compound *XVIII* (3·06 g; 10 mmol), crystalline sodium periodate (6·5 g), and 70% aqueous acetone (120 ml) there was added an aqueous solution of ruthenium hydroxytrichloride (containing 1 mg of ruthenium), the whole mixture stirred at room temperature for 2 h, filtered with suction, and the material on the filter washed with acetone (50 ml). The filtrate and washings were combined, evaporated under diminished pressure, the residue taken up into chloroform (200 ml), the solution washed with two 50 ml portions of water, dried over anhydrous magnesium sulfate, filtered, the filtrate evaporated under diminished pressure, and the residue crystallised from a mixture of ethyl acetate (20 ml) and light petroleum (100 ml) overnight at −10°C. Yield, 3·0 g (93·7%) of compound *XIX*, m.p. 118—119°C; R_F 0·65. For $C_{17}H_{20}O_6$ (320·3) calculated: 63·74% C, 6·29% H; found: 64·01% C, 6·64% H.

(±)-2,3-O-Isopropylidene-5*t*-benzoyloxymethyl-2*c*,3*c*-dihydroxycyclopentane-1*r*-carboxylic Acid (*XX*)

The acid *XX* was prepared analogously to the acid *XIX*. From compound *XVII* (10 mmol) there was obtained after crystallisation from ethanol (20 ml) and light petroleum (200 ml) at −10°C overnight 2·1 g (87%) of compound *XX*, m.p. 170−171°C; R_F 0·62. For $C_{17}H_{20}O_6$ (320·3) calculated: 63·74% C, 6·29% H; found: 63·61% C, 6·06% H.

(±)-1,2-O-Isopropylidene-3*t*-benzoyloxymethyl-5*c*-(2,2,2-trichloroethoxycarbonyl)amino-cyclopentane-1*r*,2*c*-diol (*XXIV*)

To a stirred solution of compound *XX* (1·8 g; 5·6 mmol) in acetone (25 ml) there was succesively added at 0°C triethylamine (1·15 ml), ethyl chloroformate (0·9 ml), and (after 30 min) a solution of lithium azide (0·7 g) in water (2 ml). The stirring at 0°C was continued for 2 h, the mixture taken down under diminished pressure at 30°C, the residue taken up into chloroform (100 ml), the solution washed with two 25 ml portions of water, dried over anhydrous magnesium sulfate, filtered, and the filtrate evaporated under diminished pressure at 30°C. The residue was heated with toluene (30 ml) at 95°C for 30 min and then 2,2,2-trichloroethanol (2 ml) was added. The whole mixture was heated at 95°C for 2 h, kept at room temperature overnight, and evaporated at 40°C/0·1 Torr. The residue was chromatographed on a layer of loose silica gel in chloroform. The band corresponding to the product was eluted with methanol, the eluate evaporated, and the residue crystallised from a mixture of ethyl acetate and light petroleum at −10°C to afford 1·22 g (48·5%) of compound *XXIV*, m.p. 132−134°C; R_F 0·70. For $C_{19}H_{20}Cl_3NO_5$ (448·7) calculated: 50·85% C, 4·49% H, 23·70% Cl, 3·12% N; found: 49·97% C, 4·90% H, 23·84% Cl, 2·83% N.

(±)-1,2-O-Isopropylidene-3*c*-benzoyloxymethyl-5*t*-(2,2,2-trichloroethoxycarbonyl)amino-cyclopentane-1*r*,2*c*-diol (*XXI*)

The title *XXI* was prepared analogously to compound *XXIV*. Compound *XIX* (7·8 mmol) yielded 2·25 g (64%) of the diol *XXI*, m.p. 121−122°C; R_F 0·68. For $C_{19}H_{20}Cl_3NO_5$ (448·7) calculated: 50·85% C, 4·49% H, 23·70% Cl, 3·12% N; found: 50·73% C, 4·89% H, 23·75% Cl, 3·14% N.

(±)-1,2-O-Isopropylidene-3*t*-benzoyloxymethyl-5*t*-acetylaminocyclopentane-1*r*,2*c*-diol (*XIV*)

A mixture of compound *XII* (0·45 g; 1 mmol), zinc powder (1 g), and ammonium chloride (1 g) in methanol (10 ml) was refluxed with stirring for 30 min, filtered while hot, and the material on the filter washed with methanol (50 ml). The filtrate and washings were combined, evaporated under diminished pressure, the residue extracted with two 25 ml portions of hot chloroform, the extracts filtered, the filtrate evaporated under diminished pressure, and the residue dried at 0·1 Torr for 1 h. The dry residue was then kept with chloroform (10 ml) and acetic anhydride (0·5 ml) overnight at room temperature, the mixture diluted with chloroform (50 ml), washed with saturated aqueous sodium hydrogen carbonate (25 ml) and water (25 ml), dried over anhydrous magnesium sulfate, filtered, and the filtrate evaporated under diminished pressure. The residue was dissolved in a minimum volume of hot ethanol, the solution treated with light petroleum until turbid, and then kept at 0°C overnight to deposit a solid which was collected with suction, washed with light petroleum, and dried under diminished pressure. Yield, 0·30 g (90%) of compound *XIV*, m.p. 154−156°C; R_F 0·15. For $C_{18}H_{23}NO_5$ (333·4) calculated: 64·85% C, 6·95% H, 4·20% N; found: 64·18% C, 6·99% H, 4·47% N. Mass spectrum (*m/e*): 333, 318 (M−15), 211 (M−122), 105 ($C_6H_5 \cdot CO_2H$), 43 (acetyl).

(±)-1,2-O-Isopropylidene-3*c*-benzoyloxymethyl-5*t*-acetylaminocyclopentane-1*r*,2*c*-diol (*XXIII*)

The title *XXIII* was prepared analogously to compound *XIV*. Thus, 1 mmol of compound *XXI* yielded 0·27 g (81%) of compound *XXIII*, m.p. 139–141°C (ethanol–light petroleum); R_F 0·10. For $C_{18}H_{23}NO_5$ (333·4) calculated: 64·85% C, 6·95% H, 4·20% N; found: 64·60% C, 7·17% H, 4·08% N.

(±)-1,2-O-Isopropylidene-3*t*-benzoyloxymethyl-5*c*-acetylaminocyclopentane-1*r*,2*c*-diol (*XXVI*)

The title *XXVI* was prepared analogously to compound *XIV*. Thus, 1 mmol of compound *XXIV* yielded 0·29 g (87%) compound *XXVI*, m.p. 136–138°C (ethanol–light petroleum); R_F 0·15. For $C_{18}H_{23}NO_5$ (333·4) calculated: 64·85% C, 6·95% H, 4·20% N; found: 64·92% C, 6·87% H, 4·27% N.

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