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# Synthesis of Perhydro-Furo[2,3-*b*]Pyran (and Furan)-3-yl Methanols by Oxygenative Radical Cyclization

Stanislas Mayer, Jacques Prandi*

*Institut de Chimie Organique et Analytique, Université d'Orléans, BP 6759, 45067 Orléans Cedex 2, France.*

Toufiq Bamhaoud, Salem Bakkas

*Laboratoire de Chimie Organique et Bioorganique, Université Chouaib Doukkali, BP 20, El Jadida, Maroc.*

Olivier Guillou

*Laboratoire de Chimie des Matériaux Inorganiques et de Cristallographie, INSA, 35043 Rennes Cedex, France.*

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**Abstract** : 5-*exo* radical cyclization followed by oxygenation with molecular oxygen of various 3-halogeno-2-allyloxy-perhydro-pyrans and -furans gave the perhydro-furo[2,3-*b*]pyran (and furan)-3-yl methanols in one step. Two catalytic systems were efficiently used for this transformation : tributyltin hydride/AIBN/$O_2$ and Co(salen)/$NaBH_4$/$O_2$. Yields were high and interesting selectivities were observed. The reaction is general and was successfully applied to carbohydrate derived substrates.

## Introduction

Radical mediated cyclizations are powerful tools for the formation of carbocycles and heterocycles and numerous examples of their synthetic applications can be found.[1] Radical cyclization sequences with an impressive degree of complexity have been developped and allow the one-step elaboration of polycyclic frameworks with a high level of stereocontrol.[2] Most of these reactions are terminated by an hydrogen atom transfer although carbon-centered radicals could also react with many heteroatomic reagents with introduction of a useful new carbon-heteroatom bond into the products of the reaction.[3] Apart from the atom transfer

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* Present adress : Institut de Pharmacologie et de Biologie Structurale du CNRS, 205 route de Narbonne, F-31077 TOULOUSE CEDEX. Fax : (33) (0)5 61 17 59 94. email : prandi@ipbs.fr

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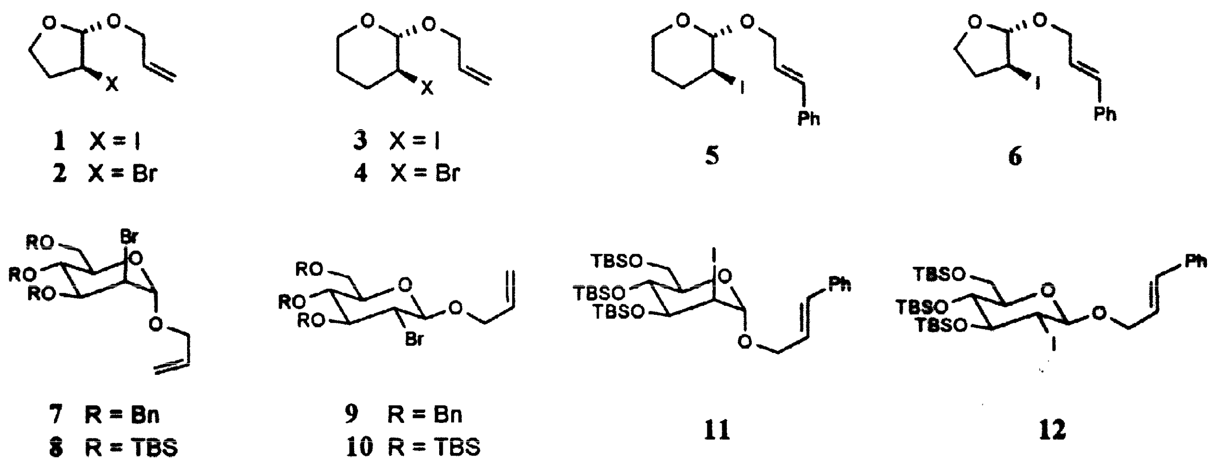
method,[4] few examples of the radical cyclization/heteroatom quench sequence are known.[5,6a] The decomposition of alkylcobalt complexes in presence of various radical trapping agents allows the same sequence to be carried out in two-steps.[3b,3c,7] Reaction of carbon-centered radicals with molecular oxygen is very fast and has been used in synthesis for the introduction of an hydroxyl group from a radical precursor.[8] In relation with studies on the mecanism of prostaglandin synthesis, it was shown as early as 1975 that 5-*exo* radical cyclization could be carried out in presence of molecular oxygen and gave the expected cyclized oxygenated products[9,10] but, except in one particular case,[10] yields were low. Radical oxygenations have been carried out successfully with nitroxyl radicals to give hydroxylamines which had then to be reduced to the alcohols.[5,11] Despite the potential interest of molecular oxygen in these tranformations and the report of its successful use by Nakamura under ultrasonic irradiation,[6a] no general system was available.

Following our preliminary work,[12,13] we now report our full results on two different systems for the oxygenative radical cyclization of various 5-hexenyl-3-oxa-radicals to perhydro-furo[2,3-b]pyran (and furan)-3-yl methanols, including sugar derivatives.

## Starting materials

All starting materials used for this study were prepared by NIS or NBS promoted addition of allyl or cinnamyl alcohol on the corresponding cyclic enol ether.[14] Sugar derivatives were prepared from the commercially available tri-*O*-acetyl-D-glucal by standard procedures.



1 X = I
2 X = Br

3 X = I
4 X = Br

5

6

7 R = Bn
8 R = TBS

9 R = Bn
10 R = TBS

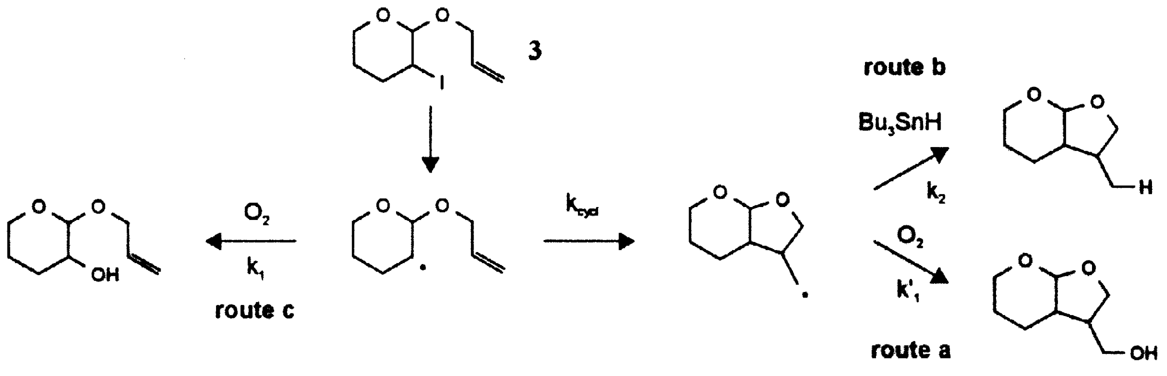
11

12

Figure 1

## The Tin Hydride System

Our first attempts were carried out with the system successfully used for radical substitution of iodides to alcohols.[15] The combination of 3 equivalents of tributyltin hydride and 1 eq. of AIBN in toluene proved effective for the generation of radicals from iodo compound **3** even in the presence of molecular oxygen and disparition of starting material was observed in a few hours at 80°C. The expected cyclized alcohols **15** and **16** were obtained (52%, scheme 1) and despite the very high rate of the reaction of carbon-centered radicals with molecular oxygen ($k_1 \sim k'_1 \sim 2.10^9$ $mol^{-1}.s^{-1}$)[16] the major byproducts were the reduced cyclized compounds (route b, 21%) and not the uncyclized oxygenated products (route c, <3%).



**15/16**

Scheme 1

This showed that, with these substrates and under these conditions, the major competitive pathway was hydrogen abstraction by the cyclized radicals on the tin hydride (route b, scheme 1) and that radical cyclization was much faster than oxygen quench. This is in sharp contrast with the reported oxygenation of the 5-hexenyl radical to 5-hexenol[17] and the preferential hydroxystannation of a triene before cyclization.[6b] In these cases, intermolecular trapping of the radicals by oxygen was found much faster than cyclization (route c). Better yields of oxygenated products were achieved by lowering the concentration of hydrogen donor in the reaction medium. This could be achieved by slow addition of the tin hydride to the reaction mixture with a syringe pump (procedure B) or, more conveniently, by using a catalytic amount of tributyltin chloride in presence of sodium borohydride (procedure A) according to the conditions described by Corey.[18] Because of the lower amount of tin compound involved in the latter case, a much easier work-up of the reaction was an additional advantage of this procedure which was more thoroughly investigated. In these conditions, all studied iodides gave good yields of products in a few hours but bromides were very reluctant to react and considerable amounts of starting material were recovered even under more forcing conditions (refluxing propanol instead of ethanol, longer reaction time). Only 25% of a 4/1 mixture of **15** and **16** was obtained from bromide **4** after 14 hours in refluxing ethanol. No reaction was observed with $(Bu_3Sn)_2$ and air under irradiation in toluene. Results are summarized in Tables 1 and 2.

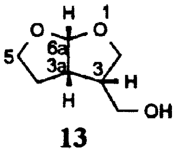
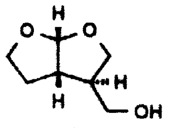
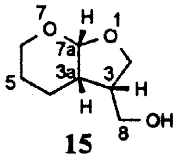
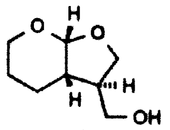
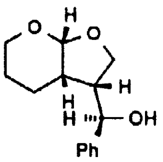
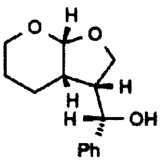
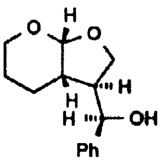
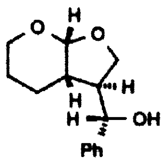
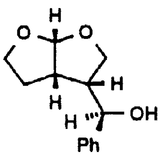
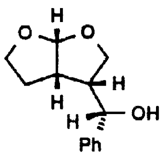
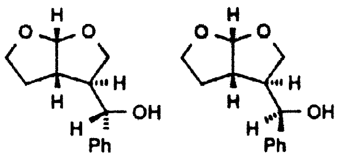
The influence of the radical initiator is crucial, attempts to run the reaction with less than 0.5-0.8 equivalent of AIBN gave lower yields and some recovered starting material. The role of the tin reagent is less clear as the reaction could be run without any tin compound.[19] Thus, the cyclization of **6** with 1.5 eq of AIBN and 6 eq. of sodium borohydride in refluxing ethanol for 8 hours gave a 52% yield of cyclized alcohols **21-24** instead of 69% in the very same conditions but with 0.06 eq. of tributyltin chloride. Althought the improvement was only minor, higher yields were obtained when a catalytic amount of tributyltin chloride was added to the reaction. The use of pure oxygen instead of air always gave lower conversions and lower yields in otherwise identical conditions.[20] Taken together, these results suggest a very short radical chain (if any) and in fact, the quench of the tributyltin radical, the chain carrier, by molecular oxygen should be a very efficient process. Minor selectivity differences were observed between the stoichiometric and the catalytic system (see entries 5 and 6 , Table 1, and entries 5 and 6, Table 2).

## The Cobalt System

In light of the limitations of the tin hydride system, we looked for a more convenient way to carry out the radical cyclization/oxygenation sequence and turned our attention to cobalt-mediated radical reactions.[21,22] It is well known that the reaction of cobalt(I) nucleophiles with halogeno compounds give alkyl cobalt(III) complexes which are good precursors of alkyl radicals under mild conditions.[3,7,21,22] Regeneration of the reduced cobalt(I) species by an appropriate reducing reagent led to catalytic reactions and numerous examples of synthetically useful processes have been described.[23] Oxygenolysis of the cobalt(III)-carbon bond is possible with molecular oxygen or nitroxyl radicals[3c,7] and allows the introduction of an oxygenated functionality into the product *via* a radical mechanism but yields are variable. The strongly reducing Co(I) complexes are very sensitive to oxidation and molecular oxygen has been shown to be a strong inhibitor of the radical rearrangement of 5-hexenyl cobalt(III) complexes to their cyclopentylmethyl isomers,[24] but some interesting catalytic reactions involving molecular oxygen and cobalt complexes under reductive conditions are known.[25]

Treatment of iodide **3** with 5% of the commercially available chloro(pyridine)bis(dimethylglyoximato) cobalt in ethanol in presence of 2 eq. $NaBH_4$ and 2 eq. NaOH under air[25] gave 21 % of the expected products after 18 hours at 40°C (**15**/**16** : 4/1). In the same conditions, a 45% yield of cyclized oxygenated products **17-20** were obtained from **5** after 5 hours at 40°C provided the cobalt catalyst (10%) was added in three portions over 4 hours. Running the reaction at higher temperature or under irradiation with visible light (150W tungsten lamp) did not improve the yields and rapid loss of activity of the catalyst was observed.

**Table 1**

| Entry | Substrate | Conditions[a]<br>yield,[b] selectivity[c] | Products | | | |
|---|---|---|---|---|---|---|
| 1 | 1 | A, 24h, 80°C<br>72%, 15/1 | <br>13 | <br>14 | | |
| 2 | 2 | C, 2h, 40°C<br>76%, 7/1 | | | | |
| 3 | 3 | A, 8h, 80°C<br>64%, 4/1 | <br>15 | <br>16 | | |
| 4 | 3 | C, 1h, rt<br>80%, 7/1 | | | | |
| 5 | 5 | A, 7h, 80°C<br>78%, 2/1/1/1 | <br>17 | <br>18 | <br>19 | <br>20 |
| 6 | 5 | B, 2h, 80°C<br>64%, 2/1.5/1/1 | | | | |
| 7 | 5 | C, 2h, rt<br>74%, 3/1/1/1 | | | | |
| 8 | 6 | A, 8h, 80°C<br>69%, 5/3/1/1 | <br>21 | <br>22 | <br>23/24 | |

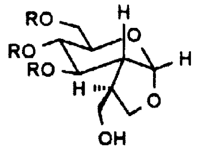
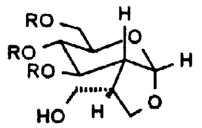
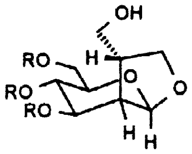
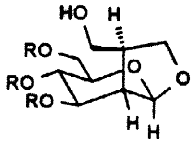
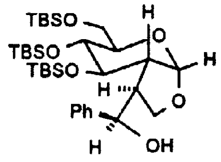
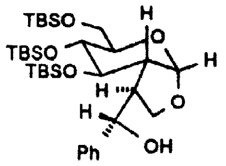
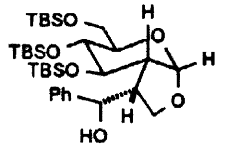
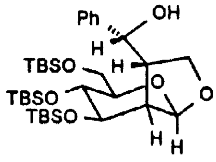
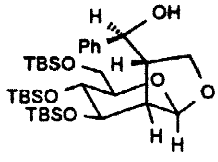
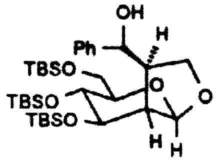
a. A, B and C refer to procedures A, B and C (see experimental). A : catalytic $Bu_3SnCl$/ $NaBH_4$; B : $Bu_3SnH$; C : Co(salen) catalysis.

b. Yields are isolated yields for the purified mixture of isomers.

c. Selectivities were obtained by integration of the $^1H$ NMR spectrum of the purified mixture of isomers before separation.

Working with 3% of Co(salen) complex[26] as catalyst, complete conversion of iodide **3** was observed in one hour at room temperature (2 eq. $NaBH_4$, 1.7 eq. NaOH, air) and compounds **15** and **16** were isolated in 80% yield and in 7/1 ratio. Once again, the only identified by-products were the reduced cyclized compounds (route b, scheme 1) and none of the uncyclized alcohols (route c) could be detected in the reaction mixture. Bromides were also reactive and could be cyclized in high yield but the temperature had to be raised to 40°C to ensure short reaction times.

**Table 2**

| Entry | Substrate | Conditions[a]<br>yield,[b] selectivity[c] | Products | | |
|---|---|---|---|---|---|
| 1 | 7 | C, 1h, 40°C<br>50%, 7/1 | <br>25 R = Bn<br>27 R = TBS | <br>26 R = Bn<br>28 R = TBS | |
| 2 | 8 | C, 6h, 40°C<br>62%, 4/1 | | | |
| 3 | 9 | C, 0.5h, 40°C<br>60%, 3/1 | <br>29 R = Bn<br>31 R = TBS | <br>30 R = Bn<br>32 R = TBS | |
| 4 | 10 | C, 3.5h, 40°C<br>70%, 3/1 | | | |
| 5 | 11 | A, 80°C<br>71%, 46/28/16/10 | <br>33 | <br>34 | <br>35/36 |
| 6 | 11 | B, 60°C<br>78%, 56/28/9/5 | | | |
| 7 | 11 | C, 0.5h, 40°C<br>84%, 6/2/1/1 | | | |
| 8 | 12 | A, 9h, 80°C<br>84%, 45/24/10/6 | <br>37 | <br>38 | <br>39/40 |

a. A, B and C refer to procedures A, B and C (see experimental). A : catalytic $Bu_3SnCl$/ $NaBH_4$; B : $Bu_3SnH$; C : Co(salen) catalysis.

b. Yields are isolated yields for the purified mixture of isomers.

c. Selectivities were obtained by integration of the $^1H$ NMR spectrum of the purified mixture of isomers before separation.

As was already noted for the tin system, pure oxygen gave lower conversions and yields than air in otherwise identical conditions, no reaction was observed when sodium hydroxyde or sodium borohydride were not added to the mixture. Comparison of the two systems revealed some slight selectivity differences (entries 3 and 4, table 1, entries 5,6 and 7, table 2 for example) but these are likely related to the lower temperature used with the cobalt system. Cyclization of some unprotected sugar derivatives were also attempted under Co(salen) catalysis but, despite complete disparition of the starting material under the standard conditions, the expected products were isolated in disappointingly low yields (25-40%) after acetylation.

## Assignment of stereochemistry of the products

The determination of the stereochemical outcome of the reaction was carried out on the isolated purified isomers whenever possible; in some cases, the alcohols had to be acetylated before separation could be obtained (see experimental). Compounds **25**/**26** and **27**/**28** could not be separated and minor isomers from cyclization of **6**, **11** and **12** were not isolated. Relative configurations of the new tetrahydrofuran ring were determined from the observed nOe effects in one and two dimensionnal $^1H$ NMR spectra (nOe difference and NOESY). Only products from 5-*exo*-cyclization with a *cis* ring junction were isolated. For all compounds of table 1, the major products were the 3a,6a-*cis*[27] and 3a,7a-*cis* isomers. For sugar derivatives of table 2 and according to the known stereochemical preferences for these reactions,[28] compounds with the α-*manno* configuration **7**, **8** and **11** gave predominantly the 3,3a-*trans* products while the 3,3a-*cis* products were obtained from the β-*gluco* compounds **9**, **10** and **12**. All experimental determinations were in good agreement with published data for related compounds.[29,30]

Introduction of three bulky tertbutyldimethylsilyl groups on the tetrahydropyran ring of α-*manno* derivative **8** had some influence on the ring which is not in the $^4C_1$(D) conformation[27] ($J_{3,4} \sim J_{4,5} \sim 7$ Hz, see experimental) but the stereochemical outcome of the reaction was not affected. In order to confirm this, a mixture of **27**/**28** was desilylated ($n$Bu$_4$NF) and acetylated and compared to the mixture obtained from **25**/**26** after hydrogenolysis ($H_2$, Pd/C) and acetylation. The major product[31] from these two sequences was identical and was identified as the isomer with H-3 and H-3a in a *trans* relationship, like **25** and **27**.

Attribution of the configuration of the exocyclic stereocenter when present, was more puzzling but could be solved in most cases from the observation of the strong shielding effect of the phenyl ring on either H-3a or H-2. Except for some sugar derivatives, a large ( > 8.0 Hz) $^3J_{H\text{-}H}$ coupling constant was observed between protons H-3 and H-8 (H-3 and H-7 for compounds **21** and **22**) in the $^1H$ NMR spectra (see Table 3). This showed the conformation around the C-3, C-8 bond (*resp.* C-3, C-7 bond) to be staggered with these protons in a *trans* relationship. A shielding effect of the phenyl ring on the nearest protons (H-2 or H-3a) was expected and the configuration of the exocyclic center was then deduced from the observed chemical shifts of these protons for each pair of epimers on this center. The stereochemistry of sugar derivatives was also deduced from the NMR data and by comparison with literature examples.[30]

Table 3

| Compound | $^{3}J_{\text{H-3,H-8}}$ (Hz) | $\delta_{\text{H-2}}$ (ppm) | $\delta_{\text{H-3a}}$ (ppm) | Relative configurations |
|---|---|---|---|---|
| **17** | 11.0 | 4.10, 3.96 | ~1.6 | 3*R**, 8*R** |
| **18** | 11.0 | 3.60, 3.34 | 2.18 | 3*R**, 8*S** |
| **19** | 8.0 | 4.21, 3.92 | 1.88 | 3*R**, 8*S** |
| **20** | 9.0 | 3.96, 3.58 | 2.10 | 3*R**, 8*R** |
|  | $^{3}J_{\text{H-3,H-7}}$ (Hz) |  |  |  |
| **21** | 10.0 | 4.24, 3.92 | 2.40 | 3*R**, 7*R** |
| **22** | 10.5 | 3.36, 3.29 | 3.07 | 3*R**, 7*S** |

Furthermore, an X-ray structural analysis of the cristalline acetate of **18** was carried out and fully confirmed the NMR assignment of stereochemistry for the C-8 center. In the solid state, the tetrahydropyran ring adopts a chair conformation with the C-7a-O-1 bond in axial orientation as expected from the anomeric effect. The dihedral angle H-8-C-8-C-3-H-3 was found to be very close to 180° with a value of 170.9°. This conformation is identical to the one which could be deduced from the NMR spectrum (see experimental) and the protons H-2, which resonate at 3.60 and 3.34 ppm were found above the phenyl ring in the shielding cone (see figure 2).

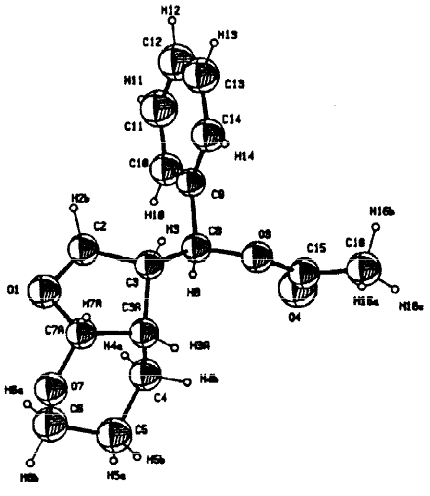


Figure 2. View of the asymetric unit of acetylated **18**

## Conclusion

Perhydro-furo[2,3-*b*]pyran and furan-3-yl methanols were easily obtained in one step from various 3-iodo (or bromo)-2-allyloxy perhydro-pyrans and -furans. Competition from oxygenation of the radical prior to cyclization as well as reduction of the radicals by the hydrogen donor could be kept to a minimum and high yields of the desired products were obtained. The reaction is general for these substrates and could be successfully applied to carbohydrate derivatives.

Catalysis with the cobalt complex Co(salen) was found much more convenient than the tin system for many reasons : a) the reaction could be carried out under milder conditions without any precautions; b) bromides and iodides could be used; c) the work-up of the reaction was much easier and the use of any toxic reagent could be alleviated; d) benzyl-protected substrates, which gave low yields with the tin system could be cyclized.

Studies aimed to the elaboration of oxygenated carbocycles under Co(salen) catalysis are currently actively pursued.[32]

## Experimental

Reactions were run in distilled solvents purified by standard procedures. Exclusion of moisture was necessary when using the stoichiometric tin system but no precautions were taken for the catalytic version or the cobalt reactions. A small fish-tank pump was used to push a current of dry air first into a flask containing the solvent used for the reaction and then into the solution (typical rate 2l/minute). All starting materials were prepared by the NBS or NIS promoted halogeno alkoxylation of the corresponding enol ether double bond by allyl or cinnamyl alcohol.[14] All glycal derivatives were prepared from commercially available tri-*O*-acetyl-D-glucal. When isomeric alcohols could not be separated, the purified mixture of alcohols was acetylated and separation of the acetates was attempted. In some difficult cases, no separation of the diastereoisomers could be obtained even after acetylation. Crystals suitable for the X-ray analysis were obtained by slow evaporation of a methanolic solution of the acetate of **10**. RMN spectra were recorded on Bruker AM 300 ($^1$H, 300 Mhz) or DPX 250 ($^1$H, 250 Mhz, $^{13}$C, 62.9 Mhz) spectrometers in $CDCl_3$ solutions unless noted, all chemical shifts are relative to internal TMS. Analytical data were obtained from the Service Central d'Analyses du CNRS at Vernaison (France).

***Typical procedures***

***Stoichiometric tin hydride reaction (procedure B, tables 1 and 2)*** : The halogeno compound was dissolved in dry toluene ($10^{-2}$ mol.l$^{-1}$) and the reaction mixture was brought to 80°C. A stream of dry air was bubbled through the solution before addition over 2 hours (syringe pump) of a solution of $Bu_3SnH$ (3 eq.) and AIBN

(1.5 eq.) in toluene and the reaction left for one more hour at 80°C. The solvent was evaporated and the tin residus were removed with KF treatment[33] or heptane/acetonitrile extraction before chromatography with petroleum ether/ethyle acetate.

***Catalytic tin hydride reaction (procedure A, tables 1 and 2)*** : A mixture of halogeno compound and sodium borohydride (4 eq.) in 95% ethanol (10-14 ml/mmole ) was brought to reflux under a stream of air. AIBN (0.5-1 eq.) and $Bu_3SnCl$ ( 0.05 eq.) were then added in three times over 5-8 hours and the reaction was left at reflux. The solvent was evaporated, the residu was coevaporated three times with methanol before filtration on silica ($CH_2Cl_2$/acetone) and chromatography.

***Cobalt-catalyzed reaction (procedure C, tables 1 and 2)*** : The halogeno compound was dissolved in ethanol (10-15 ml/mmol) at the appropriate temperature and 10% aqueous sodium hydroxide (1.7 eq.) and sodium borohydride (2 eq.) were added. Air was bubbled through the solution for ten minutes and the cobalt catalyst (0.03 eq.) was then added. After completion of the reaction, the solvent was evaporated and the residu partitionned between dichloromethane and water. Extraction and chromatography (petroleum ether/ethyl acetate) gave the products.

***Crystallographic data collection and structure determination for $C_{16}O_4H_{20}$ :***

A single crystal of $C_{16}O_4H_{20}$ was mounted on an Enraf-Nonius CAD4-f diffractometer. Unit cell dimensions and crystal orientation matrix were obtained from matrix least-squares refinements of setting angles of 25 reflections measured in the range $12.8 \leq 2\theta \leq 23.6$. The data were corrected for background and Lorentz-polarisation. The structure was solved by direct methods and difference Fourier techniques, and refined (on Fs) by full matrix least square calculations using the software package XTAL3.4.[34] All non hydrogen atoms have been anisotropically refined whereas the hydrogen atoms were placed in idealized positions.

**Allyl 3,4,6-tri-*O*-benzyl-2-bromo-2-deoxy-α-D-*manno*-hexopyranoside 7.** $[\alpha]_D^{20}$ +34 (c 1.02, $CHCl_3$). $^1H$ NMR : 7.45-7.10 (m, 15H, Ar); 5.86 (dddd, 1H, *J* 17, 10, 6, 5 Hz, H-2'); 5.28-2.20 (m, 1H, *J* 17, 1 Hz, H-3'); 5.20-5.15 (m, 1H, *J* 10, 1 Hz, H-3'); 5.14 (d, 1H, *J* 2 Hz, H-1); 4.88-4.46 (6d, 6H, $\underline{CH_2}$-Ph); 4.40 (dd, 1H, *J* 3, 2 Hz, H-2); 4.19-4.123 (m, 1H, *J* 13, 5, 1 Hz, H-1'); 4.01-3.92 (m, 3H, H-3, H-4, H-1'); 3.88-3.82 (m, 1H, *J* 6, 4, 2 Hz, H-5); 3.79 (dd, 1H, *J* 11, 4 Hz, H-6); 3.70 (dd, 1H, *J* 11, 2 Hz, H-6). $^{13}C$ NMR : 138.27, 138.17, 137.72 (Ar), 133.32 (C-2'); 128.40, 128.30, 128.27, 128.01, 127.90, 127.79, 127.66, 127.48 (Ar); 117.82 (C-3'); 99.16 (C-1); 77.39, 74.53 (C-3, C-4); 75.27, 73.36, 71.18 ($\underline{C}H_2Ph$); 72.09 (C-5); 68.80 (C-6); 68.34 (C-1'); 51.41 (C-2). Anal. Calc. for $C_{30}H_{33}O_5Br$: C, 65.00; H, 6.01. Found : C, 65.38; H, 6.00.

**Allyl 2-bromo-3,4,6-tri-*O*-*tert*butyldimethylsilyl-2-deoxy-α-D-*manno*-hexopyranoside 8**. $[\alpha]_D^{20}$ +37 (c 0.91, $CHCl_3$). $^1H$ NMR : 5.97-5.85 (m, 1H, *J* 17, 10, 6, 5 Hz, H-2'); 5.33-5.25 (m, 1H, *J* 17, 1 Hz, H-3'); 5.22-5.16 (m, 1H, *J* 10, 1 Hz, H-3'); 4.99 (d, 1H, *J* 4 Hz, H-1); 4.26-4.18 (m, 1H, *J* 13, 5, 1, 1 Hz, H-1'); 4.22 (dd, 1H, *J* 4, 4 Hz, H-2); 4.04 (m, 1H, *J* 13, 6, 1, 1 Hz, H-1'); 3.95 (dd, 1H, *J* 7, 4 Hz, H-3); 3.85 (dd, 1H, *J*

11, 3 Hz, H-6); 3.84 (dd, 1H, *J* 7, 7 Hz, H-4); 3.72 (dd, 1H, *J* 11, 6 Hz, H-6); 3.66-3.59 (m, 1H, H-5); 0.95, 0.90, 0.89 (3s, 3×9H, *t*bu); 0.14-0.05 (6s, 6×3H, (Me)Si). $^{13}$C NMR : 133.93 (C-2'); 117.16 (C-3'); 98.57 (C-1); 72.86; 69.90, 68.23; ~55.5; 26.26, 26.04, 25.91 (($\underline{C}H_3)_3C$); 18.35, 18.33, 18.01 (($CH_3)_3\underline{C}$); -3.30, -3.44, -4.38, -4.59, -5.08, -5.30 (($\underline{C}H_3$)Si). Anal. Calc. for $C_{27}H_{57}O_5Si_3Br$: C, 51.81; H, 9.17. Found : C, 52.05; H, 9.45.

**Allyl 3,4,6-tri-*O*-benzyl-2-bromo-2-deoxy-β-D-*gluco*-hexopyranoside 9**. $[\alpha]_D^{20}$ +15 (c 0.93, CHCl$_3$). $^1$H NMR : 7.40-7.15 (m, 15H, Ar); 5.96 (m, 1H, *J* 17, 10, 5 Hz, H-2'); 5.36 (m, 1H, *J* 17, 1, 1 Hz, H-3'); 5.23 (m, 1H, *J* 10, 1, 1 Hz, H-3'), 4.52 (d, 1H, *J* 8 Hz, H-1); 4.38 (m, 1H, *J* 13, 5, 1,1 Hz, H-1'); 4.17 (m, 1H, *J* 13, 6, 1, 1 Hz, H-1'); 3.85 (dd, 1H, *J* 10, 8 Hz, H-2); 3.74 (dd, 1H, *J* 10, 2 Hz, H-6); 3.72 (dd, 1H, *J* ~10 Hz, H-3); 3.69 (dd, 1H, *J* 10, 4 He, H-6); 3.61 (dd, 1H, *J* 10, 9 Hz, H-4); 3.49 (ddd, 1H, *J* 9, 4, 2 Hz, H-5). $^{13}$C NMR : 137.94, 137.81, 137.75 (Ar); 133.56 (C-2'); 128.42, 129.39, 128.35, 128.04, 127.83, 127.73, 127.64 (Ar); 117.89 (C-3'); 101.30 (C-1); 85.58 (C-3); 79.12 (C-4); 75.98, 74.98, 73.48 ($\underline{C}H_2$Ph); 75.04 (C-5); 70.30 (C-1'); 68.50 (C-6); 53.06 (C-2). Anal. Calc. for $C_{30}H_{33}O_5Br$ : C, 65.10; H, 6.01. Found : C, 65.20; H, 6.11.

**Allyl 2-bromo-3,4,6-tri-*O*-*tert*butyldimethylsilyl-2-deoxy-β-D-*gluco*-hexopyranoside 10**. $[\alpha]_D^{20}$ +2 (c 1.03, CHCl$_3$). $^1$H NMR : 5.96 (dddd, 1H, *J* 17, 10, 6, 5 H, H-2'); 5.39-5.30 (m, 1H, *J* 17, 1 Hz, H-3'); 5.25-5.19 (m, 1H, *J* 10, 1 Hz, H-3'); 5.09 (d, 1H, *J* 8 Hz, H-1); 4.39-4.30 (m, 1H, *J* 12, 5, 1 Hz, H-1'); 4.27 (ddd, 1H, *J* 3, 1, 1 Hz, H-3 ); 4.17-4.07 (m, 1H, *J* 12, 6, 1 Hz, H-1'); 3.92 (ddd, 1H, *J* 4, 1, 1 Hz, H-4); 3.89-3.75 (m, 3H, H-5, H-6); 3.74 (ddd, 1H, *J* 6, 1, 1 Hz, H-2); 0.93-0.88 (3s, 3×9H, *t*bu); 0.15-0.005 (6s, 6×3H, (Me)Si). $^{13}$C NMR : 133.89 (C-2'); 117.85 (C-3'); 99.52 (C-1); 82.47 (C-5); 79.44 (C-3); 70.60 (C-4); 70.15 (C-1'); 63.79 (C-6); 52.86 (C-2); 25.89, 25.85, 25.76 (($\underline{C}H_3)_3C$); 18.29, 18.01, 17.89 (($CH_3)_3\underline{C}$); -4.47, -4.55, -4.61, -4.72, -5.34 (($\underline{C}H_3$)Si). ). Anal. Calc. for $C_{27}H_{57}O_5Si_3Br$: C, 51.81; H, 9.17. Found : C, 52.21; H, 9.52.

**Cinnamyl 3,4,6-tri-*O*-*tert*butyldimethylsilyl-2-deoxy-2-iodo-α-D-*manno*-hexopyranoside 11**. $[\alpha]_D^{20}$ -60 (c 0.98, CHCl$_3$). $^1$H NMR (300 Mhz, CDCl$_3$): 7.41-7.14 (m, 5H, Ar); 6.63 (br d, 1H, *J* 16 Hz, H-3'); 6.28 (ddd, 1H, J 16, 6, 5 Hz, H-2'); 5.15 (d, 1H, *J* 3 Hz, H-1); 4.38 (dd, 1H, *J* 3, 3 Hz, H-2); 4.37 (ddd, 1H, *J* 13, 5, 1 Hz, H-1'); 4.16 (ddd, 1H, *J* 13, 6, 1 Hz, H-1'); 3.87 (dd, 1H, *J* 10, 3 Hz, H-6); 3.84 (dd, 1H, *J* 7, 7 Hz, H-4); 3.75 (dd, 1H, *J* 10, 6 Hz, H-6); 3.72-3.66 (m, 1H, H-5); 3.49-3.38 (m, 1H, H-3); 0.97, 0.92, 0.91 (3s, 3×9H, *t*bu); 0.17, 0.16, 0.13, 0.12, 0.10, 0.08 (6H, 6×3H, (Me)Si). Anal. Calc. for $C_{32}H_{61}O_5Si_3I$: C, 52.92; H, 8.21. Found : C, 53.17; H, 8.35.

**Cinnamyl 3,4,6-tri-*O*-*tert*butyldimethylsilyl-2-deoxy-2-iodo-β-D-*gluco*-hexopyranoside 12**. $[\alpha]_D^{20}$ +47 (c 1.09, CHCl$_3$). $^1$H NMR (300 Mhz, CDCl$_3$): 7.43-7.16 (m, 5H, Ar); 6.66 (br d, 1H, *J* 16 Hz, H-3'); 6.32 (ddd, 1H, *J* 16, 7, 5 Hz, H-2'); 5.24 (d, 1H, *J* 8 Hz, H-1); 4.49 (ddd, 1H, *J* 12, 5, 1 Hz, H-1'); 4.46-4.43 (m, 1H, H-3); 4.27 (ddd, 1H, *J* 12, 7, 1 Hz, H-1'); 3.95-3.89 (m, 2H, H-4, H-5); 3.88-3.80 (m, 2H, H-2, H-6); 3.76 (dd, 1H, *J* 9, 6 Hz, H-6); 0.91, 0.90, 0.88 (3s, 3×9H, *t*bu); 0.14, 0.11, 0.10, 0.08, 0.06, 0.05 (6s, 6×3H, (Me)Si). Anal. Calc. for $C_{32}H_{61}O_5Si_3I$: C, 52.92; H, 8.21. Found : C, 53.27; H, 8.15.

**(3*R**, 3a*R**, 6a*S**) and (3*R**,3a*S**,6a*R**) 3-hydroxymethyl-hexahydro-furo[2,3-b]furan 13 and 14. 13** $^1$H NMR : 5.76 (d, 1H, *J* 5 Hz, H-6a); 4.02 (dd, 1H, *J* 8, 7 Hz, H-2); 3.93-3.86 (m, 2H, H-5); 3.82-3.69, (m, 2H, H-7); 3.57 (dd, 1H, *J* 11, 8 Hz, H-2); 2.96-2.86 (m, 1H, *J* 8, 5 Hz, H-3a); 2.68-2.54 (m, 1H, *J* 11, 7 Hz, H-3); 2.00-1.82 (m, 2H, H-4); 1.47 (br, 1H, OH). **Acetate.** $^1$H NMR : 5.77 (d, 1H, *J* 5 Hz, H-6a); 4.22 (dd, 1H, *J* 11, 7 Hz, H-2); 4.10 (dd, 1H, *J* 11, 7 Hz, H-2); 4.01 (dd, 1H, *J* 9, 7 Hz, H-5); 3.90 (t, 2H, *J* 6 Hz, H-7); 3.58 (dd, 1H, *J* 11, 9 Hz, H-5); 2.96-2.85 (m, 1H, H-3a); 2.77-2.60 (m, 1H, H-3); 2.08 (s, 3H, Ac); 1.94-1.86 (m, 2H, H-4). $^{13}$C NMR : 170.83 (CO), 109.74 (C-6a), 70.21 (C-5), 69.20 (C-7), 62.51 (C-2), 44.20 (C-3a), 40.95 (C-3), 25.27 (C-4), 20.78 (Ac). Anal. Calc. for $C_9H_{14}O_4$ : C, 58.05; H, 7.57. Found : C, 57.72; H, 7.72.

**(3*R**, 3a*R**, 7a*S**) 3-hydroxymethyl-hexahydro-furo[2,3-b]pyran 15 (Acetate).** $^1$H NMR ($CDCl_3$) : 5.22 (d, 1H, *J* 3 Hz, H-7a); 4.21 (dd, 1H, *J* 11, 7 Hz, H-8); 4.09 (dd, 1H, *J* 11, 8 Hz, H-8); 4.01 (dd, 1H, *J* 8 Hz, H-2); 3.86-3.76 (m, 1H, H-6), 3.81 (dd, 1H, *J* 8 Hz, H-2); 3.66-3.57 (m, 1H, H-6); 2.77-2.61 (m, 1H, H-3); 2.18-2.08 (m, 1H, H-3a); 2.07 (s, 3H, Ac); 1.80-1.64 and 1.64-1.50 (2m, 1H and 3H, H-4 and H-5). $^{13}$C NMR :170.88 (CO), 101.74 (C-7a), 67.99 (C-2), 63.09 (C-8), 61.55 (C-6), 39.80 (C-3), 36.27 (C-3a), 22.84 and 19.69 (C-4 and C-5), 20.85 (Ac). Anal. Calc. for $C_{10}H_{16}O_4$ : C, 59.98; H, 8.05. Found : C, 59.90; H, 9.86.

**(3*R**, 3a*S**, 7a*R**) 3-hydroxymethyl-hexahydro-furo[2,3-b]pyran 16 (Acetate).** $^1$H NMR : 5.02 (d, 1H, *J* 4 Hz, H-7a); 4.28 (dd, 1H, *J* 8 Hz, H-2); 4.19 (dd, 1H, *J* 11, 5 Hz, H-8); 4.01 (dd, 1H, *J* 11, 7 Hz, H-8); 3.94-3.85 (m, 1H, *J* 12 Hz, H-6); 3.72 (dd, 1H, *J* 8, 7 Hz, H-2); 3.44 (ddd, *J* 12, 11, 2 Hz, H-6); 2.72-2.53 (m, 1H, H-3); 2.05 (s, 3H, Ac); 1.95-1.80 (m, 3H, H-3a, H-4); 1.75-1.64 (m, 1H, H-5); 1.45-1.33 (m, 1H, H-5). $^{13}$C NMR : 171.02 (CO), 101.80 (C-7a), 71.05, 65.34, 64.46,40.99, 37.64, 22.68, 20.85, 20.54.

**(3*R**, 3a*S**, 7a*R**, 8*R**) 3-(1-hydroxy-1-phenylmethyl)-hexahydro-furo[2,3-b]pyran 17 (Acetate).** $^1$H NMR :7.43-7.22 (m, 5H, Ar); 5.78 (d, 1H, *J* 11 Hz, H-8); 5.28 (br, 1H, H-7a); 4.10 (dd, 1H, *J* 8 Hz, H-2); 3.96 (dd, 1H, *J* 10, 8 Hz, H-2); 3.78 (ddd, 1H, *J* 11, 11, 2 Hz, H-6); 3.66-3.57 (m, 1H, H-6); 3.11-2.96 (m, 1H, H-3); 1.98 (s, 3H, Ac); 1.66-1.35 (m, 5H, H-3a, H-4, H-5). $^{13}$C NMR : 169.97 (CO), 138.69, 128.65, 127.45 (Ar), 101.48 (C-7a), 75.31 (C-8), 67.60 (C-2), 60.54 (C-6), 45.90 (C-3), 35.24 (C-3a), 22.86 and 19.29 (C-4 and C-5), 21.01 (Ac). Anal. Calc. for $C_{16}H_{20}O_4$ : C, 69.54; H, 7.29. Found : C, 69.18; H, 7.35.

**(3*R**, 3a*S**, 7a*R**, 8*S**) 3-(1-hydroxy-1-phenylmethyl)-hexahydro-furo[2,3-b]pyran 18 (Acetate).** $^1$H NMR : 7.44-7.23 (m, 1H, Ar); 5.69 (d, 1H, *J* 11 Hz, H-8); 5.34 (d, 1H, *J* 3 Hz, H-7a); 3.84-3.64 (m, 2H, H-6); 3.60 (dd, 1H, *J* 11, 8 Hz, H-2); 3.34 (dd, 1H, *J* 8, 8 Hz, H-2); 2.97 (dddd, *J* 11, 11, 8, 5 Hz, H-3); 2.24-2.12 (m, 1H, H-3a); 2.05 (s, 3H, Ac); 1.78-1.56 (m, 4H, H-4, H-5). $^{13}$C NMR : 169.81 (CO); 138.78, 128.71, 126.74, 125.97 (Ar); 101.75 (C-7a); 73.69 (C-8); 65.81 (C-2); 60.85 (C-6); 46.18 (C-3); 35.70 (C-3a); 23.03, 19.43 (C-4, C-5); 21.71 (Ac).

**(3*R**, 3a*R**, 7a*S**, 8*S**) 3-(1-hydroxy-1-phenylmethyl)-hexahydro-furo[2,3-b]pyran 19 (Acetate)**. $^1$H NMR : 7.37-7.20 (m, 5H, Ar); 5.70 (d, 1H, *J* 9 Hz, H-8); 5.01 (d, 1H, *J* 3 Hz, H-7a); 3.96 (dd, 1H, *J* 9, 9 Hz, H-2); 3.94-3.84 (m, 1H, H-6); 3.58 (dd, 1H, *J* 9, 7 Hz, H-2); 3.43 (ddd, 1H, *J* 11, 10, 2 Hz, H-6); 2.90 (m, 1H, *J* 9, 7 Hz, H-3), 2.15-2.05 (m, 1H, H-3a); 2.07 (s, 3H, Ac); 1.92-1.65 and 1.43-1.32 (2m, 3H and 1H, H-4 and H-5). $^{13}$C NMR : 169.98 (CO); 138.87, 128.58, 128.37, 126.95 (Ar); 102.32 (C-7a); 78.02 (C-8); 69.64 (C-2); 64.38 (C-6); 43.06 (C-3); 42.12 (C-3a); 21.15 (Ac); 23.55, 20.71 (C-4, C-5).

**(3*R**, 3a*R**, 7a*S**, 8*R**) 3-(1-hydroxy-1-phenylmethyl)-hexahydro-furo[2,3-b]pyran 20 (Acetate)**. $^1$H NMR : 7.43-7.22 (m, 5H, Ar); 5.69 (d, *J* 8.0 Hz, H-8); 4.99 (d, 1H, *J* 3 Hz, H-7a); 4.21 (dd, 1H, *J* ~9 Hz, H-2); 3.92 (dd, *J* 9, 7 Hz, H-2); 3.89-3.80 (m, 1H, H-6); 3.42-3.30 (m, 1H, H-6); 2.88-2.73 (m, 1H, H-3); 1.93-1.83 (m, 1H, H-3a); 1.58-1.46 and 1.27-1.07 (2m, 1H and 3H, H-4 and H-5). $^{13}$C NMR : 170.03 (CO); 139.26, 128.64, 128.29, 126.55 (Ar); 102.16 (C-7a); 77.13 (C-8); 70.48, 64.49 (C-2, C-6); 43.57 (C-3); 40.66 (C-3a); 21.11 (Ac); 22.23, 20.36 (C-4, C-6).

**(3*R**, 3a*S**, 6a*S**, 7*R**) 3-(1-hydroxy-1-phenylmethyl)-hexahydro-furo[2,3-b]furan 21**. $^1$H NMR (300 Mhz, $CDCl_3$) : 7.50-7.29 (m, 5H, Ar); 5.67 (d, 1H, *J* 5 Hz, H-6a); 4.68 (dd, 1H, *J* 10, 3 Hz, H-7); 4.24 (dd, 1H, *J* 8, 7 Hz, H-2); 4.01 (ddd, 1H, *J* 9, 7, 6 Hz, H-5); 3.92 (dd, 1H, *J* 11, 8 Hz, H-2); 3.78 (ddd, 1H, *J* 9, 7, 6 Hz, H-5); 2.88-2.75 (m, 1H, *J* 11, 10, 7, 7 Hz, H-3); 2.45-2.35 (m, 1H, H-3a); 2.08-1.93 (m, 1H, H-4); 1.82 (d, 1H, *J* 3 Hz, OH); 1.69 (dddd, 1H, *J* 13, 10, 7, 6 Hz, H-4). $^{13}$C NMR : 142.92, 128.81, 128.68, 126.45 (Ar); 109.72 (C-6a); 74.63 (C-7); 70.87 (C-2); 68.93 (C-5); 49.54 (C-3); 44.41 (C-3a); 25.18 (C-4). Anal. Calc. for $C_{13}H_{16}O_3$ : C, 70.89; H, 7.32. Found : C, 70.83; H, 7.38.

**(3*R**, 3a*S**, 6a*S**, 7*S**) 3-(1-hydroxy-1-phenylmethyl)-hexahydro-furo[2,3-b]furan 22**. $^1$H NMR (300 Mhz, $CDCl_3$) : 7.43-7.25 (m, 5H, Ar); 5.76 (d, 1H, *J* 5 Hz, H-6a); 4.60 (dd, 1H, *J* 10, 3 Hz, H-7); 4.03-3.80 (m, 2H, H-5); 3.36 (dd, 1H, *J* 10, 8 Hz, H-2); 3.29 (dd, 1H, *J* 8, 7 Hz, H-2); 3.13-3.02 (m, 1H, *J* 7, 5 Hz, H-3a); 2.80-2.67 (m, 1H, *J* 11, 10, 7, 7 Hz, H-3); 2.28-2.01 (m, 2H, H-4); 1.97 (d, 1H, *J* 3 Hz, OH). $^{13}$C NMR : 142.96, 128.89, 128.51, 125.90 (Ar); 110.17 (C-6a); 73.73 (C-7); 69.34, 69.27 (C-2, C-5); 49.94 (C-3); 44.71 (C-3a); 25.41 (C-4).

**(3*R*, 3a*R*, 4*R*, 5*S*, 6*R*, 7a*S*) and (3*S*, 3a*R*, 4*R*, 5*S*, 6*R*, 7a*S*) (4,5-dibenzyloxy-6-benzyloxymethyl-hexahydro-furo[2,3-b]pyran-3-yl)-methanol 25 and 26 (acetate)**. $^1$H NMR (300 Mhz, $CDCl_3$) :7.38-7.12 (m, 15H, Ar); 5.47 (d, 1H, *J* 5 Hz, H-7a); 4.85-4.50 (6d, 6H, C$\underline{H}_2$-Ph); 4.11 (dd, 1H, *J* 9, 7 Hz, H-2); 3.98 (d, 2H, *J* 7 Hz, H-8); 3.88-3.82 (m, 1H, H-6); 3.76 (dd, 1H, *J* 11, 3 Hz, H-9); 3.72 (dd, 1H, *J* 9, 7 Hz, H-5); 3.69 (dd, 1H, *J* 11, 3 Hz, H-9); 3.59 (dd, 1H, *J* 9, 4 Hz, H-2); 3.56 (dd, 1H, *J* 7, 7 Hz, H-4); 2.55-2.44 (m, 1H, H-3); 2.19 (ddd, 1H, *J* 7, 5, 3 Hz, H-3a); 2.00 (s, 3H, Ac). $^{13}$C NMR : 170.82; 138.27; 137.99, 137.79; 128.51;

128.46; 128.44; 128.39; 128.34; 127.95; 127.87; 127.81; 127.68; 127.65; 127.62; 100.94; 79.47; 77.16; 73.88; 73.83; 73.50; 72.16; 68.83; 68.09; 65.13; 45.92; 40.54; 20.78.

**(3*R*, 3a*R*, 4*R*, 5*S*, 6*R*, 7a*S*) and (3*S*, 3a*R*, 4*R*, 5*S*, 6*R*, 7a*S*) (4,5-di(*tert*butyldimethylsilyloxy)-6-(*tert*butyldimethylsilyloxy)methyl-hexahydro-furo[2,3-b]pyran-3-yl)-methanol 27 and 28**. **27** $^1$H NMR (300 Hz, CDCl$_3$) : 5.37 (d, 1H, *J* 5 Hz, H-7a); 4.28 (dd, 1H, *J* 8, 8 Hz, H-2); 4.05 (dd, 1H, *J* 2, 2 Hz, H-4), 3.95-3.69 (m, 6H, H-5, H-6, H-8, H-9); 3.65 (dd, 1H, *J* 8, 8 Hz, H-2); 3.11-2.97 (m, 1H, H-3); 2.31 (ddd, 1H, *J* 10, 5, 2 Hz, H-3a); 1.48 (br t, 1H, OH). $^{13}$C NMR : 97.769 (C-7a); 78.63 (C-5); 71.27 (C-4); 70.76 (C-2); 68.74 (C-6); 63.98, 62.06 (C-8, C-9); 47.75 (C-3a); 40.02 (C-3). **28** : $^{13}$C NMR : 97.54 (C-7a); 78.41 (C-5); 70.84; 70.40 (C-2); 69.41; 61.95, 61.82 (C-8, C-9); 47.34 (C-3a); 41.67 (C-3'). **Acetate** Anal. Calc. for C$_{27}$H$_{58}$O$_6$Si$_3$ : C, 57.57; H, 9.99. Found : C, 57.85; H, 10.03.

**(3*R*, 3a*S*, 4*R*, 5*S*, 6*R*, 7a*R*) (4,5-dibenzyloxy-6-benzyloxymethyl-hexahydro-furo[2,3-b]pyran-3-yl)-methanol 29 (acetate)**. $^1$H NMR : 5.13 (d, 1H, *J* 3 Hz, H-7a); 4.85-4.51 (6d, 6H, C$\underline{H}_2$-Ph); 4.49 (dd, 1H, *J* 11, 4 Hz, H-8); 4.34 (dd, 1H, *J* 9, 9 Hz, H-2); 4.30 (dd, *J* 11, 8 Hz, H-8), 3.91 (dd, 1H, *J* 9, 6 Hz, H-4); 3.80 (dd, 1H, *J* 9, 7 Hz, H-2); 3.76 (dd, 1H, *J* ~9 Hz, H-5); 3.75 (dd, 1H, *J* 11, 4 Hz, H-9); 3.69 (dd, 1H, *J* 11, 2 Hz, H-9); 3.37 (ddd, 1H, *J* 9, 4, 2 Hz, H-6); 2.95-2.80 (m, 1H, H-3); 2.50 (ddd, 1H, *J* 9, 6, 3 Hz, H-3a); 2.05 (s, 3H, Ac). $^{13}$C NMR : 170.88; 138.17; 128.52; 128.39; 128.33; 127.99; 127.88; 127.79; 127.74; 127.57; 101.89; 80.18; 75.08; 74.99; 74.36; 73.58; 73.03; 71.98; 69.01; 65.92; 46.13; 36.87; 20.85. Anal. Calc. for C$_{32}$H$_{36}$O$_7$: C, 72.16; H, 6.81. Found : C, 72.38; H, 6.81.

**(3*S*, 3a*S*, 4*R*, 5*S*, 6*R*, 7a*R*) (4,5-dibenzyloxy-6-benzyloxymethyl-hexahydro-furo[2,3-b]pyran-3-yl)-methanol 30 (acetate)** $^1$H NMR : 5.05 (d, 1H, *J* 3 Hz, H-7a); 4.74 (dd, 1H, *J* 10, 4 Hz, H-8); 4.23 (dd, 1H, *J* 11, 10 Hz, H-8); 4.19 (dd, 1H, *J* 8, 3 Hz, H-2); 4.06 (dd, 1H, *J* 8, 6 Hz, H-2); 4.01 (dd, 1H, *J* 9, 7 Hz, H-4); 3.68 (d, 2H, *J* 3 Hz, H-9); 3.64 (dd, 1H, *J* 10, 9 Hz, H-5); 3.34 (m, 1H, *J* 10, 3, 3 Hz, H-6); 2.78 (ddd, 1H, *J* 8, 7, 3 Hz, H-3a); 2.72-2.61 (m, 1H, H-3); 2.05 (s, 3H, Ac). $^{13}$C NMR : 170.59 (CO); 138.21, 138.71, 138.05, 128.45, 128.33, 128.30, 127.97, 127.79, 127.44 (Ar); 101.62 (C-7a); 80.38 (C-4); 75.72 (C-5); 74.89, 73.36, 72.15 (Bn); 73.94 (C-6); 72.95 (C-2); 68.98 (C-9), 65.81 (C-8); 45.76 (C-3a); 37.66 (C-3).

**(3*S*, 3a*S*, 4*R*, 5*S*, 6*R*, 7a*S*) 4,5-(di(*tert*butyldimethylsilyloxy)-6-(*tert*butyldimethylsilyloxy)methyl-hexahydro-furo[2,3-b]pyran-3-yl)-methanol 31** . $[\alpha]_D^{20}$ +16 (c 0.90, CHCl$_3$). $^1$H NMR : 5.22 (d, 1H, *J* 4.2 Hz, H-7a); 4.18 (dd, 1H, *J* 8, 7 Hz, H-2); 3.96 (dd, *J* 6, 5 Hz, H-4); 3.89 (dd, 1H, *J* 6, 4 Hz, H-5); 3.76 (brd, 2H, *J* 5 Hz, H-9); 3.70 (dd, 1H, *J* 8, 6 Hz, H-2); 3.62-3.55 (m, 2H, H-8); 3.44-3.37 (m, 1H, H-6); 2.78-2.65 (m, 1H, H-3); 2.58 (br s, 1H, OH); 2.29 (ddd, 1H, *J* 7, 5, 4 Hz, H-3a); 0.95 and 0.90 (2s, 3H and 6H, *t*bu); 0.16-0.05 (5s, 18H, (C$\underline{H}_3$)Si).

**(3*S*, 3a*S*, 4*R*, 5*S*, 6*R*, 7a*R*) 4,5-(di(*tert*butyldimethylsilyloxy)-6-(*tert*butyldimethylsilyloxy)methyl-hexahydro-furo[2,3-b]pyran-3-yl)-methanol 32** $[\alpha]_D^{20}$ -4.3 (c 1.10, CHCl$_3$). $^1$H NMR (CDCl$_3$): 5.05 (d, 1H, *J* 3 Hz, H-7a); 4.16 (dd, 1H, *J* 9, 8 Hz, H-2); 4.09 (dd, 1H, *J* ~9 Hz, H-4); 4.03-3.95 (m, 1H, *J* 11, 8, 2 Hz, H-8); 3.93-3.83 (m, 2H, H-5, H-2); 3.83-3.75 (m, 2H, H-9); 3.70 (dd, 1H, *J* 8, 2, OH); 3.364-3.55 (m, 1H, H-8); 3.05 (ddd, 1H, *J* 9, 3 Hz, H-6); 2.71-2.56 (m, 2H, H-3, H-3a); 0.97-0.89 (3s, 3×9H, *t*bu); 0.18-0.06 (5s, 6H and 4×3H, (Me)Si). $^{13}$C NMR : 101.39 (C-7a); 76.48 (C-6); 75.81 (C4); 71.69 (C-2); 68.74 (C-5); 64.28 (C-8); 61.74 (C-9); 49.83 (C-3a); 40.60 (C-3); 26.35, 26.21, 25.97 ($(\underline{C}H_3)_3C$); 18.49, 18.31, 18.03 ($(CH_3)_3\underline{C}$); -2.38, -3.63, -3.73, -4.32, -4.97, -5.18 ($(\underline{C}H_3)Si$). Anal. Calc. for $C_{27}H_{58}O_6Si_3$ : C, 57.57; H, 9.99. Found : C, 57.86; H, 10.69.

**(3*S*, 3a*R*, 4*R*, 5*R*, 6*R*, 7a*S*, 8*R*) 4,5-(di(*tert*butyldimethylsilyloxy)-6-(*tert*butyldimethylsilyloxy)methyl-hexahydro-furo[2,3-b]pyran-3-yl)-phenylmethanol 33** : $[\alpha]_D^{20}$ -2 (c 1.10, CHCl$_3$). $^1$H NMR (CDCl$_3$): 7.43-7.34 (m, 5H, Ar); 5.39 (d, 1H, *J* 5 Hz, H-7a); 5.10 (dd, 1H, *J* 3, 3 Hz, H-8); 4.38 (dd, 1H, J 8, 6 Hz, H-2); 4.21 (dd, *J* 2 Hz, H-4); 3.97 (dd, 1H, *J* 7, 5 Hz, H-9); 3.94-3.83 (m, 3H, H-5, H-6, H-9); 3.84 (d, 1H, *J* 3 Hz, OH); 3.79 (dd, 1H, *J* 8, 8 Hz, H-2); 2.84-2.74 (m, 1H, H-3); 2.34 (ddd, 1H, *J* 9, 5, 2 Hz, H-3a). $^{13}$C NMR : 143.66, 128.45, 127.15, 126.01 (Ar); 98.05 (C-7a); 78.06 (C-5); 70.87 (C-4); 70.27 (C-8); 69.30 (C-6); 68.38 (C-2); 62.22 (C-9); 47.53 (C-3a); 47.08 (C-3); 25.93, 25.90, 25.73 ($(\underline{C}H_3)_3C$); 18.34, 18.20, 17.85 ($(CH_3)_3\underline{C}$); -4.14, -4.35, -4.42, -4.73, -5.27, -5.31 ($(\underline{C}H_3)Si$). IR (neat) ν (cm$^{-1}$) : 3453 (OH). Anal. Calc. for $C_{27}H_{58}O_6Si_3$ : C, 57.60; H, 10.38. Found : C, 57.86; H, 10.69.

**(3*S*, 3a*R*, 4*R*, 5*R*, 6*R*, 7a*S*, 8*S*) 4,5-(di(*tert*butyldimethylsilyloxy)-6-(*tert*butyldimethylsilyloxy)methyl-hexahydro-furo[2,3-b]pyran-3-yl)-phenylmethanol 34** : $[\alpha]_D^{20}$ +4 (c 1.10, CHCl$_3$). $^1$H NMR (CDCl$_3$) : 5.48 (d, 1H, *J* 5 Hz, H-7a); 4.99 (dd, 1H, *J* 10, 4 Hz, H-8); 4.64 (br s, 1H, H-4); 3.94-3.80 (m, 4H, H-5, H-6, H-9); 3.66 (dd, 1H, *J* 8, 8 Hz, H-2); 3.39 (dd, 1H, *J* 8, 8 Hz, H-2); 2.90 (d, 1H, *J* 4 Hz, OH); 2.91-2.74 (m, 1H, H-3); 2.55 (ddd, 1H, *J* 8, 5, 1 Hz, H-3a); 0.96, 0.91, 0.90 (3s, 3×9H, *t*bu); 0.20, 0.15, 0.14, 0.07 (4s, 6H, 2×3H, 6H, (Me)Si). $^{13}$C NMR : 143.58, 128.69, 128.01, 126.45 (Ar); 99.36 (C-7a); 77.19 (C-6); 73.29 (C-8); 70.14 (C-2); 70.02, 69.85 (C-5, C-4); 63.43 (C-9); 47.67, 46.48 (C-3, C-3a); 26.12, 26.02, 25.82 ($(\underline{C}H_3)_3C$); 18.48, 18.32, 17.89 ($(CH_3)_3\underline{C}$); -3.80, -4.42, -4.57, -5.26 ($(\underline{C}H_3)Si$). IR (neat) ν (cm$^{-1}$) : 3427 (OH).

**(3*R*, 3a*R*, 4*R*, 5*R*, 6*R*, 7a*S*, 8*R*) 4,5-(di(*tert*butyldimethylsilyloxy)-6-(*tert*butyldimethylsilyloxy)methyl-hexahydro-furo[2,3-b]pyran-3-yl)-phenylmethanol 35** : $[\alpha]_D^{20}$ -7 (c 0.80, CHCl$_3$). $^1$H NMR (CDCl$_3$) : 7.44-7.28 (m, 5H, Ar); 5.39 (d, 1H, *J* 5 Hz, H-7a); 4.60 (dd, 1H, *J* 7, 3 Hz, H-8); 4.22 (dd, 1H *J* 8, 8 Hz, H-2); 4.05 (dd, 1H, *J* 8, 6 Hz, H-2); 3.82 (dd, 1H, *J* 10, 5 Hz, H-9); 3.78 (dd, 1H, *J* 10, 4 Hz, H-9); 3.72-3.66 (m, 2H, H-5, H-6); 3.62 (br s, 1H, H-4); 3.19-3.08 (m, 1H, H-3); 2.21-2.13 (m, 1H, H-3a); 1.82 (d, 1H, *J* 3 Hz, OH); 0.94, 0.89, 0.82 (3s, 3×9H, *t*bu); 008- -0.17 (6s, 6×3H, (Me)Si). IR (neat) ν (cm$^{-1}$) : 3443 (OH).

**(3*R*, 3a*R*, 4*R*, 5*R*, 6*R*, 7a*S*, 8*S*) 4,5-(di(*tert*butyldimethylsilyloxy)-6-(*tert*butyldimethylsilyloxy)methyl-hexahydro-furo[2,3-b]pyran-3-yl)-phenylmethanol 36** : $[\alpha]_D^{20}$ +22 (c 0.80, CHCl$_3$). $^1$H NMR (300 Mhz,

$CDCl_3$): 7.38-7.26 (m, 5H, Ar); 5.43 (d, 1H, *J* 5 Hz, H-7a); 4.48 (dd, 1H, *J* 9, 3 Hz, H-8); 4.38 (br, 1H, H-4); 3.95-3.71 (m, 5H, H-5, H-6, H-9, H-2); 3.44 (dd, 1H, *J* 9, 6 Hz, H-2); 3.28-3.13 (m, 1H, *J* 9, 6 Hz, H-3); 2.37-2.29 (m, 1H, H-3a); 1.08 (d,1H, *J* 3 Hz, OH). $^{13}$C NMR : 143.37, 128.69, 128.18, 128.52 (Ar); 98.80 (C-7a); 79.20 (C-8); 78.54 (C-5); 71.90 (C-4); 69.32 (C-2); 69.23 (C-6); 62.42 (C-9); 50.08 (C-3a); 44.58 (C-3); 25.97, 25.91, 25.77 ($(\underline{C}H_3)_3C$); 18.33, 18.01, 17.84 ($(CH_3)_3\underline{C}$); -4.40, -4.77, -4.81, -4.88, -5.22, -5.29 ($(\underline{C}H_3)Si$). IR (neat) ν ($cm^{-1}$) : 3444 (OH).

**(3*S*, 3a*S*, 4*R*, 5*R*, 6*R*, 7a*R*, 8*R*) 4,5-(di(*tert*butyldimethylsilyloxy)-6-(*tert*butyldimethylsilyloxy)methyl-hexahydro-furo[2,3-b]pyran-3-yl)-phenylmethanol 37**. $[\alpha]_D^{20}$ +21 (c 0.55, $CHCl_3$). $^1$H NMR (300 Mhz, $C_6D_6$) : 7.78-7.71, 7.31-7.23, 7.14-7.08 (3m, 2H, 2H, 1H, Ar); 5.59 (br s, 1H, H-8); 4.94 (s, 1H, OH); 4.93 (d, 1H, *J* 3 Hz, H-7a); 4.62 (dd, 1H, *J* 9, 2 Hz, H-2); 4.31 (dd, 1H, *J* 9, 8 Hz, H-5); 3.99 (d, 2H, *J* 3 Hz, H-9); 3.97 (dd, 1H, *J* 8, 7 Hz, H-4); 3.56 (dd, 1H, *J* 8, 7 Hz, H-2); 2.98 (dt, 1H, *J* 9, 3 Hz, H-6); 2.85-2.77 (m, 1H, H-3); 2.60 (ddd, 1H, *J* 9, 7, 3 Hz, H-3a); 1.10, 1.06, 1.05 (3s, 3×9H, *t*bu); 0.31, 0.26, 0.24, 0.23, 0.21, 0.10 (6s, 6×3H, (Me)Si). $^{13}$C NMR ($C_6D_6$): 145.56, 128.52, 127.11, 126.41 (Ar); 101.88 (C-7a); 76.74 (C-6); 75.47 (C-4); 70.04 (C-8); 69.25 (C-5); 68.85 (C-2); 62.14 (C-9); 51.04 (C-3a); 46.64 (C-3); 26.92, 26.50, 26.45 ($(\underline{C}H_3)_3C$); 18.98, 18.58, 18.33 ($(CH_3)_3\underline{C}$); -2.03, -3.25, -3.31, -4.05, -4.88, -4.93 ($(\underline{C}H_3)Si$). Anal. Calc. for $C_{32}H_{62}O_6Si_3$: C, 62.02; H, 9.78. Found : C, 62.18; H, 9.91.

**(3*S*, 3a*S*, 4*R*, 5*R*, 6*R*, 7a*R*, 8*S*) 4,5-(di(*tert*butyldimethylsilyloxy)-6-(*tert*butyldimethylsilyloxy)methyl-hexahydro-furo[2,3-b]pyran-3-yl)-phenylmethanol Compound 38**. $^1$H NMR (300 Mhz, $C_6D_6$) : 5.55 (d, 1H, *J* 5 Hz, H-7a); 4.51 (dd, 1H, *J* 8, 1 Hz, H-2); 4.42 (br d, 1H, *J* 9 Hz, H-8); 4.38 (dd, 1H, *J* 8, 6 Hz, H-2); 3.99 (dd, 1H, *J* 10, 5 Hz, H-9); 3.95, (dd, 1H, *J* 4, 1 Hz, H-5); 3.91 (dd, 1H, *J* 10, 8 Hz, H-9); 3.74 (ddd, 1H, *J* 8, 5.5, 1 Hz, H-6); 3.58-3.54 (m, 1H, H-4); 2.83-2.76 (m, 1H, H-3); 2.37 (ddd, *J* 5, 5, 3 Hz, H-3a). $^{13}$C NMR ($C_6D_6$): 144.14, 101.78 (C-7a); 80.74; 75.67; 71.67; 70.70 (C-2); 68.56; 65.27 (C-9); 47.44 (C-3a); 44.62 (C-3); 26.53, 26.25, 26.20 ($(\underline{C}H_3)_3C$); 18.63, 18.26, 17.98 ($(CH_3)_3\underline{C}$); -3.51, -4.40, -4.47, -4.92, -5.03, -5.14 ($(\underline{C}H_3)Si$).

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27. Bicyclic compounds are furo[2,3-b]furan and pyran derivatives and were numbered accordingly. Carbohydrate numbering was employed for compounds 7-12. See Table 1 for numbering.

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31. Selected $^1$H NMR data for this product : δ (ppm, CDCl$_3$, 298 K) : 5.48 (d, 1H, *J* 4. Hz, H-7a); 4.32 (dd, 1H, *J* 9., 7. Hz, H-2); 3.70 (dd, 1H, *J* 9., 4. Hz, H-2); 2.68-2.56 (m, 1H, H-3); 2.25 (ddd, 1H, *J* 8., 4., 2. Hz, H-3a).

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