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Process for large scale preparation of sphingosines and ceramides

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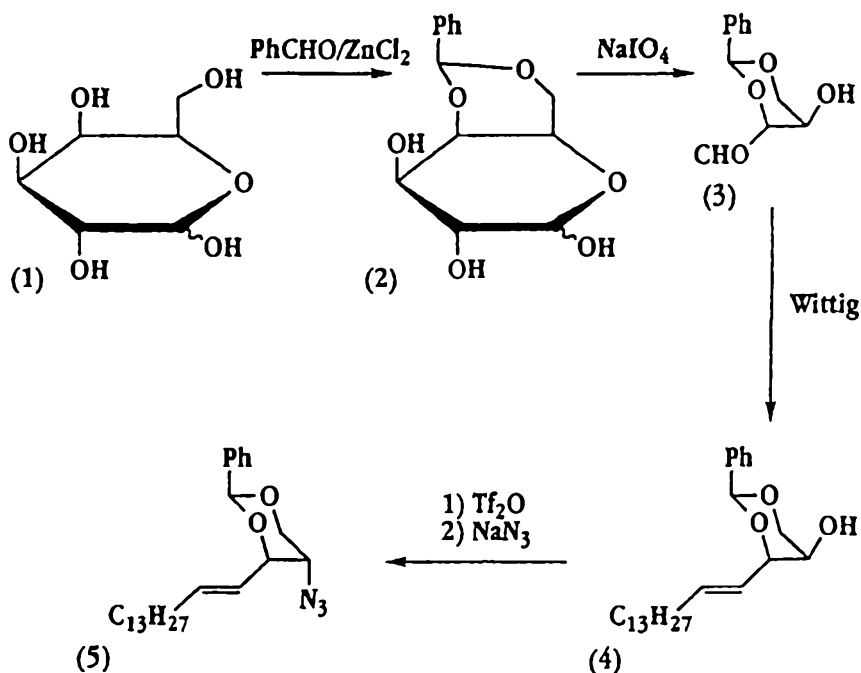
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(21) International Application Number: PCT/IL00/00264 (22) International Filing Date: 9 May 2000 (09.05.00) (30) Priority Data: 60/133,526 10 May 1999 (10.05.99) US (71) Applicant: LIPIDERM LTD. [IL/IL]; Atarot Industrial Zone, P.O. Box 34048, 91340 Jerusalem (IL). (72) Inventor: ROCHLIN, Elimelech; Moshav Zanoach 67, D.N., 99888 Shimshon (IL). (74) Agent: REINHOLD COHN AND PARTNERS; P.O. Box 4060, 61040 Tel Aviv (IL).	(81) Designated States: AU, CA, IL, JP, European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE). Published <i>With international search report.</i>	

(54) Title: PROCESS FOR LARGE SCALE PREPARATION OF SPHINGOSINES AND CERAMIDES

**(57) Abstract**

Synthetic methods for convenient large scale preparation of D-erythro sphingosines and ceramides of high isomeric purity are described.

EDITORIAL NOTE

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FIELD OF THE INVENTION

The present invention relates to synthetic methods for the preparation of D-erythro sphingosines and ceramides of high isomeric purity, and in particular to methods
5 suitable for large scale production.

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BACKGROUND OF THE INVENTION

Sphingosines constitute a group of related long-chain aliphatic 2-amino-1,3-diols, of which Derythro-1,3-
5 dihydroxy-2-amamino-1,3-diols, of which D-erythro-1,3-dihydroxy-2-amino-4,5-trans-octadecene is the most frequently occurring in animal tissues. N-acylsphingosines are also referred to as ceramides. Sphingosines, ceramides, and their glycosides, glycosphingolipids, are
10 of great interest because of their diverse bioactivities and biological roles. These activities include inhibition of protein kinase C activity and transfer of information between developing vertebrate cells. Sphingosines also serve as chain terminators in various gangliosides.
15 Galactosyl ceramide has been shown to be a receptor for HIV binding in cells lacking the CD4 receptor.

Skin ceramides are also believed to play an important role in the water permeability properties of the skin,
20 providing an epidermal water barrier which strengthens the skin structure and reduces water loss. Ceramides and synthetic analogs have thus been used as components of skin care compositions, and have been found effective in restoring the water content of dry skin and in relieving
25 atopic eczema (Kerscher et al.; Imokawa et al.).

These compounds have proven difficult to extract from natural sources, where they are present in low concentrations. Chemical synthetic methods reported to
30 date have generally been laborious and expensive. Several reported methods of synthesizing optically pure sphingosines and their derivatives rely on the use of serine as a chiral building block. See, for example, Polt et al., Herold, and U.S. Pat. No. 5,110,987. However,
35 methods utilizing serine as a starting material are quite lengthy and thus are not amenable to potential scale-up. Other synthetic approaches to the preparation of

isomerically pure sphingosines and ceramides have employed other chiral starting materials, such as carbohydrates, L-glyceric and D-tartaric acids, and/or asymmetric reactions. Although successful as gram-scale procedures, these strategies generally fail or become prohibitively expensive when applied to kilogram scale processes. Enzymatic methods of synthesis have also been described but are often unpredictable, giving varying results depending on medium or the particular enzyme preparation.

Accordingly, a reliable, convenient and versatile method of large scale preparation of these compounds is desirable.

SUMMARY OF THE INVENTION

The present invention includes, in one aspect, a convenient process for the large scale preparation of sphingosine, a sphingosine analog, or a ceramide. The process comprises the following series of steps. A stirred slurry of benzaldehyde and a Lewis acid, preferably ZnCl_2 , is formed and contacted with D-galactose, with continued stirring. The resulting mixture is filtered to obtain a solid precipitate and a filtrate. The filtrate is then diluted with a mixture of diethyl ether and a hydrocarbon solvent, preferably a paraffinic solvent such as hexane, ligroin, or, more preferably, petroleum ether, typically in approximately equal proportions. The resulting mixture is extracted with cold water to provide an aqueous extract, which is treated with a base, such as an alkaline or alkaline earth carbonate or bicarbonate, to produce a precipitate of zinc salts. This precipitate is removed to provide an aqueous solution of 4,6-O-benzylidene-D-galactose. Alternatively, the zinc cation may be removed by treatment with an ion exchange resin. The resulting solution is then treated, preferably without isolation, with an oxidizing agent, preferably sodium periodate,

which oxidatively cleaves the 4,6-O-benzylidene-D-galactose, to produce the protected hydroxy aldehyde, 2,4-O-benzylidene-D-threose. This compound is then reacted with a Wittig reagent, e.g. $(\text{Ar})_2\text{P}=\text{CHR}$, where Ar is aryl and R is a $\text{C}_4\text{-C}_{26}$ branched or unbranched alkyl or alkenyl chain, to produce a hydroxy olefin.

The hydroxyl group of the resulting hydroxy olefin is then converted to a suitable leaving group, such as a tosylate, mesylate, or trifluoromethanesulfonate. Preferably, the hydroxy olefin is reacted with a tritlating agent, such as trifluoromethyl sulfonic anhydride. Subsequent reaction with sodium azide, followed by a hydride reducing agent, such as LiAlH_4 or NaBH_4 , produces an amino olefin. Finally, this compound is deprotected (i.e. the benzylidene group is removed) by contacting it with an acidic ion exchange resin, to produce sphingosine (where R is $n\text{-C}_{13}\text{H}_{27}$, tridecyl) or a sphingosine analog (where R is a longer or shorter alkyl chain, e.g. $\text{C}_4\text{-C}_{12}$ or $\text{C}_{14}\text{-C}_{26}$).

Alternatively, for the production of ceramides, the amino olefin is acylated, by treating with a $\text{C}_2\text{-C}_{26}$ acylating agent, such as an acyl halide, anhydride, or carboxylic acid, in the presence of any necessary acylating catalyst, prior to the deprotection step.

The invention also provides convenient large scale processes for the production of two of the intermediates, i.e. 4,6-O-benzylidene-D-galactose and 2,4-O-benzylidene-D-threose, by carrying out the process described above up to the oxidative cleavage step, or through the oxidative cleavage step, respectively. D-threose may also be obtained in large quantities by deprotection of the intermediate, 2,4-O-benzylidene-D-threose.

These and other objects and features of the invention will become more fully apparent when the following detailed

description of the invention is read in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

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FIG. 1 shows a synthetic scheme for the large scale preparation of 1,3-O-benzylidene-2-azido-(D-erythro-sphingosine) (5) from D-galactose (1);

10

FIG. 2 shows a synthetic scheme for the large scale preparation of sphingosine (7), dihydrosphingosine (14), and a ceramide (9) from the intermediate (5); and

15

FIG. 3 shows a synthetic scheme for the large scale preparation of N-alkylated sphingosines.

DETAILED DESCRIPTION OF THE INVENTION

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The process described herein, suitable for large scale production of sphingosines and ceramides, is based in part on the preparation of 1,3-O-benzylidene-2-azido-(D-erythro-sphingosine) (5) from D-galactose (1) as reported by Schmidt and Zimmerman (1986, 1988, 1990) and the sphingosine and ceramide preparations reported by Kiso et al. (1986). However, the present process incorporates significant modifications, resulting in substantial reductions in expenditure of time and labor. As used herein, "large scale" refers to kilogram, preferably multikilogram, quantities. The term "sphingosines" includes sphingosine itself and analogs which have the basic structure of sphingosine but vary in the length of the fatty alkyl chain.

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As shown in FIGS. 1-3, the process may be used for the production of derivatives such as dihydrosphingosines, N,N-dimethyl- and N,N,N-trimethyl sphingosines, and ceramides having fatty acid components of various lengths.

The process can also be modified for the preparation of phosphoand glycosphingolipids. The individual steps of the process will now be described.

5 A. Benzvlidenation of D-Qalactose

The procedure followed by Schmidt and Zimmerman is based on that reported by Gros and Deulofeu (1964). The product, 4,6-O-benzylidene-D-galactose (BG) and 1,2,3,4-O-
10 dibenzylidene-D-galactose. The products was isolated by a time- and labor-intensive procedure which included the following steps:

1. Decomposition of the reaction mixture in water,
15
2. Slow (overnight) separation of organic and aqueous phases at 5° C.,
3. Washing of the organic phase with water,
20
4. Neutralization and ZnCO₃ precipitation from the combined aqueous solution,
5. Filtration of ZnCO₃ and washing of the filter with
25 additional water,
6. Evaporation of the resulting aqueous solution to dryness in vacuo at .about.40-45° C.,
- 30 7. Extraction of the solid residue with boiling ethyl acetate to separate the 4,6-O-benzylidene galactose (BG) from unreacted galactose and salts, and
8. Concentration of resulting ethyl acetate solution and
35 crystallization of BG (2).

Stages of this procedure which are likely to be

problematic for scaleup include the extended phase separation (step 2), during which the product is exposed to low pH, the extended evaporation (step 6), and the prolonged extraction of the solid residue with hot ethyl acetate (step 7). The quality of extraction may depend very much on the purity of the ethyl acetate. In some cases, the prolonged hot ethyl acetate exposure causes caramelization of galactose-BG-salt mixture and prevents complete extraction of the product.

In accordance with the present invention, the procedure was modified to overcome these problems, based in part on the following observations made by the inventors:

(1.) The undissolved residue remaining in the reaction mixture following the benzylidenation is not ZnCl_2 as previously reported (Gros and Deulofeu), but unreacted D-galactose. When this residue was filtered off, no D-galactose was detected by TLC in the reaction mixture. Therefore, the unreacted D-galactose can be separated from the product by simple filtration of the reaction mixture prior to its decomposition by water, rather than by later extraction of the product with a hot solvent.

(2.) The phase separation after decomposition of the reaction mixture by water is accelerated by addition of an ether/hydrocarbon (preferably ether/petroleum ether) mixture.

(3.) After the aqueous phase is neutralized by K_2CO_3 or (Na_2CO_3) , and ZnCO_3 is filtered off (or, alternatively, Zn^{2+} cations are removed by ion-exchange resin IRC-50S), an aqueous solution of BG and salts (KCl or NaCl) is obtained. This aqueous solution is suitable for the further oxidation by NaIO_4 ; it is not necessary to isolate the product (4,6-O-benzylidene-D-galactose).

An exemplary embodiment of this procedure is described in detail in Example 1, below. The process has also been carried out successfully using p-methoxybenzaldehyde in place of benzaldehyde.

5

B. Oxidative Cleavage of (2)

In the procedure of Schmidt and Zimmerman, isolated (2) was oxidized in aqueous solution by addition of solid NaIO_4 in the presence of phosphate buffer ($\text{pH}=7.0-7.6$). The product, 2,4-O-benzylidene-D-threose (3), was isolated by evaporation of resulting aqueous solution to dryness and extraction of the solid residue with THF, a very prolonged operation.

15

As stated above, in the present procedure, the aqueous solution of (2) from the previous step is oxidized directly, without isolation of (2). The solution thus obtained is concentrated to about one third of its initial volume and then extracted with dichloromethane (CH_2Cl_2). Other organic solvents such as n-butanol or methyl ethyl ketone may also be used. The organic solution is rapidly dried by filtering through a short silica/ MgSO_4 (or silica/ Na_2SO_4) column. Evaporation of the solvent gave pure (3) as a white fragile foam that was easily broken up to a fine powder.

An alternative and possibly more convenient method of isolating (3) from the reaction mixture employs salting out with Na_2SO_4 (rather than concentrating the solution) and then extracting with CH_2Cl_2 . This method would avoid prolonged concentration of the aqueous solution of (3), but larger amounts of CH_2Cl_2 would be necessary in this case due to the high solubility of (3) even in concentrated brines.

35

An exemplary embodiment of the oxidation procedure is

described in Example 2, below.

C. Wittig Alkenation of (3); Preparation of Azide (5)

5 For these steps, conventional procedures, such as described by Schmidt and Zimmerman, were generally suitable for kilogram scale reaction. The Wittig reaction gave a high trans selectivity (approx. 97% by NMR) and yielded about 4 kg of olefin (4) from 4 kg of (3). Wittig
10 reagents having alkyl components of different lengths may be used to prepare various sphingosine analogs.

The Wittig reagent is typically of the form $(Ar)_2P=CHR$, where Ar is aryl and R is a C_4 - C_{26} branched or unbranched
15 alkyl or alkenyl chain. Ar is typically phenyl but may also include C_1 - C_4 alkyl substituted phenyl or naphthyl. Wittig-type reactions in which Ar is other substituted phenyl, such as nitrophenyl or carboxyphenyl, have also been described (Schiemenz et al.). Phosphorus ylids
20 suitable for use in the reaction can also be prepared from trialkylphosphines and trialkylphosphonates (Wittig-Horner reaction), according to methods well known in the art. However, triarylphosphines are generally preferred.

25 Triflation and azidolysis reactions were carried out according to known methods, using sodium trifluoromethyl sulfonate and sodium azide, respectively, to give 1,3-O-benzylidene-azidosphingosine (5).

30 D. Deprotection Reactions

Schmidt et al. used azidosphingosine, prepared by HCl- or pTsOH-catalyzed deprotection of (5), as a key intermediate in the synthesis of sphingosine, ceramides, and other
35 sphingolipids. These deprotection conditions, however, present disadvantages which become more pronounced in medium (ca. 50 g) to large scale (1 kg or more)

production. The deprotection is incomplete even after extended reaction (12-78 hours) at room temperature, and the reaction mixture contains an appreciable amount of starting material and by-products. Heating the CH_2Cl_2 /MeOH medium or employing THF/HCl leads to degradation of the product. (Although Schmidt et al., 1986, reported that the method was "also successful in larger scale preparations", this observation referred to a 20 g scale synthesis.)

In addition, use of sphingosine (7) as a starting material in ceramide synthesis generally requires protection of the OH groups or, alternatively, use of more selective and accordingly more expensive acylating agents. Otherwise, partial acylation of the OH groups occurs, requiring the time consuming purification procedures.

For these reasons, 1,3-O-benzylidene sphingosine (6), prepared by reduction of (5) prior to deprotection, was used as the key intermediate in the present process (FIGS. 2 and 3). It was synthesized by NaBH_4 reduction of (5) in refluxing isopropanol (FIG. 2), as described in Example 3, below, or alternatively, by LiAlH_4 reduction in ether at room temperature. This product was then used for the synthesis of D-erythro-sphingosine (7), ceramides (9), D-erythro-dihydrosphingosine (14), N,N-dimethylsphingosine (11), and N,N,N-trimethylsphingosine (13) (FIGS. 2 and 3).

The procedure used for deprotection (FIGS. 2 and 3) differed from that of Kiso et al, who used isopropylidene, rather than benzylidene, derivatives. Benzylidene derivatives give substantially better E/Z selectivity in Wittig alkenation than isopropenylidene derivatives. However, benzylidene deprotection under the conditions used by Kiso (acetic acid with small amounts of water) progresses very slowly at 5-50° C. At higher temperatures (60-80° C.), the rate is still unsatisfactory and formation of by-products occurs.

Accordingly, more suitable procedures for deprotection of benzylidene derivatives (6), (8), (10), and (12), using ion exchange resins, were used for the present processes. Exemplary procedures, for conversion of (6) to sphingosine (7), and for deprotection of 1,3-O-benzylidene ceramides (8), are described below in Examples 4 and 5.

FIG. 3 illustrates the N-alkylation of (6), followed by deprotection, to give N,N-dimethyl sphingosine (11) and the N,N,N-trimethyl ammonium salt (13). The alkylations were carried out using formaldehyde/sodium cyanoborohydride and dimethylsulfate/sodium bicarbonate, respectively. Preferably, alkylation is carried out prior to deprotection. As shown in FIG. 2, catalytic hydrogenation of D-erythro sphingosine (7) gave D-erythro dihydrosphingosine (14); this reaction may be carried out before or after deprotection. All of the reactions illustrated in FIGS. 2-3 have been carried out successfully on a large scale.

The following examples illustrate but are not intended in any way to limit the invention.

EXAMPLES

Example 1

Preparation of 4,6-O-benzylidene-D-galactose (2) (BG)

A portion of ZnCl_2 (23 kg, 171 mol) was placed into a reactor, taking measures to exclude moisture. Benzaldehyde (70 L, 680 mol) was poured into the reactor, and the mixture was stirred for about 30 minutes using a powerful mechanical stirrer. After initial dissolution of zinc chloride, a thick slurry of a benzaldehyde- ZnCl_2 complex forms. Anhydrous D-galactose (30 kg, 164 mol) and more benzaldehyde (60 L, 570 mol) were added to the warm

slurry, and the mixture was allowed to react at RT for 24 hours with vigorous stirring. The precipitate was filtered off and washed portionwise with benzaldehyde (10-15 L total) and then with acetone, to give, after air-drying, 5 6-7 kg of unreacted D-galactose, probably as the monohydrate. The combined filtrate and benzaldehyde washings were diluted with ether (70 L) and petroleum ether (80 L), and the mixture was extracted with ice-cold water (140 L). The organic layer was washed 3 times with 10 ice water (70 L each time), and the combined aqueous layers were neutralized by rapid addition of a solution of potassium carbonate (38 kg of anhydrous carbonate in approximately 45-50 L of water). The resulting thick suspension of zinc salts was filtered, and the precipitate 15 was washed thoroughly with water until 500-600 L of filtrate were collected. After extraction with chloroform (70 L) and with petroleum ether (70 L), the filtrate, containing 4,6-O-benzylidene-D-galactose (2) and a mixture of KCl and KHCO_3 , and having a pH of about 8.7, was used 20 directly for the following oxidation.

Example 2

Preparation of 2,4-O-benzylidene-D-threose (3)

25 The solution from Example 1 was placed into a reactor and buffered with a mixture of K_2HPO_4 trihydrate (11 kg) and KH_2PO_4 (4.5 kg). Sodium periodate (about 39 kg) was introduced into the solution by portions (approximately 30 0.5 kg) during 5-6 hours with vigorous stirring, maintaining the pH within 7.0-7.5 by periodic addition of 20% aq. KOH. During the addition, the temperature was kept at 20-25° C. by external cooling. The reaction was deemed complete when introduction of further NaIO_4 did not lower 35 the pH of the reaction mixture and testing with iodide-starch paper showed an excess of NaIO_4 which persisted for 0.5 h. Completion was further verified by TLC (silica gel,

toluene-ethanol 3:1).

The reaction suspension was concentrated in vacuo (at ~40° C.), without prior filtering, to approximately 150 L.

- 5 Dichloromethane (160 L) was added, and the precipitate of inorganic salts was filtered off and washed thoroughly with CH₂Cl₂ (additional 70 L). The two-phase filtrate was allowed to separate, and the lower layer (CH₂Cl₂ solution of (3)) was passed through a column (D=30 cm) filled with
10 dry MgSO₄ (10 cm column), followed by silica gel (30 cm) and another layer of MgSO₄ (10 cm). The aqueous layer was extracted 3 times with 70 L portions of dichloromethane, and the extract was passed through the same column. The column was then eluted with 115 L chloroform to wash
15 residual (3) from the silica gel. The combined eluates were concentrated in vacuo to a syrup and diluted with benzene to approximately 90 L. The solution was immediately (to prevent crystallization of (3)) dried in vacuo to give a solid foam. Yields of 2,4-O-benzylidene-D-
20 treose (3) ranged from 12.5 kg to 13.6 kg (about 36-39% from D-galactose).

Example 3

- 25 Reduction of 1,3-O-benzylidene azidosphingosine (5)

Azido derivative (5) (100 g, 0.25 mol) was refluxed with 19 g (0.5 mol) NaBH₄ in 1 L of 2-propanol for 48 hours. The reaction mixture was cooled to room temperature, filtered,
30 and treated with acetone to decompose the unreacted borohydride. The resulting solution was then evaporated to dryness under reduced pressure. The solid residue was extracted with 3.times.500 ml of boiling petroleum ether (60-80°) or hexane, and the combined extracts were filtered
35 and evaporated. The residue was recrystallized from EtOH/H₂O to give 70 g (75%) of derivative (6): mp 51-52° C; [α]_D +38.4 (c=0.6, CHCl₃).

Example 4

Deprotection of 1,3-O-benzylidene-D-erythro-sphingosine (6)

A 50 g portion (0.129 mole) of 1,3-O-benzylidene-D-erythro-sphingosine (6) was dissolved in 1.5 L of 90% MeOH and passed through a column filled with ~400 ml of a strongly acidic ion exchange resin such as Dowex.TM.-50 or Amberlite.TM. The column was then slowly eluted with 90% MeOH up to disappearance of benzaldehyde in the eluate (determined by TLC, HPLC or UV). The reaction is usually complete within 20-30 minutes at room temperature. The final product was then eluted with a 9:1 mixture of MeOH/conc. NH_4OH . Dichloromethane and water, were then added to the eluate to give a ratio of $\text{CH}_2\text{Cl}_2/\text{MeOH}/\text{H}_2\text{O}$ 8:4:3. The organic (lower) phase was separated, dried over Na_2SO_4 , and evaporated to give ~36 g (94%) of 97-98% pure D-erythro-sphingosine, mp 73-76° C.; ^1H NMR spectrum in accordance with literature.

Example 5

Preparation and deprotection of 1,3-O-benzylidene-ceramides (8) with Different Fatty Acid Chains

Acylation of 1,3-O-benzylidene-D-erythro-sphingosine (6) was carried out using a variety of carboxylic acids (C_2 - C_{26}), catalyzed by DCC, in CH_2Cl_2 , or acid chlorides in CH_2Cl_2 , according to known procedures. Yields of acyl derivatives (8) were 92-98%.

Protected ceramide (8) ~0.1 mol) was dissolved in 1.5-3.0 L (depending on the solubility of the ceramide) acetic acid at 60-70° C. Then ~200 g of strongly acidic ion exchange resin were added with stirring, followed by 90%

MeOH (about 15-20% of the total volume). The reaction mixture was stirred at 60-70° C. for 3-8 hours until deprotection was complete by TLC and rapidly filtered while hot. The filter was washed with 100-200 ml hot acetic acid, and the combined filtrate was allowed to stand overnight at 0-4° C. The precipitate was filtered off, washed with 200 mL cold acetic acid, 1.5-2.0 L water, 500 mL satd. NaHCO₃, and 1-1.5 L water. After lyophilization, 70-85% yield of 95% pure material was obtained. For higher purity, the precipitate was dissolved (without lyophilization) in CHCl₃ or CH₂Cl₂, dried with Na₂SO₄ and purified by column chromatography (1-5 % MeOH/CH₂Cl₂), giving >99% pure ceramide (9).

Example 6

Preparation of D-erythro-dihydrosphingosine

A 0.67 mole portion of sphingosine or a sphingosine analog, prepared by the above methods, was dissolved in 3 L of absolute methanol, and 10 g of 5% Pd/C were added. Hydrogenation was carried out at room temperature under 1 atm pressure of H₂. The reaction mixture was filtered and concentrated by evaporation, and the residue was recrystallized from n-hexane, giving the product in 80-86% yield with 96-98% purity.

While the invention has been described with reference to specific methods and embodiments, it will be appreciated that various modifications may be made without departing from the invention.

IT IS CLAIMED:

1. A process for the large scale preparation of sphingosine, a sphingosine analog, or a ceramide,
5 comprising the steps of:
 forming a stirred slurry of benzaldehyde and ZnCl_2 ;
 contacting the stirred slurry with D-galactose;
 filtering the resulting mixture to obtain a solid precipitate and a filtrate;
10 diluting the filtrate with diethyl ether and a hydrocarbon solvent;
 extracting the resulting mixture with cold water to provide an aqueous extract;
 removing Zn^{+2} from the aqueous extract by treatment
15 with base or an ion exchange resin, to provide an aqueous solution of 4,6-O-benzylidene-D-galactose;
 treating the solution with an oxidizing agent effective to oxidatively cleave said galactose, to produce a hydroxy aldehyde;
20 contacting the hydroxy aldehyde with a reagent of the form $(\text{Ar})_2\text{P}=\text{CHR}$, where Ar is aryl and R is a $\text{C}_2\text{-C}_{24}$ alkyl chain, to produce a hydroxy olefin;
 reacting the hydroxy olefin with a triflating agent, followed by sodium azide, followed by a hydride reducing
25 agent, to produce an amino olefin; and
 deprotecting the amino olefin by contacting the amino olefin with an acidic ion exchange resin, to produce sphingosine or a sphingosine analog.
- 30 2. The process of claim 1, for the large scale preparation of a ceramide, further comprising the step of acylating said amino olefin prior to said deprotecting step.
- 35 3. The process of claim 2, wherein said acylating employs a $\text{C}_2\text{-C}_{26}$ acylating agent.

4. A process for the large scale preparation of 4,6-O-benzylidene-D-galactose, comprising the steps of:

forming a stirred slurry of benzaldehyde and ZnCl_2 ;

contacting the stirred slurry with D-galactose;

5 filtering the resulting mixture to obtain a solid precipitate and a filtrate;

diluting the filtrate with diethyl ether and a hydrocarbon solvent;

10 extracting the resulting mixture with cold water to provide an aqueous extract; and

removing Zn^{+2} from the aqueous extract by treatment with base or an ion exchange resin, to provide an aqueous solution of 4,6-O-benzylidene-D-galactose.

15 5. A process for the large scale preparation of 2,4-O-benzylidene-D-threose, comprising the steps of:

forming a stirred slurry of benzaldehyde and ZnCl_2 ;

contacting the stirred slurry with D-galactose;

20 filtering the resulting mixture to obtain a solid precipitate and a filtrate;

diluting the filtrate with diethyl ether and a hydrocarbon solvent;

extracting the resulting mixture with cold water to provide an aqueous extract;

25 removing Zn^{+2} from the aqueous extract by treatment with base or an ion exchange resin, to provide an aqueous solution of 4,6-O-benzylidene-D-galactose; and

treating the solution with an oxidizing agent effective to oxidatively cleave said galactose.

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Dated this 6th day of January 2004

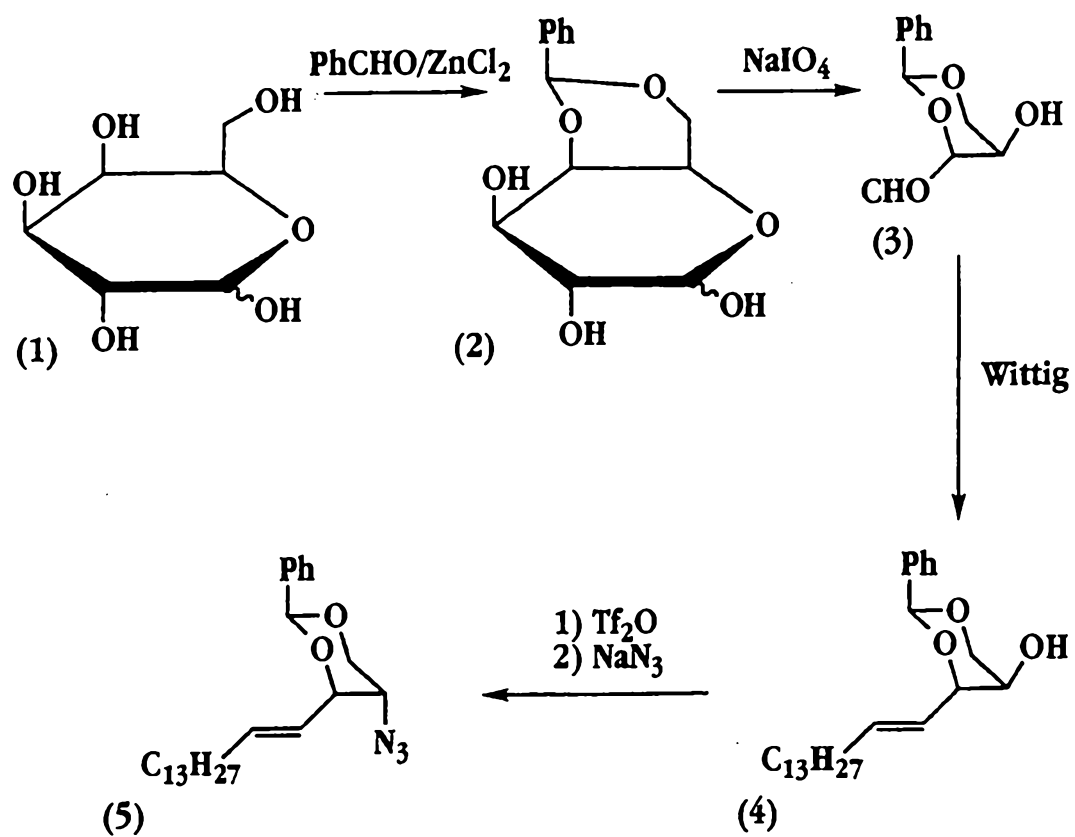
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**Fig. 1**

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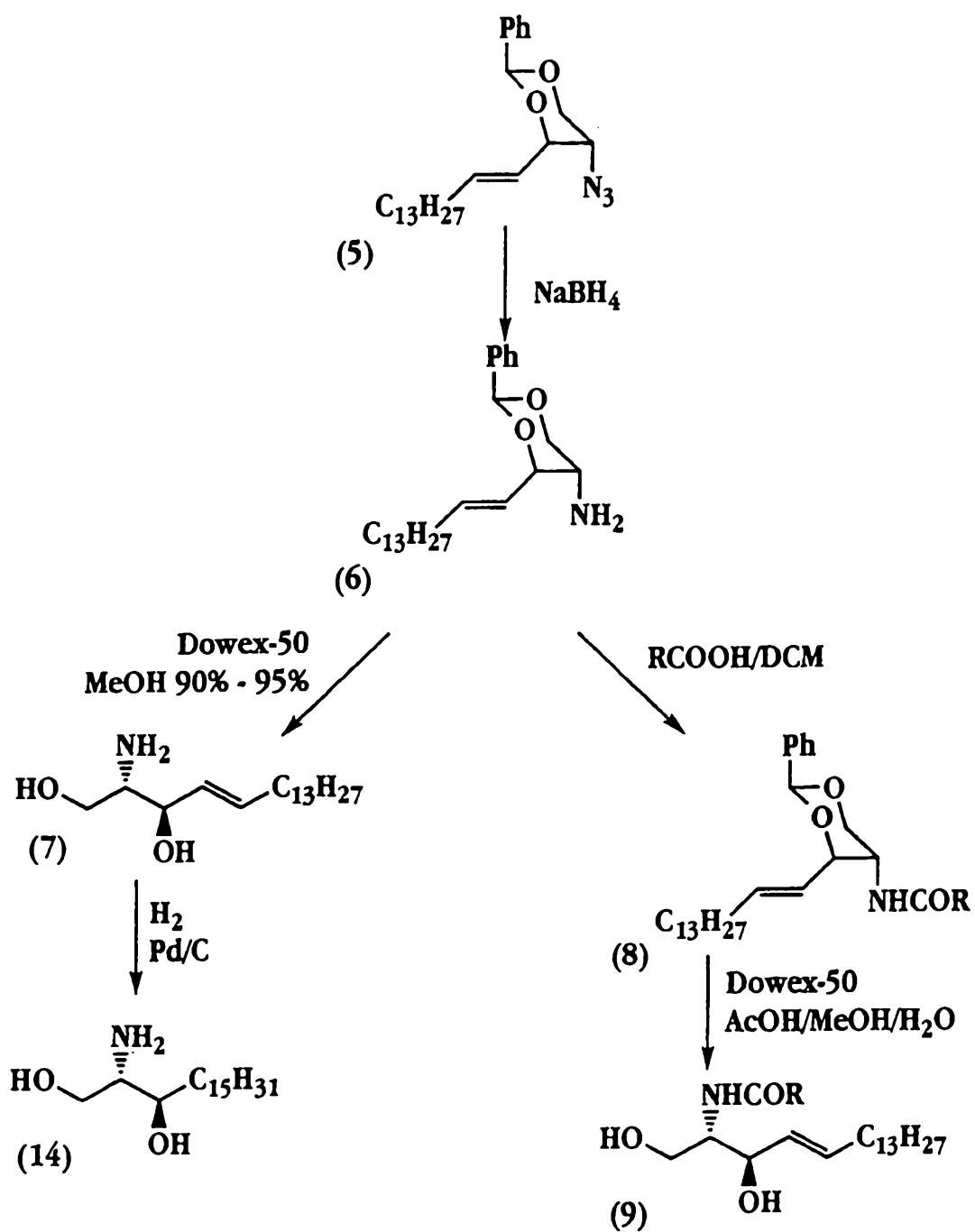


Fig. 2

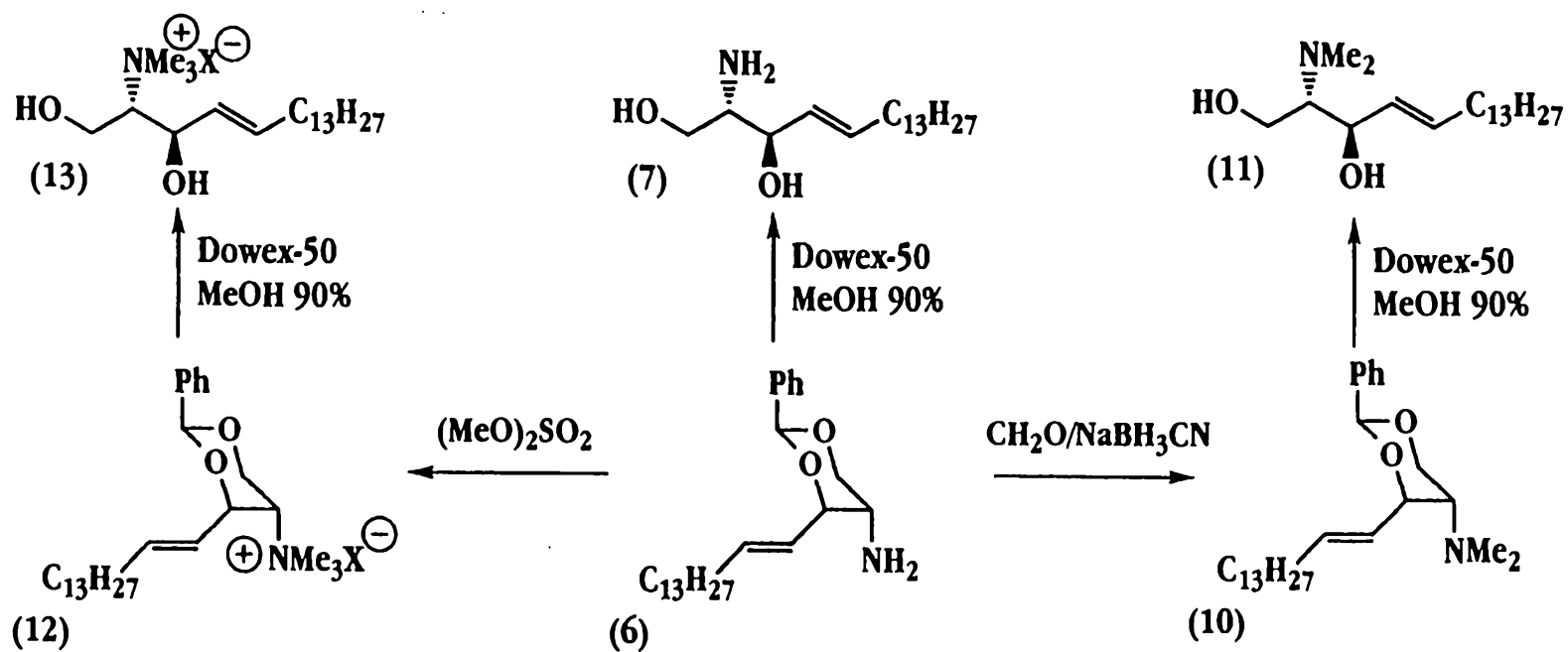


Fig. 3