A class of novel compounds is described for use in affecting lymphatic absorption of cholesterol. Compounds of particular interest are defined by Formula I:
OTHER PUBLICATIONS


FIG. 2

Oleic acid output (μmol/h)

Time (h)

Control

Compound I

Time (h)
FIG. 3

Inhibition (%)

1st
2nd
FIG. 4

Concentration (µM)

Inhibition (%)

Concentration (µM)

— Ferroverdin A
1
COMPOUNDS AFFECTING CHOLESTEROL ABSORPTION

STATEMENT AS TO FEDERALLY SPONSORED RESEARCH

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TECHNICAL FIELD

This invention relates to novel organic compound and methods for their synthesis. More particularly, the invention relates to novel compounds affecting lymphatic absorption of cholesterol.

BACKGROUND

Atherosclerosis is a major cause of heart attack, stroke, and gangrene of the extremities and can be attributed directly to having high levels of cholesterol in the body. Cholesterol can enter the body by absorption from foods by the intestinal mucosal cells and the lymphatic system (i.e., exogenous sources). Cholesterol also is produced in the liver by a sequence of enzymatic reactions (i.e., endogenous biosynthesis). Endogenous biosynthesis of cholesterol involves a key enzyme, HMG-CoA (3-hydroxy-3-methylglutaryl coenzyme A) reductase. HMG-CoA reductase inhibitors can be used to lower total plasma cholesterol. See, e.g., U.S. Pat. Nos. 5,246,960, 5,175,186, 5,215,972, 5,495,048, 5,856,503, and 5,637,771. Currently, a lipase inhibitor termed Xenical® has been offered for obesity management. Xenical® has been reported to achieve a slight reduction in cholesterol.

SUMMARY

The invention features a compound of Formula I:

R₁ can be independently hydrido, halo, alkyl, alkenyl, alkyl, haloalkyl, hydroxalkyl, hydroxy, alkoxy,
alkoxyalkyl, haloalkoxy, haloalkoxyalkyl, aryl, heterocyclic, heteroaryl, alkyloxy, arylalkyl, N-alkylsufamyl, N,N-dialkylsufamyl, N-arylsulfonyl, N-alkyl-N-arylsulfonyl, carboxy, carboxynalkyl, alkyloxy, alkylcarbonyl, alkyloxy, alkylcarbonyloalkyl, amido, N, N-alkylamido, N,N-dialkylamido, N,N-diarylamido, N,N-dialkylhydroxamido, N-alkyl-N-hydroxamido, amidoalkyl, aminoaalkyl, alkyloxyalkylamido, amidino, cyanoamino, heterocycloalkyl, aralkyl, cyclalkyl, cycloalkenyl, alkylthio, alkyloxy, acyl, acylamino, arylamino, amino, cyano, nitro, sulfonate, alklysilyl, phenylseleneny, thiol, arylsufenyl, arylsulfonyl, arylsulfonyl, or arylsilyloxy,

R₂ can be independently hydrido, halo, alkyl, alkenyl, alkyl, haloalkyl, hydroxalkyl, hydroxy, alkoxy, alkoxyalkyl, haloalkoxy, haloalkoxyalkyl, aryl, heterocyclic, heteroaryl, alkyloxy, arylalkyl, N-alkylsulfamyl, N,N-dialkylsulfamyl, N-arylsulfonyl, N-alkyl-N-arylsulfonyl, carboxy, carboxynalkyl, alkyloxy, alkylcarbonyl, alkyloxy, alkylcarbonyloalkyl, amido, N, N-alkylamido, N,N-dialkylamido, N,N-diarylamido, N,N-dialkylhydroxamido, N-alkyl-N-hydroxamido, amidoalkyl, aminoaalkyl, alkyloxyalkylamido, amidino, cyanoamino, heterocycloalkyl, aralkyl, cyclalkyl, cycloalkenyl, alkylthio, alkyloxy, acyl, acylamino, arylamino, amino, cyano, nitro, sulfonate, alklysilyl, phenylseleneny, thiol, arylsufenyl, arylsulfonyl, arylsulfonyl, or arylsilyloxy,

R₃ can be independently hydrido, halo, alkyl, alkenyl, alkyl, haloalkyl, hydroxalkyl, hydroxy, alkoxy,
alkoxyalkyl, haloalkoxy, haloalkoxyalkyl, aryl, heterocyclic, heteroaryl, alkyloxy, arylalkyl, N-alkylsulfamyl, N,N-dialkylsulfamyl, N-arylsulfonyl, N-alkyl-N-arylsulfonyl, carboxy, carboxynalkyl, alkyloxy, alkylcarbonyl, alkyloxy, alkylcarbonyloalkyl, amido, N, N-alkylamido, N,N-dialkylamido, N,N-diarylamido, N,N-dialkylhydroxamido, N-alkyl-N-hydroxamido, amidoalkyl, aminoaalkyl, alkyloxyalkylamido, amidino, cyanoamino, heterocycloalkyl, aralkyl, cyclalkyl, cycloalkenyl, alkylthio, alkyloxy, acyl, acylamino, arylamino, amino, cyano, nitro, sulfonate, alklysilyl, phenylseleneny, thiol, arylsufenyl, arylsulfonyl, arylsulfonyl, or arylsilyloxy,

R₄ can be independently hydrido, halo, alkyl, alkenyl, alkyl, haloalkyl, hydroxalkyl, hydroxy, alkoxy, alkoxyalkyl, haloalkoxy, haloalkoxyalkyl, aryl, heterocyclic, heteroaryl, alkyloxy, arylalkyl, N-alkylsulfamyl, N,N-dialkylsulfamyl, N-arylsulfonyl, N-alkyl-N-arylsulfonyl, carboxy, carboxynalkyl, alkyloxy, alkylcarbonyl, alkyloxy, alkylcarbonyloalkyl, amido, N, N-alkylamido, N,N-dialkylamido, N,N-diarylamido, N,N-dialkylhydroxamido, N-alkyl-N-hydroxamido, amidoalkyl, aminoaalkyl, alkyloxyalkylamido, amidino, cyanoamino, heterocycloalkyl, aralkyl, cyclalkyl, cycloalkenyl, alkylthio, alkyloxy, acyl, acylamino, arylamino, amino, cyano, nitro, sulfonate, alklysilyl, phenylseleneny, thiol, arylsufenyl, arylsulfonyl, or arylsilyloxy,

R₅ can be independently hydrido, halo, or hydroxalkyl.

R₆ can be independently hydrido, halo, or hydroxalkyl.

R₇ can be independently hydrido, halo, or hydroxalkyl.

In some embodiments, R₁ is halo, R₂ and R₃ are hydroxy, and R₂ and R₃ are alkyl in the compound, e.g., R₁ is chloro and R₂ and R₃ are methyl. In other embodiments, R₁ is halo, R₂ and R₃ are alkylsilyloxy, and R₄ and R₅ are alkyl, e.g., R₁ is chloro, R₂ and R₃ are OSi-1t-Bue₂, and R₄ and R₅ are methyl. In one embodiment, the compound has Formula (24):
In some embodiments, R₁ is halo, R₂ and R₃ are selected from hydroxy and alkylsilyloxy, and R₄ and R₅ are alkyl, e.g., R₁ is chloro, R₂ and R₃ are hydroxy, and R₄ and R₅ are methyl. In some embodiments, R₁ is halo, R₂ and R₃ are alkylsilyloxy, and R₄ and R₅ are methyl, e.g., R₁ is chloro, R₂ and R₃ are OSi-t-BuMe₂, and R₄ and R₅ are methyl. In some embodiments the compound has Formula (23):

The invention also features a compound of Formula II:

R₁ can be independently any of the groups described above for R₁ of Formula I. R₂ and R₃ can be independently any of the groups described above for R₂ of Formula I. R₄ can be independently any of the groups described above for R₃ of Formula I. R₄ can be independently hydrido, alkyl, or hydroxyalkyl. R₅ can be independently hydrido, alkyl, or hydroxyalkyl. However, when R₁ is chloro, R₂ and R₃ are not hydroxy and R₄ and R₅ are methyl.

In some embodiments, R₁ is halo, R₂ and R₃ are hydroxy, and R₄ and R₅ are alkyl. In some embodiments, R₁ is halo, R₂ and R₃ are alkylsilyloxy; and R₄ and R₅ are alkyl, e.g., R₁ is chloro, R₂ and R₃ are OSi-t-BuMe₂, and R₄ and R₅ are methyl.

The invention also features a compound of Formula III:

In these compounds, R₁ can be independently any of the groups described above for R₁ of Formula I.

R₂ can be independently any of the groups described above for R₂ of Formula I. R₃ can be independently any of the groups described above for R₃ of Formula I. R₄ can be independently hydrido, alkyl, or hydroxyalkyl. R₅ can be independently hydrido, alkyl, or hydroxyalkyl.

R₁ can be independently any of the groups described above for R₁ of Formula I. R₂ can be independently any of the groups described above for R₂ of Formula I. R₃ can be independently any of the groups described above for R₃ of Formula I. R₄ can be independently hydrido, alkyl, or hydroxyalkyl. R₅ can be independently hydrido, alkyl, or hydroxyalkyl. However, when R₁ is chloro, R₂ and R₃ are not hydroxy and R₄ and R₅ are methyl.

In some embodiments, R₁ is halo, R₂ and R₃ are alkylsilyloxy, and R₄ and R₅ are alkyl, e.g., R₁ is chloro, R₂ and R₃ are OSi-t-BuMe₂, and R₄ and R₅ are methyl.

In other embodiments, R₁ is chloro, R₂ and R₃ are hydroxy, R₄ and R₅ are methyl, R₆ is hydrido, and R₇ is methyl. In some embodiments, R₁ is chloro; R₂ and R₃ are aralkyloxy; R₄ and R₅ are methyl, R₆ is hydrido, and R₇ is arylselenylalkyl. In some embodiments, R₁ is chloro, R₆ is arylselenylalkyl, and R₇ is methyl. In some embodiments, R₆ is acyloxy, and R₇ is arylselenylalkyl. In some embodiments, R₆ is acyloxy, and R₇ is arylselenylalkyl. In some embodiments, R₆ is acyloxy, and R₇ is arylselenylalkyl. In some embodiments, R₆ is acyloxy, and R₇ is arylselenylalkyl. In some embodiments, R₆ is acyloxy, and R₇ is arylselenylalkyl. In some embodiments, R₆ is acyloxy, and R₇ is arylselenylalkyl. In some embodiments, R₆ is acyloxy, and R₇ is arylselenylalkyl. In some embodiments, R₆ is acyloxy, and R₇ is arylselenylalkyl. In some embodiments, R₆ is acyloxy, and R₇ is arylselenylalkyl. In some embodiments, R₆ is acyloxy, and R₇ is arylselenylalkyl. In some embodiments, R₆ is acyloxy, and R₇ is arylselenylalkyl. In some embodiments, R₆ is acyloxy, and R₇ is arylselenylalkyl. In some embodiments, R₆ is acyloxy, and R₇ is arylselenylalkyl. In some embodiments, R₆ is acyloxy, and R₇ is arylselenylalkyl. In some embodiments, R₆ is acyloxy, and R₇ is arylselenylalkyl. In some embodiments, R₆ is acyloxy, and R₇ is arylselenylalkyl. In some embodiments, R₆ is acyloxy, and R₇ is arylselenylalkyl. In some embodiments, R₆ is acyloxy, and R₇ is arylselenylalkyl. In some embodiments, R₆ is acyloxy, and R₇ is arylselenylalkyl. In some embodiments, R₆ is acyloxy, and R₇ is arylselenylalkyl. In some embodiments, R₆ is acyloxy, and R₇ is arylselenylalkyl. In some embodiments, R₆ is acyloxy, and R₇ is arylselenylalkyl. In some embodiments, R₆ is acyloxy, and R₇ is arylselenylalkyl. In some embodiments, R₆ is acyloxy, and R₇ is arylselenylalkyl. In some embodiments, R₆ is acyloxy, and R₇ is arylselenylalkyl. In some embodiments, R₆ is acyloxy, and R₇ is arylselenylalkyl. In some embodiments, R₆ is acyloxy, and R₇ is arylselenylalkyl. In some embodiments, R₆ is acyloxy, and R₇ is arylselenylalkyl. In some embodiments, R₆ is acyloxy, and R₇ is arylselenylalkyl. In some embodiments, R₆ is acyloxy, and R₇ is arylselenylalkyl. In some embodiments, R₆ is acyloxy, and R₇ is arylselenylalkyl. In some embodiments, R₆ is acyloxy, and R₇ is arylselenylalkyl. In some embodiments, R₆ is acyloxy, and R₇ is arylselenylalkyl. In some embodiments, R₆ is acyloxy, and R₇ is arylselenylalkyl. In some embodiments, R₆ is acyloxy, and R₇ is arylselenylalkyl. In some embodiments, R₆ is acyloxy, and R₇ is arylselenylalkyl. In some embodiments, R₆ is acyloxy, and R₇ is arylselenylalkyl. In some embodiments, R₆ is acyloxy, and R₇ is arylselenylalkyl. In some embodiments, R₆ is acyloxy, and R₇ is arylselenylalkyl. In some embodiments, R₆ is acyloxy, and R₇ is arylselenylalkyl. In some embodiments, R₆ is acyloxy, and R₇ is arylselenylalkyl. In some embodiments, R₆ is acyloxy, and R₇ is arylselenylalkyl. In some embodiments, R₆ is acyloxy, and R₇ is arylselenylalkyl. In some embodiments, R₆ is acyloxy, and R₇ is arylselenylalkyl. In some embodiments, R₆ is acyloxy, and R₇ is arylselenylalkyl. In some embodiments, R₆ is acyloxy, and R₇ is arylselenylalkyl. In some embodiments, R₆ is acyloxy, and R₇ is arylselenylalkyl. In some embodiments, R₆ is acyloxy, and R₇ is arylselenylalkyl. In some embodiments, R₆ is acyloxy, and R₇ is arylselenylalkyl. In some embodiments, R₆ is acyloxy, and R₇ is arylselenylalkyl. In some embodiments, R₆ is acyloxy, and R₇ is arylselenylalkyl. In some embodiments, R₆ is acyloxy, and R₇ is arylselenylalkyl. In some embodiments, R₆ is acyloxy, and R₇ is arylselenylalkyl. In some embodiments, R₆ is acyloxy, and R₇ is arylselenylalkyl. In some embodiments, R₆ is acyloxy, and R₇ is arylselenylalkyl. In some embodiments, R₆ is acyloxy, and R₇ is arylselenylalkyl. In some embodiments, R₆ is acyloxy, and R₇ is arylselenylalkyl.
The invention also features a compound of Formula V:

\[
\begin{align*}
\text{R}_1, & \text{ can be independently any of the groups described}\nonumber \\
\text{R}_2, & \text{ can be independently any of the groups described above for } \text{R}_1, \text{ of Formula I. R}_3, \text{ can be independently any of the groups described above for } \text{R}_1, \text{ of Formula I. R}_4, \text{ can be independently hydrido, alkyl, or hydroxyalkyl. R}_5 \text{ is independently hydrido, alkyl, or hydroxyalkyl. R}_6 \text{ can be hydrido. R}_7 \text{ can be independently hydrido, or alkylsilyloxy.}
\end{align*}
\]

In some embodiments, \( \text{R}_1 \) is halo; \( \text{R}_2 \) and \( \text{R}_3 \) are arylalkyloxy; \( \text{R}_4 \) and \( \text{R}_5 \) are alkyl; \( \text{R}_6 \) is hydroxy; and \( \text{R}_7 \) is selected from hydroxy and alkylsilyloxy, e.g., \( \text{R}_7 \) is chloro; \( \text{R}_2 \) and \( \text{R}_3 \) are OBn; and \( \text{R}_4 \) and \( \text{R}_5 \) are methyl; \( \text{R}_6 \) is hydroxy; and \( \text{R}_7 \) is OSi-t-BuMe\(_2\). In some embodiments, \( \text{R}_1 \) is chloro; \( \text{R}_2 \) and \( \text{R}_3 \) are OBn; \( \text{R}_4 \) and \( \text{R}_5 \) are methyl; \( \text{R}_6 \) is hydroxy; and \( \text{R}_7 \) is hydroxy.

The invention also features a method of synthesizing a compound of Formula I:

\[
\begin{align*}
\text{wherein } \text{R}_1 & \text{ is chloro; R}_2 \text{ and R}_3 \text{ are OSi-t-BuMe}\(_2\). \text{ The method further comprises isolating compound (18) and deprotecting compound (18). The result is a compound of Formula I.}
\end{align*}
\]

The invention also features a method of synthesizing (+) chloropuanphenone. The method comprises hydrogenating compound (19) to form compound (25).

Desilylation of compound (25) forms compound (26).
Oxidation of compound (26) forms (+) chloropuupe-henone (27).

The invention also features a pharmaceutical composition comprising a pharmaceutically-acceptable carrier and a compound of Formula 1:

\[
\begin{align*}
\text{Cl} & \quad \text{OH} \\
\text{OH} & \quad \text{OH}
\end{align*}
\]

The composition can be in the form of a capsule or a liquid emulsion. The composition can in a controlled release formulation, e.g., a dispersion in hydroxypropylmethyl cellulose, or in a formulation suitable for parenteral administration, e.g., a lipid emulsion. The composition can comprise a diluent such as polyethylene glycol, propylene glycol, ethanol, corn oil, cottonseed oil, peanut oil, sesame oil, or benzyl alcohol. The pharmaceutically-acceptable carrier material can be lactose, sucrose, starch powder, cellulose esters of alkanolic acids, cellulose alkenyl esters, talc, stearic acid, magnesium stearate, magnesium oxide, sodium and calcium salts of phosphoric and sulfuric acids, gelatin, acacia gum, sodium alginate, microcrystalline cellulose, sodium starch glycolate, sodium lauryl sulfate, povidone, polyvinylpyrrolidone, or polyvinyl alcohol.

The invention also features a method for identifying a compound that inhibits lymphatic absorption of cholesterol. The method comprises administering a known amount of cholesterol and a compound of claim 1 to a non-human mammal, and determining the amount of administered cholesterol that is absorbed by the lymph. A statistically significant decrease in lymphatic cholesterol absorption relative to the lymphatic cholesterol absorption of a corresponding control mammal indicates that the compound is effective for inhibiting lymphatic absorption of cholesterol. A statistically insignificant change or a statistically significant increase in lymphatic cholesterol absorption relative to the lymphatic cholesterol absorption of a corresponding control mammal indicates the compound does not inhibit lymphatic absorption of cholesterol. The cholesterol and the compound can be administered in a lipid emulsion.

The invention also features a method of treating a cholesterol-related condition. The method comprises administering an effective amount of a compound of Formula I to a mammal. The cholesterol-related condition can be, for example, atherosclerosis, hypercholesterolemia, heart attack, gangrene, and stroke. The compound can be administered orally, intravenously, intraperitoneally, subcutaneously, intramuscularly, or topically, and in an amount from about 4 mg/kg to about 4 g/kg of body weight per day. The compound can be administered in a composition as described above. The method can be part of a treatment regimen comprising a diet low in cholesterol, or as part of a treatment regimen that includes administering an HMG-CoA reductase inhibitors. The method can be used to treat humans. The method can include administering the compound for 7 days or more, e.g., for one year or more.

Unless otherwise defined, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention pertains. Although methods and materials similar or equivalent to those described herein can be used to practice the invention, suitable methods and materials are described below. All publications, patent applications, patents, and other references mentioned herein are incorporated by reference in their entirety. In case of conflict, the present specification, including definitions, will control. In addition, the materials, methods, and examples are illustrative only and not intended to be limiting.

The details of one or more embodiments of the invention are set forth in the accompanying drawings and the description below. Other features, objects, and advantages of the invention will be apparent from the description and drawings, and from the claims.

DESCRIPTION OF DRAWINGS

FIG. 1 is a graph showing hourly rates of lymphatic absorption of cholesterol in lymph-cannulated rats. Values are expressed as means±SD, n=5. *Indicates a significant difference between treatments at p<0.05.

FIG. 2 is a graph showing hourly rates of lymphatic absorption of oleic acid in lymph-cannulated rats. Values are expressed as means±SD, n=5. *Indicates a significant difference between treatments at p<0.05.

FIG. 3 is a graph showing percent inhibition of cholesterol ester transfer protein (CETP) activity in the presence of various concentrations of compound 24. The results from two replicates of the assay are shown.

FIG. 4 is a graph showing percent inhibition of CETP activity in the presence of various concentrations of Ferroverdin A.

DETAILED DESCRIPTION

Compounds of Formula I

A class of compounds useful for inhibiting lymphatic absorption of cholesterol is defined by Formula I:

\[
\begin{align*}
R_1 & \quad R_2 \\
R_3 & \quad R_4 \\
R_5 & \quad R_6
\end{align*}
\]

wherein \( R_1 \) is selected from hydrido, halo, alkyl, alkenyl, alkyllyl, haloalkyl, hydroxyalkyl, hydroxy, alkoxy,
A second class of compounds is defined by Formula II:

\[
A \cdot B \cdot C \cdot D \cdot E \cdot F \cdot G \cdot H \cdot I \cdot J \cdot K \cdot L \cdot M \cdot N \cdot O \cdot P \cdot Q \cdot R \cdot S \cdot T \cdot U \cdot V \cdot W \cdot X \cdot Y \cdot Z
\]

wherein R<sub>1</sub> is selected from the moieties described above for R<sub>1</sub> groups of Formula I, R<sub>2</sub> is selected from the moieties described above for R<sub>2</sub> groups of Formula I, R<sub>3</sub> is selected from the moieties described above for R<sub>3</sub> groups of Formula I, R<sub>4</sub> is selected from hydroxy, and hydroxysilyloxy; and R<sub>5</sub> is selected from hydroxy, and hydroxysilyloxy. The class of compounds also includes pharmaceutically-acceptable salts thereof.

An exemplary class of compounds includes those compounds of Formula II wherein R<sub>1</sub> is halo, R<sub>2</sub> is selected from hydroxy and alkoxyalkyl, R<sub>3</sub> is selected from hydroxy and alkyloxycarbonyl, and R<sub>5</sub> is selected from hydroxy and hydroxysilyloxy.

A family of specific compounds of particular interest within Formula II consists of compounds and their pharmaceutically acceptable salts as follows:

(4aS,6aS,12bS)-2H-9,10-Bis-(t-butyldimethylsilyloxy)-11-chloro-1,3,4,4a,5,6,6a,12b-octahydro-4,4a,6a,12b-tetramethyl-benzo[a]xanthene (19).

A third class of compounds is defined by Formula III:

\[
\text{Compositions of Formula III}
\]

wherein R<sub>1</sub> is selected from the moieties described above for R<sub>1</sub> groups of Formula I, R<sub>2</sub> is selected from the moieties described above for R<sub>2</sub> groups of Formula I, R<sub>3</sub> is selected from the moieties described above for R<sub>3</sub> groups of Formula I, R<sub>4</sub> is selected from hydroxy, and hydroxysilyloxy; R<sub>5</sub> is selected from hydroxy, and hydroxysilyloxy. An exemplary class of compounds includes those compounds of Formula III wherein R<sub>1</sub> is halo, R<sub>2</sub> is selected from hydroxy and alkoxyalkyl, R<sub>3</sub> is selected from hydroxy, and hydroxysilyloxy; and R<sub>5</sub> is selected from hydroxy, and hydroxysilyloxy.
hydrido, alkyl, and hydroxyalkyl; and R₅ is selected from hydrido, alkyl, and hydroxyalkyl.

A family of specific compounds of particular interest within Formula III includes compounds and their pharmaceutically acceptable salts as follows:

(4aS,6aR,12aR,12bS)-2H-9,10-Bis-(1-butyl dimethylsilyloxy)-11-chloro-1,3,4,4a,5,6,6a,12,12a,12b-decahydro-4,4,6a,12b-tetramethyl-benz[a]xanthene (21); and
(4aS,6aR,12aR,12bS)-2H-11-Chloro-1,3,4,4a,5,6,6a,12,12a,12b-decahydro-4,4,6a,12b-tetramethyl-benz[a]xanthene-9,10-diol (22).

A second family of specific compounds of particular interest within Formula III includes oxidation products and their pharmaceutically acceptable salts as follows:

(4aS,6aR,12aR,12bS)-2H-11-Chloro-1,3,4,4a,5,6,6a,9,10,12a,12b-dodecahydro-4,4,6a,12b-tetramethyl-benz[a]xanthene-9,10-dione (23); and
(4aS,6aR,12aR,12bS)-2H-11-Chloro-1,3,4,4a,5,6,6a,12,12a,12b-decahydro-4,4,6a,12b-tetramethyl-benz[a]xanthene-9,10-diol (22).

Compounds of Formula IV

A fourth class of compounds is defined by Formula IV:

wherein R₁ is selected from the moieties described above for R₁ groups of Formula I, R₂ is selected from the moieties described above for R₂ groups of Formula I, R₃ is selected from hydrido, alkyl, and hydroxyalkyl, R₄ is selected from hydrido, alkyl, and hydroxyalkyl, R₅ is selected from hydrido, hydroxy, and R₆ is selected from alkyl and arylselenylalkyl. The class of compounds also includes pharmaceutically acceptable salts thereof.

An exemplary class of compounds includes those compounds of Formula IV wherein R₁ is halo, R₂ is selected from hydrido, alkylsilyloxy, and aralkyloxy; R₃ is selected from hydrido, alkylsilyloxy, and aralkyloxy; R₄ is selected from hydrido, alkyl, and hydroxyalkyl; R₅ is selected from hydrido, alkyl, and hydroxyalkyl; R₆ is selected from hydrido, hydroxy, and acyloxy; and R₇ is selected from alkyl and arylselenylalkyl.

A family of specific compounds of particular interest within Formula IV includes the following compounds and their pharmaceutically acceptable salts as follows:

(4aS,6aS,12aR,12bS)-2H-9,10-Bis-(1-butyl dimethylsilyloxy)-11-chloro-1,3,4,4a,5,6,6a,12,12a,12b-decahydro-4,4,6a,12b-tetramethyl-benz[a]xanthene (25); (4aS,6aS,12aR,12bS)-2H-11-Chloro-1,3,4,4a,5,6,6a,12,12a,12b-decahydro-4,4,6a,12b-tetramethyl-benz[a]xanthene-9,10-diol (26); (4aS,6aR,12aS,12bS)-2H-9,10-Bis(benzyloxy)-11-chloro-hydroxy-6a-(phenylselenylmethyl)-1,3,4,4a,5,6,6a,12,12a,12b-decahydro-4,4,12b-trimethyl-benzo[a]xanthene (40); (4aS,6aR,12aS,12bS)-2H-12-Acetoxy-9,10-bis-(benzyloxy)-11-chloro-1,3,4,4a,5,6,6a,12,12a,12b-decahydro-4,4,6a,12b-tetramethyl-benz[a]xanthene (42).

Compounds of Formula V

A fifth class of compounds is defined by Formula V:

wherein R₁ is selected from the moieties described above for R₁ groups of Formula I, R₂ is selected from the moieties described above for R₂ groups of Formula I, R₃ is selected from hydrido, alkyl, and hydroxyalkyl, R₄ is selected from hydrido, alkyl, and hydroxyalkyl, R₅ is hydroxy, and R₆ is selected from hydroxy and alkylsilyloxy. The class of compounds also includes pharmaceutically acceptable salts thereof.

An exemplary class of compounds includes those compounds of Formula V wherein R₁ is halo; R₂ is selected from hydroxy, alkylsilyloxy and aralkyloxy; R₃ is selected from hydroxy, alkylsilyloxy, and aralkyloxy; R₄ is selected from hydrido, alkyl, and hydroxyalkyl; R₅ is selected from hydrido, alkyl, and hydroxyalkyl; R₆ is hydroxy; and R₇ is selected from hydroxy and alkylsilyloxy.

A family of specific compounds of particular interest within Formula V includes the following compounds and their pharmaceutically acceptable salts as follows: (4aS,8aS)-1-[[2-chloro-3,4-dibenzyloxy-6-(1-butyl dimethylsilyloxy)phenyl hydroxy methyl]2-methylene-5,5,8a-trimethyldecahydro naphthalene (37); and (4aS,8aS)-1-[[2-chloro-3,4-dibenzyloxy-6-hydroxy]phenyl hydroxy methyl]2-methylene-5,5,8a-trimethyldecahydro naphthalene (38).

The term “alkyl” embraces linear or branched saturated aliphatic radicals having one to about twenty carbon atoms or, preferably, one to about twelve carbon atoms. More preferred alkyl radicals are “lower alkyl” radicals having one to about ten carbon atoms. Most preferred are lower alkyl radicals having one to about four carbon atoms. Examples of such radicals include methyl, ethyl, n-propyl, iso-propyl, n-butyl, isobutyl, sec-butyl, tert-butyl, pentyl, iso-amyl, hexyl, octyl and the like. The term alkyl also includes cycloalkyl (alicyclic) groups (cyclopentyl, cyclohexyl, cycloheptyl, cyclooctyl), aralkyl substituted cycloalkyl groups, and cycloalkyl substituted alkyld radicals.
The term alkyl includes both “unsubstituted alkyls” and “substituted alkyls”, the latter of which refers to alkyl moieties having substituents replacing a hydrogen on one or more carbons of the hydrocarbon backbone. Such substituents can include, for example, alkenyl, alkynyl, halogen, hydroxyl, alkylcarbonyloxy, arylicarboxyloxy, alkoxyarboxyloxy, aryloxyarboxyloxy, carboxylate, alkylcarbonyl, arylcarbonyl, alkoxycarbonyl, aminocarbonyl, alkylaminocarbonyl, dialkylaminocarbonyl, alkylthiocarbonyl, alkoxycarbonyl, phosphonato, phosphonato, phosphinato, cyano, amino (including alkyl amino, dialkylamino, arylamino, and arylarylamino), aminocarbonyl (including alkylcarbonylamino, arylcarbonylamino, carbamoyl and ureido), amidino, imino, sulfonyl, alkylthio, arylthio, thiocarboxylate, sulfates, alkylsulfanyl, sulfonato, sulfamoyl, sulfonamido, nitro, trifluoromethyl, cyano, azido, heterocyclyl, alkyryl, or an aromatic or heteroaromatic moiety. Cycloalkyls can be further substituted, e.g., with the substituents described above. An “arylkyl” moiety is an alkyl substituted with an aryl (e.g., phenylmethyl (benzyl)). The term “n-alkyl” means a straight chain (i.e., unbranched) unsubstituted alkyl group. The term “alkenyl” includes unsaturated aliphatic groups analogous in length and possible substitution to the alkyls described above, but that contain at least one double bond and must contain at least two carbon atoms. For example, the term “alkenyl” includes straight-chain alkenyl groups (e.g., ethylenyl, propenyl, butenyl, pentenyl, hexenyl, heptenyl, octenyl, nonenyl, decaenyl, etc.), branched-chain alkenyl groups, cycloalkenyl (alicyclic) groups (cyclopropenyl, cyclohexenyl, cycloheptenyl, cyclooctenyl), alkyl or arylalkenyl substituted cycloalkenyl groups, and cycloalkenyl or arylcycloalkenyl substituted alkynyl groups.

The term alkynyl includes both “unsubstituted alkenyls” and “substituted alkenyls”, the latter of which refers to alkenyl moieties having substituents replacing a hydrogen on one or more carbons of the hydrocarbon backbone. Such substituents can include, for example, alkyl groups, alkenyl groups, halogens, hydroxyl, alkylcarbonyloxy, arlycarbonyloxy, alkoxyarboxyloxy, aryloxyarboxyloxy, carboxylate, alkylcarbonyl, arylcarbonyl, alkoxycarbonyl, aminocarbonyl, alkylaminocarbonyl, dialkylaminocarbonyl, alkylthiocarbonyl, alkoxycarbonyl, phosphonato, phosphinato, cyano, amino (including alkyl amino, dialkylamino, arylamino, and arylarylamino), aminocarbonyl (including alkylcarbonylamino, arylcarbonylamino, carbamoyl and ureido), amidino, imino, sulfonyl, alkylthio, arylthio, thiocarboxylate, sulfates, alkylsulfanyl, sulfonato, sulfamoyl, sulfonamido, nitro, trifluoromethyl, cyano, azido, heterocyclyl, alkyryl, or an aromatic or heteroaromatic moiety.

The term “alkynyl” includes unsaturated aliphatic groups analogous in length and possible substitution to the alkyls described above, but which contain at least one triple bond and two carbon atoms. For example, the term “alkynyl” includes straight-chain alkynyl groups (e.g., ethynyl, propynyl, butynyl, pentynyl, hexynyl, heptynyl, octynyl, nonynyl, decynyl, etc.), branched-chain alkynyl groups, and cycloalkynyl or arylcycloalkynyl substituted alkynyl groups.

The term “hydrido” denotes a single hydrogen atom (H). This hydrido radical may be attached, for example, to an oxygen atom to form a hydroxyl radical or two hydrido radicals may be attached to a carbon atom to form a methylene (—CH2—) radical. The term “halo” means halogens such as fluorine, chlorine, bromine or iodine atoms. The term “haloalkyl” embraces radicals wherein any one or more of the alkyl carbon atoms is substituted with halo as defined above. Specifically embraced are monohaloalkyl, dihaloalkyl and polyhaloalkyl radicals. A monohaloalkyl radical, for one example, may have either a bromo, chloro or a fluoro atom within the radical. Dihalo radicals may have two or more of the same halo atoms or a combination of different halo radicals and polyhaloalkyl radicals may have more than two of the same halo atoms or a combination of different halo radicals.

The term “hydroxylalkyl” embraces linear or branched alkyl radicals having one to ten carbon atoms any one of which may be substituted with one or more hydroxyl radicals. The terms “alkoxy” and “alkoxyalkyl” embrace linear or branched oxy-containing radicals. Examples of unsaturated heterocyclic radicals also embrace alkyl radicals having two or more alkyl radicals attached to the alkyl radical, that is, to form monoalkoxyalkyl and dialkoxyalkyl radicals. The “alkoxy” or “alkoxyalkyl” radicals may be further substituted with one or more halo atoms, such as fluoro chloro or bromo to provide “haloalkoxy” or “haloalkoxyalkyl” radicals. Examples of “alkoxy” radicals include methoxy butoxy and trifluoro-methoxy. The term “aryl” alone or in combination, means a carbocyclic aromatic system containing one or more aromatic or heteroaromatic moieties such as phenylene, naphtylene, dibenzofuryl, thiophene, pyrrole, pyridine, pyrimidine, pyrazine, pyrazolyl, oxazolyl, isoxazolyl, imidazolyl, pyridazinyl, pyrazynyl and tetrazolyl. The term “heteroaryl” embraces aromatic radicals such as phenyl, napthyl, tetrahydronaphthyl, indane and biphenyl. The term “heterocyclic” embraces saturated, partially saturated and unsaturated heteroatom-containing ring-shaped radicals, where the heteroatoms may be selected from nitrogen, sulfur and oxygen. Examples of saturated heterocyclic radicals include pyrrolidyl and morpholinyl. The term “heteroaryl” embraces unsaturated heterocyclic radicals. Examples of unsaturated heterocyclic radicals also termed “heteroaryls” also embrace thienyl, pyrrol, furyl, pyridyl, pyrimidyl, pyrazinyl, pyrazolyl, oxazolyl, isoxazolyl, imidazolyl, thiazolyl, pyridazinyl and tetrazolyl. The term also embraces radicals where heterocyclic radicals are fused with aryl radicals. Examples of such fused bicyclic radicals include benzo[4,6]benzothiophene, and the like. The term “sulfonyl”, whether used alone or linked to other terms such as alkylsulfonfyl, denotes respectively divalent radicals —SO2—.

The terms “N-alkylsulfonfyl” and “N,N-dialkylsulfonfyl”, embrace alkyl radicals attached to a sulfonfyl radical, where alkyl is defined as above. The term “arylsulfonfyl” embraces sulfonfyl radicals substituted with an aryl radical. The terms “sulfamidyl” or “sulfonamidyl”, whether alone or used with terms such as “N-alkylsulfamidyl”, “N,N-dialkylsulfamidyl” and “N,N,N-arylsulfamidyl”, denotes a sulfonfyl radical substituted with an amine radical, forming a sulfonamide (—SO2NH2). The terms “N-alkylsulfamidyl” and “N,N-dialkylsulfamidyl” denote sulfonfyl radicals substituted, respectively, with one alkyl radical, a cycloalkyl ring, or two alkyl radicals. The terms “N,N,N-arylsulfamidyl” and “N-alkyl-N,N-arylsulfamidyl” denote sulfamidyl radicals substituted, respectively, with one aryl radical, and one alkyl and one aryl radical. The terms “carboxy” or “carboxyl”, whether used alone or with other terms, such as “carboxyalkyl”, denotes —CO2H. The term “carboxyalkyl” embraces radicals having a carboxy radical as defined above, attached to an alkyl radical. The term “carboxyl”, whether used alone or with other terms, such as “alkylcarboxyl”, denotes —(C=O)−. The term “alkylcarboxyl” embraces radicals having a carboxy radical substituted one, two or three carbon atoms. An example of an “alkylcarboxyl” radical is CH3—(C=O)—. The term “alkylcarboxylalkyl” denotes an alkyl radical substituted with an “alkylcarboxyl” radical. The term...
“alkoxy carbonyl” means a radical containing an alkoxy or aralkyl radical, as defined above, attached via an oxygen atom to a carbonyl (C=O) radical. Examples of such “alkoxy carbonyl” radicals include (CH₂)₂CO—C(O)— and (O—C(=O)CH₂). The term “alkoxy carbonylalkyl” embraces radicals having “alkoxy carbonyl” as defined above, substituent to an alkyl radical. Examples of such “alkoxy carbonylalkyl” radicals include (CH₂)₃CO—C(O)CH₃ and (CH₂)₃CO—COCH₃. The term “amido” when used by itself or with other terms such as “amidoalkyl”, “N-monoamidylamido”, “N,N-dialkylamido”, “N-alkyl-N-aryl amido”, “N-aryl-N-hydroxyamido” and “N-alkyl-N-hydroxyamidoalkyl”, embraces a carbonyl radical substituted with an amino radical. The terms “N-alkylamido” and “N,N-dialkylamido” denote amido groups which have been substituted with one alkyl radical and with two alkyl radicals, respectively. The terms “N-monoamidylamido” and “N-alkyl-N-aryl amido” denote amido radicals substituted, respectively, with one aryl radical and with one alkyl radical. The term “N-alkyl-N-hydroxyamido” embraces amido radicals substituted with a hydroxyl radical and with an aryl radical. The term “N-alkyl-N-hydroxyamidoalkyl” embraces amido radicals substituted with an aryl radical and with an alkyl radical. The term “N-aryl-N-hydroxyamido” embraces amido radicals substituted with an aryl radical and with an alkyl radical. The term “N-aryl-N-hydroxyamidoalkyl” embraces amido radicals substituted with an aryl radical and with an alkyl radical.

The present invention includes a pharmaceutical composition for inhibiting lymphatic absorption of cholesterol, comprising a therapeutically-effective amount of a compound of Formula I in association with at least one pharmaceutically-acceptable carrier, adjuvant or diluent.

A pharmaceutical composition comprises one or more compounds of Formulae I-V in association with one or more pharmaceutically acceptable carriers and/or adjuvants (collectively referred to herein as “carrier” materials) and, if desired, other active ingredients. A compound of the present invention may be administered by any suitable route, preferably in the form of a pharmaceutical composition adapted to such a route, and in a dose effective for the treatment intended. A compound may, for example, be administered orally, intravascularly, intraperitoneally, subcutaneously, intramuscularly or topically.

For oral administration, a pharmaceutical composition may be in the form of, for example, a tablet, capsule, emulsion, suspension or solution. A pharmaceutical composition is preferably made in the form of a dosage unit containing a particular amount of the active ingredient. Examples of such dosage units are tablets or capsules. The active ingredient may also be administered by injection as a composition wherein, for example, saline, dextrose or water may be used as a suitable carrier.

The amount of therapeutically-active compound that is administered and the dosage regimen for treating a disease condition with the compounds and/or compositions of this invention depends on a variety of factors, including the age, weight, sex and medical condition of the subject, the sever-
of the disease, the route and frequency of administration, and the particular compound employed, and thus may vary widely.

If administered per os, the compounds may be admixed with lactose, sucrose, starch powder, cellulose esters of alkanoic acids, cellulose alkyl esters, talc, stearic acid, magnesium stearate, magnesium oxide, sodium and calcium salts of phosphoric and sulfuric acids, gelatin, acacia gum, sodium alginate, microcrystalline cellulose, sodium starch glycolate, sodium lauryl sulfate, povidone, polyvinylpyrrolidone, and/or polyvinyl alcohol, and then tableted or encapsulated, or for convenient administration. Capsule or tablet shells can contain, e.g., gelatin, titanium dioxide, and dyes. Such capsules or tablets may contain a controlled-release formulation as may be provided in a dispersion of active compound in hydroxypropylmethyl cellulose. Formulations for parenteral administration may be in the form of aqueous or non-aqueous isotonic sterile injection solutions or suspensions. These solutions and suspensions may be prepared from sterile powders or granules having one or more of the carriers or diluents mentioned for use in the formulations for oral administration. The compounds may be dissolved in water, polyethylene glycol, propylene glycol, ethanol, corn oil, cottonseed oil, peanut oil, sesame oil, benzyl alcohol, sodium chloride, and/or various buffers. Other adjuvants and modes of administration are well and widely known in the pharmaceutical art.

Methods

Compounds of Formula I and related compounds can be utilized in the treatment of cholesterol-related conditions in mammals, including humans, dogs and cats. Cholesterol-related conditions include, for example, atherosclerosis, hypercholesterolemia, heart attack, stroke, and gangrene of the extremities. A method of treatment includes administering an effective amount of a compound of Formula I. The compound can be administered as a pharmaceutical composition, as described above. A compound of the present invention may be administered by any suitable route, typically in the form of a pharmaceutical composition adapted to such a route, and in a dose effective for the treatment intended. A compound may, for example, be administered orally, intravascularly, intraperitoneally, subcutaneously, intra muscularly or topically.

The amount of compound that is administered and the dosage regimen for treating a disease condition with the compounds and/or compositions of this invention depends on a variety of factors and may be determined by an attending physician. These factors include the age, body weight, sex and medical condition of the subject, the severity of the disease, the route and frequency of administration, the particular compound employed, health status, diet, other medications, and other relevant clinical factors. The amount of compound administered can range from about 4 mg/kg body weight per day to about 4 g/kg of body weight per day. For example, a compound can be administered at a daily dosage of 5 mg/kg, 10 mg/kg, 100 mg/kg, 250 mg/kg, 1000 mg/kg, 1500 mg/kg, 2000 mg/kg, or 3000 mg/kg. The daily dosage can be administered once per day, twice per day, three times per day, or four or more times per day. Variations in these dosage levels can be adjusted using standard empirical routines for optimization.

The concentration of a compound of the present invention effective to treat a cholesterol-related condition in a mammal may vary, depending on a number of factors, including the preferred dosage of the compound to be administered, the chemical characteristics of the compounds employed, the formulation of the compound excipients and the route of administration. The optimal dosage of a pharmaceutical composition to be administered may also depend on such variables as the overall health status of the particular patient and the relative biological efficacy of the compound selected. The amount and dosage regimen effective for treating a cholesterol-related condition in a mammal can be determined by, e.g., measuring cholesterol levels prior to the start of treatment and at various times after treatment has commenced. Assays for the quantitation of cholesterol are known, including assays for the level of cholesterol in blood or in lymph. Administration of an effective amount results in a decrease in lymphatic absorption of cholesterol that is statistically significant at p < 0.05 with an appropriate parametric or non-parametric statistic, e.g., chi-square test, Student’s t-test, Mann-Whitney test, or F-test. In some embodiments, a difference in cholesterol level is statistically significant at p < 0.01, p < 0.005, or p < 0.001.

A compound of the present invention can be administered as a single dose or can be administered for a period of from one day to many years, e.g., for 3 days or more, for 7 days or more, for 14 days or more, for 30 days or more, for one year or more, or for 3 years or more. The duration of the administration period depends upon, e.g., the daily dosage, the type of cholesterol-related condition and the patient’s response to the compound.

A compound of the present invention can be administered in conjunction with a diet low in cholesterol as part of a cholesterol lowering treatment regime. A compound of the present invention also can be administered in conjunction with drugs such as Lovastatin (sold as Mevacor from Merck Co.), Mevalotin (from Sankyo Co., Japan), and analogs thereof (e.g., compounds sold under the trade names Sivastatin, Meva, and gangues of the extremities). A compound of the invention also can be administered in conjunction with Xenical®, a prescription medication offered for use in weight loss regimens.


Typically, a method of measuring inhibition of cholesterol absorption in vivo involves administering a predetermined amount of cholesterol and a test compound of Formulae I-V to the intestine of a mammal. Typically, the animal is a fasted mammal. The cholesterol and test compound can be administered in a lipid emulsion into the duodenum of the mammal over a period of a few hours. Suitable non-human mammals include rats, mice, guinea pigs, and hamsters. The amount of administered cholesterol that appears in the lymph of the test animal is determined at various times during and after administration, typically at hourly intervals. The amount of cholesterol present in the lymph is compared to the amount present in a control animal that has had cholesterol but no test compound administered. If the amount of cholesterol appearing in the lymph of the test animal is statistically significantly less than the amount of cholesterol in the lymph of the control animal, it is concluded that the compound can inhibit intestinal absorption of cholesterol.

General Synthetic Procedures

The compounds of the invention can be synthesized according to the procedures of Schemes 1–6, wherein the R₁-R₅ substituents are as defined for Formulae I-V, above, except where further noted.
Scheme 1 shows the synthesis of enantiopure A-B fragment 3 from commercially available 3αR-(+)-sclareolide 5 (purchased from Aldrich Chemical Company). Deprotonation of optically pure lactone 5 with LDA (lithium diisopropylamide) in THF at -78°C, followed by treatment with MoO₃-pyridine-HMPA complex gave two diastereomers, 6 (65.6% yield) and 7 (12.4% yield) (which were separated by silica gel chromatography), along with 20% recovery of starting sclareolide 5. Treatment of a mixture of 6 and 7 with lithium aluminum hydride in THF at room temperature gave triol 8 (70% yield) and lactol 9 (30% yield). Oxidative cleavage of 8 with lead tetraacetate in benzene at 25°C provided an 90% yield of 10, and oxidative cleavage of 9 under similar conditions gave an 85% yield of 11. Dehydration of alcohol 10 with p-toluenesulfonyl chloride in refluxing toluene for 2 h gave a 78% yield of enal 3. Basic hydrolysis of the formyl ester group of 11 with potassium carbonate in methanol at 0°C provided a 92% yield of 10, which was converted into 3, as described above. The preparation of compound 3 from (-)-sclareol using a different synthetic method has been reported previously (Reeves, P. G. (1996).

Scheme 2 shows the preparation of D-ring fragment 4 starting from 3-chlorovanillin 12, derived from the chlorination of vanillin with chlorine in acetic acid (85% yield), according to the procedure of Ham et al. (J. Am. Chem. Soc., 1927, 49, 535-7). Demethylation of 12 with BBr₃ in CH₂Cl₂ (94% yield) followed by protection of the diol with tert-butyldimethylsilyl chloride, triethylamine, and 4-dimethylaminopyridine (DMAP) gave aldehyde 13 (93% yield) (Jong, T. T.; Williard, P. G.; Porwoll, J. P., J. Org. Chem., 1984, 49, 735-6). Baeyer-Villiger oxidation of 13 with m-chloroperbenzoic acid (MCPBA) in methylene chloride (70% yield) followed by basic hydrolysis with potassium carbonate (90% yield) and silylation of the resulting phenol with tert-butyldimethylsilyl chloride (83% yield) provided trisilyl ether 14. Selective C₄ (less hindered site compared with C₆) bromination of 14 with N-bromosuccinimide (NBS) in N,N-dimethylformamide (DMF) at 25°C gave an 67% yield of 4 as the sole product; no C₆ isomer 15 was isolated. Interestingly, when the bromination was carried out at 50°C, a 2:1 ratio of 15 and 4 was obtained.

Alternatively, compound 4 was also obtained from the bromination of phenol 16 (obtained from 13 with MCPBA and potassium carbonate) with N-bromosuccinimide (NBS) in DMF to give a 70% yield of bromide 17. Silylation of 17 with tert-butyldimethylsilyl chloride afforded a 99% yield of 4.
Scheme 3 shows a procedure for preparing compounds embraced by Formulae I and II from enantiopure A-B fragment 3 and D-ring fragment 4. Treatment of 4 with 2 equiv of t-BuLi in diethyl ether at -78°C followed by aldehyde 3 afforded a mixture of two stereoisomers at C6a, 18 (45% yield) and 19 (9.1% yield). Removal of the silyl ether protecting groups of 18 and 19 separately gave compound 1 (82% yield) and compound 2 (81.4% yield), respectively. Spectral data of compound 2 was identical with those reported (Nasu, S. S.; Yeung, B. K. S.; Hamann, M. T.; Scheuer, P. J.; Kelly-Borges, M.; Goins, K., J. Org. Chem. 1995, 60, 7290-7292).
Scheme 4 shows the preparation of compounds embraced by Formulae III, IV, and VI. Selective hydrogenation of 18 with 1 atmosphere of hydrogen in the presence of palladium/carbon in ethanol gave a 99% yield of tetracyclic pyran 21 as a single diastereomer (Scheme 4a). Removal of the silyloxy protecting group of 21 with tetra-n-butylammonium fluoride in THF afforded an 83% yield of diol 22.

Oxidation of diol 22 with pyridinium dichromate (PDC) in dichloromethane gave a mixture of quinones 23 and 24 in a ratio of 6:1. Quinone structures 23 and 24 were assigned based on "H NMR spectrum.

Similarly, hydrogenation of 19 with 1 atmosphere of hydrogen and palladium/carbon (90% yield) followed by desilylation with tetra-n-butylammonium fluoride in THF (31% yield) and oxidation with pyridinium dichromate afforded (+)-chloropuupehenone (27) in 50% yield.
Schemes 5 and 6 show a procedure for preparation of C6a-S tetracyclic pyran compounds embraced by Formulae IV and V. Scheme 5 shows the preparation of (1R,4aS,6aS)-2,5,5,8a-tetramethyl-1,4,4a,5,6,7,8,8a-octahydronaphthalene-1-carboxaldehyde (33) and (1R,4aS,6aS)-2-Methylene-5,5,8a-trimethyl-1,2,3,4,4a,5,6,7,8,8a-decahydrod naphtalene-1-carboxaldehyde (35). Reduction of aldehyde 10 with lithium aluminum hydride in diethyl ether at 0°C produced a 97% yield of diol 28. Silylation of the less hindered primary alcohol of 28 with t-butyldimethylsilyl chloride and imidazole in DMF gave alcohol 29 (98% yield). Elimination of 29 with methane-sulfonyl chloride (MsCl) and triethylamine in dichloromethane afforded a mixture of alkenes 30 and 31 (1:1; 90% yield), which were separated by silica gel column chromatography. Desilylation of 30 with tetra-n-butylammonium fluoride in THF (88% yield) followed by oxidation with Dess-Martin Periodinane in dichloromethane provided aldehyde 33 (67% yield). Similarly, silyl ether 31 was converted to aldehyde 35 under similar reaction conditions.
Referring to synthetic Scheme 6, Bromide 36 was synthesized from the dibenzylolation of 3,4-dihydroxy-5-chlorobenzaldehyde (see Scheme 2) with NaH and benzyl chloride in THF followed by a similar reaction sequence described for the synthesis of 4 from 13. Treatment of bromide 36 with 1.1 equivalent of t-butyllithium in diethyl ether at -78°C, followed by 1 equivalent of aldehyde 35 gave alcohol 37 (62% yield), which was desilylated with n-Bu$_4$NF in THF to give alcohol 38 (63% yield). Ring closure of 38 with phenylselenylphthalimide and tin tetrachloride in dichloromethane afforded tetracyclic pyran 40 (50% yield) with the C6a-S configuration. The phenylselenyl reagent approaches C6a exo double bond from the opposite face of C12a alkyl group and C7 oxygen attacks the carbocation from the opposite side of the selenium ion to give 40 as the major product. Acetylation of 40 with acetic anhydride and pyridine in dichloromethane (89% yield) followed by removal of the selenyl function with AIBN (2,2'-azobisisobutyronitrile) and tri-n-butyltin hydride in refluxing toluene gave pyran 42 (90% yield). Removal of the hydrogen and palladium-carbon in methanol provided diol 26, which has identical proton NMR spectrum as that obtained in Scheme 4.
Nuclear magnetic resonance spectra were obtained at 400 MHz for $^1$H and 100 MHz for $^{13}$C in deuteriochloroform, and reported in ppm. Infrared spectra are reported in wave-numbers (cm$^{-1}$). Elemental analysis data were obtained from Desert Analytics, Tucson, Ariz., USA, and are reported as % C and % H. Mass spectra were taken from a Hewlett Packard 5890A Series II, GC-MS. Davishsilica gel, grade 643 (200-425 mesh), was used for the flash column chromatographic separation. Tetrahydrofuran and diethyl ether were distilled over CaH$_2$ and toluene and benzene were distilled over LiAlH$_4$. Chemicals and reagents were distilled over sodium and benzophenone before use. Methylene chloride was distilled over CaH$_2$ and toluene and benzene were distilled over LiAlH$_4$. Chemicals and reagents were purchased either from Aldrich Chemical Company or Fisher Chemical Company, and were used without further purification.

Example 1

(4S,8aS)-3,4,4a,5,6,7,8,8a-Octahydropentalaphene-1-carboxaldehyde

Step 1: Preparation of (1S,3aR,5aS,9aS,9bR)-1-Hydroxydodecahydro-3a,6,6,9a-tetramethylnaphthalene-1-carboxaldehyde

To a cold ($-78^\circ$C) solution of 1.02 mL (7.79 mmol) of disopropylamine in 40 mL of THF under argon, was added 1.02 mL (7.79 mmol) of sodium hydride. The solution was stirred at $-78^\circ$C for 1 h. After the solution was stirred at $-78^\circ$C for 1 h, the solution was added to a 5.10 g (0.12 mmol) of (+)-sclareolide 5 in 20 mL of THF. The mixture was then added to a cold (-78$^\circ$C) solution of 1.02 mL (7.79 mmol) of lead tetraacetate. After stirring at 25$^\circ$C for 4 h, the mixture was diluted with diethyl ether, the organic layer was washed with water, and brine, dried (Na$_2$SO$_4$), concentrated, and column chromatographed on silica gel using a mixture of hexane and ethyl acetate as an eluent to give 0.65 g (65.6% yield) of compound 6 and 0.195 g (12% yield) of compound 9 along with 0.296 g (20% recovery) of compound 10.

Step 2: Preparation of (1S,1,2-Dihydroxyethyl)-(1R,2R,4aS,8aS)-Dodecahydro-2,5,5,8a-tetramethylnaphthalen-2-ol (8S) and (1S,3aR,5aS,9aS,9bR)-Dodecahydro-3a,6,6,9a-tetramethylnaphthalene-2,1-bifuran-1,2-diol (9S)

The following representative method describes the reduction of 6 and 7 to triol 8 and lactol 9. A solution of 0.90 g (3.4 mmol) of 6 in 20 mL of THF under argon, was added 0.66 g (17.3 mmol) of LiAlH$_4$, and the mixture was stirred for 4 h at 25$^\circ$C. To it, 60 mL of water and 16 mL of 1 N HCl was added, and the solution was extracted with diethyl ether three times (50 mL each). The combined ether extracts were washed with brine, dried (Na$_2$SO$_4$), and column chromatographed on silica gel using a gradient mixture of hexane and ethyl acetate as an eluent to give 0.65 g (71% yield) of triol 8S and 0.273 g (30% yield) of lactol 9S.

Compound 8S: $^1$H NMR (CDCl$_3$) $\delta$ 4.53 (m, 1H, CHO), 4.08 (dd, J=10, 8Hz, 1H, CHO), 1.95 (d, J=4Hz, 1H), 1.70-1.01 (m, 11H), 1.43 (s, 3H, Me), 0.82 (s, 3H, Me), $^{13}$C NMR (CDCl$_3$) $\delta$ 82.9, 75.2, 71.8, 68.8, 48.7, 42.4, 38.3, 34.9, 33.7, 33.2, 28.3, 23.0, 21.9, 20.0, 18.5. Compound 9S (as a mixture of 2 diastereomers at C2): $^1$H NMR (CDCl$_3$) $\delta$ 5.38 (broad s, 1H), 5.33 (s, 1H), 4.35 (t, J=5Hz, 1H), 2.5 (broad s, 1H, OH), 1.9-0.9 (m, 12H), 1.49 (s, 3H, Me), 0.86 (s, 3H, Me), 0.84 (s, 3H, Me).

For the 8R isomer, (1S,1,2-Dihydroxyethyl)-(1R,2R,4aS,8aS)-Dodecahydro-2,5,5,8a-tetramethylnaphthalen-2-ol (8R). $^1$H NMR (CDCl$_3$) $\delta$ 4.38 (m, 1H, CHO), 4.06 (dd, J=10, 8Hz, 1H, CHO), 1.95 (d, J=4Hz, 1H), 1.70-1.01 (m, 11H), 1.43 (s, 3H, Me), 1.10 (s, 3H, Me), 0.90 (s, 3H, Me), $^{13}$C NMR (CDCl$_3$) $\delta$ 82.9, 75.2, 71.8, 68.8, 48.7, 42.4, 38.3, 34.9, 33.7, 33.2, 28.3, 23.0, 21.9, 20.0, 18.5. Compound 9S (as a mixture of 2 diastereomers at C2). $^1$H NMR (CDCl$_3$) $\delta$ 5.38 (broad s, 1H), 5.33 (s, 1H), 4.35 (t, J=5Hz, 1H), 2.5 (broad s, 1H, OH), 1.9-0.9 (m, 12H), 1.49 (s, 3H, Me), 0.86 (s, 3H, Me), 0.84 (s, 3H, Me).

For the 9R isomer, (1S,3aR,5aS,9aS,9bR)-Dodecahydro-3a,6,6,9a-tetramethylnaphthalene-2,1-bifuran-1,2-diol (9S) (as a mixture of 2 diastereomers at C2). $^1$H NMR (CDCl$_3$) $\delta$ 5.32 (broad s, 1H), 5.22 (dd, J=6Hz, 1H, CHO), 3.15 (broad s, 3H, OH), 1.80-0.8 (m, 12H), 1.54 (s, 3H, Me), 0.99 (s, 3H, Me), 0.87 (s, 3H, Me), 0.87 (s, 3H, Me).

To a solution of 0.65 g (2.4 mmol) of a mixture of triol 8S and 8R in 25 mL of benzene under argon was added 1.3 g (2.9 mmol) of lead tetraacetate. After stirring at 25$^\circ$C for 4 h, the mixture was diluted with ethyl ether, the organic layer was washed with water, and brine, dried (Na$_2$SO$_4$), concentrated, and column chromatographed on silica gel using a gradient mixture of hexane and ethyl ether as an eluent to give 1.045 g (65.6% yield) of compound 6 and 0.195 g (12% yield) of compound 9 along with 0.296 g (20% recovery) of compound 10.
eluent to give 0.516 g (90% yield) of aldehyde 10. [α]D =
+31.0° (c 0.0075, CHCl3); 1H NMR (CDCl3) δ 10.06 (d, J=
3H, CHO), 2.93 (broad s, 1H, OH), 2.15 (d, J=3Hz, 1H,
C1-H), 1.8-0.9 (a series of m, 11H), 1.20 (s, 3H, Me),
1.17 (s, 3H, Me), 0.90 (s, 3H, Me), 0.86 (s, 3H, Me); 13C
NMR (CDCl3) δ 208.3, 72.9, 71.4, 35.5, 42.9, 41.8, 39.9,
37.5, 33.5, 30.5, 25.4, 21.0, 18.5, 17.7.
Step 4: Preparation of (4aS,4aS)-2,5,5,8a-tetramethylnaphthalene-
1-carboxaldehyde (3)
To a flask equipped with a Dean-Stark apparatus under argon,
10 mg (0.042 mmol) of aldehyde 10, 10 mL of toluene, and 3 mg (0.017 mmol) of p-toluenesulfonic acid were added. After the solution was reflux for 2 h, the solution was cooled to 25° C., diluted with saturated aqueous sodium bicarbonate, and extracted three times with ethyl acetate. The combined extracts were washed with brine, dried (MgSO4), concentrated, and column chromatographed on silica gel using a gradient mixture of hexane and ethyl acetate as eluent to give 0.241 g (92% yield) of aldehyde 10.

Preparation of 5-Chloro-6-chloro-1,2,4-tris-(t-butyldimethylsilyl oxy)benzene
Step 1: Preparation of 3-Chloro-4-hydroxy-5-methoxybenzaldehyde (12)
Compound 12 was prepared according to the procedure of Hann et al. (J. Am. Chem. Soc. 1927, 49, 535-7). To a solution of 2.50 g (16.4 mmol) of vanillin in 15 mL of glacial acetic acid was added chlorine gas through a glass tubing over 30 minutes (with a slow gas flow) at 25° C. White solid product was collected by filtration, washed with 50 mL of hexane, and dried in vacuo to give 2.033 g of 12. The white solids were used in next step without purification. 1H NMR (CDCl3) δ 10.04 (s, 1H, CHO), 9.76 (s, 1H, CHO), 7.56 (d, J=1.6Hz, 1H, Ar), 3.91 (s, 3H, OMe); 13C NMR (CDCl3) δ 190.5 (C=O), 149.0 (s, 2C), 128.2 (s), 126.5 (d), 120.1 (s), 109.2 (d), 56.3 (q).

Step 2: Preparation of 5-Chloro-3,4-dihydroxybenzaldehyde
To a solution 2.00 g (10.7 mmol) of benzaldehyde 12 in 20 mL of dichloromethane under argon at 0° C. was added 1.20 mL (11.8 mmol) of boron tribromide. The solution was stirred at 0° C. for 1 h and 25° C. for 4 h, diluted with 40 mL of methanol, and the solvents were removed on a rotary evaporator (the trimethylborate was removed). To it was added 40 mL of methanol and methanol and trimethyl borate were removed by evaporation on a rotary evaporator, and this process was repeated three times. The residue was diluted with dichloromethane and filtered and washed with a small amount of dichloromethane to give 1.722 g (94% yield) of pure 5-chloro-3,4-dihydroxybenzaldehyde. This material was used in next step without purification. 1H NMR (CDCl3) δ 10.43 (2H, OH), 9.70 (s, 1H, CHO), 7.42 (d, J=2.0Hz, 1H, C6-H), 7.32 (d, J=2.0Hz, 1H, C2-H); 13C NMR (DMSO-d6) δ 190.6 (C=O), 148.3 (s), 146.9 (s), 128.4 (d), 124.2 (d), 120.3 (s), 112.5 (s).

Step 3: Preparation of 3,4-bis-(2Butyldimethylsilyloxy)-5-
chlorobenzaldehyde (13)
To a solution of 1.68 g (9.70 mmol) of 5-chloro-3,4-
dihydroxybenzaldehyde and 0.212 g (2.80 mmol) of 4-dimethylaminopyridine (DMAP) in 20 mL of dichloromethane under argon at 0° C. were added 9.80 mL (68.0 mmol) of distilled triethylamine and 4.40 g (59.2 mmol) of t-butyldimethylsilyl chloride. The reaction mixture was stirred at 0° C. for 1 h and 25° C. for 3 h, 100 mL of saturated aqueous NH4Cl was added, and extracted three times with
diethyl ether (80 mL each). The combined extracts were washed with 60 mL of brine, dried (MgSO$_4$), concentrated, and column chromatographed on silica gel using a gradient mixture of hexane and diethyl ether as eluent to give 3.64 g (93% yield). $^1$H NMR (CDCl$_3$) $\delta$ 6.977 (s, 1H, CHO), 7.50 (d, J=2.0 Hz, 1H, C6-H), 7.27 (d, J=2.0 Hz, 1H, C2-H), 1.04 (s, 9H, t-Bu), 0.98 (s, 9H, t-Bu), 0.26 (s, 6H, Me), 0.23 (s, 6H, Me); $^{13}$C NMR (CDCl$_3$) $\delta$ 189.3 (C=O), 149.5 (s), 149.2 (s), 127.8 (s), 125.7 (d), 118.8 (d), 26.1 (q, 3C, t-Bu), 26.0 (q, 3C, t-Bu), 18.7 (s, 2C, t-Bu), -3.4 (q, 2C, Me), -3.6 (q, 2C, Me). Anal. Calc for C$_{31}$H$_{33}$O$_2$Si: C, 55.90; H, 8.29. Found: C, 56.62; H, 8.41.

Step 4: Preparation of 3,4-bis-(t-Butyldimethylsilyloxy)-5-chlorophenol Formate

To a solution of 1.73 g (4.30 mmol) of 16 in 15 mL of dichloromethane under argon was added 2.03 g (6.50 mmol) of 55% m-chloroperbenzoic acid (MCPBA). After refluxing for 10 h, the solution was diluted with 30 mL of water and extracted three times with diethyl ether (50 mL each). The combined extracts were washed with 30 mL of water, extracted three times with diethyl ether (50 mL each), and the combined extracts were washed with brine, dried (MgSO$_4$), and concentrated to give 1.100 g (83% yield) of 14. $^1$H NMR (CDCl$_3$) $\delta$ 8.22 (s,$, 1H, CHO), 6.79 (d, J=3.2 Hz, 1H), 6.58 (d, J=3.2 Hz, 1H), 1.03 (s, 9H, t-Bu), 0.96 (s, 9H, t-Bu), 0.22 (s, 6H, Me), 0.19 (s, 6H, Me); $^{13}$C NMR (CDCl$_3$) $\delta$ 159.0 (s, C=O), 148.8 (s), 143.0 (s), 142.4 (s), 127.1 (s), 115.5 (d), 113.1 (d), 26.2 (q, 6C, t-Bu), 18.8 (s, 2C, t-Bu), -3.3 (q, 2C, Me), -3.6 (q, 2C, Me). Anal. Calc for C$_{29}$H$_{31}$ClO$_3$Si: C, 55.57; H, 8.11.

Example 4

5-Bromo-6-chloro-1,2,4-tris-(t-butyldimethylsilyloxy)benzene

Step 1: Preparation of 3,4-bis-(t-Butyldimethylsilyloxy)-5-chlorophenol (16)

To a solution of 1.236 g (2.97 mmol) of 3,4-bis-(t-butyldimethylsilyloxy)-5-chlorophenyl formate in 10 mL of methanol was added 2.05 g (15.0 mmol) of potassium carbonate at 25°C. The solution was stirred for 30 min., diluted with 35 mL of water, and extracted three times with diethyl ether (50 mL each). The combined extracts were washed with brine, dried (MgSO$_4$), concentrated, and purified. $^1$H NMR (CDCl$_3$) $\delta$ 6.49 (d, J=2.8 Hz, 1H), 6.31 (d, J=2.8 Hz, 1H), 1.00 (s, 9H, t-Bu), 0.93 (s, 9H, t-Bu), 0.18 (s, 6H, Me), 0.15 (s, 6H, Me), 0.17 (s, 6H, Me); $^{13}$C NMR (CDCl$_3$) $\delta$ 149.7 (s), 148.9 (s), 137.7 (s), 126.9 (s), 109.8 (d), 107.8 (d), 26.3 (q, 3C), 26.2 (q, 3C), -3.6 (q, 2C, Me), -3.4 (q, 2C, Me). Anal. Calc for C$_{31}$H$_{33}$ClO$_2$Si: C, 55.57; H, 8.85. Found: C, 55.39; H, 8.87.

Step 2: Preparation of 2-Bromo-3-chloro-4,5-bis-(t-butyldimethylsilyloxy)phenol (17)

A solution of 0.050 g (0.12 mmol) of 16 and 0.023 g (0.12 mmol) of NBS in 2 mL of DMF under argon was stirred at 25°C for 1 day. The reaction mixture was diluted with 30 mL of water, extracted three times with diethyl ether (40 mL each), and the combined extracts were washed with brine (30 mL), dried (MgSO$_4$), and concentrated to give 0.042 g (70% yield). This material was used in next step without purification. $^1$H NMR (CDCl$_3$) $\delta$ 6.53 (s, 1H, Ar, C6-H), 1.03 (s, 9H, t-Bu), 0.96 (s, 9H, t-Bu), 0.22 (s, 6H, Me), 0.17 (s, 6H, Me); $^{13}$C NMR (CDCl$_3$) $\delta$ 148.3 (s), 147.4 (s), 138.8 (s), 127.0 (s), 109.6 (d), 107.8 (d), 26.3 (q, 3C), 26.2 (q, 3C), -3.6 (q, 2C, Me), -3.4 (q, 2C, Me). Anal. Calc for C$_{31}$H$_{33}$ClO$_2$Si: C, 55.57; H, 8.85. Found: C, 55.39; H, 8.87.

Step 3: Preparation of 5-Bromo-6-chloro-1,2,4-tris-(t-butyldimethylsilyloxy)benzene

A mixture of 0.650 g (1.30 mmol) of 14 and 0.276 g (1.60 mmol) of N-bromosuccinimide (NBS) in 10 mL of DMF under argon was stirred at 25°C for 5 days. The reaction mixture was diluted with 30 mL of water, extracted three times with diethyl ether (50 mL each), and the combined extracts were washed with 30 mL of water, and 30 mL of brine, dried (MgSO$_4$), concentrated, and column chromatographed on silica gel using a gradient mixture of hexane and diethyl ether as eluent to give 0.506 g (67% yield) of bromide 4. $^1$H NMR (CDCl$_3$) $\delta$ 6.61 (s, 1H, Ar, C6-H), 1.03 (s, 9H, t-Bu), 1.02 (s, 9H, t-Bu), 0.97 (s, 9H, t-Bu), 0.23 (s, 6H, Me), 0.22 (s, 6H, Me), 0.18 (s, 6H, Me); $^{13}$C NMR (CDCl$_3$) $\delta$ 147.3 (s), 147.2 (s), 139.4 (s), 128.3 (s), 111.1 (d), 108.4 (s), 29.9 (q, t-Bu), 26.3 (q, t-Bu), 26.2 (q), 26, 18.9 (s), 18.6 (s), -3.3 (q, Me), -3.4 (q, Me), -3.5 (q, Me), -4.0 (q). Anal. Calc for C$_{32}$H$_{34}$BrClO$_2$Si: C, 49.51; H, 6.76. Found: C, 49.78; H, 8.11.
placed, it was dried by adding 1 mL of freshly distilled SO2.

To a solution of 0.100 g (0.20 mmol) of NBS in 2 mL of DMF under argon was o.20 3H, Me), 0.18 3H, Me), 0.15 3H, Me); 13C NMR (CDC13) δ 151.9, 147.5, 146.0, 138.0, 123.8, 116.5, 111.9, 108.0, 78.0, 52.2, 41.4, 39.3, 39.1, 34.0, 33.0, 31.1, 26.4, 26.3, 26.2 (SC, t-Bu), 26.1, 25.1, 23.7, 21.4, 19.2, 18.9, 18.8, 17.6, -3.3, -3.4, -3.5. Anal. Calc'd for C33H33C103Siz: c, 67.02; H, 9.37. Found: c, 67.11; H, 9.16.

Example 6

Step 1: Preparation of (4aS,6aR,12bS)-2H-11-Chloro-13,4,4a,5,6,6a,12b-octahydro-4,4,6a,12b-tetramethyl-benzof[a]xanthene (18) and (4aS,6aS,12bS)-2H-9,10-bis-(t-Butylidemethylsilyloxy)-11-chloro-1,3,4,4a,5,6,6a,12b-octahydro-4,4,6a,12b-tetramethyl-benzof[a]xanthene (19)

In a dried flask, 2.600 g (4.50 mmol) of bromide 4 was stirred at 50° C. for 2 day. The solution was diluted with 30 mL of water, extracted three times with diethyl ether (30 mL each), and the combined extracts were washed with brine, dried (MgSO4), concentrated, and column chromatographed on silica gel using a gradient mixture of hexane and toluene and then hexane and ether as eluents to give 0.980 g (45% yield) of 15, Compound 15: 'H NMR (CDC13) 6 151.9, 147.5, 146.0, 138.0, 123.8, 116.5, 111.9, 108.0, 78.0, 52.2, 41.4, 39.3, 39.1, 34.0, 33.0, 31.1, 26.4 (SC, t-Bu), 26.3, 25.1, 23.7, 21.4, 19.2, 18.9, 18.8, 17.6, -3.3, -3.4, -3.5. Anal. Calc'd for C33H33C103Siz: c, 67.02; H, 9.37. Found: c, 67.11; H, 9.16.

Example 7

(4aS,6aS,12bS)-2H-11-Chloro-1,3,4,4a,5,6,6a,12b-octahydro-4,4,6a,12b-tetramethyl-benzof[a]xanthene-9,10-diol (1)

To a solution of 0.160 g (0.270 mmol) of 18 in 3 mL of THF under argon at 25° C. was added 0.58 mL (0.600 mmol) of tetra-n-butylammonium fluoride (1.0 M in THF). After stirring at 25° C. for 5 min., 0.30 mL of acetic acid was added, the resulting solution was concentrated on a rotary evaporator, and column chromatographed on silica gel using a gradient mixture of hexane and ethyl acetate as eluent to give 0.080 g (82% yield) of 1. [α]22D=+560 (c 0.033, CHC13); 'H NMR (CDC13) 6 6.43-6.20 (broad s, 1H, OH), 2.18 (d, J=12 Hz, 1H), 2.02 (d, J=12 Hz, 1H), 1.86-0.90 (a series of m, 11H), 1.31 (d, J=12 Hz, 1H), 1.23 (s, 3H, Me), 1.03 (s, 3H, Me), 0.18 (s, 3H, Me), 0.15 (s, 3H, Me); 13C NMR (CDC13) δ 151.3, 147.3, 146.1, 138.1, 123.6, 115.7, 111.7, 107.9, 78.0, 42.3, 41.8, 38.2, 34.0, 33.9, 33.5, 33.0, 21.9, 21.4, 20.9, 19.5, 19.1.
tetra-n-butylammonium fluoride (1 M in THF). After stirring at 25°C for 10 min., 0.10 mL of acetic acid was added, the solution was concentrated on a rotary evaporator, and the residue was column chromatographed on silica gel using a gradient mixture of hexane and ethyl acetate as eluent to give 30 mg (81.4% yield) of 2, [α]D = +1,1~ (21).

Step 2: Preparation of tetra-n-butylammonium fluoride (1 M in THF). After 14.6, 13.7, 12.6, 11.4, 10.8, 7.68, 5.6, 5.22, 4.21, 4.11, 3.94, 3.71, 3.37, 3.34, 2.64 (3C, t-Bu), 2.53 (3C, t-Bu), 2.52, 2.41, 2.18, 2.07, 2.00, 1.8.7, 15.0 – 3.2 (MeSi), 3.4, – 3.5 (2C). Anal. Caled for C22H34Cl2Si2O: C, 66.79; H, 6.98. Found: C, 67.15; H, 9.45.

Step 2: Preparation of (4aS,6aR,12aR,12bS)-21-11-Chloro-1,3,4,4a,5,6,6a,9,10,12,12b-decahydro-l,3,4,4a,5,6,6a,12,12b-tetramethyl-benzo[a]xanthene-9,10-diol (22). To a solution of 39 mg (0.066 mmol) of 21 in 2 mL of THF under argon at 25°C was added 0.20 mL (0.20 mmol) of tetra-n-butylammonium fluoride (1 M in THF). The solution was stirred for 30 min. 1 drop of acetic acid was added, the resulting red solution was concentrated to dryness, and column chromatographed on silica gel using a gradient mixture of hexane and ethyl acetate to give 20 mg (83% yield) of diol 22. [α]D NMR (CDCl3) δ 6.35 (s, 1H, C8H), 5.63 (broad s, 1H, OH), 5.06 (broad s, 1H, OH), 2.61 (d, J=17 Hz, 1H, C12H), 2.34 (m, 1H, C12H), 2.02 (m, 1H), 1.80 – 0.90 (a series of m, 11H), 1.14 (s, 3H, Me), 0.91 (s, 6H, Me), 0.85 (s, 3H, Me). When the proton NMR spectrum was measured in benzene-d6 solvent, all methyl groups are separated, δ 0.99 (s, 3H, Me), 0.77 (s, 3H, Me), 0.71 (s, 3H, Me), 0.61 (s, 3H, Me). 13C NMR (CDCl3) (22) (the aromatic carbons are not well defined and are not described here) 76.6, 55.9, 51.9, 41.9, 41.0, 39.0, 36.8, 34.3, 33.1, 30.0, 21.6, 19.8, 19.1, 18.7, 14.7.

Step 3: (4aS,6aR,12aR,12bS)-21-11-Chloro-1,3,4,4a,5,6,6a,9,10,12,12b-decahydro-4,4a,5,6a,12b-tetramethyl-benzo[a]xanthene-9,10-dione (24). To a solution of 10 mg (0.027 mmol) of diol 22 in 1 mL of dichloromethane under argon at 25°C was added 3 mg of pyridinium dichromate (PDC). After stirring for 2 h, the mixture was diluted with a small amount of dichloromethane, filtered through Celite, and concentrated to dryness to give 0.9 mg of a mixture of 23 and 24 in a ratio of 6:1 (obtained from NMR spectrum). [α]D NMR (CDCl3) δ 6.74 (s, 1H, C8H), 5.95 (s, 1H, C8H of 24), 5.80 (s, 1H, C8H of 23), 2.84 (dd, J=20, 5 Hz, 1H, C12H of 23), 2.50 (dd, J=20, 13 Hz, C12H of 23), 2.11 (dt, J=13, 3 Hz, 1H, 23), 2.22 – 0.90 (a series of m, 11H of 23 and 11H of 24), 1.33 (s, 3H, Me of 23), 0.93 (s, 3H, Me of 23), 0.92 (s, 3H, Me of 23), 0.85 (s, 3H, Me of 23).

Example 9

Step 1: Preparation of (4aS,6aR,12aR,12bS)-21-11-Chloro-1,3,4,4a,5,6,6a,12,12a,12b-decahydro-4,4a,5,6a,12b-tetramethyl-benzo[a]xanthene (25). A mixture of 0.060 g (0.10 mmol) of compound 18 and 0.080 g of 10% palladium/carbon in 2 mL of distilled water was charged with 1 atmosphere of hydrogen gas (by stirring at 25°C for 2 h). The reaction mixture was filtered through a short Celite column, washed the column with ethanol, and the combined filtrate was concentrated, and column chromatographed on silica gel using a gradient mixture of hexane and toluene to give 0.194 g of 20% palladiumicarbon in 7 mL of distilled water was charged with 1 atmosphere of hydrogen gas (by stirring at 25°C for 2 h). The reaction mixture was filtered through a short Celite column, washed the column with ethanol, and the combined filtrate was concentrated, and column chromatographed on silica gel using a gradient mixture of hexane and toluene to give 0.180 g (99% yield) of 21. [α]D NMR (CDCl3) δ 6.22 – 3.56 (6C, 0.988, CH2Cl2), [α]D NMR (CDCl3) δ 6.23 (6C, 0.988, CH2Cl2), 2.64 (dd, J=17, 5 Hz, 1H, C12H), 2.33 (dd, J=17, 12 Hz, 1H, C12H), 2.02 (dt, J=12, 3 Hz, 1H), 1.80 – 1.15 (a series of m, 11H), 1.12 (s, 3H, Me), 1.03 (s, 3H, t-Bu), 0.95 (s, 3H, t-Bu), 0.90 (s, 6H, Me), 0.85 (s, 3H, Me), 0.194 (s, 3H, MeSi), 0.191 (s, 3H, MeSi), 0.17 (s, 3H, MeSi), 0.15 (s, 3H, MeSi); 13C NMR (CDCl3) δ 147.4, 146.5, 137.4, 126.8, 114.4, 108.2, 76.8, 56.4, 52.2, 42.1, 41.1, 39.4, 37.1, 33.7, 33.4, 26.4 (3C, t-Bu), 26.3 (3C, t-Bu), 25.2, 24.1, 21.8, 20.7, 20.0, 18.9, 18.7, 15.0 – 3.2 (MeSi), 3.4, – 3.5 (2C).

Example 8

**(21)** (+)-Chloropuupehenone

Example 9

**Example 8**
ethanol was charged with 1 atmosphere of hydrogen gas (by the use of a hydrogen balloon), and the mixture was stirred at 25°C for 2 h. The reaction mixture was filtered through Celite, washed with dichloromethane, and the combined filtrate was concentrated, and column chromatographed on silica gel using a gradient mixture of hexane and toluene as eluent to give 0.54 g (90% yield) of compound 25. [a]_20^D = −35° (c 0.007, CHCl_3). 1H NMR (CDCl_3) δ 6.21 (s, 1H, CH), 7.75 (d, J=18 Hz, 1H, C12H), 9.24 (dd, J=18, 8 Hz, 1H, C12H), 2.10 (d, J=11 Hz, 1H), 1.85 (d, J=12 Hz, 1H), 1.62–1.10 (a series of m, 10H), 1.11 (s, 3H, Me), 1.03 (s, 3H, t-Bu), 0.95 (s, 9H, t-Bu), 0.89 (s, 3H, Me), 0.81 (s, 3H, Me), 0.64 (s, 3H, Me), 0.20 (s, 3H, MeSi), 0.18 (s, 3H, MeSi), 0.16 (s, 3H, MeSi), 0.157 (s, 3H, MeSi). 13C NMR (CDCl_3) δ 148.9, 146.3, 137.3, 126.0, 114.6, 108.4, 75.4, 55.5, 49.7, 42.1, 40.7, 40.3, 38.6, 33.9, 33.5, 27.1, 26.4 (3C, t-Bu), 26.3 (3C, t-Bu), 22.1, 21.9, 18.9, 18.7, 18.5, 14.1, −3.3 (2C, MeSi), −3.5, −3.6. Anal. Calcd for C_{58}H_{52}BrClO_5Si: C 58.48; H, 5.66. Found: C, 58.81; H, 5.67.

To a solution of 50 mg (0.084 mmol) of 25 in 2 mL of THF under argon at 25°C. was added 0.25 mL (0.25 mmol) of teta-n-butylammonium fluoride (1 M in THF). The solution was stirred for 15 min., 1 drop of acetic acid was added, the resulting red solution was concentrated to dryness, and column chromatographed on silica gel using a gradient mixture of hexane and ethyl acetate to give 10 mg (50% yield) of diol 26. [a]_20^D = +40.2° (c 0.036, CHCl_3). 1H NMR (CDCl_3) δ 6.33 (s, 1H, CH), 5.20 (broad s, 2H, OH), 2.72 (d, J=17 Hz, 1H, C12H), 2.64 (dd, J=17, 7 Hz, 1H, C12H), 1.84 (d, J=13 Hz, 1H), 1.60–0.90 (a series of m, 11H), 1.12 (s, 3H, Me), 0.89 (s, 3H, Me), 0.81 (s, 3H, Me), 0.67 (s, 3H, Me). 13C NMR (CDCl_3) δ 149.1, 143.1, 133.3, 119.1, 112.4, 103.3, 75.7, 68.2, 55.4, 49.4, 42.1, 40.6, 40.3, 38.5, 33.9, 33.4, 27.1, 22.1, 18.7, 18.3, 14.3.

At 6 wk, rats were starved overnight for 17 h but allowed water ad libitum prior to the surgical placement of a lymph cannula and duodenal infusion catheter. The mesenteric lymph duct was cannulated as described in Koo et al., J. Nutr. 131: 717–722 (2001). Briefly, while rats were under anesthesia (2.0% halothane in 2.0 L O_2/min delivered via a halothane vaporizer), a midline abdominal incision was made. The superior mesenteric lymph duct was cannulated with polyethylene tubing (SV3.1 tubing, i.d. 0.50 mm, o.d. 0.80 mm; Dural Plastics, Auburn, Australia). The cannula was fixed in place with cyanoacrylate glue (Elmer’s Products, Columbus, Ohio) and externalized through the right flank. An indwelling infusion catheter (Silastic® laboratory tubing, i.d. 1.0 mm, o.d. 2.2 mm; Dow Coming, Midland, Mich.) was introduced via the gastric fundus into the upper duodenum and secured in place with a purse-string suture (4-0 Silk, Ethicon, Somerville, N.J.) around the fundic incision. The infusion catheter was exteriorized alongside the lymph cannula. After the abdominal incision was closed, the rats were placed in restraining cages and housed in a recovery chamber at 30°C. For postoperative recovery for 22–24 h. During the recovery period, rats were infused continuously with glucose in phosphate buffered saline (PBS) (in mmol/L: 277 glucose, 6.75 Na,HPO_4, 16.5 NaHPO_4, 115 NaCl, and 5 KCl; pH 6.7) v infusion catheter at 3.0 mL/h by a syringe pump (Harvard Apparatus, Model 935, South Natick, Mass.) to ensure adequate hydration and nutritional status of the animals.

<table>
<thead>
<tr>
<th>TABLE 1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Diet composition</strong></td>
</tr>
<tr>
<td>Egg white</td>
</tr>
<tr>
<td>Cornstarch</td>
</tr>
<tr>
<td>Dextrinized cornstarch</td>
</tr>
<tr>
<td>Dextrose</td>
</tr>
<tr>
<td>Cellulose</td>
</tr>
<tr>
<td>Soybean oil</td>
</tr>
<tr>
<td>Mineral mix</td>
</tr>
<tr>
<td>Vitamin mix</td>
</tr>
<tr>
<td>Biotin (1 mg/kg biotin sucrose mix)</td>
</tr>
<tr>
<td>Choline bitartrate</td>
</tr>
</tbody>
</table>

**1** Formulated and supplied from Dyets, Bethlehem, PA, according to the recommendations of the AIN-93G.

**2** Contained 0.02% tert-butylhydroquinone.
20.7 μmol cholesterol, 3.1 μmol α-tocopherol (all-rac-dl-α-tocopherol, 97%, Aldrich Chemical, Milwaukee, Wis.) as an antioxidant, and 396.0 μmol sodium taurocholate (Sigma Chemical, St. Louis, Mo.) in 24 mL of PBS buffer, pH 6.5. For half of the rats, the lipid emulsion contained 114.9 μmol compound 1 (41.9 mg). Lipid emulsion was prepared under a gentle N₂ stream and subbed light for 55 min using a microprocessor-controlled ultrasonicator equipped with a microtip (XI-2020 Ultrasonic Liquid Processor, Misonix, Farmingdale, N.Y.).

During the duodenal infusion of lipid emulsion, lymph samples were collected hourly in preweighed ice-chilled centrifuge tubes containing 4 mg Na₂-EDTA and 30 μg n-propyl gallate (Sigma Chemical, St. Louis, Mo.) as antioxidants. A portion of each lymph sample (100 μL) was mixed with scintillation liquid (ScintiVerse; Fisher Scientific, Fair Lawn, N.J.) and counted by scintillation spectrometry (Beckman LS-6500; Beckman Instruments, Fullerton, Calif.). The total 14C-radioactivity appearing in hourly lymph volume (the hourly rates of 14C-CH₃ absorption) was expressed as a percentage of the total radioactivity infused (% dose). All samples were ice chilled and handled in subdued light.

**Fatty Acid Analysis**

Total lipids were extracted from each lymph sample with a chloroform/methanol mixture. Lipid extracts were then hydrolyzed with methanolic NaOH, and fatty acids were saponified and methylated simultaneously with BF₃-methanol. Fatty acid methyl esters (FAME) were analyzed by capillary gas chromatography (Hewlett-Packard, Model 6890, Palo Alto, Calif.) using a HP-INNOWax cross-linked polyethylene glycol phase capillary column (15 m, i.d. 0.53 mm; Restek Corp., Bellefonte, Pa.).

**Statistical analysis**

All statistical analyses were performed using PC SAS (SAS Institute, Cary, N.C.). Repeated measures ANOVA and the least significance difference that were used to compare group means. The level of significance was determined at P<0.05.

**Results**

Table 2 shows the lymphatic absorption of 14C—cholesterol and triolein, as well as lymph flow in rats infused for eight hours with lipid emulsion only (control) or containing compound 1. The lymph volume was not significantly different between the two treatments. However, total cholesterol absorption was significantly less in rats infused with compound 1, compared to control rats. In addition, absorption of triolein was significantly less in rats infused with compound 1 compared to control rats. Table 3 and FIG. 1 show the percent dose of 14C-cholesterol absorbed at hourly intervals. FIG. 2 shows the amount of oleic acid absorbed in the lymph at hourly intervals.

**Example 11**

The inhibitory effect of compound 1 on the activity of cholesterol ester transfer protein (CETP) was measured, using a crude CETP preparation derived from hamster plasma. The results suggested that when the dose of compound 1 exceeded 250 μM, there was an increase in HDL total cholesterol, HDL free cholesterol, and HDL cholesterol ester. These increased HDL levels suggest that compound 1 is an inhibitor of CETP activity in vitro.

The effect of compound 24 on inhibition of CETP was tested using a purified CETP preparation. CETP was purified and assayed according to procedures described in Tomada, H.; Tabata, N.; Shinose, M.; Takahashi Y.; Woodruff, H. B.; Omura, S. J. Antibiotics, 52: 1101–1107 (1999). As shown in FIG. 3, there was 50% inhibition (IC50) of CETP activity at 31 μM of compound 24. In comparison, Ferroverdin A, a known CETP inhibitor, resulted in an IC50 of about 22 μM (FIG. 4). The data for compound 24 suggest that compound 24 can inhibit CETP activity in vitro.

A number of embodiments of the invention have been described. Nevertheless, it will be understood that various modifications may be made without departing from the spirit and scope of the invention. Accordingly, other embodiments are within the scope of the following claims.

**What is claimed is:**

1. A compound of Formula I:

```
R1
O
R2
H
R3
```

wherein R₁ is independently hydrido, halo, alkyl, alkenyl, alkyl, haloalkyl, hydroxyalkyl, hydroxy, alkoxyl, ...
alkoxyalkyl, haloalkoxy, haloalkoxyalkyl, aryl, heterocyclic, heteroaryl, alkylsulfonyl, arylsulfonyl, N-alkylsulfamyl, N,N-dialkylsulfamyl, N-aryl sulfonamides, N-alkyl-N-aryl sulfonamides, carboxy, carboxyalkyl, alkylcarbonyl, alkylcarbonylalkyl, alkoxy carbonyl, alkoxycarbonylalkyl, amido, amidoalkyl, alkylamido, N,N-dialkylamido, N-monoarylamido, N-alkyl-N-aryl amido, aminooalkyl, alkylaminoalkyl, amidino, cyanoamidino, heterocycloalkyl, aralkyl, cycloalkyl, cycloalkenyl, alkylthio, alkylsulfinyl, N-alkylamino, N,N-dialkylamino, acyl, acyloxy, aryl oxy, acylamino, aminoo, cyano, nitro, sulfonate, alkylsilyl, phenylethlenyl, thiol, aryl sulfenyl, alkylsilyloxy, alkylsilyllox; R₃ is independently hydrido, halo, alkyl, alkenyl, alkyl hal, haloalkyl, hydroxyalkyl, hydroxy, alkoxy, alkoxyalkyl, haloalkoxy, haloalkoxyalkyl, aryl, heterocyclic, heteroaryl, alkylsulfonyl, arylsulfonyl, N-alkylsulfamyl, N,N-dialkylsulfamyl, N-aryl sulfonamides, N-alkyl-N-aryl sulfonamides, carboxy, carboxyalkyl, alkylcarbonyl, alkylcarbonylalkyl, alkoxy carbonyl, alkoxycarbonylalkyl, amido, amidoalkyl, alkylamido, N,N-dialkylamido, aminooalkyl, alky laminoalkyl, amidino, cyanoamidino, heterocycloalkyl, aralkyl, cycloalkyl, cycloalkenyl, alkylthio, alkylsulfinyl, N-alkylamino, N,N-dialkyl amino, acyl, acyloxy, aryl oxy, acylamino, aminoo, cyano, nitro, sulfonate, thiol, aryl sulfenyl, alkylsilyl, phenylethlenyl, or alky lsilyloxy; R₄ is independently hydrido, halo, alkyl, alkenyl, alkyl hal, haloalkyl, hydroxyalkyl, hydroxy, alkoxy, alkoxyalkyl, haloalkoxy, haloalkoxyalkyl, aryl, heterocyclic, heteroaryl, alkylsulfonyl, arylsulfonyl, N-alkylsulfamyl, N,N-dialkylsulfamyl, N-aryl sulfonamides, N-alkyl-N-aryl sulfonamides, carboxy, carboxyalkyl, alkylcarbonyl, alkylcarbonylalkyl, alkoxy carbonyl, alkoxycarbonylalkyl, amido, amidoalkyl, alkylamido, N,N-dialkylamido, aminooalkyl, alky laminoalkyl, amidino, cyanoamidino, heterocycloalkyl, aralkyl, cycloalkyl, cycloalkenyl, alkylthio, alkylsulfinyl, N-alkylamino, N,N-dialkyl amino, acyl, acyloxy, aryl oxy, acylamino, aminoo, cyano, nitro, sulfonate, thiol, aryl sulfenyl, alkylsilyl, phenylethlenyl, or alky lsilyloxy; R₅ is independently hydrido, halo, alkyl, alkenyl, alkyl hal, haloalkyl, hydroxyalkyl, hydroxy, alkoxy, alkoxyalkyl, haloalkoxy, haloalkoxyalkyl, aryl, heterocyclic, heteroaryl, alkylsulfonyl, arylsulfonyl, N-alkylsulfamyl, N,N-dialkylsulfamyl, N-aryl sulfonamides, N-alkyl-N-aryl sulfonamides, carboxy, carboxyalkyl, alkylcarbonyl, alkylcarbonylalkyl, alkoxy carbonyl, alkoxycarbonylalkyl, amido, amidoalkyl, alkylamido, N,N-dialkylamido, aminooalkyl, alky laminoalkyl, amidino, cyanoamidino, heterocycloalkyl, aralkyl, cycloalkyl, cycloalkenyl, alkylthio, alkylsulfinyl, N-alkylamino, N,N-dialkyl amino, acyl, acyloxy, aryl oxy, acylamino, aminoo, cyano, nitro, sulfonate, thiol, aryl sulfenyl, alkylsilyl, phenylethlenyl, or alky lsilyloxy; R₆ is independently hydrido, halo, alkyl, alkenyl, alkyl hal, haloalkyl, hydroxyalkyl, hydroxy, alkoxy, alkoxyalkyl, haloalkoxy, haloalkoxyalkyl, aryl, heterocyclic, heteroaryl, alkylsulfonyl, arylsulfonyl, N-alkylsulfamyl, N,N-dialkylsulfamyl, N-aryl sulfonamides, N-alkyl-N-aryl sulfonamides, carboxy, carboxyalkyl, alkylcarbonyl, alkylcarbonylalkyl, alkoxy carbonyl, alkoxycarbonylalkyl, amido, amidoalkyl, alkylamido, N,N-dialkylamido, aminooalkyl, alky laminoalkyl, amidino, cyanoamidino, heterocycloalkyl, aralkyl, cycloalkyl, cycloalkenyl, alkylthio, alkylsulfinyl, N-alkylamino, N,N-dialkyl amino, acyl, acyloxy, aryl oxy, acylamino, aminoo, cyano, nitro, sulfonate, thiol, aryl sulfenyl, alkylsilyl, phenylethlenyl, or alky lsilyloxy; 2. The compound of claim 1, wherein R₂ is halo, R₂ and R₅ are hydroxy, and R₁ and R₀ are alkyl. 3. The compound of claim 2, wherein R₂ is hydroxy and R₁ and R₀ are methyl. 4. The compound of claim 1, wherein R₂ is chloro and R₁ and R₀ are alkylsilyloxy. 5. The compound of claim 4, wherein R₁ is chloro, R₂ and R₅ are OSi-t-BuMe₃, and R₁ and R₀ are alkylsilyloxy. 6. A compound of Formula (24): \[
\text{Formula (24):}
\]

7. A compound of Formula II:

wherein R₁ is independently hydrido, halo, alkyl, alkenyl, alkyl hal, haloalkyl, hydroxyalkyl, hydroxy, alkoxy, alkoxyalkyl, haloalkoxy, haloalkoxyalkyl, aryl, heterocyclic, heteroaryl, alkylsulfonyl, arylsulfonyl, N-alkylsulfamyl, N,N-dialkylsulfamyl, N-aryl sulfonamides, N-alkyl-N-aryl sulfonamides, carboxy, carboxyalkyl, alkylcarbonyl, alkylcarbonylalkyl, alkoxy carbonyl, alkoxycarbonylalkyl, amido, amidoalkyl, alkylamido, N,N-dialkylamido, aminooalkyl, alky laminoalkyl, amidino, cyanoamidino, heterocycloalkyl, aralkyl, cycloalkyl, cycloalkenyl, alkylthio, alkylsulfinyl, N-alkylamino, N,N-dialkyl amino, acyl, acyloxy, aryl oxy, acylamino, aminoo, cyano, nitro, sulfonate, thiol, aryl sulfenyl, alkylsilyl, phenylethlenyl, or alky lsilyloxy; R₂ is independently hydrido, halo, alkyl, alkenyl, alkyl hal, haloalkyl, hydroxyalkyl, hydroxy, alkoxy, alkoxyalkyl, haloalkoxy, haloalkoxyalkyl, aryl, heterocyclic, heteroaryl, alkylsulfonyl, arylsulfonyl, N-alkylsulfamyl, N,N-dialkylsulfamyl, N-aryl sulfonamides, N-alkyl-N-aryl sulfonamides, carboxy, carboxyalkyl, alkylcarbonyl, alkylcarbonylalkyl, alkoxy carbonyl, alkoxycarbonylalkyl, amido, amidoalkyl, alkylamido, N,N-dialkylamido, aminooalkyl, alky laminoalkyl, amidino, cyanoamidino, heterocycloalkyl, aralkyl, cycloalkyl, cycloalkenyl, alkylthio, alkylsulfinyl, N-alkylamino, N,N-dialkyl amino, acyl, acyloxy, aryl oxy, acylamino, aminoo, cyano, nitro, sulfonate, thiol, aryl sulfenyl, alkylsilyl, phenylethlenyl, or alky lsilyloxy; or a pharmaceutically-acceptable salt thereof.
aryl sulfenyl, alkylsulfenyl, aryl disulfenyl, alkyl disulfenyl, phenyl selenyl, or alkyl silyloxy; or a pharmaceutically-acceptable salt thereof, wherein

R₃ is independently hydrido, halo, alkyl, alkenyl, alkylid, haloalkyl, hydroxyalkyl, hydroxy, alkoxy, alkoxyalkyl, haloalkoxy, haloalkoxyalkyl, aryl, heterocyclic, heteroaryl, alkylsulfonyl, arylsulfonyl, N-alkylsulfamyl, N,N-dialkylsulfamyl, N-aryl sulfonamido, N-alkyl-N-aryl sulfonamido, N-acylcarbonylalkyl, alkoxy carbonylalkyl, alkoxy carbonylamido, amidino, N-alkyl amido, N,N-dialkyl amido, N,N-dialkylsulfamyl, N,N-dialkylsulfonamido, cycloalkenyl, alkyl thio, alkyl sulfinyl, N-alkylamino, N,N-dialkylamino, acyl, acyl oxo, aryl oxo, acyl amino, amin o, cyano, nitro, sulfonate, thi ol, aryl sulfenyl, alkyl sulf enyl, aryl sulf enyl, alkyl silyl, phenyl selenyl, or alkyl silyloxy; and

R₄ is independently hydrido, halo, alkyl, alkenyl, alkylid, haloalkyl, hydroxyalkyl, hydroxy, alkoxy, alkoxyalkyl, haloalkoxy, haloalkoxyalkyl, aryl, heterocyclic, heteroaryl, alkylsulfonyl, arylsulfonyl, N-alkylsulfamyl, N,N-dialkylsulfamyl, N-aryl sulfonamido, N-alkyl-N-aryl sulfonamido, N-acylcarbonylalkyl, alkoxy carbonylalkyl, alkoxy carbonylamido, amidino, N-alkyl amido, N,N-dialkyl amido, N,N-dialkylsulfamyl, N,N-dialkylsulfonamido, cycloalkenyl, alkyl thio, alkyl sulfinyl, N-alkylamino, N,N-dialkylamino, acyl, acyl oxo, aryl oxo, acyl amino, amin o, cyano, nitro, sulfonate, thi ol, aryl sulfenyl, alkyl sulf enyl, aryl sulf enyl, alkyl silyl, phenyl selenyl, or alkyl silyloxy; and

R₅ is independently hydrido, halo, alkyl, alkenyl, alkylid, haloalkyl, hydroxyalkyl, hydroxy, alkoxy, alkoxyalkyl, haloalkoxy, haloalkoxyalkyl, aryl, heterocyclic, heteroaryl, alkylsulfonyl, arylsulfonyl, N-alkylsulfamyl, N,N-dialkylsulfamyl, N-aryl sulfonamido, N-alkyl-N-aryl sulfonamido, N-acylcarbonylalkyl, alkoxy carbonylalkyl, alkoxy carbonylamido, amidino, N-alkyl amido, N,N-dialkyl amido, N,N-dialkylsulfamyl, N,N-dialkylsulfonamido, cycloalkenyl, alkyl thio, alkyl sulfinyl, N-alkylamino, N,N-dialkylamino, acyl, acyl oxo, aryl oxo, acyl amino, amin o, cyano, nitro, sulfonate, thi ol, aryl sulfenyl, alkyl sulf enyl, aryl sulf enyl, alkyl silyl, phenyl selenyl, or alkyl silyloxy.
amidoalkyl, aminoalkyl, alkylaminoalkyl, amidino, cyanoamidino, heterocycloalkyl, aralkyl, cycloalkyl, cycloalkenyl, alkylthio, alkylsulfinyl, N-alkylamino, N,N-dialkylamino, acyl, acyloxy, aryl, acylamino, amino, cyano, nitro, sulfonate, thiol, arylsulfenyl, alkylsulfenyl, arylsulfinyl, alkylsilyl, phenylselenyl, or alkylsilyloxy;

R₃ is independently hydrido, halo, alkyl, alkenyl, alkyl, haloalkyl, hydroxyalkyl, hydroxy, alkoxy, alkoxyalkyl, haloalkoxyalkyl, aryl, heterocyclic, heteroaryl, alkylsulfonyl, arylsulfonyl, N-alkylsulfamyl, N,N-dialkylsulfamyl, N-arylsulfonyl, N-alkyl-N-arylsulfonyl, carboxy, carboxyalkyl, alkylcarbonyl, alkylcarbonylalkyl, alkyloxycarbonylalkyl, amidino, N-alkylamido, N,N-dialkylamido, N-arylamido, N-alkyl-N-aryl amido, N-alkyl-N-hydroxyamido, N-aryl-N-hydroxyamido, N-alkyl-N-hydroxyamidoalkyl, aminoalkyl, aminoalkyl, alkylaminoalkyl, amidino, cyanoamidino, heterocycloalkyl, aralkyl, cycloalkyl, cycloalkenyl, alkylthio, alkylsulfinyl, N-alkylamino, N,N-dialkylamino, acyl, acyloxy, aryl, acylamino, amino, cyano, nitro, sulfonate, thiol, arylsulfenyl, alkylsulfenyl, arylsulfinyl, alkylsilyl, phenylselenyl, or alkylsilyloxy;

R₄ is independently hydrido, halo, alkyl, or hydroxyalkyl;

R₅ is independently hydrido, alkyl, or hydroxyalkyl;

R₆ is hydroxy; and

R₇ is independently hydroxy, or alkylsilyloxy;

or a pharmaceutically-acceptable salt thereof.

25. The compound of claim 24, wherein R₁ is halo; R₂ and R₃ are aralkyloxy; R₄ and R₅ are alkyl; R₆ is hydroxy; and R₇ is selected from hydroxy and alkylsilyloxy.

26. The compound of claim 25, wherein R₁ is chloro; R₂ and R₃ are OBn; and R₄ and R₅ are methyl; R₆ is hydroxy; and R₇ is OSi-t-BuMe₂.

27. The compound of claim 25, wherein R₁ is chloro; R₂ and R₃ are OBn; R₄ and R₅ are methyl; R₆ is hydroxy; and R₇ is hydroxy.

28. A method of synthesizing a compound of Formula I:

29. A method of synthesizing (+) chloropuphephenone comprising:

a) hydrogenating compound (19) to form compound (25);

b) disilylating compound (25) to form compound (26); and

c) deprotecting said intermediate compound.

30. A method of synthesizing a compound of Formula I:

wherein, R₁ is chloro, R₂ and R₃ are OSi-t-BuMe₂, and R₄ is halo; R₅ and R₆ are methyl, comprised of:

a) reacting compound (4),
A composition comprising a compound of Formula 1:

\[
\text{(1)}
\]

at least one pharmaceutically-acceptable carrier material.
It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Title page,
Item [75], Inventors, please delete “Wrillimantic” and insert -- Willimantic -- therefor; and please delete “US” and insert -- Korea -- therefor;
Item [56], References Cited, OTHER PUBLICATIONS, “Hamann and Scheuer” reference, please delete “Sesquitepene” and insert -- Sesquiterpene -- therefor.

Signed and Sealed this
Fourth Day of January, 2005

JON W. DUDAS
Director of the United States Patent and Trademark Office