

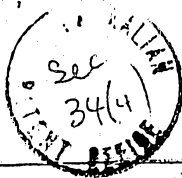
COMMONWEALTH OF AUSTRALIA

The Patents Act 1952

CONVENTION APPLICATION FOR A PATENT

12055/88

602190



SECTION 34(4)(a) DIRECTION SEE FOLIO 5a suite 1625,
NAME DIRECTED Research Development Foundation ply for the
102 North Division Street, Carson City, Nevada 89703
U.S.A. AR LIPOSOMES

HAVING A BIOLOGICALLY ACTIVE SUBSTANCE ENCAPSULATED THEREIN IN THE
PRESENCE OF A HYDROCHLORIDE" which is described in the accompanying
complete specification.

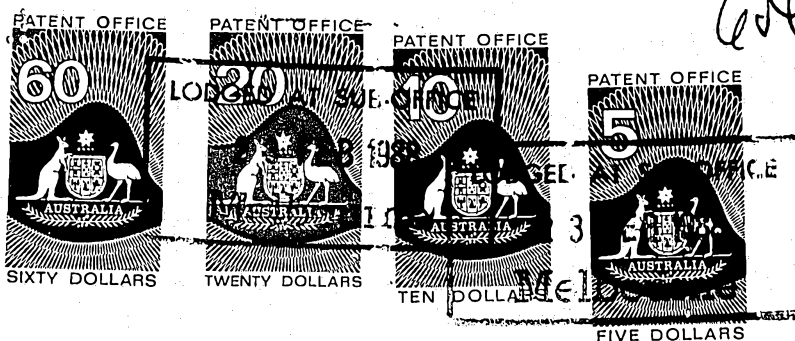
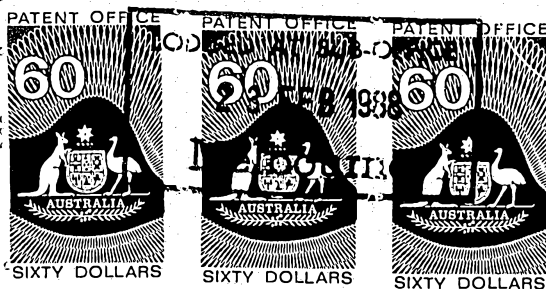
ADDITIONAL CLAIMS AND AMENDMENTS

24-7-90

This application is a Convention application and is based on the
application numbered 8704171 for a patent or similar protection made
in the United Kingdom on 23rd February, 1987.

Our address for service is care of CALLINANS, Patent Attorneys, of 48
Bridge Road, Richmond, 3121, Victoria, Australia.

D A T E D this 23rd day of February, 1988.

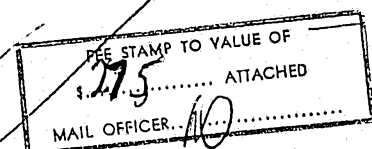


CLAYTON FOUNDATION FOR RESEARCH

By its Patent Attorneys:

CALLINANS

Colin Callinans



LODGED AT SUB-OFFICE

23 FEB 1988

Melbourne

To: The Commissioner of Patents.

PATENTS
May be filed after application

CALLINAN and ASSOCIATES

Patent and Trade Mark Attorneys
Post Office Box No. 238, East Melbourne, 3002, Australia

AUSTRALIA
No legalization required

Form 6
Form 7

AUSTRALIA
Patents Act 1952-1973

Regulation 11 (1)
Regulation 11 (2)

- 1) Delete for Non-Convention Application.
2) Delete for Convention Application.

Declaration in Support of
(a) A Convention Application
(b) ~~An Application~~
for a Patent ~~or Patent of Addition~~

- 3) Insert Full Name of Applicant.

In support of the ~~Application~~/Convention Application made by
(c) CLAYTON FOUNDATION FOR RESEARCH, hereinafter termed
"the applicant"

- 4) Insert Title of Invention.

for a patent/~~patent of addition~~ for an invention entitled:

"MULTIVESICULAR LIPOSOMES HAVING A BIOLOGICALLY ACTIVE
(d) SUBSTANCE ENCAPSULATED THEREIN IN THE PRESENCE OF A
HYDROCHLORIDE"

- 5) Insert Full Names of Declarant(s).

I/~~We~~ (e) C. W. WELLEN
Three Riverway, Suite 1625
of (f) Houston, Texas 77056, U.S.A.

- 6) Insert Address(es) of Declarant(s).

do solemnly and sincerely declare as follows:—

- 7) Delete when Applicant is a Company.

1. (g) ~~I am/we are the applicant(s) for the patent/patent of addition~~
~~of~~

- 8) Delete when Applicant is an Individual. Fill in Name of Applicant if a Company.

(h) I am/~~we are~~ authorised by the said Applicant

~~the applicant~~ for the patent/~~patent of addition~~ to make this declaration on its behalf.

- 9) For Non-Convention Application, delete. For Convention Application, fill in details of basic application.

2. (i) The basic application(s) as defined by Section 141 of the Act was/~~were~~ made
in the U.K. on the 23 day of February 19 87
by STEPHEN BARNARD HOWELL and SINIL KIM

- 10) Delete for Non-Convention Application by Assignee of Inventor and for Convention Application.

3. (j) ~~I am/we are the actual inventor(s) of the invention~~

~~of~~

- 11) Delete for Non-Convention Application by Inventor and for Convention Application by Assignee.

(k) ~~I am/we are the actual inventor(s) of the invention referred to in the basic application.~~

~~of~~

STEPHEN BARNARD HOWELL, 13612 Nogales Drive, Del Mar,
California 92014, and

- 12) Delete for Application by Inventor. For Application by Assignee, insert name, address and occupation of Inventor.

(l) SINIL KIM, 4016 Camino Calma, San Diego, California
~~of~~ 92122

~~is/are~~ the actual inventor(s) of the invention and the facts upon which the applicant

~~I am/we are/the said Company~~ is entitled to make the application are as follows:

- 13) Insert details of Assignment, etc. Date of Assignment only is insufficient.

(m) The said applicant is the assignee of the invention
and of the priority right from the actual inventors.

- 14) Delete for Non-Convention Application.

4. The basic application referred to in paragraph 2 of this Declaration was the first
application made in a Convention country in respect of the invention the subject of the

(12) PATENT ABRIDGMENT (11) Document No. AU-B-12055/88
(19) AUSTRALIAN PATENT OFFICE (10) Acceptance No. 602190

(54) Title
MULTIVESICULAR LIPOSOMES

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(51)⁵ A61K 009/127

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(22) Application Date : 23.02.88

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(56) Prior Art Documents
US 4224179

(57) Claim

1. A process for producing multivesicular lipid vesicles or liposomes comprising the steps of:

(a) dissolving a lipid component in one or more organic solvents wherein the said lipid component contains at least one neutral lipid and at least one amphipathic lipid with at least one net negative charge;

(b) adding into the said lipid component an immiscible first aqueous component containing a hydrochloride and one or more substances to be encapsulated;

(c) forming a water-in-oil emulsion from the two immiscible components;

(d) transferring and immersing the water-in-oil

emulsion into a second immiscible aqueous component;

(e) dispersing the water-in-oil emulsion to form solvent spherules containing multiple droplets of the first aqueous component therein; and

(f) evaporating the organic solvents from the solvent spherules to form the multivesicular liposomes.

23. A multivesicular liposome containing at least one neutral lipid, one amphipathic lipid with a net negative charge, and a biologically active substance encapsulated in the presence of a hydrochloride, where the said hydrochloride may be chemically bound, free in solution, or in any other state.

Australia

662190

PATENTS ACT 1952

Form 10

COMPLETE SPECIFICATION

(ORIGINAL)

FOR OFFICE USE

Short Title:

Int. Cl:

Application Number:

Lodged:

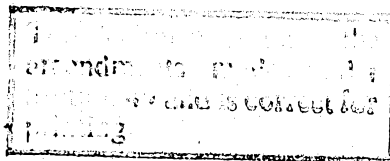
Complete Specification—Lodged:

Accepted:

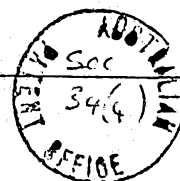
Lapsed:

Published:

Priority:



Related Art:



Name of Applicant:

TO BE COMPLETED BY APPLICANT
GLAYTON FOUNDATION FOR RESEARCH
Research Development Foundation

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Actual Inventor:

STEPHEN BARNARD HOWELL and SINIL KIM

Address for Service:

CALLINANS Patent Attorneys, of
48-50 Bridge Road, Richmond, State of Victoria, Australia.

Complete Specification for the invention entitled:

"MULTIVESICULAR LIPOSOMES HAVING A
BIOLOGICALLY ACTIVE SUBSTANCE ENCAPSU-
LATED THEREIN IN THE PRESENCE OF A
HYDROCHLORIDE"

The following statement is a full description of this invention, including the best method of performing it known to me:—

* Note: The description is to be typed in double spacing, pica type face, in an area not exceeding 250 mm in depth and 160 mm in width, on tough white paper of good quality and it is to be inserted inside this form.

Multivesicular Liposomes Having a Biologically
Active Substance Encapsulated Therein
In the Presence of a Hydrochloride

Field of the Invention

5 The invention relates to synthetic multivesicular lipid vesicles or liposomes encapsulating biologically active substances and processes for their manufacture.

Background of the Invention

10 Multivesicular liposomes are one of the three main types of liposomes, first made by Kim, et. al. (1983, Biochim. Biophys. Acta 782, 339-348), and are uniquely different from the unilamellar (Huang, 1969, Biochemistry 8, 334-352; Kim, et. al. 1981, Biochim. Biophys. Acta 646, 1-10) and multilamellar (Bangham, et. al. 1965, J. Mol. Bio. 13, 238-252), liposomes in
15 that there are multiple non-concentric aqueous chambers within. The prior art describes a number of techniques for producing liposomes, but all of these techniques relate to the production of non-multivesicular liposomes; for example, U.S. Patent No. 4,522,803 to Lenk; 4,310,506 to Baldeschwieler;
20 4,235,871 to Papahadjopoulos; 4,224,179 to Schneider; 4,078,052 to Papahadjopoulos; 4,394,372 to Taylor; 4,308,166 to Marchetti; 4,485,054 to Mezei; and 4,508,703 to Redziniak, all describe non-multivesicular vesicles. For a comprehensive review of various methods of liposome preparation, refer to
25 Szoka, et. al., 1980, Ann. Rev. Biophys. Bioeng. 9:467-508.

 The method of Kim, et. al. (1983, Biochim. Biophys. Acta 782,339-348) is the only report that describes multivesicular liposomes, but the encapsulation efficiency of some of the small molecules such as ara-C was relatively low,
30 and the leakage rate of encapsulated molecules in biological fluid was high.

 Optimal treatment with many drugs requires maintenance of a drug level for a prolonged period of time. For example, optimal anti-cancer treatment with cell cycle-specific

antimetabolites requires maintenance of a cytotoxic drug level for a prolonged period of time. Cytarabine is a highly scheduled-dependent anti-cancer drug. Because this drug kills cells only when they are making DNA, a prolonged exposure at therapeutic concentration of the drug is required for optimal cell kill. Unfortunately, the half-life of Cytarabine after an intravenous (IV) or subcutaneous (SC) dose is very short. To achieve optimal cancer cell kill with a cell cycle phase-specific drug like Cytarabine, two major requirements need to be met: first, the cancer must be exposed to a high concentration of the drug without doing irreversible harm to the host; and second, the tumor must be exposed for a prolonged period of time so that all or most of the cancer cells have attempted to synthesize DNA in the presence of Cytarabine.

Prior to the present invention, the only way of achieving a prolonged plasma cell is through continuous IV or SC infusion, both of which are inconvenient and costly. Therefore, an acceptable slow-release in depot preparation of these drugs is needed. In the past, investigators have attempted to achieve this by chemical modification of the drug molecule to retard metabolism or covalent attachment of a hydrophobic moiety to retard solubilization. Such manipulations have resulted in new toxic effects, Finkelstein, et. al., Cancer Treat Rep 63:1331-1333, 1979, or unacceptable pharmacokinetic or formulation problems, Ho et. al., Cancer Res. 37:1640-1643, 1977.

Accordingly, a slow release depot preparation which provides a prolonged and sustained exposure at therapeutic concentration of a biologically-active substance is needed.

The present invention is directed to such a preparation.

Summary of the Invention

The present invention provides a multivesicular liposome containing a biologically active substance

encapsulated in the presence of a hydrochloride which provides a prolonged and sustained exposure at therapeutic concentration of the biologically active substance for optimal results. The present invention also provides methods of making such

5 multivesicular liposomes.

The multivesicular liposomes have high encapsulation efficiency, low leakage rate of the encapsulated substance, well defined, reproducible size distribution, spherical shape, adjustable average size that can be easily increased or
10 decreased, adjustable internal chamber size and number.

The process for producing the multivesicular lipid vesicles or liposomes comprises dissolving in one or more organic solvents a lipid component containing at least one neutral lipid and at least one amphipathic lipid with one or
15 more net negative charges, adding into the lipid component an immiscible first aqueous component containing a hydrochloride and one or more substances to be encapsulated, forming a water and oil emulsion from the two immiscible components, transferring and immersing the water and oil emulsion into a
20 second immiscible aqueous component, dispersing the water and oil emulsion to form solvent spherules containing in them multiple droplets of the first aqueous component, and evaporating the organic solvents from the solvent spherules to form the multivesicular liposomes. The use of hydrochlorides,
25 such as hydrochloric acid, is essential for high encapsulation efficiency and for slow leakage rate of encapsulated molecules in biological fluids and in vivo. When the hydrochloride is acidic, it is also essential to use a neutralizing agent of low ionic strength to prevent solvent spherules from sticking to
30 each other.

Accordingly, it is an object of the present invention to provide a slow release depot preparation which provides a

prolonged and sustained exposure of a biologically active substance at a therapeutic concentration.

It is a further object of the present invention to provide a method of preparing such a depot preparation.

- 5 A further object of the present invention is the provision of a multivesicular liposome having a biologically active substance encapsulated therein and having a prolonged and sustained exposure at a therapeutic concentration.

It is a further object of the present invention is the provision of a multivesicular liposome containing at least one neutral lipid, one amphipathic lipid with a net
10 negative charge, and a biologically active substance encapsulated in the presence of a hydrochloride, where the said hydrochloride may be chemically bound, free in solution, or in any other state. This provides a prolonged exposure at therapeutic concentration of the biological active substance for optimal results.

A further object of the present invention is the provision of a method of
15 preparing such a multivesicular liposome.

Other and further objects, features, and advantages of the invention are inherent therein and appear throughout the specification and claims.

Description of Preferred Embodiments

The term "multivesicular liposomes" as used throughout the specification and
20 claims means man-made, microscopic lipid-vesicles consisting of lipid bilayer membranes, enclosing multiple non-concentric aqueous chambers. In contrast, unilamellar liposomes have a single aqueous chamber; and multilamellar liposomes have multiple "onion-skin" type of concentric membranes, in between which are shell-like concentric aqueous compartments.

- 25 The term "solvent spherule" as used throughout the specification and claims means a microscopic spheroid droplet of organic solvent, within which is multiple small droplets



of aqueous solution. The solvent spherules are suspended and totally immersed in a second aqueous solution.

The term "neutral lipid" means oil or fats that have no membrane-forming capability by themselves and lack
5 hydrophilic "head" group.

The term "amphipathic lipids" means those molecules that have a hydrophilic "head" group and hydrophobic "tail" group and have membrane-forming capability.

The term "ionic strength" is defined as: Ionic
10 strength = $1/2 (M_1 Z_1^2 + M_2 Z_2^2 + M_3 Z_3^2 + \dots)$
where $M_1 M_2 M_3 \dots$ represent the molar concentrations of various ions in the solution and $Z_1 Z_2 Z_3 \dots$ are their respective charges.

The term "low ionic strength" is ionic strength less
15 than approximately 0.05, and preferably less than 0.01.

Briefly, "water-in-lipid" emulsion is first made by dissolving amphipathic lipids in a volatile organic solvent for the lipid component, adding to the lipid component an immiscible first aqueous component, the substance to be
20 encapsulated and a hydrochloride, and then emulsifying the mixture mechanically. In the emulsion, the water droplets suspended in the organic solvent will form the internal aqueous chambers, and the monolayer of amphipathic lipids lining the aqueous chambers will become one leaflet of the bilayer
25 membrane in the final product. The whole emulsion is then immersed in the second aqueous component containing one or more nonionic osmotic agents and an acid-neutralizing agent of low ionic strength and then agitated either mechanically, by ultrasonic energy, nozzle atomizations or combinations thereof
30 to form solvent spherules suspended in the second aqueous component. The solvent spherules contain multiple aqueous droplets with the substance to be encapsulated dissolved in

spherules by passing a stream of gas over the suspension. When the solvent is completely evaporated, the spherules convert into multivesicular liposomes. Representative gases satisfactory for use include nitrogen, helium, argon, oxygen, hydrogen and carbon dioxide.

The use of a hydrochloride is essential for high encapsulation efficiency and for a slow leakage rate of encapsulated molecules in biological fluids and in vivo. When the hydrochloride is acidic, it is also essential to use a neutralizing agent of low ionic strength to prevent the solvent spherules from sticking to each other. Hydrochloric acid is preferred but other hydrochlorides which are satisfactory include lysine hydrochloride, histidine hydrochloride and combinations thereof. The amounts of both the hydrochloride and the neutralizing agent used can range from about 0.1mM to about 0.5M concentrations and preferably from about 10mM to about 200mM concentration.

Many different types of volatile hydrophobic solvents such as ethers, hydrocarbons, halogenated hydrocarbons, or Freons may be used as the lipid-phase solvent. For example, diethyl ether, isopropyl and other ethers, chloroform, tetrahydrofuran, halogenated ethers, esters and combinations thereof are satisfactory.

In order to prevent the solvent spherules from sticking to each other and to the vessel wall, at least 1 percent molar ratio of an amphipathic lipid with a net negative charge needs to be included in the spherules, the suspending aqueous solution needs to have a very low ionic strength, and, when the hydrochloride is an acid, a neutralizing agent of low ionic strength is needed to absorb the hydrochloride; otherwise, the solvent spherules coalesce to form a messy scum. One or more nonionic osmotic agents are needed in the suspending aqueous solution to keep the osmotic pressure within

and without the liposome balanced. Various types of lipids can be used to make the multivesicular liposomes, and the only two requirements are that one neutral lipid and one amphipathic lipid with a net negative charge be included. Examples of neutral lipids are triolein, trioctanion, vegetable oil such as soybean oil, lard, beef fat, tocopherol, and combinations thereof. Examples of amphipathic lipids with net negative charge are cardiolipin, the phosphatidylserines, phosphatidylglycerols, and phosphatidic acids. Other lipids that can be used to make the multivesicular liposomes include positively charged lipids, such as stearylamine and other primary, secondary, tertiary or quaternary ammonium amphipathic lipids. The presence of these positively charged lipids are not required to make liposomes but may be added.

The second aqueous components is an aqueous solution containing solutes such as carbohydrates including glucose, sucrose, lactose, and amino acids such as lysine, free-base histidine and combinations thereof.

Many and varied biological substances can be incorporated by encapsulation within the multivesicular liposomes. These include drugs, and other kinds of materials, such as DNA, RNA, proteins of various types, protein hormones produced by recombinant DNA technology effective in humans, hematopoietic growth factors, monokines, lymphokines, tumor necrosis factor, inhibin, tumor growth factor alpha and beta, Mullerian inhibitory substances, nerve growth factor, fibroblast growth factor, platelet-derived growth factor, pituitary and hypophyseal hormones including LH and other releasing hormones, calcitonin, proteins that serve as immunogens for vaccination, and DNA and RNA sequences.

The following Table 1 includes a list of representative biologically active substances which can be encapsulated in multivesicular liposomes in the presence of a hydrochloride and which are effective in humans.



Table 1

<u>Antiasthma</u>	<u>Antiarrhythmic</u>	<u>Tranquilizers</u>
5 metaproterenol aminophylline theophylline terbutaline Tegretol ephedrine isoproterenol 10 adrenalin norepinephrine	propanolol atenolol verapamil captopril isosorbide	chlorpromazine benzodiazepine butyrophenones hydroxyzines meprobamate phenothiazines reserpine thioxanthines
<u>Cardiac glycosides</u>	<u>Hormones</u>	<u>Steroids</u>
15 digitalis digitoxin lanatoside C digoxin	antidiuretic corticosteroids testosterone estrogen thyroid growth ACTH 20 progesterone gonadotropin mineralocorticoid LH LHRH 25 FSH calcitonin	prednisone triamcinolone hydrocortisone dexamethasone betamethasone prednisolone
<u>Antihypertensives</u>	<u>Antidiabetic</u>	<u>Antihistamines</u>
30 apresoline atenolol	Diabenese insulin	pyribenzamine chlorpheniramine diphenhydramine
<u>Antiparasitic</u>	<u>Anticancer</u>	<u>Sedatives & Analgesic</u>
35 praziquantel metronidazole pentamidine	azathioprine bleomycin cyclophosphamide adriamycin daunorubicin vincristine methotrexate 6-TG 6-MP 40 vinblastine VP-16 VM-26 45 cisplatin FU	morphine dilaudid codeine codeine-like synthetics demerol oxymorphone phenobarbital barbiturates

Antibiotic

Immunotherapies

Vaccines

penicillin
tetracycline
erythromycin
cephalothin
imipenem
cefotaxime
carbenicillin
vancomycin
gentamycin
tobramycin
piperacillin
moxalactam
amoxicillin
ampicillin
cefazolin
cefadroxil
cefoxitin
other aminoglycosides

interferon
interleukin-2
monoclonal antibodies
gammaglobulin

Antifungal

amphotericin B
myconazole
muramyl dipeptide
clotrimazole

Antihypotension

dopamine
dextroamphetamine

influenza
respiratory syncytial
virus
Hemophilus influenza
vaccine

Antiviral

acyclovir and deriva-
tives
Winthrop-51711
ribavirin
rimantadine/amantadine
azidothymidine & deriva-
tives
adenine arabinoside
amidine-type protease
inhibitors

Proteins and Glycoproteins

lymphokines
interleukins - 1, 2, 3, 4, 5, and 6
cytokines
GM-CSF
M-CSF
G-CSF
tumor necrosis factor
inhibin
tumor growth factor
mullerian inhibitors substance
nerve growth factor
fibroblast growth factor
platelet derived growth factor
coagulation factors (e.g. VIII, IX, VII)
insulin
tissue plasminogen activator
histocompatibility antigen
oncogene products
myelin basic protein
collagen
fibronectin
laminin
other proteins made by recombinant DNA
technology

Other

cell surface receptor
blockers

Nucleic Acids & Analogs

DNA
RNA
methylphosphonates
and analogs

The dosage range appropriate for human use include the
range of 1-6000 mg/m to body surface area. The reason that
this range is so large is that for some applications, such as
subcutaneous administration, the dose required may be quite
small, but for other applications, such as intraperitoneal
administration, the dose desired to be used may be absolutely
enormous. While doses outside the foregoing dose range may be

given, this range encompasses the breadth of use for practically all the biologically active substances.

The multivesicular liposomes may be administered by any desired route; for example, intrathecal, intraperitoneal, subcutaneous, intravenous, intralymphatic, oral and submucosal, under many different kinds of epithelia including the bronchial epithelia, the gastrointestinal epithelia, the urogenital epithelia, and various mucous membranes of the body, and intramuscular.

The following examples represent presently preferred methods of preparing these multivesicular liposomes encapsulating biologically active substances.

EXAMPLE 1

Step 1) In a clean one-dram glass vial (1.4 cm diameter X 4.5 cm height in external dimensions), 9.3 umoles of dioleoyl lecithin, 2.1 umoles of dipalmitoyl phosphatidylglycerol, 15 umoles of cholesterol, 1.8 umoles of triolein and one ml of chloroform were placed (the lipid phase).

Step 2) One ml of aqueous phase, cytosine arabinoside (20 mg./ml) dissolved in 0.136 N hydrochloric acid solution, is added into the above one-dram vial containing lipid phase.

Step 3) For making the water-in-oil emulsion, the vial is sealed and attached to the head of a vortex shaker and shaken at maximum speed for 6 minutes.

Step 4) For making the chloroform spherules suspended in water, half of the emulsion is then each squirted rapidly through a narrow tip Pasteur pipette into one dram vials, each containing 4 percent dextrose in water and 40 mM lysine, free base, and then shaken on the vortex shaker for 3 seconds at half speed to form the chloroform spherules.

Step 5) The chloroform spherule suspensions in the two vials are poured into the bottom of a 250 ml Erlenmeyer flask containing 5 ml of water, glucose (3.5 g/100 ml), and

free-base lysine (40 mM) and a stream of nitrogen gas at 7 l/minute is flushed through the flask to slowly evaporate chloroform over 10 - 15 minutes at 37°C. The liposomes are then isolated by centrifugation at 600 X g for 5 minutes.

5 The average volume-adjusted size of the resulting liposomes ($\pm$ standard deviation of the distribution) was 19.4 ± 6.5 μ m. Percentage of capture was 59 ± 7 percent and capture volume was 36 ± 4 μ l/mg of total lipids used. The addition of hydrochloric had marked influence on the rate
10 of cytosine arabinoside leakage from the multivesicular liposomes incubated in human plasma. Half of the drug leaked out in 12 days when hydrochloric acid is added in the example above, whereas half of the drug leaked out in only 12 hours when the hydrochloric acid was omitted in step 2 above. When
15 tested in animals, the addition of hydrochloric again had marked influence on the rate of cytosine arabinoside release; the drug stayed within mouse peritoneal cavity much longer when hydrochloric acid is added during manufacture.

 The following example illustrates a scale up of the
20 procedure for making large batches of multivesicular liposomes.

EXAMPLE 2

 Step 1) In a stainless-steel homogenizer (Omni-Mixer 17150, Sorval Co., Newtown, CT) add 186 μ moles of dioleoyl lecithin, 42 μ moles of dipalmitoyl phosphatidylglycerol, 300
 25 μ moles of cholesterol, 36 μ moles of triolein and 20 ml of chloroform were placed (the lipid phase).

 Step 2) Twenty ml of aqueous phase, cytosine arabinoside (20 mg/ml) dissolved in 0.136 N hydrochloric acid solution is added into the above stainless-steel mixer
30 containing lipid phase while swirling.

Step 3) For making the water-in-oil emulsion, the homogenizer is sealed and run at "7" setting for 3 minutes.

Step 4) For making the chloroform spherules suspended in water, half of the emulsion is then each poured (while swirling) into two other stainless-steel homogenizer vessels, each containing 200 ml of 4 percent dextrose in water and 40 mM lysine, free base, and then homogenized on the Omni-Mixer for 3 seconds at "1" setting.

Step 5) The chloroform spherule suspensions in each homogenizer vessels are poured into a flat-bottomed, rectangular steel container, 8 in X 12 in the bottom dimension and a stream of nitrogen gas or air at 14 l/minute was flushed through the flask to slowly evaporate chloroform over 10 - 15 minutes. The liposomes are then isolated by centrifugation at 600 X g for 5 minutes.

The following example illustrates methods of making smaller or larger liposomes.

EXAMPLE 3

To make liposomes smaller than that in Example 1 or 2, the mechanical strength or duration of shaking or homogenization in Step 4 of Example 1 or 2 was increased. To make liposomes larger, the mechanical strength or duration of shaking or homogenization in Step 4 of Example 1 or 2 was decreased.

The following Example 4 illustrates representative methods of making liposomes of various lipid compositions and incorporating various materials into liposomes.

EXAMPLE 4

In Step 1) of Example 1 or 2, other amphipathic lipids such as phosphatidyl cholines (PC), cardiolipin (CL), dimyristoyl phosphatidylglycerol (DMPG), phosphatidyl ethanolamines (PE), phosphatidyl serines (PS), dimyristoyl phosphatidic acid (DMPA) in various combinations can be used with similar results. For example, PC/C/CL/TO in 4.5/4.5/1/1 molar ration; DOPC/C/PS/TO in 4.5/4.5/1/1 molar ratio;

PC/C/DPPG/TC in 5/4/1/1 molar ratio; 1 PC/C/PG/TC in 5/4/1/1
molar ratio; PE/C/CL/TO in 4.5/4.5/1/1 molar ratio;
PC/C/DMPA/TO in 4.5/4.5/1/1 molar ratio can all be used. To
incorporate other biogenetic active materials, simply
5 substitute the cytosine arabinoside with a desired material or
combination of materials of Table 1 in Step 2 of Example 1 or
2. All of these provide multivesicular liposomes which are
effective in humans and provide prolonged exposure of the
biologically-active substance at therapeutic concentration.

10 Thus, the present invention provides "depot"
preparations of wide application and uses in which biologically
active substances are encapsulated in relatively large amounts
and provide prolonged exposure at therapeutic concentrations of
these substances for optimal results which avoid high peaking
15 of dosage, which could be toxic.

The present invention, therefore, is well suited and
adapted to attain the ends and objects and has the advantages
and features mentioned as well as others inherent therein.

20 While presently preferred embodiments of the invention
have been given for the purpose of disclosure, changes may be
made therein which are within the spirit of the invention as
defined by the scope of the appended claims.

The claims defining the invention are as follows:-

1. A process for producing multivesicular lipid vesicles or liposomes comprising the steps of:

(a) dissolving a lipid component in one or more organic solvents wherein the said lipid component contains at least one neutral lipid and at least one amphipathic lipid with at least one net negative charge;

(b) adding into the said lipid component an immiscible first aqueous component containing a hydrochloride and one or more substances to be encapsulated;

(c) forming a water-in-oil emulsion from the two immiscible components;

(d) transferring and immersing the water-in-oil emulsion into a second immiscible aqueous component;

(e) dispersing the water-in-oil emulsion to form solvent spherules containing multiple droplets of the first aqueous component therein; and

(f) evaporating the organic solvents from the solvent spherules to form the multivesicular liposomes.

2. The process according to Claim 1 wherein the lipid component is selected from the group consisting of a phospholipid and an admixture of phospholipids.

3. The process according to Claim 2 wherein

the phospholipids are selected from the group consisting of phosphatidylcholine, cardiolipin, phosphatidylethanolamine, sphingomyelin, lysophosphatidylcholine, phosphatidylserine,

phosphatidylinositol, phosphatidylglycerol, and phosphatidic acid.

4. The process according to Claim 2 wherein
at least one of the phospholipids is selected
from the group with at least one net negative charge.
5. The process according to Claim 2 wherein
the phospholipid is provided in admixture with
cholesterol.
6. The process according to Claim 2 wherein
the phospholipid is provided in admixture with
stearylamine.
7. The process according to Claim 1 wherein
a lipophilic biologically active material is
provided in admixture with the lipid component.
8. The process according to Claim 1 wherein
the neutral lipid is selected from the group
consisting of triolein, trioctanoin, vegetable oil,
lard, beef fat, tocopherol, and combinations thereof.
9. The process according to Claim 1 wherein,
the organic solvent is selected from the group
consisting of diethyl ether, isopropyl ether,
chloroform, tetrahydrofuran, ethers, hydrocarbons,
halogenated hydrocarbons, halogented ethers, esters,
and combinations thereof.
10. The process according to Claim 1 wherein the
hydrochloride is selected from the group consisting of

hydrochloric acid, lysine hydrochloride, histidine hydrochloride, and combinations thereof.

11. The process according to Claim 1 where the substance is a hydrophilic biologically active material.

12. The process according to Claim 1 wherein the emulsification of the two said components is carried out using a method selected from the group consisting of mechanical agitation, ultrasonic energy, and nozzle atomization.

13. The process according to Claim 12 wherein the liposome's average size and number of the aqueous chambers within them are determined by the type, intensity, and duration of the method selected.

14. The process according to Claim 1 wherein the hydrochloride is acidic, and the second aqueous component contains at least one neutralizing agent.

15. The process according to Claim 14 wherein the neutralizing agent is selected from the group consisting of free-base lysine and free base histidine and a combination thereof.

16. The process according to Claim 1 wherein the second aqueous component is of low ionic strength.

17. The process according to Claim 16 wherein
the second aqueous component is an aqueous
solution containing solutes selected from the group
consisting of carbohydrates and amino acids.
18. The process according to Claim 16 wherein
the second aqueous component is an aqueous
solution containing solutes selected from the group
consisting of glucose, sucrose, lactose, free-base
lysine, free-base histidine, and combinations thereof.
19. The process according to Claim 1 wherein
the formation of the solvent spherules is carried
out using methods selected from the group consisting
of mechanical agitation, ultrasonic energy, nozzle
atomization, and combinations thereof.
20. The process according to Claim 19 wherein
the liposome's average size is determined by the
type, intensity, and duration of the energy used.
21. The process according to Claim 1 wherein
the evaporation of the organic solvent is
provided by passing gas over the second aqueous
components.
22. The process of Claim 1 where,
the substance to be encapsulated is selected from
the group consisting of the compositions of Table 1
(as hereinbefore described)
and combinations thereof.



23. A multivesicular liposome containing at least one neutral lipid, one amphipathic lipid with a net negative charge, and a biologically active substance encapsulated in the presence of a hydrochloride, where the said hydrochloride may be chemically bound, free in solution, or in any other state.

5 24. A multivesicular liposome containing a biologically active substance encapsulated in the presence of an acid hydrochloride and neutralized with a neutralizing agent.

25. The multivesicular liposome of Claims 23 or 24 where,
the biologically active substance is selected from the group
consisting of the compositions of Table 1 (as hereinbefore
described) and combinations thereof.

26. A method for the treatment of a patient with a biologically active compound comprising,

15 administering said compound to the patient encapsulated in a multivesicular liposome in the presence of a hydrochloride, where the said hydrochloride may be chemically bound, free in solution, or in any other state.

27. A method for the treatment of a patient with a biologically active compound comprising,

20 administering to the patient multivesicular liposomes encapsulating the biologically active substance selected from the group of Claims 23, 24 and 25.

28. A process for producing multivesicular lipid vesicles or liposomes substantially as hereinbefore described with reference to any one of the Examples.



29. A multivesicular liposome substantially as hereinbefore described with reference to any one of the Examples.

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