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(54) **LIPID-CONTAINING PSA COMPOSITIONS, METHODS OF ISOLATION AND METHODS OF USE THEREOF**

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(58) **Field of Classification Search**

None
See application file for complete search history.

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ABSTRACT

The invention provides compositions comprising lipid-conjugated forms of capsular polysaccharide A (PSA) from *B. fragilis* (referred to herein as PSA-LT), methods of isolating such forms and of making such compositions and methods for their use.

16 Claims, 12 Drawing Sheets

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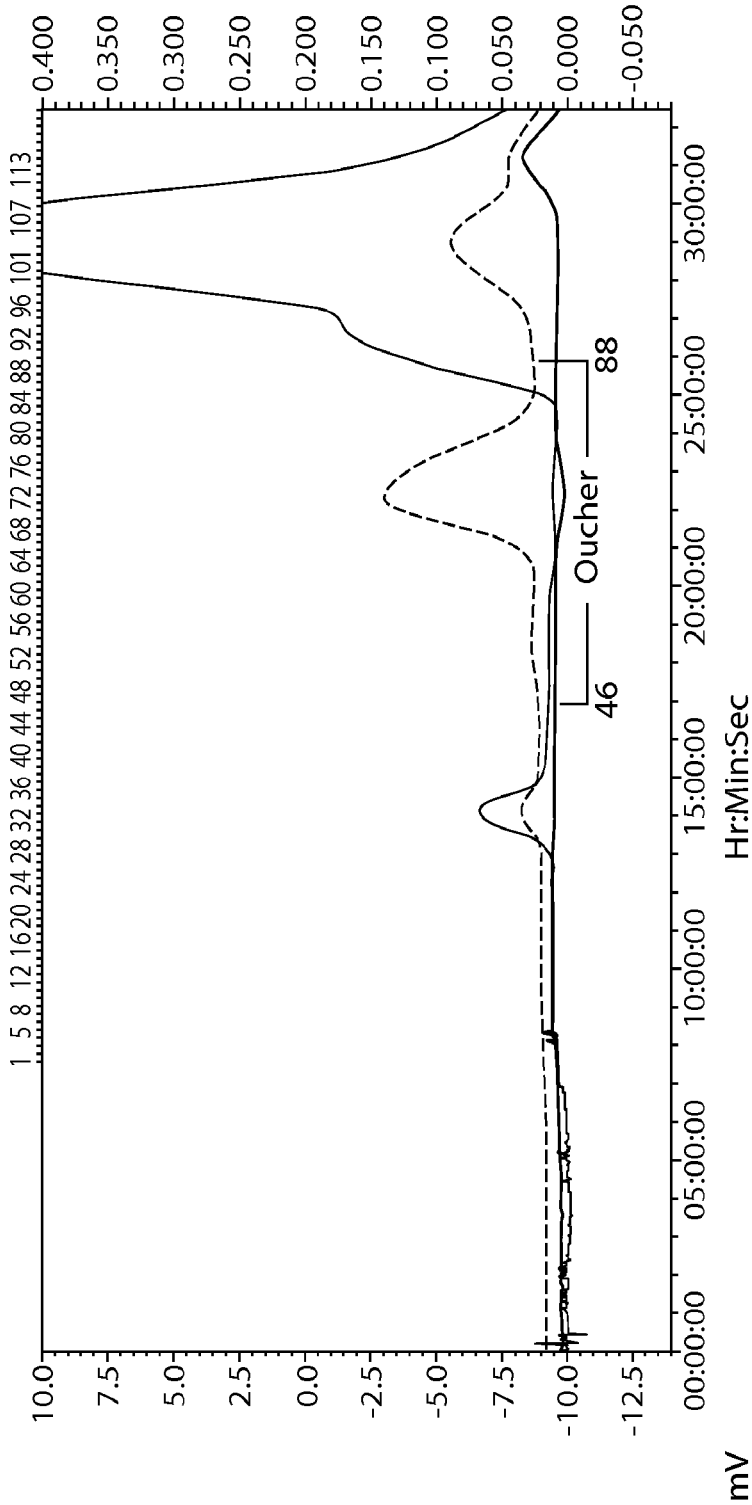
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Project: S400
Method: S400 5/200 2ml/min
Run: PSA 24 Run A-1

BioLogic HR Run Report

User: bgr



Sample: PSA 24 Run A-1
Column: S400HR 50/200
Buffer A: PBSA
Buffer B: Buffer B
Operator: bgr

Flow Rate: 2.0
Gradient:
Fraction Size: 25
Method Description: 3880ml, 25ml frac
Run Description: 9ml sample

Fig. 1

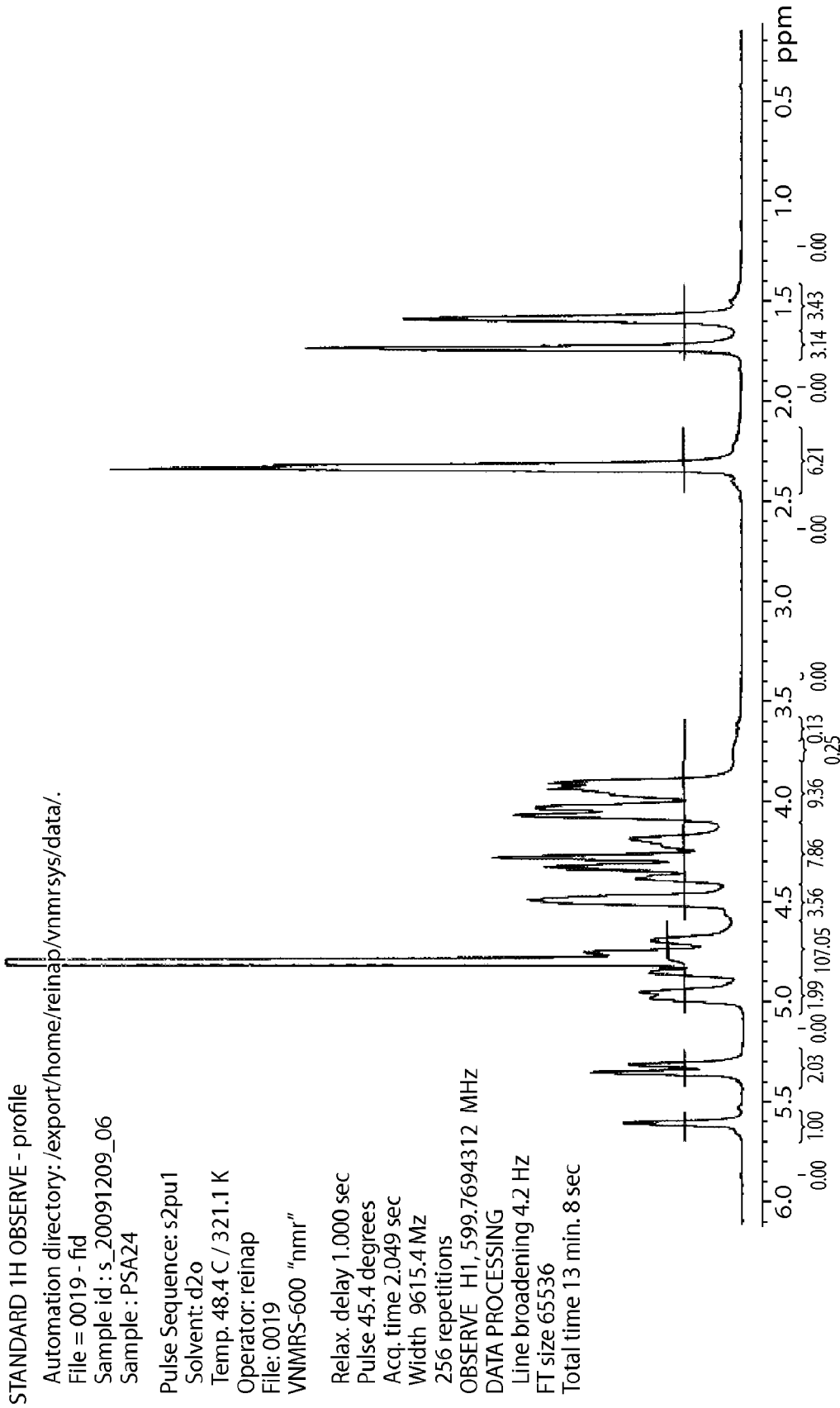


Fig. 2

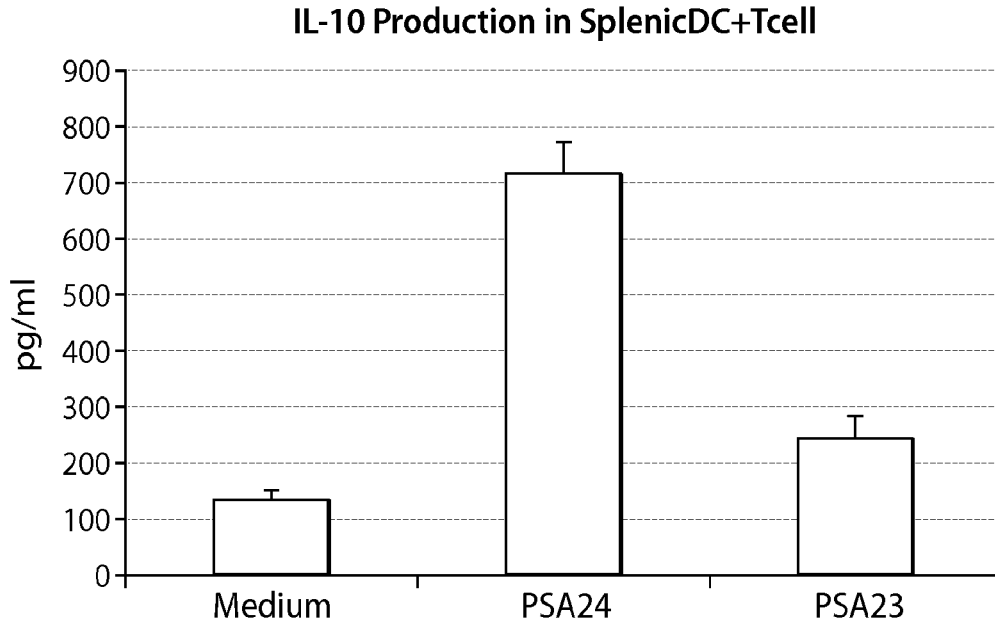


Fig. 3

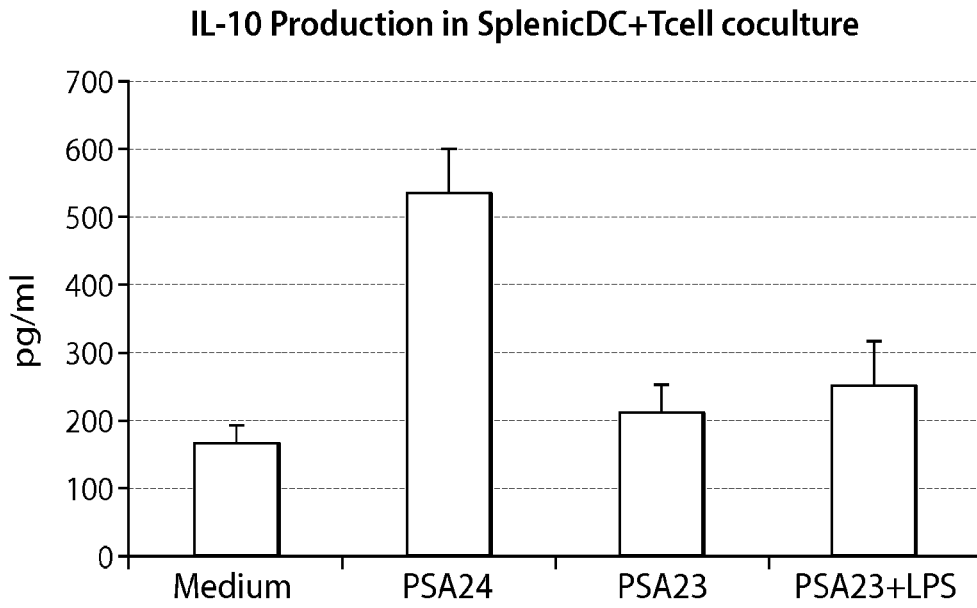


Fig. 4

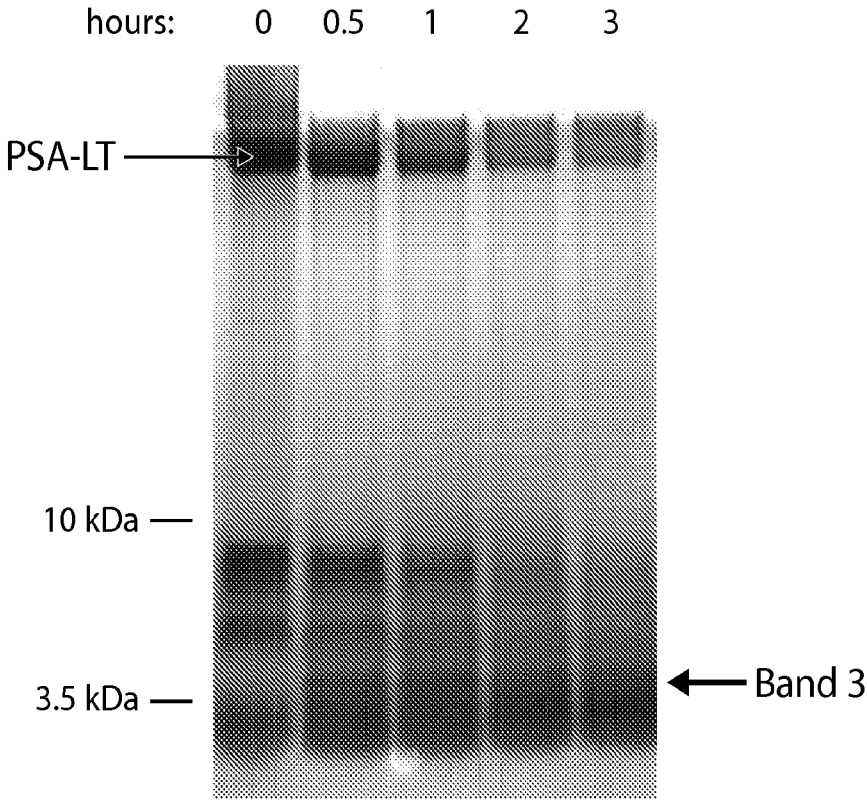


Fig. 5

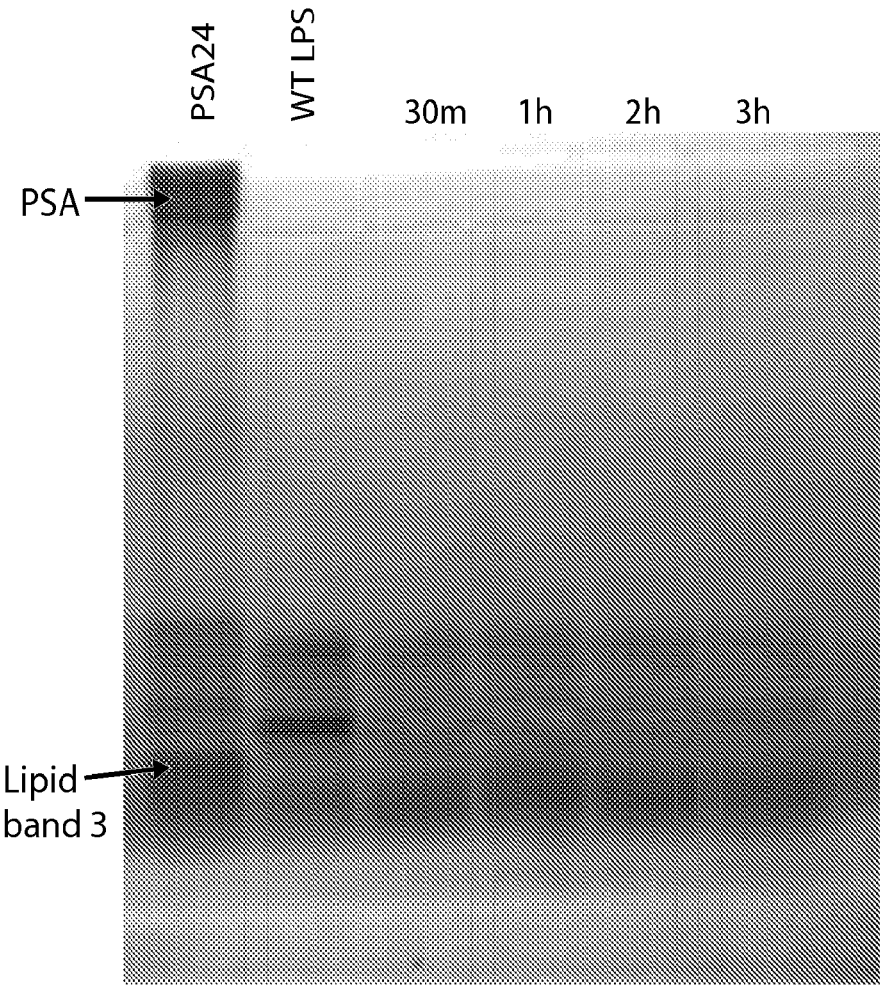


Fig. 6

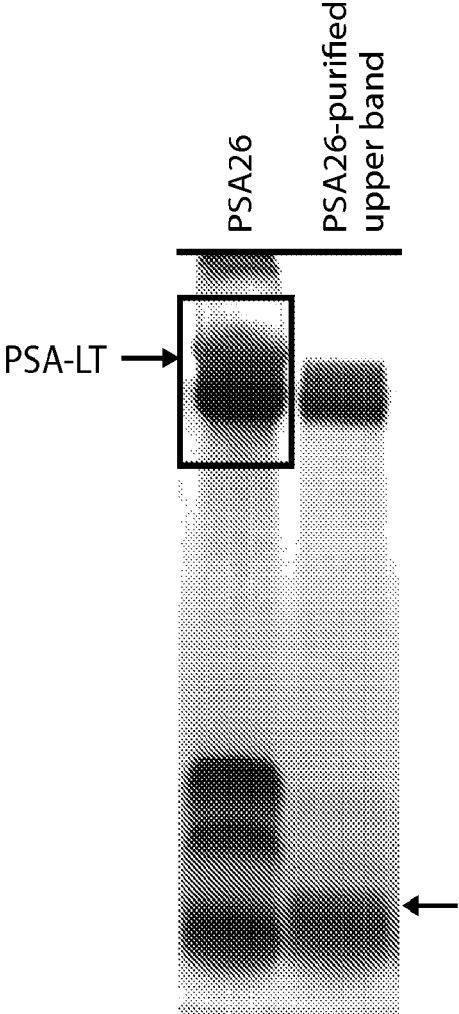


Fig. 7

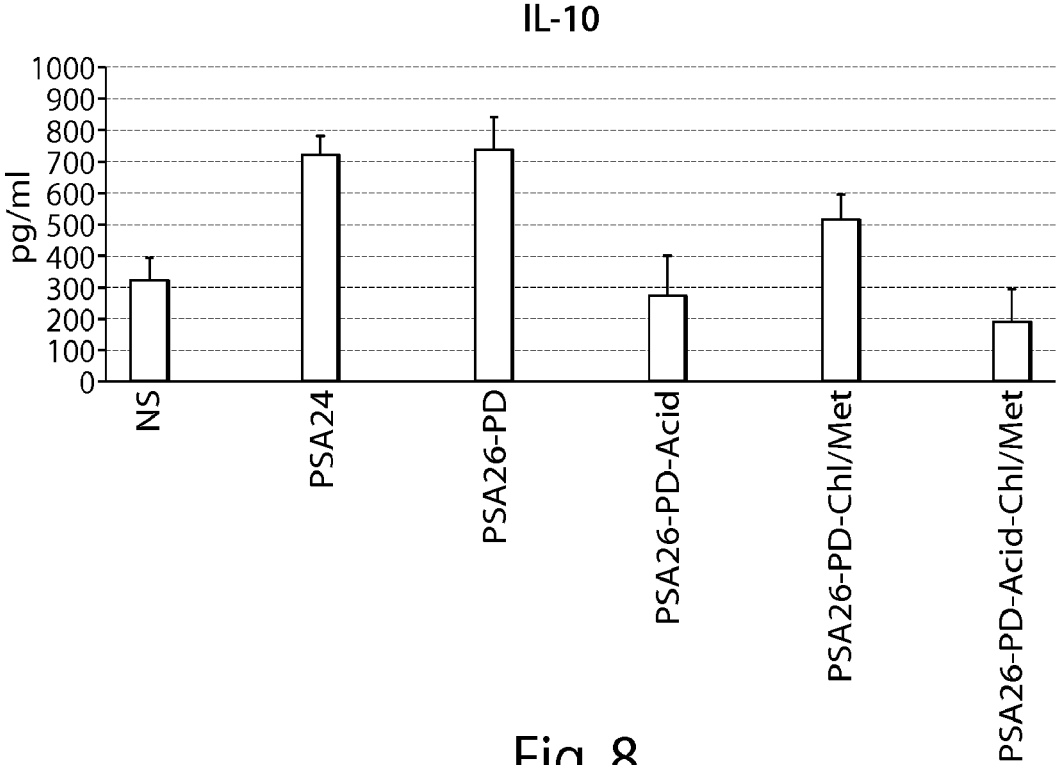


Fig. 8

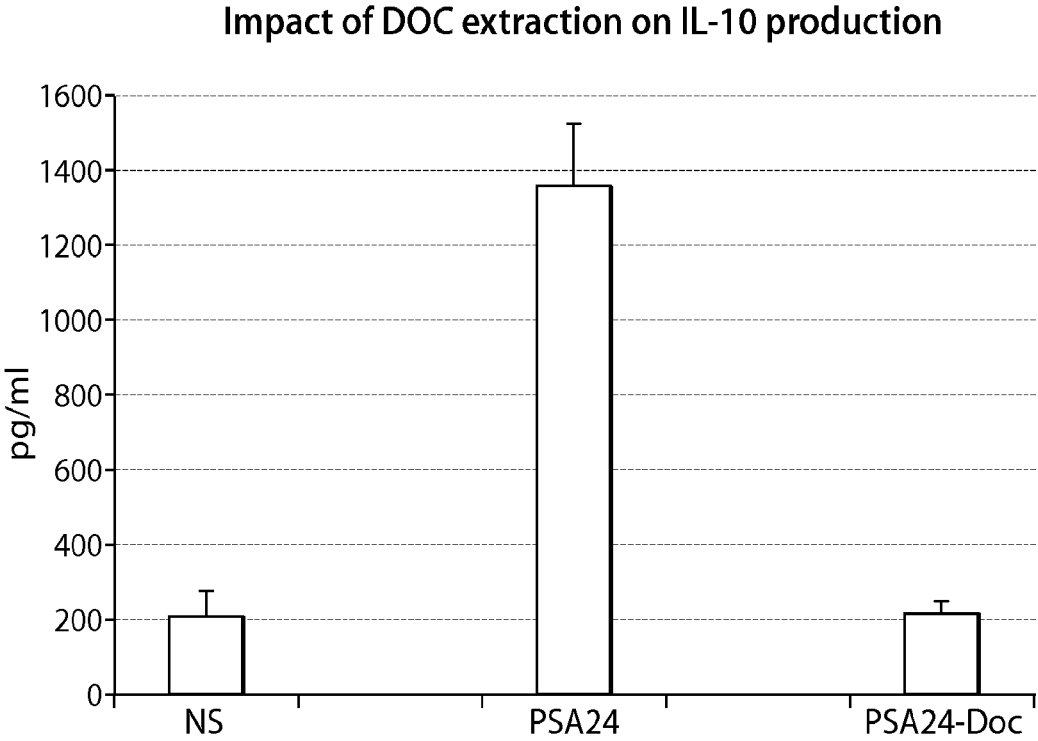


Fig. 9

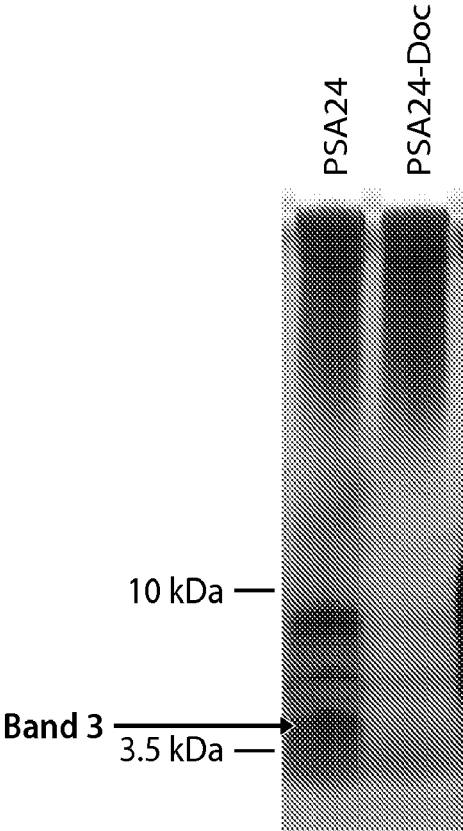


Fig. 10

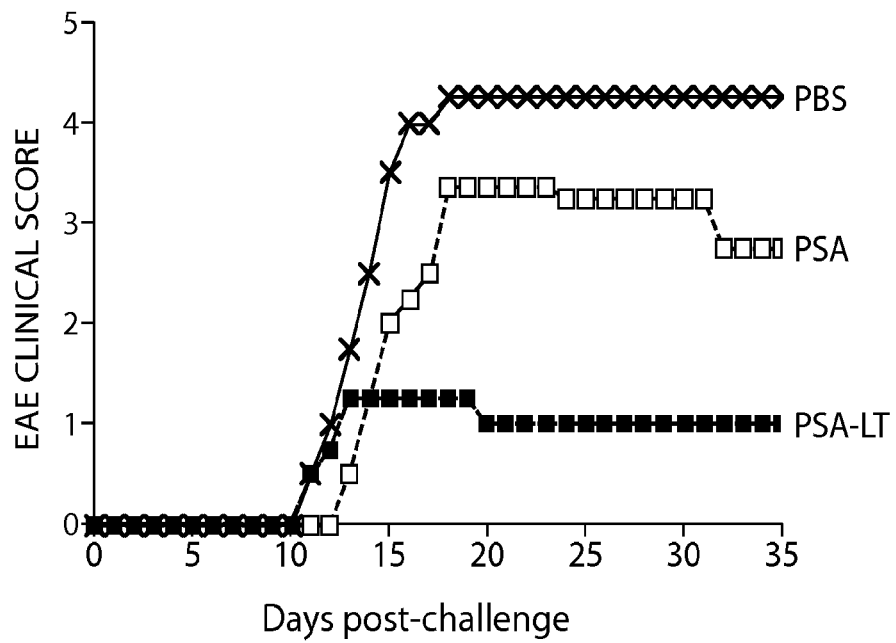


Fig. 11

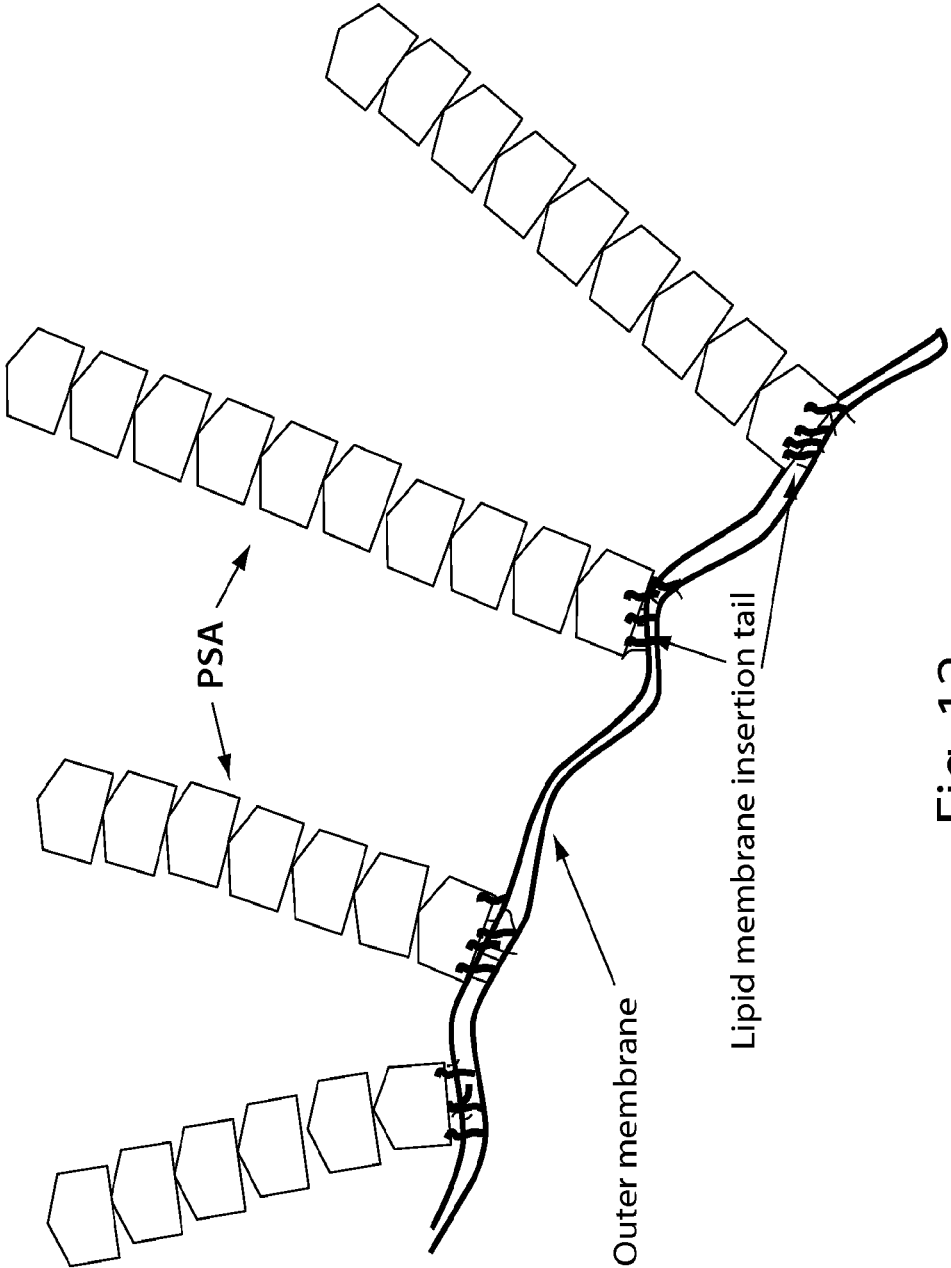


Fig. 12

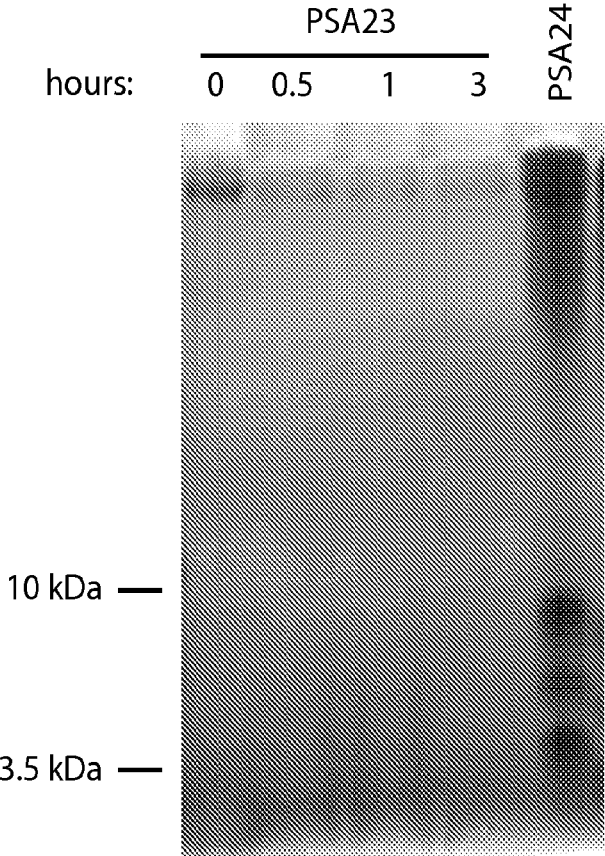


Fig. 13

1

LIPID-CONTAINING PSA COMPOSITIONS, METHODS OF ISOLATION AND METHODS OF USE THEREOF

RELATED APPLICATIONS

This application is a national stage filing under 35 U.S.C. §371 of International Application No. PCT/US2012/046384 filed Jul. 12, 2012, which was published under PCT Article 21(2) in English, and which claims the benefit of U.S. Provisional Application Ser. No. 61/507,074, filed on Jul. 12, 2011, both entitled "LIPID-CONTAINING PSA COMPOSITIONS, METHODS OF ISOLATION AND METHODS OF USE THEREOF", the entire contents of each of which are incorporated by reference herein.

FIELD OF THE INVENTION

The invention relates to compositions of capsular polysaccharide A (PSA) isolated from *B. fragilis*, and methods of isolation and purification and/or use thereof.

BACKGROUND OF THE INVENTION

Capsular polysaccharide A (PSA) of *Bacteroides fragilis* (*B. fragilis*) NCTC9343 has been reported to be an immunomodulator with therapeutic and preventative applications. U.S. Pat. Nos. 5,679,654 and 5,700,787; Tzianabos A O et al. (2000) J Biol Chem 275:6733-40.

SUMMARY OF THE INVENTION

Polysaccharide A (PSA), a polysaccharide of the bacterium *Bacterioides fragilis* (*B. fragilis*), has potent anti-inflammatory capacity mediated, at least in part, by its ability to activate CD4+ T regulatory cells to produce the cytokine IL-10.

The invention is based on the discovery of a significantly more potent form of PSA, made by *B. fragilis*, that comprises a lipid. This lipid is likely used by the microbe to anchor PSA in its outer membrane. Extraction techniques used heretofore do not yield this lipid-conjugated PSA. The lipid typically comprises less than 2% (w/w) of the native PSA-LT molecule. Proton NMR analysis of PSA does not distinguish the lipidated and non-lipidated forms. Rather, it has been found in accordance with the invention that presence of the lipidated form can only be visualized using specific gel staining techniques.

In accordance with the invention, it has been shown that the lipid may be removed from PSA-LT using mild hydrolysis (e.g., with dilute acetic acid) and subsequent extraction with an organic solvent (e.g., chloroform). This hydrolyzed form of PSA has an activity that is markedly reduced compared to the lipidated form of PSA (i.e., PSA-LT), and that its activity is at a level comparable to the earlier described PSA (i.e., the non-lipidated form of PSA). Accordingly, the invention provides, inter alia, a more potent form of PSA (i.e., PSA-LT) having enhanced IL-10 inducing activity and Treg maturation activity. It has also been found, in accordance with the invention, that PSA-LT is significantly more protective and therapeutic in animal models of inflammatory conditions such as but not limited to multiple sclerosis (i.e., the EAE animal model) and inflammatory bowel disease than the originally described non-lipidated form of PSA.

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The invention therefore provides, inter alia, compositions comprising the lipidated form of PSA, methods for its isolation and purification, and in vitro and in vivo methods of use thereof.

Thus, in one aspect, the invention provides a method comprising extracting, into an aqueous phase, a capsular complex from *B. fragilis* using a mixture of phenol and water at high temperature, precipitating polysaccharide A (PSA) from the aqueous phase using ethanol, acid-treating the precipitate using 2% acetic acid at high temperature, wherein the method is performed at a pH equal to or less than about 9. In some embodiments, the pH ranges from about 4 to about 9, or from about 4 to less than about 9.

In another aspect, the invention provides a method comprising extracting, into an aqueous phase, a capsular complex from *B. fragilis* using a mixture of phenol and water at high temperature, precipitating polysaccharide A (PSA) from the aqueous phase using ethanol, acid-treating the precipitate using 2% acetic acid at high temperature, wherein the method is performed in the absence of sodium deoxycholate.

In some embodiments, each method may further comprise, after acid-treatment, a step of purifying PSA by size exclusion in a detergent-free buffer. In some embodiments, each method may further comprise dialysis of size excluded PSA.

In some embodiments, extraction occurs at 60-75° C. In some embodiments, extraction occurs at about 68° C.

In some embodiments, acid-treatment occurs at about 90° C. for about 3 hours.

In some embodiments, each method is performed in the absence of sodium deoxycholate. In some embodiments, each method is performed in the absence of detergent.

In some embodiments, *B. fragilis* is a PSA-overexpressing strain of *B. fragilis* such as but not limited to strain 9343.

In another aspect, the invention provides a composition comprising isolated lipid-containing polysaccharide A (PSA-LT) produced by any of the foregoing methods. The isolated lipid-conjugated polysaccharide A comprises one or more non-LPS lipids. In some embodiments, the composition is formulated for oral administration to a subject.

In another aspect, the invention provides a composition comprising isolated *B. fragilis* non-LPS lipid-conjugated polysaccharide A (PSA). The non-LPS lipid may be covalently conjugated to PSA. In some embodiments, the isolated *B. fragilis* non-LPS lipid-conjugated PSA comprises less than 1%, less than 0.5%, less than 0.1%, less than 0.05%, or less than 0.01% (w/w) of non-LPS lipid conjugated to PSA. In some embodiments, the isolated *B. fragilis* non-LPS lipid-conjugated PSA comprises non-LPS lipid in the range of about 0.1% to 2% (w/w) or about 0.1% to 1% (w/w), including about 0.5% (w/w). The isolated lipid-conjugated polysaccharide A comprises one or more non-LPS lipids. In some embodiments, the composition is formulated for oral administration to a subject.

In another aspect, the invention provides a composition comprising isolated *B. fragilis* lipid-conjugated polysaccharide A (PSA) and less than or about 0.5% (w/w) LPS, wherein the composition comprising the isolated *B. fragilis* lipid-conjugated polysaccharide A, when treated with 2% acetic acid and run on a 16.5% Tris-Tricine SDS-PAGE gel and reverse-stained using zinc sulphate and imidazole, demonstrates a band at above 60 kD (PSA-LT) and a band at about 5 kD. The isolated *B. fragilis* lipid-conjugated polysaccharide A comprises one or more non-LPS lipids. The lipid(s) may be covalently conjugated to the carbohydrate portion of PSA-LT. Under some circumstances, the bond

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between the lipid(s) and the carbohydrate portion of PSA-LT is not susceptible to cleavage by snake venom phosphodiesterase. In some embodiments, the composition demonstrates LPS bands at 6 and 8 kD of less intensity than the band at about 5 kD. In some embodiments, the composition is formulated for oral administration to a subject.

In another aspect, the invention provides a composition comprising isolated *B. fragilis* lipid-conjugated polysaccharide A wherein the composition comprises about 99% PSA, about 0.5% non-LPS lipid, and about 0.5% LPS.

In another aspect, the invention provides a composition comprising isolated *B. fragilis* lipid-conjugated polysaccharide A wherein the composition comprises about 97%-99% PSA, about 0.5%-2% non-LPS lipid, and about 0.5% LPS.

In another aspect, the invention provides a composition comprising isolated PSA-LT wherein the isolated PSA-LT comprises about 99.5% (w/w) of the composition and LPS represents about 0.5% (w/w) of the composition.

In various embodiments of the foregoing aspects, the compositions are essentially free of nucleic acids, proteins and/or other bacterial contaminants.

In another aspect, the invention provides a method comprising administering to a subject having a condition associated with inflammation an effective amount of any of the foregoing PSA-LT-comprising compositions. In another aspect, the invention provides a method comprising administering to a subject at risk of a recurrence of a condition associated with inflammation an effective amount of any of the foregoing PSA-LT-comprising compositions.

In some embodiments, the method is a method of reducing the likelihood of a recurrence of the condition or reducing the frequency of future recurrences. In some embodiments, the method is a method of reducing the severity of symptoms associated with the condition, whether such symptoms are present in the first manifestation, in a recurrence, or chronically.

In some embodiments, the condition is an autoimmune disease. The autoimmune disease may be multiple sclerosis, Crohn's disease, ulcerative colitis, rheumatoid arthritis, or type I diabetes.

In some embodiments, the condition is asthma. In some embodiments, the condition is obesity.

In some embodiments, the composition may be administered to the subject by inhalation (e.g. nebulization), by oral administration, or by injection. In some embodiments, the composition is orally administered to the subject.

In another aspect, the invention provides a method comprising administering to a subject at risk of developing a post-surgical adhesion an effective amount of any of the foregoing PSA-LT comprising compositions. In some embodiments, the PSA-LT comprising composition is administered prior to surgery, during surgery, after surgery, or any combination thereof including but not limited to prior to and during surgery.

In another aspect, the invention provides a method comprising administering to a subject having or at risk of developing an abscess an effective amount of any of the foregoing PSA-LT comprising compositions. In some embodiments, the subject is also administered an antibacterial agent such as an antibiotic. In some embodiments, the PSA-LT comprising composition is administered prior to development of an abscess and/or prior to the manifestation of symptoms associated with an abscess. In some embodiments, the PSA-LT comprising composition is administered after an abscess has been detected or diagnosed and/or after symptoms associated with an abscess are manifested.

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In still another aspect, the invention provides a method comprising analyzing a composition suspected of comprising PSA-LT using a Tris-Tricine SDS-PAGE gel that is reversed stained with zinc sulphate and imidazole. In some embodiments, the gel is a 16.5% Tris-Tricine SDS-PAGE gel. In some embodiments, the composition is a bacterial fraction, such as a *B. fragilis* fraction. In some embodiments, the bacterial fraction has been subjected to a hot phenol/water extraction, an ethanol precipitation, a mild acid-treatment (e.g., at an acidic pH at or above 4, typically in the range of 4-5), and/or size exclusion. In some embodiments, the composition, including the bacterial fraction, has not been contacted with sodium deoxycholate. In some embodiments, the composition, including the bacterial fraction, has not been contacted with a detergent. In some embodiments, the method is a method of detecting presence of a non-LPS lipid in the composition. In some embodiments, the method is a method of detecting PSA-LT in the composition. The presence of PSA, LPS and/or non-LPS lipid may be detected using the method. The amount of PSA, LPS and/or non-LPS lipid may be measured using the method.

It should be appreciated that all combinations of the foregoing concepts and additional concepts discussed in greater detail below (provided such concepts are not mutually inconsistent) are contemplated as being part of the inventive subject matter disclosed herein. In particular, all combinations of claimed subject matter appearing at the end of this disclosure are contemplated as being part of the inventive subject matter disclosed herein. It should also be appreciated that terminology explicitly employed herein that also may appear in any disclosure incorporated by reference should be accorded a meaning most consistent with the particular concepts disclosed herein.

BRIEF DESCRIPTION OF THE FIGURES

It is to be understood that the Figures are not necessarily to scale, emphasis instead being placed upon generally illustrating the various concepts discussed herein.

FIG. 1 is an elution profile of an S400 column.

FIG. 2 is a proton nuclear magnetic resonance spectroscopy profile of purified PSA-LT.

FIG. 3 is a histogram of IL-10 production in a splenic dendritic cell (DC) T cell co-culture system using lipidated (PSA24) and non-lipidated (PSA23) forms of PSA.

FIG. 4 is a histogram of IL-10 production in a splenic dendritic cell (DC) T cell co-culture system using lipidated (PSA24) and non-lipidated (PSA23) forms of PSA, and non-lipidated (PSA23) form of PSA with added LPS (PSA23+LPS).

FIG. 5 is a photograph of a gel showing the results of an acid treatment time course of PSA-LT containing composition.

FIG. 6 is a photograph of a gel showing the effect of acid treatment on *B. fragilis* LPS compared to lipidated-PSA (PSA24).

FIG. 7 is a photograph of a gel showing the presence of lipid (arrow) in the PSA-LT preparation (PSA26). The higher molecular weight PSA (shown in the box) was cut out from and eluted from the gel using 5% triethylamine. The gel-extracted PSA shows the lipid band (labeled with the arrow).

FIG. 8 is a histogram showing IL-10 production as a function of PSA-LT preparation protocol, acid hydrolysis and/or organic solvent dissolution.

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FIG. 9 is a histogram showing the effect of sodium deoxycholate during PSA-LT preparation on IL-10 production.

FIG. 10 is a photograph of a gel showing loss of the lipid band (Band 3) after sodium deoxycholate based extraction. The gel in this Figure, as in other Figures, is a 16.5% Tris-Tricine-SDS-PAGE gel that is reversed-stained with zinc sulphate and imidazole.

FIG. 11 is a graph showing the effect of non-lipidated (PSA) and lipidated (PSA-LT) forms of PSA on outcome in an experimental autoimmune encephalitis (EAE) animal model system.

FIG. 12 is a schematic illustrating an embodiment of PSA-LT attachment to the outer membrane of *B. fragilis*.

FIG. 13 is a photograph of a gel showing the results of an acid treatment time course of a PSA-containing composition (PSA23) produced using a prior art isolation method and a PSA-LT containing composition (PSA24). Notably, there is no Band 3 following acid treatment of PSA23.

DETAILED DESCRIPTION OF THE INVENTION

The invention is premised on the surprising and unexpected discovery of a lipidated form of polysaccharide A (PSA), referred to herein as PSA-LT, from *B. fragilis*. It has been found, according to the invention, that the prior art methods for isolating and purifying PSA from *B. fragilis* inadvertently and unknowingly removed a lipid component that is conjugated to native PSA. The native, lipidated form of PSA is more potent than the non-lipidated form that has been previously isolated and purified, as demonstrated by both in vitro and in vivo assays. As demonstrated in the Examples, the lipidated form of PSA is better able to induce IL-10 production (and therefore better able to interact with Treg cells) and better able to prevent an experimentally induced murine form of multiple sclerosis (i.e., experimental autoimmune encephalitis, EAE).

Accordingly, the invention provides compositions comprising the isolated lipidated form of PSA (PSA-LT), methods of isolating and purifying PSA-LT from *B. fragilis*, and methods of using isolated PSA-LT in vitro and in vivo. The invention contemplates that the isolated PSA-LT may be completely (or fully) lipidated or it may be partially lipidated. The degree of lipidation will depend upon the isolation methods, including for example the degree of acid hydrolysis. It is also to be understood that the compositions of the invention typically comprise a plurality of PSA-LT molecules, and that the plurality may exhibit variation in the degree of lipidation. Accordingly, in some instances the characteristics provided herein relate to the composition comprising a plurality of PSA-LT rather than a single PSA-LT molecule.

Structure of PSA and PSA-LT

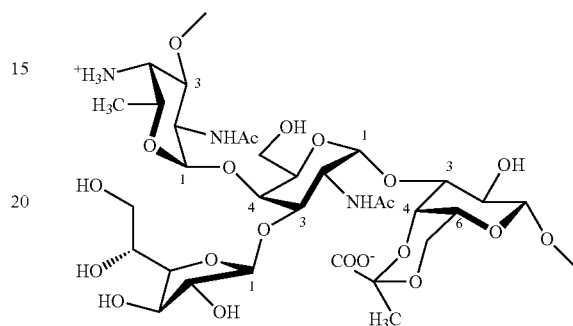
The invention relates in part to a newly discovered lipidated form of PSA from *B. fragilis*. The lipidated form is referred to as PSA-LT. This lipidated form is comprised of a polysaccharide and one or more lipid chains (or tails). The carbohydrate portion of the newly discovered molecule is referred to as PSA. This is also the form of the polysaccharide that has been previously isolated and analyzed. It was not known prior to the invention that this polysaccharide existed in nature in a lipid-conjugated form.

Polysaccharide A (PSA) comprises a tetrasaccharide repeating unit that is $\rightarrow 3$ α -D-AAT Galp-(1 \rightarrow 4)-[β -D-Galp-(1 \rightarrow 3) α -D-GalpNAc-(1 \rightarrow 3)-[4,6-pyruvate]- β -D-Galp-(1 \rightarrow]. It possesses zwitterionic behavior as conferred by a

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positive charge on its free amine group and a negative charge on its free carboxyl group (per repeating tetrasaccharide unit). Its naturally occurring state is composed of over 60 tetrasaccharide repeating units (e.g., up to and including in some instances about 100, or about 200, or about 300 repeated units on average), and it has an average molecular size of about 150 kD (with a range of about 60 kD to 2000 kD).

The repeating tetrasaccharide unit of PSA has a structure as follows:



The invention is based in part on the isolation of a lipidated form of PSA from *B. fragilis* using isolation and purification methods that maintain the lipid conjugated to the PSA. The lipidated form of PSA, referred to herein as PSA-LT, comprises tetrasaccharide repeating unit structure of PSA covalently conjugated to one or more lipid chains (or tails or moieties, as used interchangeably herein). The bond between the lipid and PSA is not susceptible to cleavage using phosphodiesterases extracted from snake venom. The lipid moieties may be conjugated to PSA via ester or amide linkages. There may be one or more lipid chains (or tails) per PSA molecule.

The invention further provides compositions comprising isolated PSA-LT. As used herein, with respect to PSA-LT, the term "isolated" intends that the PSA-LT is physically separated from its natural environment (i.e., a *B. fragilis* cell). Compositions comprising isolated PSA-LT may comprise other components including LPS and/or non-lipidated PSA. In some embodiments, the amount of LPS present in such compositions is about 0.5% (w/w) or less.

In some embodiments, the compositions of the invention comprise about 99% PSA, 0.5% non-LPS lipid, and about 0.5% LPS. It will be understood that in some instances the compositions comprise PSA conjugated to its lipid(s) (i.e., PSA-LT), even though characterization of such compositions may require cleavage of the lipid from PSA (e.g., in the gel systems described herein). As will be understood in the art, LPS refers to lipopolysaccharide. As used herein, a non-LPS lipid is a lipid that is not LPS. The amounts of PSA, LPS and non-LPS lipid can be determined using a gel system such as that described herein. In some embodiments, the compositions are essentially free of contaminants such as nucleic acids such as DNA and RNA and proteins. Essentially free, as used herein, intends that these contaminants represent about or less than 0.1% (w/w) of the composition. In some instances, such contaminants may be undetectable.

The invention provides compositions for use in vitro and in vivo. In vitro, the compositions may be used as analytical tools or assay standards. In vivo, the compositions may be used or in experimental models, such as animal models, of human disease or in humans or other subjects in need of

immune regulation. When used in vivo, the compositions are pharmaceutically acceptable, intending that they are suitable for administration into a subject. They may or may not be used prophylactically or therapeutically in such subjects.

PSA-LT Isolation Methods

The method provides general and specific methods for isolating and purifying PSA-LT from *B. fragilis*. It is to be understood that these methods may be performed on any strain of *B. fragilis* provided it produces PSA. Such strains include naturally occurring strains or mutant strains such as the overexpressing strain 9343.

It has been found that the prior art methods used to isolate and purify PSA removed the lipid tail from the polysaccharide. The invention provides methods that spare the lipid tail, and thereby yield a lipidated form of PSA that is functionally more potent than its previously isolated non-lipidated form. The isolation methods of the invention differ from the prior art isolation methods in a number of ways. First, the instant methods perform hydrolysis with mild acid (e.g., at a pH of about 4, or in the range of 4-5) at an early step in the purification process rather than a later step as was done in the prior art. Second, the instant methods perform molecular sieve chromatography in a neutral buffer solution (Tris) in the absence of sodium deoxycholate (DOC) which was used in the prior art methods. Third, the pH throughout the isolation is 9 or less (e.g., about 4 to about 9 or less), and in most steps is maintained in a neutral range.

Briefly, isolation and purification of PSA-LT comprises (1) growth of *B. fragilis* (wild type or mutant strain that produces PSA, including strains that overexpress PSA) under anaerobic conditions, (2) isolation of the capsular complex from *B. fragilis*, and (3) ethanol precipitation of PSA-LT, (4) mild acid-treatment. The capsular complex may be isolated using for example a hot phenol/water extraction. Ethanol precipitation of PSA-LT may be preceded by treatment with DNase, RNase and/or pronase. The acid-treatment may be performed using dilute acid (e.g., 2% acetic acid) at elevated temperature. The elevated temperature may range from 80-100° C., 85-95° C., and in some instances is about 90° C. The treatment may last for 1 hour, 2 hours, 3 hours or longer. In some instances, the acid treatment is performed using 2% acetic acid at 90° C. for 3 hours.

PSA-LT may be further purified from the precipitate by size exclusion. For example, the precipitate may be dissolved in a neutral buffer such as but not limited to PBS, and then applied on a S-400 size exclusion column. This size exclusion step is performed in the absence of sodium deoxycholate, and in some instances in the absence of any detergent. PSA-LT containing fractions are then pooled, optionally analyzed, and dialyzed. The final dialysate may be lyophilized.

Purity may be assessed by nuclear NMR and/or SDS PAGE gel as described in greater detail herein. Analysis and Characterization of PSA-LT and Comparison to PSA

A. Structural Characterization of PSA-LT

FIG. 1 shows an elution profile of an S400 column in Tris buffered saline monitored by absorption at 280 nm. As stated above, fractions were tested by double diffusion in agar with an antibody to PSA-LT.

FIG. 2 is a proton nuclear magnetic resonance spectroscopy profile of purified PSA-LT done on a 600 MHz NMR. The carbohydrate structure of this molecule precisely fits the published spectrum for PSA. This indicates that the carbohydrate portion of PSA-LT is identical to PSA. The very small percentage (m/m) of PSA-LT that is attributable to lipid is not observed by this high-resolution technique.

FIG. 5 shows the results of an acid treatment time course of PSA-LT using a 16.5% Tris-Tricine SDS-PAGE gel reverse stained with zinc sulphate/imidazole staining. This staining protocol allows one to observe both the carbohydrate (i.e., PSA) and lipid portions of PSA-LT in the same gel system. Four mg of a 5 mg/ml PSA-LT (Lot 26) was treated with 2% acetic acid at 90° C. for various periods of time followed by neutralization with NaOH and dialysis. One hundred micrograms of the resultant product was run on a 16.5% Tris-Tricine SDS-PAGE gel and reverse-stained as described above. The Figure clearly shows the disappearance of the LPS bands (at about 6 and 8 kD) and the emergence of a lipid band (labeled Band 3) at about 5 kD with increasing hydrolysis time.

To determine whether Band 3 emanated as a hydrolytic product of PSA-LT (very top of the gel) or LPS (Bands at approximately 8 kDa and 6 kDa), we took purified *B. fragilis* LPS and hydrolyzed under identical conditions to which we had hydrolyzed PSA-LT. Importantly, no Band 3 appeared after hydrolysis of LPS, but was distinctly present after hydrolysis of PSA-LT (Lot 24). (FIG. 6)

In addition, no Band 3 has been observed in PSA-containing compositions prepared using prior art isolation methods, such as for example Lot 23 (PSA23, FIG. 13). The Figure shows the results of an acid treatment on 1 mg of 1.3 mg/ml PSA23 in water (2% acetic acid at 90° C. and neutralized with NaOH). 100 ug of the treated fraction was run on a 16.5% Tris-Tricine SDS-PAGE gel and reverse-stained with zinc sulphate/imidazole. A PSA24 preparation comprising PSA-LT was run alongside as a comparator.

To confirm that Band 3 was a hydrolytic product of PSA-LT, the large molecular weight PSA-LT, as observed in the gel on the left in FIG. 7, was further analyzed. The box indicates the band cut out of the gel for further analysis. The product eluted from the gel was then hydrolyzed and studied again by running it in the same gel system, as seen in the right hand column of FIG. 7. Band 3 can be observed, as indicated by the arrow, after hydrolysis of the large molecular weight PSA-LT.

B. Functional Characterization of PSA-LT

Experiments were then performed to determine if the immunologic activity of the PSA-LT preparation was affected by the step in the prior purification process where hydrolysis likely takes place. PSA-LT (Lot 24) was hydrolyzed very early in the purification process at a time immediately after separation of the aqueous phase from the initial phenol/water extraction step.

PSA-LT was tested for its ability to induce IL-10 production in a splenic dendritic cell and T cell co-culture. This assay was performed as follows: (1) splenic DCs are isolated using mouse anti-CD11c microbeads (Miltenyi Biotec cat#130-052-001); (2) CD4⁺ T cells are isolated using Mouse T cell CD4 Subset Column Kit (R&D systems cat#MCD4C-1000); (3) 2x10⁴ CD11c⁺ DCs and 10⁵ CD4⁺ T cells are mixed and 1 µg/ml anti-CD3 (BD Pharmingen cat#553057) is added; (4) the culture is then stimulated with 100 µg/ml PSA and the cells are incubated for 5 days; and (5) supernatants are harvested and analyzed by ELISA for the presence of IL-10.

FIG. 3 demonstrates that, in terms of IL-10 production in this co-culture system, PSA-LT (shown as PSA24) is approximately 3 fold more potent than PSA made by the prior art method (shown as PSA 23).

Because PSA24 had small amounts of contaminating LPS (approximately 0.5%, w/w) we added purified *B. fragilis* LPS to PSA Lot 23 (PSA23) and determined that the addition of LPS to a PSA lot containing no LPS did not

enhance (and thus did not reconstitute) its ability to induce IL-10 in the co-culture system. (FIG. 4)

As shown in FIG. 8, PSA-LT 24 was quite active in inducing IL-10 production in the DC T cell co-culture system. PSA-LT (Lot 26, and shown as PSA26-PD in this Figure) was similarly active prior to any hydrolysis step. Following further purification of unhydrolyzed PSA-LT (Lot 26) by 5400 chromatography, this material was hydrolyzed under the same conditions as the earlier phase hydrolysis of PSA-LT (Lot 24). In contrast to PSA-LT hydrolyzed early in the purification process, the PSA-LT hydrolyzed later in the process had lost much of its capacity to induce IL-10 in the co-culture system. If unhydrolyzed PSA-LT (Lot 26) was extracted directly with chloroform there was no statistically significant loss of IL-10 inducing capacity. Finally, if later stage PSA-LT (Lot 26) was hydrolyzed and chloroform extracted, all residual IL-10 inducing capacity was lost. Therefore, the lipid fraction of PSA-LT is significantly removed by hydrolysis but not by organic solvents.

However, following hydrolysis the material is soluble in an organic solvent indicating that there is a hydrolysable covalent bond between PSA and a lipid. The fact that chloroform extraction directly on PSA-LT did not remove IL-10 inducing capacity unless PSA-LT was first hydrolyzed indicates that the lipid component is covalently attached. The fact that the lipid is not seen on NMR, combined with the finding of Band 3 after hydrolysis of PSA-LT indicates that the lipid is an extremely small percent of the overall mass of PSA-LT and most likely represents the covalently linked lipids at the reducing terminus of the polysaccharide. Such lipids may be used by Gram negative bacteria for membrane insertion of a polysaccharide.

Another major difference in our purification protocol for PSA-LT, compared to our previous isolation process for PSA, is the elimination of a chromatography step in a sodium deoxycholate (DOC) containing buffer. The difference in activity as a result of contact with DOC is shown in FIG. 9. Lot 24 PSA-LT was suspended in the DOC containing buffer under the pH 9 conditions used in our purification of PSA. The pH of the DOC was 8.0, but the pH was quickly brought up to pH 9 with NaOH and back again with dilute HCl. After extensive dialysis, Lot 24 lost its ability to induce IL-10 in the DC T cell co-culture system. In FIG. 10, Band 3 which is seen after hydrolysis of PSA-LT (Lot 24) is no longer seen after hydrolysis of DOC-treated Lot 24. The elimination of the DOC containing step represents a major departure from all earlier protocols and differentiates methods used currently for preparation of PSA-LT from methods used for preparation of PSA.

C. In Vivo Efficacy of PSA-LT Compared to PSA in an Animal Model of Multiple Sclerosis (EAE).

The above data demonstrate a significant in vitro enhancement of IL-10 induction in DC T cell co-cultures by PSA-LT when compared to PSA. To determine whether this enhancement of IL-10 production in vitro represented a potential therapeutic advantage in vivo, we compared PSA-LT (Lot 24) with PSA (Lot 23) (FIG. 11). Groups of 6 week old female naïve C57 BL/6 mice were treated with 100 µg of either PSA-LT, PSA, or phosphate buffered saline (PBS) every three days starting 6 days before EAE induction. Mice were challenged subcutaneously with 250 µg of MOG₃₃₋₅₅ (Peptides International) in 200 µl of complete Freund's adjuvant (Sigma). On days 0 and 2 after challenge, mice received intraperitoneal injections of 250 ng of *Bordetella pertussis* toxin (List Biological Laboratories). Disease was scored on an established 0 to 5 scale, with 5 being advanced neurological disease. Mice were monitored and scored daily

for disease progression. When compared to PBS treated controls, animals receiving PSA had a statistically significant reduction in disease severity; however, animals receiving PSA-LT had an even more marked reduction in disease severity with nearly complete protection against the development of EAE.

These studies show a critical enhanced protective capacity of PSA-LT when compared to PSA in a very significant animal model of human disease.

Methods of Detection

The invention provides methods for detecting the presence of PSA-LT and in some instances quantitating the amount of PSA-LT in a sample or a composition. These methods employ the Tris-Tricine SDS-PAGE gel system described herein. Samples are run on such 16.5% Tris-Tricine SDS-PAGE gels and then reverse stained with zinc sulphate and imidazole. The presence of PSA-LT is indicated by the presence of a band at about 5 kD. The major band above 60 kD represents PSA (lipidated or non-lipidated versions).

The compositions analyzed using this system may be obtained as described herein, including for example following a phenol/water extraction, ethanol precipitation, mild acid hydrolysis, and size exclusion, or they may be obtained and/or prepared in other ways.

Methods of Use

The invention provides various methods of in vitro and in vivo use of the compositions provided herein. In vitro uses include use as an analytical tool (e.g., as a marker of the presence of *B. fragilis*) and as an assay standard or control (e.g., as a positive marker of PSA-LT).

In vivo uses include but are not limited to those involving human subjects. For example, in vivo uses include administration of the compositions of the invention to a non-human subject in order to modulate an immune response.

The invention generally provides methods of modulating immune responses in a subject having or likely to develop an aberrant immune response. Typically, the aberrant immune response is an enhanced immune response and the composition acts to down-regulate the immune response. Enhanced immune responses are typically associated with inflammatory conditions, such as but not limited to autoimmune diseases.

Accordingly, the compositions of the invention may be used to modulate (and typically down-regulate) immune responses in subjects having or at risk of developing autoimmune diseases. As will be understood by those of ordinary skill in the art, subjects having autoimmune diseases typically experience one or more "events" or recurrences associated with the autoimmune disease. For example, a subject having inflammatory bowel disease may experience temporally isolated attacks of the disease, characterized by the presence of symptoms or increased severity of symptoms. The invention contemplates that the compositions may be used in such subjects to reduce the likelihood of such future recurrences of the disease or to reduce the severity of symptoms associated with the disease (e.g., pain, fever, discomfort, fatigue, etc.). Thus, the compositions may be administered prior to such recurrence, and in this manner may be chronically administered, optionally at a regular frequency. Examples include once a day, once every 2, 3, 4, 5 or 6 days, or once a week, etc. The invention also contemplates that the compositions may be administered to the subject during a recurrence in order to reduce the severity of symptoms or shorten the time of the recurrence.

Autoimmune diseases are known in the art. Examples of autoimmune diseases include but are not limited to multiple

sclerosis, inflammatory bowel disease including Crohn's Disease and ulcerative colitis, rheumatoid arthritis, psoriasis, type I diabetes, uveitis, Celiac disease, pernicious anemia, Srojen's syndrome, Hashimoto's thyroiditis, Graves' disease, systemic lupus erythematosis, acute disseminated encephalomyelitis, Addison's disease, Ankylosing spondylitis, Antiphospholipid antibody syndrome, Guillain-Barre syndrome, idiopathic thrombocytopenic purpura, Goodpasture's syndrome, Myasthenia gravis, Pemphigus, giant cell arteritis, aplastic anemia, autoimmune hepatitis, Kawasaki's disease, mixed connective tissue disease, Ord thyroiditis, polyarthritis, primary biliary sclerosis, Reiter's syndrome, Takaysu's arteritis, vitiligo, warm autoimmune hemolytic anemia, Wegener's granulomatosis, Chagas' disease, chronic obstructive pulmonary disease, and sarcoidosis.

In important embodiments, the autoimmune disease is multiple sclerosis. In other important embodiments, the autoimmune disease is an inflammatory bowel disease including but not limited to ulcerative colitis and Crohn's disease.

In some instances, the compositions of the invention may be administered to a subject who has yet to manifest an autoimmune disease (including symptoms thereof) yet is at risk of developing such as disease based on a known genetic or familial predisposition. Such a subject may have one or more family members that are afflicted with the disease.

In some instances, the compositions of the invention are administered to subject having or at risk of developing graft-versus-host disease. Administration may occur prior to, during and/or after transplantation of an organ or tissue (including blood or a blood product) into the subject.

In still other instances, the compositions may be administered to subjects having or at risk of developing a condition associated with inflammation.

As an example, the composition may be administered to a subject having asthma. As will be understood in the art, subjects having asthma typically experience asthmatic attacks or events characterized by impaired breathing. The invention contemplates that the compositions described herein may be administered acutely (e.g., a single large dose) or chronically (e.g., repeated, smaller doses) to asthmatic subjects. Accordingly, in some instances, the compositions may be administered prior to an asthmatic attack in order to prevent the occurrence of the attack, reduce the frequency of attacks, and/or to lessen the severity of the attack. In some instances, the compositions may be administered during an attack in order to reduce its severity and/or reduce its duration.

Another condition associated with inflammation is a post-surgical adhesion. The invention contemplates administration of the compositions described herein to subjects having or at risk of developing a post-surgical adhesion. The compositions may be administered prior to, during, and/or immediately following surgery in order to prevent the occurrence of such adhesions and/or reduce their severity. The compositions may be administered repeatedly following surgery, including for example every day, every two days, every three days, etc. for a week, two weeks, three weeks, a month, or several months post-surgery.

Another condition associated with inflammation is an abscess, including but not limited to an abdominal abscess as may occur upon leakage of intestinal contents into the peritoneum. In these instances, the subjects being treated may also be administered anti-bacterial agents such as antibiotics.

Another condition associated with inflammation is obesity, and accordingly the invention also contemplates admin-

istration of the compositions described herein in subjects that are obese. Such subjects are typically defined as having a body mass index (BMI) of 30 or more. In some instances, the compositions may be administered to a subject having a BMI greater than 20 or greater than 25. The compositions are intended to prevent further weight gain and/or induce weight loss in such subjects.

A subject intends any subject that would benefit from administration of a composition of the invention or that could be administered the composition of the invention. In important embodiments, the subject is a human subject. The subject may also be a companion animal such as a dog or cat, agricultural livestock such as horses, cattle, pigs, sheep, etc., laboratory animals such as mice, rats, rabbits, monkeys, etc., or animals such as those maintained in zoos or otherwise in captivity.

A variety of administration routes are available. The particular mode selected will depend, of course, upon the particular condition being treated, the severity of the condition being treated, and the dosage required for therapeutic efficacy. The methods of the invention, generally speaking, may be practiced using any mode of administration that is medically acceptable, meaning any mode that produces effective levels of the active compounds without causing clinically unacceptable adverse effects. Such modes of administration include oral, rectal, topical, nasal, inhalation, or parenteral routes. The term "parenteral" includes subcutaneous, intravenous, intramuscular, intraperitoneal, or infusion.

Formulations

When administered, the active agents of the invention are formulated as pharmaceutically acceptable compositions or preparations. Such compositions or preparations may routinely contain pharmaceutically acceptable carriers, concentrations of salt, buffering agents, preservatives, other immune modulators, and optionally other therapeutic ingredients. The term "pharmaceutically-acceptable carrier" as used herein, and described more fully below, means one or more compatible solid or liquid filler, dilutants or encapsulating substances which are suitable for administration to a human or other animal. The term "carrier" denotes an organic or inorganic ingredient, natural or synthetic, with which the active ingredient is combined to facilitate the application. The components of the pharmaceutical compositions also are capable of being commingled with active agents of the present invention, in a manner such that there is no interaction which would substantially impair the desired pharmaceutical efficacy.

The pharmaceutical compositions may conveniently be presented in unit dosage form and may be prepared by any of the methods well-known in the art of pharmacy. All methods include the step of bringing PSA-LT (and/or compositions comprising PSA-LT) into association with a carrier which constitutes one or more accessory ingredients. In general, the compositions are prepared by uniformly and intimately bringing the PSA-LT composition into association with a liquid carrier, a finely divided solid carrier, or both, and then, if necessary, shaping the product. Compositions suitable for oral administration may be presented as discrete units, such as capsules, tablets, lozenges, each containing a predetermined amount of the active agent. Other compositions include suspensions in aqueous liquids or non-aqueous liquids such as a syrup, elixir or an emulsion.

The active agent may be administered per se (neat) or in the form of a pharmaceutically acceptable salt. When used in medicine the salts should be pharmaceutically acceptable,

but non-pharmaceutically acceptable salts may conveniently be used to prepare pharmaceutically acceptable salts thereof and are not excluded from the scope of the invention. Such pharmacologically and pharmaceutically acceptable salts include, but are not limited to, those prepared from the following acids: hydrochloric, hydrobromic, sulphuric, nitric, phosphoric, maleic, acetic, salicylic, p-toluene sulphonic, tartaric, citric, methane sulphonic, formic, malonic, succinic, naphthalene-2-sulphonic, and benzene sulphonic. Also, pharmaceutically acceptable salts can be prepared as alkyl metal or alkyl earth salts, such as sodium, potassium or calcium salts of the carboxylic acid group.

Suitable buffering agents include: acetic acid and a salt (1-2% w/v); citric acid and a salt (1-3% w/v); boric acid and a salt (0.5-2.5% w/v); and phosphoric acid and a salt (0.8-2% w/v). Suitable preservatives include benzalkonium chloride (0.003-0.03% w/v); chlorobutanol (0.3-0.9% w/v); parabens (0.01-0.25% w/v) and thimerosal (0.004-0.02% w/v).

Compositions suitable for parenteral administration conveniently comprise a sterile aqueous preparation of the polysaccharide, which can be isotonic with the blood of the recipient. Among the acceptable vehicles and solvents that may be employed are water, Ringer's solution, and isotonic sodium chloride solution. In addition, sterile, fixed oils are conventionally employed as a solvent or suspending medium. For this purpose any bland fixed oil may be employed including synthetic mono- or di-glycerides. In addition, fatty acids such as oleic acid find use in the preparation of injectables. Carrier formulations suitable for subcutaneous, intramuscular, intraperitoneal intravenous, etc. administrations may be found in Remington's Pharmaceutical Sciences, Mack Publishing Company, Easton, Pa.

The pharmaceutical preparations, as described above, are administered in effective amounts. For therapeutic applications, it is generally that amount sufficient to achieve a medically desirable result. In general, a therapeutically effective amount is that amount necessary to delay the onset of, inhibit the progression of, or halt altogether the particular condition being treated, including reducing the likelihood, frequency and/or severity of a recurrence of the condition. As an example, the effective amount may be that amount which serves to reduce, alleviate, or delay the onset of the symptoms (e.g., pain, fever, etc.) of the disorder being treated or prevented. The effective amount will depend upon the mode of administration, the particular condition being treated and the desired outcome. It will also depend upon the stage of the condition, the severity of the condition, the age and physical condition of the subject being treated, the nature of concurrent therapy, if any, the duration of the treatment, the specific route of administration and like factors within the knowledge and expertise of the medical practitioner. For prophylactic applications, it is that amount sufficient to delay the onset of, inhibit the progression of, or halt altogether the particular condition being prevented, and may be measured by the amount required to prevent the onset of symptoms.

Generally, doses of active compounds of the present invention may be from about 0.01 mg/kg per day to 1000 mg/kg per day, preferably from about 0.1 mg/kg to 200 mg/kg and most preferably from about 0.2 mg/kg to about 20 mg/kg, in one or more dose administrations daily, for one or more days. It is expected that doses ranging from 1-500 mg/kg, and preferably doses ranging from 1-100 mg/kg, and even more preferably doses ranging from 1-50 mg/kg, will be suitable. The preferred amount can be determined by one of ordinary skill in the art in accordance with standard

practice for determining optimum dosage levels of the agent. It is generally preferred that a maximum dose is the highest safe dose according to sound medical judgment be used.

In some instances, the total daily dose for a human subject may range from about 50-100 micrograms of PSA-LT.

The pharmaceutical preparation may be administered alone or in conjunction with other compounds. In one embodiment the pharmaceutical preparation is given in conjunction with one or more anti-bacterial agents including antibiotics selected from the group consisting of penicillin G, penicillin V, ampicillin, amoxicillin, bacampicillin, cyclacillin, epicillin, hetacillin, pivampicillin, methicillin, nafcillin, oxacillin, cloxacillin, dicloxacillin, flucloxacillin, carbenicillin, ticarcillin, avlocillin, mezlocillin, piperacillin, amdinocillin, cephalixin, cephradine, cefadroxil, cefaclor, cefazolin, cefuroxime axetil, cefamandole, cefonicid, cefoxitin, cefotaxime, ceftizoxime, cefmenoxime, ceftriaxone, moxalactam, cefotetan, cefoperazone, ceftazidime, imipenem, clavulanate, timentin, sulbactam, neomycin, erythromycin, metronidazole, chloramphenicol, clindamycin, lincomycin, vancomycin, trimethoprim-sulfamethoxazole, aminoglycosides, quinolones, tetracyclines and rifampin.

The following Examples are included for purposes of illustration and are not intended to limit the scope of the invention.

EXAMPLES

Example 1

Summary of Isolation of PSA-LT (Lot 24, PSA24)

B. fragilis was grown in anaerobic conditions. The capsular complex from *B. fragilis* was isolated with hot phenol/water extraction. PSA-LT was precipitated with ethanol after DNase, RNase and pronase treatments. The precipitate was then acid treated with 2% acetic acid at 90° C. for 3 hours. PSA-LT was further purified on S-400 size exclusion column in PBS. The fractions were analyzed and pooled, then dialyzed and lyophilized. The purity of PSA was assessed by nuclear magnetic resonance spectroscopy and SDS PAGE gel, as described herein.

Example 2

Specific Isolation of PSA-LT (Lot 24, PSA24)

The isolation and purification process of PSA-LT is provided below in greater detail.

B. fragilis strain 9343 which overexpresses polysaccharide A (PSA) was plated onto a blood agar plate and grown overnight at 37° C. A swab from a heavily colonized plate was sub-cultured into a 500 ml starter culture of peptone yeast broth. The starter culture was inoculated into 16 liter culture of the same media and pH was titrated to neutrality with 5M NaOH. An anaerobic gas mix was bubbled into the sealed culture.

After an overnight culture maintained at pH 7, bacteria were checked by Gram stain and subculture. Organisms were collected by centrifugation at 8,000×g for 20 minutes. Bacterial pellets were washed two times with saline yielding approximately one liter of bacterial pellet.

The bacterial pellet was suspended in 68° C. melted crystalline phenol to a final concentration of phenol of about 37% v/v (yielding a phenol/water preparation) and mixed for 30 minutes at 68° C. followed by stirring at 4° C. for 48 hours. The phenol/water preparation was aliquoted into

glass bottles which were then centrifuged at 1500 rpm. The upper water layer was harvested. Any residual phenol contained in the harvested aqueous phase was extracted with an equal volume of ethyl ether. The ether phase was then removed using a separatory funnel and any residual ether in the aqueous phase was evaporated, yielding the final aqueous phase from the phenol/water preparation.

The aqueous phase was dialyzed versus water with multiple changes over 5 days at 4° C. and subsequently lyophilized until it was nearly dry (approximately 5 ml water remaining). 0.05M Tris with magnesium, calcium and sodium azide (total volume 61 ml) was added to the lyophilized product to bring the total volume to about 66 ml.

To the dissolved product was added 10 ml of Tris buffer with DNase (0.07 mg/ml) and RNAase (0.33 mg/ml). The entire suspension was filtered through a 0.45 micron filter and the filtrate was stirred at 37° C. The DNase/RNAase treatment was repeated by adding fresh enzyme to the mixture, at similar concentrations, and stirred for two hours.

The pH of the mixture was then raised to 7.5 with 2M NaOH and 25 mg pronase in 10 ml Tris/magnesium/calcium solution was added and the mixture stirred for 24 hours at 37° C. This step was repeated.

The PSA-LT was precipitated by adding 5 volumes of ethanol at 4° C. to the mixture. The solution was then centrifuged at 12,000×g for 30 minutes to pellet PSA-LT. The supernatant was removed and the pellet was resuspended in 392 ml type 1 H₂O.

Acid treatment was then carried out by adding 8 mls acetic acid to the solution, and heating it for three hours at 90° C. The solution was then cooled slightly, neutralized with NaOH, and cooled to 4° C.

Following repeat centrifugation, precipitate was discarded and the supernatant was dialyzed against two changes of 16 liters type 1 H₂O at 4° C. The volume was reduced by lyophilization to approximately 50 mls. Twenty ml aliquots were chromatographed on a 5×200 cm column of S400 suspended in PBS and fractions were collected. Fractions were tested by double diffusion in agar with an antibody that reacts with both lipidated and non-lipidated PSA to determine where PSA-LT eluted. PSA-LT was found in fractions 46 to 88, as shown in FIG. 1. Aliquots of these were tested for UV absorption at 280 nm and it was determined that PSA-LT containing fractions had no UV absorbable material.

Fractions containing PSA-LT were then pooled and concentrated and dialyzed against type 1 H₂O on a Minitan concentrator (Millipore) with 10,000 mw cutoff membranes until conductivity of 100 ml was less than 50 µS.

PSA-LT was then lyophilized. Recovery of total PSA was 739 mg.

The degree of contaminating LPS was determined by Pro Q LPS stain on an SDS PAGE gel system and determined to be approximately 0.5%. Polysaccharide purity and structure was determined by proton nuclear magnetic resonance spectroscopy on a 600 MHz spectrometer.

EQUIVALENTS

While several inventive embodiments have been described and illustrated herein, those of ordinary skill in the art will readily envision a variety of other means and/or structures for performing the function and/or obtaining the results and/or one or more of the advantages described herein, and each of such variations and/or modifications is deemed to be within the scope of the inventive embodiments described herein. More generally, those skilled in the art will

readily appreciate that all parameters, dimensions, materials, and configurations described herein are meant to be exemplary and that the actual parameters, dimensions, materials, and/or configurations will depend upon the specific application or applications for which the inventive teachings is/are used. Those skilled in the art will recognize, or be able to ascertain using no more than routine experimentation, many equivalents to the specific inventive embodiments described herein. It is, therefore, to be understood that the foregoing embodiments are presented by way of example only and that, within the scope of the appended claims and equivalents thereto, inventive embodiments may be practiced otherwise than as specifically described and claimed. Inventive embodiments of the present disclosure are directed to each individual feature, system, article, material, kit, and/or method described herein. In addition, any combination of two or more such features, systems, articles, materials, kits, and/or methods, if such features, systems, articles, materials, kits, and/or methods are not mutually inconsistent, is included within the inventive scope of the present disclosure.

All definitions, as defined and used herein, should be understood to control over dictionary definitions, definitions in documents incorporated by reference, and/or ordinary meanings of the defined terms.

All references, patents and patent applications disclosed herein are incorporated by reference with respect to the subject matter for which each is cited, which in some cases may encompass the entirety of the document.

The indefinite articles “a” and “an,” as used herein in the specification and in the claims, unless clearly indicated to the contrary, should be understood to mean “at least one.”

The phrase “and/or,” as used herein in the specification and in the claims, should be understood to mean “either or both” of the elements so conjoined, i.e., elements that are conjunctively present in some cases and disjunctively present in other cases. Multiple elements listed with “and/or” should be construed in the same fashion, i.e., “one or more” of the elements so conjoined. Other elements may optionally be present other than the elements specifically identified by the “and/or” clause, whether related or unrelated to those elements specifically identified. Thus, as a non-limiting example, a reference to “A and/or B,” when used in conjunction with open-ended language such as “comprising” can refer, in one embodiment, to A only (optionally including elements other than B); in another embodiment, to B only (optionally including elements other than A); in yet another embodiment, to both A and B (optionally including other elements); etc.

As used herein in the specification and in the claims, “or” should be understood to have the same meaning as “and/or” as defined above. For example, when separating items in a list, “or” or “and/or” shall be interpreted as being inclusive, i.e., the inclusion of at least one, but also including more than one, of a number or list of elements, and, optionally, additional unlisted items. Only terms clearly indicated to the contrary, such as “only one of” or “exactly one of,” or, when used in the claims, “consisting of,” will refer to the inclusion of exactly one element of a number or list of elements. In general, the term “or” as used herein shall only be interpreted as indicating exclusive alternatives (i.e. “one or the other but not both”) when preceded by terms of exclusivity, such as “either,” “one of,” “only one of,” or “exactly one of.” “Consisting essentially of,” when used in the claims, shall have its ordinary meaning as used in the field of patent law.

As used herein in the specification and in the claims, the phrase “at least one,” in reference to a list of one or more

elements, should be understood to mean at least one element selected from any one or more of the elements in the list of elements, but not necessarily including at least one of each and every element specifically listed within the list of elements and not excluding any combinations of elements in the list of elements. This definition also allows that elements may optionally be present other than the elements specifically identified within the list of elements to which the phrase "at least one" refers, whether related or unrelated to those elements specifically identified. Thus, as a non-limiting example, 'at least one of A and B' (or, equivalently, "at least one of A or B," or, equivalently 'at least one of A and/or B') can refer, in one embodiment, to at least one, optionally including more than one, A, with no B present (and optionally including elements other than B); in another embodiment, to at least one, optionally including more than one, B, with no A present (and optionally including elements other than A); in yet another embodiment, to at least one, optionally including more than one, A, and at least one, optionally including more than one, B (and optionally including other elements); etc.

It should also be understood that, unless clearly indicated to the contrary, in any methods claimed herein that include more than one step or act, the order of the steps or acts of the method is not necessarily limited to the order in which the steps or acts of the method are recited.

In the claims, as well as in the specification above, all transitional phrases such as "comprising," "including," "carrying," "having," "containing," "involving," "holding," "composed of," and the like are to be understood to be open-ended, i.e., to mean including but not limited to. Only the transitional phrases "consisting of" and "consisting essentially of" shall be closed or semi-closed transitional phrases, respectively, as set forth in the United States Patent Office Manual of Patent Examining Procedures, Section 2111.03.

The invention claimed is:

1. A pharmaceutical composition comprising: an isolated lipidated polysaccharide A (PSA) comprising a PSA polysaccharide covalently conjugated to a lipid, and a pharmaceutically-acceptable carrier or excipient, wherein the composition is suitable for administration to a human.
2. The pharmaceutical composition of claim 1, wherein the lipid represents 0.1-2% (w/w) of the lipidated PSA.
3. The pharmaceutical composition of claim 1, wherein the lipid represents less than 1% (w/w) of the lipidated PSA.
4. The pharmaceutical composition of claim 1, wherein the composition is substantially free of LPS.
5. The pharmaceutical composition of claim 1, wherein the pharmaceutically-acceptable carrier or excipient is orally-acceptable, and the composition is a formulation for oral delivery.
6. The pharmaceutical composition of claim 1, wherein the lipid and PSA are covalently conjugated by a bond that is not susceptible to cleavage by snake venom phosphodiesterase.

7. The pharmaceutical composition of claim 1, wherein the lipidated PSA comprises 99% PSA (w/w) and 0.5% lipid (w/w).

8. The pharmaceutical composition of claim 1, wherein the lipidated-PSA is isolated from *B. fragilis* cells that overexpress PSA relative to a parental strain of *B. fragilis*, under conditions that maintain the lipid conjugated to PSA.

9. The pharmaceutical composition of claim 1, wherein the lipidated PSA comprising polysaccharide A (PSA) covalently conjugated to a lipid, is in a lyophilized form.

10. A pharmaceutical composition comprising isolated lipidated polysaccharide A (PSA) comprising polysaccharide A (PSA) covalently conjugated to a lipid.

11. The pharmaceutical composition of claim 1, wherein the pharmaceutical composition is sterile.

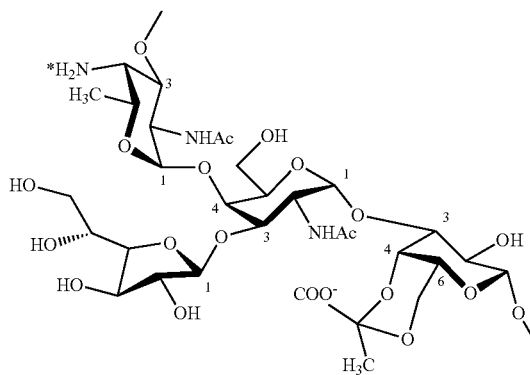
12. The pharmaceutical composition of claim 1, further comprising a preservative.

13. The pharmaceutical composition of claim 5, wherein the formulation for oral delivery is selected from the group consisting of a capsule, tablet, lozenge, syrup, elixir or an emulsion.

14. The pharmaceutical composition of claim 5, wherein the lipidated PSA is characterized by being soluble in an aqueous solution.

15. A pharmaceutical composition formulated for oral administration, the composition comprising:

a preparation of an isolated polysaccharide whose structure comprises a tetrasaccharide repeating unit as set forth below:



which preparation comprises the isolated polysaccharide conjugated to a non-LPS lipid; and

a pharmaceutically acceptable carrier;

wherein the composition is essentially free of a *B. fragilis* nucleic acid and/or protein.

16. The pharmaceutical composition of claim 15, further comprising an immune modulator other than the preparation of polysaccharide.

* * * * *