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(71) Applicant: THE ADMINISTRATORS OF THE TULANE EDUCATIONAL FUND [US/US]; 1430 Tulane Avenue, New Orleans, LA 70012 (US).

(72) Inventor: DiLUZIO, Nicholas, R. (deceased) ;

(74) Agent: MISROCK, S., Leslie; Pennie & Edmonds, 1155 Avenue of the Americas, New York, NY 10036 (US).

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(54) Title: SOLUBLE PHOSPHORYLATED GLUCAN

(57) Abstract

A new class of soluble phosphorylated glucans as well as the process for making the same. According to a preferred embodiment, the soluble phosphorylated glucan is derived from the yeast *Saccharomyces cerevisiae.* The soluble phosphorylated glucans are useful for prophylactic and therapeutic applications against neoplastic, bacteria, viral, fungal and parasitic diseases. Additionally, they may be administered as a non-toxic adjuvant, in combination with chemotherapy. The soluble phosphorylated glucans are also useful for stimulating macrophage cells, either *in vivo* or *in vitro*, to produce a cytotoxic/cytostatic factor effective against cancer cells.

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SOLUBLE PHOSPHORYLATED GLUCAN

1. FIELD OF THE INVENTION

This invention relates to a new class of soluble glucans and, more particularly, to soluble phosphorylated glucans in which the poly-[β-(1-3)glucopyranose] chains are phosphorylated in varying degrees as well as to processes for preparing these new soluble phosphorylated glucans from various microorganisms, such as Saccharomyces cerevisiae and Coriolus versicolor. The new soluble phosphorylated glucans of the invention are non-toxic, non-immunogenic, substantialy non-pyrogenic, and exert pronounced immunobiological responses when administered in vivo in animals and humans, the most striking activity being immunostimulation of macrophage activity with resulting activation of other immunoactive cells. Additionally, these soluble phosphorylated glucans exhibit cytostatic effects against adenocarcinomas and sarcomas in vivo as well as against lymphocytic leukemia cells in vitro.

2. BACKGROUND OF THE INVENTION

The term "glucan" refers generically to a variety of naturally occurring homopolysaccharides or polyglucoses, including polymers such as cellulose, amylose, glycogen, laminarians, starch, etc. Glucan encompasses branched and unbranched chains of glucose units linked by 1-3, 1-4, and 1-6 glucosidic bonds that may be of either the alpha or beta type.

As defined herein, "particulate glucan" designates a water-insoluble particulate (about 1-3 μ) polyglucose such as that derived from the cell wall of the yeast Saccharomyces cerevisiae. Particulate glucan is macromolecular and comprises a closed chain of glucopyranose units united by a series of β-1-3 glucosidic linkages. (Hassid et al., 1941, J. Amer. Chem. Soc. 63: 295-298; Di Luzio et al., 1979, Int'l J. Cancer 24: 773-779). X-ray diffraction studies have demonstrated that particulate glucans exist in the form of a triple-stranded helices. (Sarko et al., 1983, Biochem. Soc. Trans. 11: 139-142).

2.1. IMMUNOBIOLOGICAL ACTIVITY OF PARTICULATE GLUCANS

Particulate glucan is a potent activator of the macrophage/monocyte cell series, complement, as well as of B cell lymphocytes. Thus, particulate glucan has profound effects on both the reticuloendothelial and immune systems.

Previous studies have demonstrated that in vivo administration of particulate glucan to a variety of experimental animals induces a number of profound immunobiological responses, including the following: (1) enhanced proliferation of monocytes and macrophages (Deimann and Fahimi, 1979, J. Exper. Med. 149: 883-897; Ashworth et al., 1963, Exper. Molec. Pathol., Supp. 1: 83-103); (2) enhanced macrophage phagocytic function (Riggi and Di Luzio, 1961, Am. J. Physiol. 200: 297-300); (3) enhanced macrophage secretory activity (Bärlin et al., 1981, in Heterogeneity of Mononuclear Phagocytes, Forster and Landy, eds., Academic Press, New York, pp. 243-252); (4) increased macrophage size (Patchen and Lotzova, 1980, Exper. Hematol. 8: 409-422); (5) enhanced macrophage adherence and chemotactic activity

(Niskanen et al., 1978, Cancer Res. 38: 1406-1409); and (6) enhanced complement activation (Glovsky et al., 1983, J. Reticuloendothel. Soc. 33: 401-413). Increased cytolytic activity against tumor cells has been demonstrated in macrophages from animals and man treated with particulate glucan in both in vivo (Mansell and Di Luzio, 1976, in "The Macrophage in Neoplasia", Fink, ed., Academic Press, New York, pp. 227-243) and in vitro studies (Chirigos et al., 1978, Cancer Res. 38: 1085-1091).

Stimulation of the reticuloendothelial system by in vivo administration of particulate glucan leads to inhibition of allogenic or xenogenic bone marrow graft acceptance in lethally irradiated animals. (See, e.g. Wooles and Di Luzio, 1964, Proc. Soc. Exper. Biol. Med. 115: 756-759). This finding denotes that glucan will induce host defense mechanisms even against normal cells if they are genetically different from the host.

In addition to effects on reticuloendothelial and immune responses, in vivo administration of particulate glucan has been demonstrated to enhance hemopoietic activity including granulopoiesis, monocytopoiesis and erythropoiesis leading to greater recovery from a lethal dose of whole body irradiation (Patchen, 1983, Surv. Immunol. Res. 2: 237-242).

A number of studies have indicated that in vivo administration of particulate glucan significantly modifies host resistance to a wide variety of infectious diseases induced by bacterial, fungal, viral and parasitic organisms. In particular, enhanced host resistance to infection has been shown when animals are challenged by microorganisms such as Eshericheria coli, Staphylococcus aureus, Francisella

tularensis, Mycobacterium leprae, Streptococcus pneumoniae, Candida albicans, Sporotrichum schenckii, as well as viruses such as Venezuelan equine encephalomyelitis virus, Rift Valley fever virus, murine hepatitis virus, frog virus III, Herpes simplex I and II, and parasites such as Leishmania donovani (see review by Di Luzio, 1983, Trends in Pharmacol. Sci. 4: 344-347 and references cited therein).

Extensive studies have indicated that particulate glucan has potent anti-tumor activity. For example, particulate glucan has been shown to inhibit tumor growth and prolong survival in four syngeneic murine tumor models including adenocarcinoma BW 10232, anaplastic carcinoma 15091A, melanoma B16, and spontaneous lymphocytic leukemia BW5147 (Di Luzio et al, 1979, in Advances in Experimental Medicine and Biology, Vol. 121A: 269-290).

To evaluate the cellular basis of the anti-tumor activity of particulate glucan, the anti-tumor cytotoxic activity of peritoneal macrophages, derived from control and particulate glucan-treated mice, was studied (Mansell and Di Luzio, 1976, in The Machrophage in Neoplasia, Fink, ed. Academic Press, New York, pp. 227-243). These studies indicated that peritoneal macrophages from glucan-treated mice produced a significant cytotoxic response compared to normal macrophages. This observation has been confirmed (See, e.g., Bärlin et al. 1981,, in Heterogenity of Mononuclear Phagocytes, Forster and Landy, eds., Academic Press, New York, pp. 243-252) and Chirigos et al., 1978, Cancer Res. 38: 1085-1091).

Additionally in vitro studies using normal and tumor cells incubated with particulate glucan have demonstrated

that glucan exerts a direct cytostatic effect on sarcoma and melanoma cells and a proliferative effect on normal spleen and bone marrow cells (Williams et al., 1985, Hepatology, 5: 198-206). These studies indicate that glucan, studied when administered therapeutically, will (1) significantly inhibit hepatic metastases; (2) inhibit the growth of the primary tumor; and (3) enhance survival, possibly by increased Kupffer cell tumoricidal activity as well as by a direct cytostatic effect of such glucan on sarcoma cells.

Notwithstanding these biological properties, the adverse side effects of particulate glucans have made these compounds all but useless in clinical medicine.

2.2. ADVERSE SIDE EFFECTS OF PARTICULATE GLUCANS

When particulate glucan is administered in vivo to animals, a number of severe side effects have become apparant, the most notable being:

(1) formation of granuloma (sarcoidosis);
(2) development of hepatosplenomegaly;
(3) increased susceptibility to gram-negative infections and endotoxins;
(4) activation of complement (anaphylyotoxin);
(5) development of pulmonary granulomatous vasculitis;
(6) development of hypotension following intravenous administration; and
(7) development of microembolism when administered at high concentrations.

Additionally, there is a relatively high degree of acute toxicity observed when particulate glucan is administered in

vivo. For example, following a single intravenous injection of an aqueous suspension of particulate glucan, 20% and 100% morality were observed in mice receiving glucan at 250 and 500 mg/kg body weight respectively.

Moreover, due to the particulate nature of the glucan preparation (1-3 μ), it is difficult to administer via an intravenous route. By way of illustration, one patient receiving particulate glucan required constant supervision during intravenous (IV) administration, continuous shaking of the IV drip bottle being essential to maintain the particulate glucan in suspension to avoid formation of emboli in the patient.

Although slightly soluble neutral gluans are commerically available, these preparations are not suitable for intravenous administration because the aqueous solutions have very high viscosity and, more importantly, because their use when administered to experimental animals has inevitably been accompanied by considerable toxicity.

Lentinan, a high molecular weight and poorly soluble β-1,3 and β-1,6 glucan obtained from Lentinus edodes, has been studied following intravenous administration to dogs. A variety of adverse clinical effects were observed following adminstration of lentinan (Ajinomoto Co. Inc., Tokyo, Japan) at doses of 2.0, 8.0 and 30 mg/kg/day for 5 weeks. Adverse effects included vomiting, erythema, discoloration of the sclera, and facial swelling. Circulatory collapse, unsteady gait, altered behavioral patterns, excessive salivation were also seen in individual beagles. At autopsy, congestion of the gastrointestinal mucosa was observed in animals treated with 2.0 or 8.0 mg/kg/day. Morphological changes of liver

indicated intracytoplasmic material, possibly lentinan, accumulating in liver cells. One animal showed circulatory collapse upon the first injection at 8.0 mg/kg. While he did recover, the animal experienced repeated vomiting episodes with presence of blood indicating hemorrhaging of the gastrointestinal tract. Another animal appeared to show a marked allergic response, as demonstrated by erythema and subcutaneous swelling (edema) of the face. Autopsy findings demonstrated extensive edema of subcutaneous tissue, and congestion of the gastrointestinal tract with hemorrhaging. Macrophage cells showed accumulation of material, possibly lentinan. (Chesterman et al.,1981, Toxicol. Lett. 9: 87-90)

Additional toxicity studies were performed in which a variety of doses of lentinan ranging from 0.1 to 1.0 mg/kg/day were given intravenously to rats for 9 weeks. Toxicity was manifested by the development of cutaneous lesions and discoloration of the ears suggesting thromboembolic events. (Cozens et al., 1981, Toxicol. Lett. 9: 55-64).

2.3. UNSUCCESSFUL ATTEMPTS TO SOLUBILIZE PARTICULATE GLUCANS

In view of these disadvantages of particulate β-1,3 glucans for *in vivo* administration, extensive studies were undertaken to develop a soluble β-1,3 polyglucose which might be non toxic, induce no significant pathology, and yet retain significant immunobiological activity.

A low molecular weight non-phosphorylated soluble glucan preparation prepared by formic acid hydroylsis of particulate glucan has been shown to have anti-tumor and anti-staphylococcal activity (Di Luzio *et al.*, 1979, Internat'l J.

Cancer 24: 773-779). Unfortunately, the low yield and diversity of fractions obtained by this method made this preparation non-useful for prophylactic and therapeutic applications. (see Di Luzio, 1983, Trends in Pharmacological Sciences 4: 344-347).

Similarly, attempts to solubilize particulate glucan by the addition of dimethylsulfoxide (DMSO) a "molecular relaxant" were also unsuccessful. It was thought the DMSO would "relax" the triple helical configuration of the glucan molecule. Indeed, particulate glucan dissolves in the presence of DMSO. All attempts to isolate a soluble glucan from the DMSO solution, however, resulted in failure. Upon dilution of the DMSO-glucan solution with various aqueous media such as glucose or saline solutions, the particulate glucan was reformed. Following dilution of the DMSO-soluble glucan solution with saline, all animals receiving injections of these solutions died immediately upon injection due to high concentration of DMSO or the reformation of the particulate glucan. Upon precipitation of the glucan in DMSO solution by the additon of ethanol (100%), the precipitate was collected and lyophilized. When this lyophilized glucan was added to water, the particulate glucan reformed.

Attempts to convert the neutral glucan preparation of particulate glucan to a polar-charged preparation by the addition of phosphate or sulfate groups as well as by acetylation were also unsuccessful. Each of these procedures was conducted following the solubilization of particulate glucan by DMSO and in each instance the particulate glucan was reformed.

3. SUMMARY OF THE INVENTION

During an exhaustive investigation of methods by which the triple-stranded helices of glucan might be "relaxed" sufficiently to permit reaction of each of the chains, it was found that when particulate glucan was dissolved in a highly polar solvent (such as DMSO) in the presence of a strong chaotropic agent (such as urea), the glucan is sufficiently structurally disrupted to allow phosphorylation of each of the single chains (or strands) such that the resultant phosphorylated glucan shows the substantially complete absence of the characteristic triple helical structure of particulate glucan. Removal of the resultant phosphorylated glucan shows it to be soluble in water, non-toxic, non-immunogenic, substantially non-pyrogenic and capable of exerting profound immunobiological responses when administered in vivo to animals and humans.

Based on these discoveries, the invention provides a new class of soluble phosphorylated glucans (a) in which the poly-[β-(1-3) glucopryanose] chains are phosphorylated in varying degrees; (b) which are non-toxic, non-immunogenic, substantially non-pyrogenic, and (c) which are capable of exerting pronounced immunobiological responses when administered in vivo in animals and humans. These new soluble phopsphorylated glucans, which are further characterized by a substantial absence of the triple helical structure of particulate glucans, immunostimulate macrophage activity with resulting activation of other immunoactive cells in the reticuloendothelial and immune systems. Additionally these soluble phosphorylated glucans enhance hemopoietic activity including but not limited to leukopoiesis. These soluble phosphorylated glucans exhibit

cytostatic effects against adenocarcinomas and sarcomas in vivo, and against lymphocytic leukemia cells in vitro. Not only do these soluble phosphorylated glucans stimulate macrophage cells in vivo, but they exert profound stimulatory effects on macrophage cells cultured in vitro. Such immunostimulation of macrophage cells is invariably accompanied by production of a macrophage cytotoxic/cytostatic factor (MCT), protein or proteins of unknown structure, which are selectively toxic to cancers cells, particularly adenocarcinomas.

Additionally, the invention provides a process for producing these soluble phosphorylated glucans by dissolving a particulate glucan (preferably prepared from Saccharomyces cerevisiae although other microbial sources may be used) in a highly polar solvent which contains a strong chaotropic agent, and reacting the resultant glucan with phosphoric acid to form a soluble phosphorylated glucan, and recovering the resultant phosphorylated glucans from the reaction mixture.

Further, the invention provides methods for therapeutic and prophylactic treatment of infection induced by bacteria, fungi, viruses and parasitic organisms by administering a soluble phosphorylated glucan or a pharmaceutical composition comprising soluble phosphorylated glucan in combination with a physiologically acceptable carrier to an animal or a human. Moreover, methods are provided for therapeutic treatment of infections induced by such agents by administering an effective amount of a soluble phosphorylated glucan in combination with a bioactive agent effective against said infection.

Additionally, the present invention provides methods for treatment of malignant neoplastic disease in animals and humans by administering to an animal or a human a therapeutically effective amount of a soluble phosphorylated glucan alone or in combination with an anti-cancer agent. The invention also provides methods for prevention of leukopenia induced by administration of an anti-cancer agent by administering to an animal or a human, an effective amount of soluble phosphorylated glucan in combination with said anti-cancer agent.

Furthermore, the invention provides methods for stimulating animal and human macrophage cells (in vivo or in vitro) to produce and secrete a soluble cytotoxic/cytostatic factor (MCT) and the product so produced. Specifically, MCT is produced by administering to an animal or a human a soluble phosphorylated glucan or by culturing animal or human macrophage cells in vitro in culture medium containing soluble phosphorylated glucan.

The immunobiological properties of the soluble phosphorylated glucans of the invention include (1) the ability to prevent mortality due to overwhelming gram negative bacterial infections; (2) the ability to prevent mortality due to gram positive bacterial infections; (3) the ability to modify mortality from spontaneous infections in profoundly immuno-suppressed animals and man; (4) the ability to modify enhanced susceptibility of immunosuppressed animals and man to gram negative bacterial infections; (5) the ability to significantly modify viral infections; (6) the ability to modify spontaneous infections induced by fungal and other parasitic microorganisms; (7) the ability to significantly inhibit primary tumor growth when used alone

and to exert a synergistic effect against primary tumor growth when used in combination with anti-cancer agents; (8) the ability to act synergistically with anti-cancer agents in the regression of primary malignant lesions as well as metastatic lesions in animals and man.

Because of these unique properties, the soluble phosphorylated glucans are particularly useful for prophylactic and therapeutic applications against a variety of diseases induced by bacteria, viruses, fungi and parasitic organisms, as well as a number of neoplastic conditions. The soluble phosphorylated glucan compositions may advantageously be used with a physiologically acceptable pharmaceutical carrier, either alone or in combination with other bioactive or pharmacological agents and therapeutic modalities.

4. BRIEF DESCRIPTION OF THE FIGURES

The present invention may be more fully understood by reference to the following detailed description of the invention, examples of specific embodiments of the invention, and the appended figures in which:

FIG. 1 is a representation of the nuclear magnetic resonance spectrum of soluble phosphorylated glucan at 27 mg/ml.

FIG. 2 is representation of the nuclear magnetic resonance spectrum of a commercially available preparation of lentinan (Ajinomoto co. Inc., Tokyo, Japan). FIG. 2A is an illustration of the spectrum obtained at a concentration of 40 mg/ml. FIG. 2B is an illustration of the spectrum obtained at a concentration of 3 mg/ml lentinan.

FIG. 3 is a graph illustrating the effect on survival of corticosteroid-immunosuppressed mice receiving twice weekly injections of soluble phosphorylated glucan. FIG. 3 also illustrates the effect of chronic administration of soluble phosphorylated glucan on survival of normal mice.

FIG. 4 is a graph illustrating the effect of prior in vivo administration of soluble phosphorylated glucan on resistance of both normal and corticosteroid-immunosuppressed mice to Eschericheria coli infection.

FIG. 5 is a graph showing the effect of prior treatment with soluble phosphorylated glucan on the lethal effects of a subsequent experimentally induced Staphylococcus aureus infection.

FIG. 6 is a graph illustrating the effect of prior treatment with soluble phosphorylated glucan on survival of mice with subsequent experimentally induced viral hepatitis.

FIG. 7 is a graph illustrating the effect of prior oral administration of soluble phosphorylated glucan on survival of mice with experimentally induced Candida albicans infection.

FIG. 8 is a graph showing the effect of soluble phosphorylated glucan on Interleukin I production.

FIG. 9 is a chart showing that the tumor cell cytotoxic/cytostatic factor obtained from soluble phosphorylated glucan-activated macrophage cultures consists of two major fractions with molecular weights of 38,500 and 84,000 daltons.

5. DETAILED DESCRIPTION OF THE INVENTION

5.1. PROCESS FOR PREPARATION OF SOLUBLE PHOSPHORYLATED GLUCAN

Aqueous soluble phosphorylated glucan is prepared by a process which results in a unique class of products different from any other glucans previously described.

According to a preferred embodiment of the present invention, soluble phosphorylated glucan is prepared as follows: particulate glucan, a neutral polyglucose derived from Saccharomyces cerevisiae is suspended in a solution of a strong chaotropic agent in an aprotic solvent such as dimethylsulfoxide (DMSO) with constant stirring. The strong chaotropic agent "relaxes" hydrogen bonding along the polyglucose chain, thus unfolding the molecule. It is preferred to use a fairly high concentration of a strong chaotropic agent such as urea ranging from about 4-12 M to prevent reformation of hydrogen bonds. The mixture is then heated and maintained at about 50-150 °C and phosphoric acid is slowly added with constant stirring. A precipitate comprising the soluble phosphorylated glucan product is apparent after about 1 hour. It is preferred to maintain the reaction mixture at about 100 °C for about 3-12 hours to increase the yield of bioactive product. In practice, after reaction for about 6 hours at about 100 °C, the yield is approximately 70-90%. The degree of phosphorylation of the soluble product varies slightly with reaction time (e.g., 1.48% for 3 hours; 2.23% for 6 hours).

The bioactive soluble phosphorylated glucan product is isolated from the reaction mixture as follows: the mixture is cooled to stop the phosphorylation reaction and diluted with a volume of distilled water sufficient to resuspend the

precipitate. The resulting solution is filtered through coarse, medium and fine sintered funnels to remove any remaining precipitate. The solution is then molecularly sieved to remove all components of less than about 10,000 daltons molecular weight (MW). Thus, DMSO, urea, glucose and any unreacted phosphoric acid are removed from the solution. Molecular sieving may be accomplished by any method that removes these low (i.e., less than about 10,000 daltons) MW components. In one illustrative example, the solution is sieved using Spectrapor membrane dialysis tubing and dialyzing against running distilled water for about 5 days. In another illustrative example, the solution is sieved using a Millipore dialyzer/concentrator with a 10,000 daltons MW membrane filter and a large volume of dialyzing solution. Following molecular sieving, the resulting solution is concentrated and lyophilized to yield the final soluble phosphorylated glucan in the form of a fluffy powder composition. Crystalline structures are not observed.

The particulate glucan used in the process for preparing the soluble phosphorylated glucan according to the present invention may be isolated from the cell wall of S. cerevisiae by known methods (see e.g., Di Luzio et al., 1979, Internat'l J. Cancer 24: 773-779; Hassid et al., 1941, J. Amer. Chem. Soc. 63: 295-298 incorporated herein by reference). Briefly, in practice the particulate glucan is prepared as follows: dry yeast is digested in aqueous sodium hydroxide solution and heated to about 100°C for about 4 hours, then maintained overnight. The supernatant is decanted and the procedure is repeated three times. The residue is acidified using hydrochloric acid, heated to and maintained at 100°C for about 4 hours, and cooled overnight. The supernatant is decanted and the acid digestion is repeated twice. The

residue is then washed repeatedly with distilled water and extracted with ethanol for at least 24 hours. The reddish-brown supernatant is then aspirated and discarded. The ethanol extraction is repeated until the supernatant is essentially colorless. The ethanol is removed by repeatedly washing the residue with distilled water. The particulate glucan is collected by centrifugation or filtration.

A variety of compounds, other than urea, known to function as "molecular relaxants" were also evaluated to prevent reformation of hydrogen bonds after DMSO had been used to "relax" the triple helical configuration of particulate glucan. These include (1) ethylene diamene tetracetic acid; (2) hydrazine sulfate; (3) monoethanol amine; (4) guanandine; (5) guanine, and (6) thiourea. Additionally, surfactants and emulsifying agents such as Tween-20 and phospholipid emulsifying agents such as Alcolec and Centrolex f (lecithin) were also employed in an attempt to solubilize and phoshorylate particulate glucan. In no case was a soluble immunobiologically active preparation obtained.

According to alternative embodiments of the present invention, soluble phosphorylated glucan can be prepared from neutral polyglucose or polyglucose-protein products derived from a variety of other microbial sources. A non-exhaustive list of such sources is presented in Table I.

TABLE 1

EXAMPLES OF SOURCES OF GLUCAN WHICH CAN BE EMPLOYED FOR THE PREPARATION OF SOLUBLE PHOSPHORYLATED GLUCAN

Alcaligenes faecalis
Auricularia auricula-judae
Auricularia polytricha
Candida utilis
Cladosporium fulvum
Claviceps purpurea
Cochiliobolus sativus
Coriolus versicolor
Corlinellus shiitake
Corticium vagum
Grifola umbellata
Lentinus edodes
Pichia fermentans
Poria cocos
Saccharomyces cerevisiae
Sclerotium coffeicolum
Sclerotium delphnii
Sclerotium glucanium
Sclerotium rolsfi
Shizophyllum commune
Streptococcus salvarius
Stereum sanguinolentum
Wingea robertsii

5.2. CHARACTERIZATION OF SOLUBLE PHOSPHORYLATED GLUCAN

The solubility of the soluble phosphorylated glucan obtained from S. cerevisiae prepared according to the present invention is greater than about 50 mg/ml in water. Aqueous solutions of the soluble phosphorylated glucan are non-viscous and do not taste sweet.

5.2.1. ELEMENTAL COMPOSITION

The elemental composition of the soluble glucan preparation, determined by Gailbraith Laboratories, (Knoxville, TN) is ilustrated in Table 2. The data presented in Table 2 permits the average empirical formula of this preparation to be written as follows:

$$C_{40}H_{87}PO_{37}.$$

Thus, there is an average of one phosphate group for every 6.6 glucose residues in the soluble phosphorylated glucan.

TABLE 2

ELEMENTAL COMPOSITION OF SOLUBLE PHOSPHORYLATED GLUCAN[a]

Element or Component	Mole %
Carbon	34.66
Hydrogen	6.29
Oxygen	42.83
Nitrogen	0.64
Sulfur	0.11
Phosphorus	2.23
Water of Hydration	11.78

[a] Determined after 6 hours phosphorylation.

5.2.2. STRUCTURAL CONFIGURATION

A number of methods were utilized to determine the molecular weight (MW) and various features of the structural configuration of the soluble phosphorylated glucan.

5.2.2.1. MOLECULAR SIEVING

Column chromatography using Sepharose CL-6B-200 (Pharmacia Fine Chemicals, Piscataway, NJ) indicated that 80% of the soluble glucan has a MW range from 10,000 to 100,000 daltons, while 20% has a MW range from about 100,000 to about 500,000 daltons.

5.2.2.2. NUCLEAR MAGNETIC RESONANCE SPECTROSCOPY

Carbon-13 nuclear magnetic resonance (^{13}C-NMR) spectroscopy using a Brucker WP-200 spectrometer (Brucker Instruments, Billerica, MA) was performed to determine several structural properties of the soluble phosphorylated glucan from S. cervisiae prepared according to the present invention.

The samples for NMR studies were prepared using a 10% deuterium oxide (D_2O) in water. Samples were first run with no reference material, and then after the addition of a small aliquot of 1,4-dioxane. All samples were placed in 10 mm diameter tubes.

The ^{13}C-NMR spectral study of soluble phosphorylated glucan indicated a β-1-3 glucan structure with no branching at the C-6 carbon (see FIG. 1). The NMR spectrum indicates a substantial absence of the triple helical structure of particulate glucans. The degree of phosphorylation was

estimated to be 3.6% which is in essential accord with analytical data.

In contrast to the spectra of soluble phosphorylated glucan from S. cerevisiae prepared according to the present invention, a lentinan preparation (Ajinomoto Co. Inc., Tokyo Japan), a branched β-1-3 and 1-6 D glucan, at either 40 mg/ml (FIG. 2A) or 3 mg/ml (FIG. 2B) demonstrated attenuation of the NMR spectra. This is presumed to be due to the gel state of this molecule, particularly at 40 mg/ml concentration. No signals were obtained in a 10% D_2O solution in the non-gel 3 mg/ml concentration.

Comparison of FIG. 1 with FIG. 2 demonstrates complete structural and conformational differences between lentinan and soluble phosphorylated glucan. In contrast to the disordered conformation of lentinan at the β-1-6 linkages (Saito et al., 1977, Carbohydrate Research, 58: 293-305) ordered conformation of soluble phosphorylated glucan according to the present invention is manifested.

5.3. NON-TOXICITY, NON-PYROGENICITY NON-IMMUNOGENICITY OF SOLUBLE PHOSPHORYLATED GLUCAN

Since the soluble phosphorylated glucan offers important advantages over particulate glucan as an injectable biological response modulator, characteristic toxicity, pyrogenicity and immunogenicity of the soluble glucan are described below with particular reference to comparison of these properties of particulate glucan.

5.3.1 NON-TOXICITY

Acute toxicity was evaluated following a single intravenous injection of soluble phosphorylated glucan at a variety of doses into normal animals. Treated animals were observed for 30 days post-injection.

In one series of experiments, 49 ICR/HsD mice were divided into 3 groups of 15 mice each and 2 groups of 2 mice each. Groups 1-3 received 0.5 ml saline solution containing soluble phosphorylated glucan at respectively 40, 200 and 1000 mg/kg; Groups 4 and 5, 1600 and 2000 mg/kg. No mortality was observed in any group. Moreover, no physiological or behaviorial alterations were apparent. In marked contrast, in mice treated similarly with particulate glucan, 20% mortality was observed at 250 mg/kg and 100% mortality at 500 mg/kg.

In another series of experiments, two groups of 5 Sprague Dawley rats each were treated with soluble phosphorylated glucan at respectively 250 and 500 mg/kg via intravenous injection. No mortality or alteration of physiological or behavioral functions was apparent in either group. In contrast, 30% and 100% mortality were observed following intravenous injection of particulate glucan at 75 and 150 mg/kg respectively.

Chronic toxicity was evaluated following twice weekly intravenous injections of saline solution containing soluble phosphorylated glucan at 0, 40, 200 and 1000 mg/kg doses. Body and organ weights, gross and microscopic pathology, serum electrolytes, solutes and serum enzymes indicative of renal and hepatic function were monitored.

In one series of experiments mice were weighed respectively at 0, 8, 11, 15, 22 and 30 days post-treatment with soluble phosphorylated glucan. No significant difference was observed in body weight at any dose of soluble phosphorylated glucan administered. After 30 days chronic treatment, animals were sacrificed. No change was seen in weight of liver, lung and kidney. A statistically significant increase in spleen weight was noted in mice treated with 40 and 100 mg/kg soluble glucan ($.01<p\leq 0.001$), but not in mice treated with 200 mg/kg.

In another series of experiments, mice were weighed respectively at 0, 15, 30, 49 and 60 days post-treatment (twice weekly) with soluble phosphorylated glucan. No significant difference was observed in body weight at any dose of soluble phosphorylated glucan administered. After 60 days chronic treatment with soluble phosphorylated glucan, animals were sacrificed. No significant difference was observed in weight of the liver, kidney or lung. A statistically significant increase in spleen weight was apparent in mice treated with 1000 mg/kg soluble phosphorylated glucan ($p<.001$).

After 30 or 60 days chronic treatment, no significant alteration was apparent in the following serum components: glucose, blood urea nitiogen (BUN), uric acid, cholesterol, triglycerides, total protein, albumin, globulin, creatinine, calcium, phosphorous, sodium, potassium, chloride, bicarbonate and anion gap. Moreover, no significant alteration was apparent in the following enzymes: alkaline phosphatase, lactic dehydrogenase, serum glutamic oxalacetic transaminase, serum glutamic pyruvic transaminase and

creatinine phosphokinase. No change was detectable in serum bilirubin.

Histological studies on tissues obtained from mice following 30 days chronic treatment showed essentially normal liver histology in mice receiving 40 and 200 mg/kg soluble phosphrylated glucan per injection. In animals receiving 1000 mg/kg soluble phosphorylated glucan, monocytic infiltrates were readily apparent in the liver. Lung and kidney tissues were essentially normal in all mice.

Histological studies on tissues obtained from mice following 60 days chronic treatment showed few hepatic granuloma of an isolated nature in animals receiving injections at 40 and 200 mg/kg doses. A higher number of monocytic infiltrates was observed in mice receiving injections at 1000 mg/kg. In all autopsied animals, lung tissue was essentially normal.

Chronic toxicity was further evaluated using guinea pigs (Harlan Sprague Dawley, Houston, TX) receiving 5 ml intraperitoneal injections of saline solution containing soluble phosphorylated glucan at 250 mg/kg for 7 days (FDA required test). Results presented in Table 3 indicate that there was an impairment of growth of guinea pigs receiving soluble glucan treatment when compared to controls receiving an equivalent volume of 0.9% saline solution. Following 7 days chronic treatment, body weight of treated animals was, however, significantly increased by 9% as compared to initial weight.

TABLE 3

EFFECT OF CHRONIC ADMINISTRATION OF SOLUBLE PHOSPHORYLATED GLUCAN ON BODY WEIGHT

Treatment	Mean Body Weight (gm)[a] Days						
	1	2	3	4	5	6	7
Saline	213.8 ± 4.0	225.2 ± 6.6	227.4 ± 7.1	234.2 ± 7.3	239.7 ± 6.1	244.2 ± 5.2	253.8 ± 7.5
SPG[b]	208.9 ± 2.9	202.3 ± 5.0	203.9 ± 5.3	207.4 ± 5.3	214.3 ± 6.0	215.6 ± 6.6	227.3* ± 6.6

[a] Values represent mean body weight (gm) ± standard error. N=5 animals.

[b] SPG designates soluble phosphorylated glucan

* $p < .0.01$

Chronic Toxicity was also evaluated in 2 adult female dogs receiving twice weekly intravenous administration (5mg/kg) of soluble phosphorylated glucan for 120 days. The dogs were fed Purina Chow and water ad libitum supplemented with one can commercial dog food (Alpo™) twice weekly. Body weight and serum solutes, electrolytes and enzymes were monitored at 0, 17, 24, 38, 80 and 120 days. Following 120 days chronic treatment, a mean weight gain of 2.8 kg or about 22% body weight was observed.

No significant difference was observed in the following serum solutes: glucose, BUN, uric acid, cholesterol,

creatinine. No significant difference was observed in the following serum electrolytes: calcium, phosphorous, sodium, potassium, chloride, bicarbonate, and anion gap. No significant difference was observed in the following serum enzymes: alkaline phosphatase, lactic dehydrogenase, serum glutamic oxalacetic transaminase, serum glutamic pyruvic transaminase and creatinine phosphokinase.

Additonally, no significant difference has been observed in the serum biochemistry of a patient following therapy for 3 months with soluble phosphorylated glucan at 50 mg/ml, administered three times per week.

5.3.2. NON-PYROGENICITY

Pyrogenicity of soluble phosphorylated glucan was evaluated following a single intravenous injection to conscious dogs at doses of 7.5 mg/kg and 30 mg/kg. Body temperature was monitored for 14 days post-injection.

Results presented in Table 4, demonstrate no pyrogenic reaction in this chronic animal model.

TABLE 4

ABSENCE OF AN ACUTE OR CHRONIC PYROGENIC RESPONSE IN DOGS

Treatment Dose[a] (mg/kg)	Mean Body Temperature (°C) Time (Hours)					
	0	1	6	24	144	336
7.5	38.3	37.4	38.3	38.3	38.3	38.4
30.0	38.6	37.0	38.0	38.5	38.4	38.6

[a] N = 3 dogs/group.

Pyrogenicity was also evaluated using three dogs anesthetized with Nembutal (30 mg/kg) receiving multiple injections of increasing doses of 1, 5, 10, 15, 25 and 50 mg/kg of soluble phosphorylated glucan over a three hour period. Body temperature was determined at 15 minutes following bolus injections. No pyrogenic effect was observed at any dose.

Pyrogenicity of soluble phosphorylated glucan was also evaluated in rabbits. Seven rabbits were divided into 2 groups of 2 and 5 rabbits each. Group 1 received an isovolumetric saline solution; Group 2, received 5 mg/kg soluble phosphorylated glucan in saline solution by intravenous injection. Core body temperature was monitored at 15 minute intervals for 100 minutes following a single bolus injection. Control rabbits showed a mild decrease of 0.2°C in body temperature. Rabbits treated with soluble

phosphorylated glucan showed a mean increase of 0.44°C. Thus, there was a slight pyrogenicity seen in rabbits.

5.3.3. NON IMMUNOGENICITY

The interfacial ring test, designed to detect the presence of IgG antibodies, was used to evaluate the immunogenicity of soluble phosphorylated glucan when chronically administered to dogs for 120 days.

Serum samples were obtained from an adult female dog following 120 days chronic treatment with twice weekly intravenous injections of 5 mg/kg sterile, pyrogen-free soluble phosphorylated glucan. The interfacial ring precipitin test was performed as follows: 0.1 ml of undiluted antisera was pipetted into test tubes. The antigen or phosphorylated soluble glucan at dilutions of 1:2, 1:4, 1:8, 1:16 and 1:32 was layered onto the anti-sera to form a straight interface. Formation of a white precipitin ring at the interface, indicates that presence of antibody specific for the glucan. No precipitin ring was detected at any antigen dilution.

5.4. USES OF SOLUBLE PHOSPHORYLATED GLUCAN

5.4.1. PROPHYLAXIS AND THERAPY OF INFECTIOUS DISEASES

Due to the potent activity of the soluble phosphorylated glucan in stimulating the immune response and reticuloendothelial system, it is advantageously useful in prophylactic and therapeutic applications against diseases induced by a variety of microorganisms. Because soluble phosphorylated glucan influences very fundamental host

defense systems of the body regulating the number, functional activity and interaction of macrophages, T and B lymphocytes, leukocytes and natural killer cells as well as their humoral and secretory components, it possesses the potential for non-specifically modifying an extensive array of infections diseases.

The soluble phosphorylated glucan can be used either alone or in combination with known antimicrobial agents to prevent and treat diseases induced by gram positive bacteria including, but not limited to: Staphylococcus aureus, Streptococcus pneumoniae, Mycobacterium tuberculosis, Haemophilus influenzae, Diplococcus pneumoniae; gram negative bacteria including, but not limited to: Escherichia coli; Bacterium enteritis, Francisella tularensis; acid-fast bacteria including, but not limited to Mycobacterium leprae; viruses including but not limited to: Hepatitis; Herpes simplex I and II; etc.; fungi including, but not limited to: Candida albicans; Sporotrichum schenkii; and protozoal parasites including but not limited to Leishmania donovani, Schistosoma mansoni, etc.

Additionally, the soluble phosphorylated glucan may be used for the prevention and treatment of opportunistic infections in animals and man which are immunosuppressed either as a result of congential or acquired immunodeficiency or as a side-effect of chemotherapeutic treatment.

Soluble phosphorylated glucan demonstrates a number of characteristics which make it particularly advantageous for the treatment of infections including, but not limited to the following advantages:

(1) Soluble phosphorylated glucan has a broad range of activity. It is effective against infections induced by bacteria, fungi, viruses and parasitic organisms;

(2) Soluble phosphorylated glucan has additive or synergistic effects in combination with bioactive agents conventionally used to treat infections including but not limited to aminoglycoside antibiotics, etc.;

(3) Soluble phosphorylated glucan does not induce the development of resistance in causative organisms because its effects are mediated by the host;

(4) Soluble phosphorylated glucan has very low toxicity;

(5) Soluble phosphorylated glucan prevents and corrects the development of leukopenia;

(6) Soluble phosphorylated glucan enhances a variety of diverse aspects of cellular and humoral immune responses of the host; and

(7) Soluble phosphorylated glucan prevents or reverses the development of immunosuppression in the host.

5.4.2. THERAPY OF NEOPLASMS

Due to the stimulation of macrophage phagocytic and secretory activity and increased proliferation of macrophages caused by soluble phosphorylated glucan, this composition can advantageously be used either alone or in combination with other modalities such as surgery and chemotherapy, to treat malignant neoplastic diseases including, but not limited to adenocarncioma, reticulum cell sarcoma, etc.

Additionally, because soluble phopsphorylated glucan exerts direct inhibitory effects on the proliferation of tumor cells including but not limited to lymphocytic leukemic cells, this composition can advantageously be used to inhibit tumor growth and metastases.

Finally, soluble phosphorylated glucan is demonstrated (see Section 7) to stimulate the production and secretion of a soluble cytotoxic/cytostatic factor in macrophage cells (hereinafter, macrophage cytotoxic factor "MCT"). MCT is a soluble protein fraction of unknown structure isolated from the supernatant culture medium of macrophage cells that is toxic to cancerous cells including but not limited to adenocarcinoma, etc. Thus, the soluble phosphorylated glucan may be advantageously used to stimulate MCT production in vivo. Additionally, soluble phosphorylated glucan can be used to stimulate production of MCT by macrophage cells in vitro.

5.5. ROUTES OF ADMINISTRATION

The soluble phosphorylated glucans of the present invention can be administered for prophylatic and therapeutic applications by a number of routes, including but not limited to: orally, by injection including but not limited to intraveneously, intraperitoneally, subcutaneously, intramuscularly, etc., by topical application to nasal and nasopharyngeal linings, and by inhalation via aerosolization and application to respiratory tract linings, etc.

When administered to an animal or a human, the soluble phosphorylated glucan may be combined with water, an aqueous

solution or any physiologically acceptable pharmaceutical carrier or vehicle.

The following series of Examples are presented for purposes of illustration and not by way of limitation on the scope of the invention.

6. PREPARATION OF SOLUBLE PHOSPHORYLATED GLUCAN

Particulate glucan was prepared from Saccharomyces cerevisiae according to the method of Di Luzio et al. (1979, Int'l J. Cancer 24: 773-779). Briefly, using a 6 l flask, 540 gm of dry yeast (Universal Foods Corp., Milwaukee, WI) was suspended in 3 l of 3% aqueous sodium hydroxide solution. The suspension was placed in boiling water bath 4 hours, cooled overnight and the supernatant decanted. This procedure was repeated three times. The residue was then acidified with 800 ml of concentrated hydrochloric acid plus 2 l of 3% hydrochloric acid and placed in a boiling water bath for 4 hours. The suspension was allowed to stand overnight and the supernatant decanted. The residue was further digested with 3 l of 3% hydrochloric acid at 100 °C for 4 hours, cooled overnight and decanted. The 3% hydrochloric acid digestion was repeated twice. The residue was then washed three times with distilled water (20 °C) and twice with distilled water at 100 °C. One l of ethyl alcohol was added to the residue, mixed thoroughly and allowed to stand a minimum of 24 hours for maximum extraction. The dark reddish-brown alcohol supernatant was aspirated from the residue and discarded. The alcohol extraction procedure was repeated until the alcohol supernatant was essentially colorless. The alcohol was removed by washing the residue four times with hot water;

the particulate glucan preparation was then collected by centrifugation, frozen and lyophilized.

Soluble phosphorylated glucan was prepared according to the present invention by solubilization and phosphorylation of the particulate glucan as follows:

18 gm of urea (8 M) was dissolved in a flask containing 50 ml dimethylsulfoxide (DMSO) with constant stirring. One gm of particulate glucan was added to form a finely divided suspension. The flask was heated to 100°C and 10 ml of phosphoric acid (85%) was added slowly dropwise. The mixture was maintained at 100°C for 3-12 hours by immersion in a boiling water bath. It is preferred to allow the reaction to proceed for about 6 hours.

During the heating process, a precipitate was formed which became visible after about 1 hour and increased in amount thereafter. After about 6 hours, the mixture was cooled and diluted with 200 ml distilled water to resuspend the precipitate. The mixture was then filtered through course, medium and fine sintered funnels to remove the precipitate.

The resulting solution was then molecularly sieved in order to remove low molecular weight (MW) fractions including glucose, DMSO and urea.

In one series of experiments, molecular sieving was accomplished by dialysis for 5 days against running distilled water using Spectrapor membrane dialysis tubing (Fisher Scientific Co; Pittsburgh, PA). The MW size range

of pores of this tubing is about 12,000 daltons. In another series of experiments, molecular sieving was accomplished using a Millipore dialyzer/concentrator (Millipore Corp., Bedford, MA) with a 10,000 MW membrane filter. About 70 l of dialyzing solution were used to remove low MW compounds. In either case, tests for the presence of glucose in the final preparation were negative. Moreover, using high performance gas-liquid chromatography, no DMSO was detectable in the final preparation.

Following molecular sieving, the solution containing the phosphorylated soluble glucan was concentrated and lyophilized. This phosphorylated glucan is stable in a lyophilized state for at least 2 years and at least for 15 months in solution maintained at -20°C.

7. IMMUNOBIOLOGICAL PROPERTIES OF SOLUBLE PHOSPHORYLATED GLUCAN

In all experiments reported below, animals were maintained on Purina Laboratory Chow ad libitum in air-conditioned rooms maintained on 12 hour light/dark cycles.

7.1. MODIFICATION OF ENHANCED SUSCEPTIBILITY TO OPPORTUNISTIC INFECTIONS IN IMMUNOSUPPRESSED ANIMALS

Animals which are immunosuppressed either because of chemotherapy, congenital or acquired immunodeficiency (e.g., acquired immunodeficiency syndrome or AIDS) are susceptible to infection by a variety of opportunistic organisms. For example, a major cause of death in patients suffering AIDS is pneumonia caused by Penumocystis carinii (see e.g., Jaffee et al., 1983, J. Infect. Dis. 148:339-

345; Gottlieb et al., 1981, New Eng. J. Med. 305:1425-1431).

Previous studies by Walzer et al. (1983, J. Reticuloendothel. Soc. 33:1-9; 1979; Infec. Immunol. 24:939-947) have demonstrated that when immunosuppressed by chronic administration of a corticosteroid, the C3H/HeJ strain of mice is more susceptible to pneumonia induced by P. carinii than are other mouse strains. In these animals, like man, development of Pneumocystis pneumonia represents activation of latent infection due to the development of immunosuppression.

The following experiments demonstrate that administration of soluble phosphorylated glucan to chronically immunosuppressed C3H/HeJ mice significantly enhanced survival and reduced susceptibility of these animals to opportunistic infections.

7.1.1. ENHANCED SURVIVAL

In one series of experiments, 100 C3H/HeJ mice (Jackson Laboratories, Bar Harbor, ME) were divided into 4 groups of 25 mice each. Group 1 received 0.5 ml of a 5% glucose solution intravenously; Group 2, 5 mg soluble phosphorylated glucan intravenously; Group 3, 1.5 mg cortisone acetate (Upjohn, Kalamazoo, MI) subcutaneously; and Group 4, both 5 mg soluble phosphorylated glucan intravenously and 1.5 mg cortisone acetate subcutaneously. All mice were treated twice weekly for 5 weeks, and survival was monitored for 60 days. It should be noted that animals treated with cortisone acetate were severely

immunosuppressed since the dose of steroid administered was well above that shown by Walzer (supra) to be required.

Results are illustrated in FIG. 3. As demonstrated in FIG. 3, there was no mortality in mice treated either solely with glucose (Group 1) or soluble phosphorylated glucan (Group 2). By day 24, survival of mice treated with corticosteroid alone was 12% (Group 3). Histopathological studies indicated that contributing causes of death were bacterial and fungal infections, including those of the brain. In contrast, by day 24, survival in mice treated with corticosteroid and soluble phosphorylated glucan was about 68% (Group 4). Long term survival of such mice was 66%, highly statisically significant when compared to corticosteroid-treated mice ($p<0.001$).

7.1.2. ENHANCED RESISTANCE IMMUNO-SUPPRESSED MICE TO ESHERISCHIA COLI INFECTION

The following experiment demonstrates that administration of soluble phosphyorylated glucan enhanced resistance of both normal and chronically immunosuppressed mice to infection by E. coli.

Sixty C3H/HeJ mice were divided into 4 groups of 15 mice each. Group 1 recieved three injections of 5% glucose (0.5 ml) intravenously; Group 2, three injections of 4 mg/animal soluble phosphorylated glucan intravenously; Group 3, three injections of 1.5 mg/animal cortisone acetate subcutaneously; and Group 4, three injections of a combined 4 mg/animal soluble phosphorylated glucan intravenously and 1.5 mg/animal cortisone acetate subcutaneously at three day intervals. Three days

following the last injection, the mice received 2.5×10^7 E. coli bacteria intraperitoneally. Survival was monitored for 15 days post-infection with E. coli.

Results illustrated in FIG. 4 demonstrate 65% survival in normal glucose-treated mice infected with E. coli (Group 1). No deaths occurred in this group after 7 days post-infection with E. coli. In contrast, 0% mortality was observed in normal mice treated with soluble phosphorylated glucan (Group 2). Thus, pretreatment with soluble phosphorlylated glucan significantly enhanced resistance to E. coli infection in normal animals.

Results presented in FIG. 4 also demonstrate marked mortality of mice chronically immunosuppressed by administration of corticosteroid. In immunosuppressed mice treated with glucose (Group 3), 50% mortality was noted at 40 hours and 75% mortality, at 5 days. In marked contrast, in immunosuppressed mice treated with soluble phosphorylated glucan (Group 4) 0% mortality was observed. Thus in both control and cortisone-treated mice, soluble glucan was able to enhance host resistance resulting in complete protection to a Gram-negative infection both in normal and cortisone-immunosuppressed mice.

These studies, demonstrate that the administration of soluble glucan to mice receiving immunosuppressive doses of cortisone results in modification of the cortisone-induced susceptibility to infection. Therefore, glucan is capable of modifying not only the immunosuppressive effects of chronic administration of cortisone leading to decreased mortality from spontaneous infections, but also the relatively acute immunosuppressive effects of cortisone.

7.2. MODIFICATION OF BACTERIAL DISEASES IN ANIMALS BY IN VIVO ADMINISTRATION OF SOLUBLE PHOSPHORYLATED GLUCAN

7.2.1. MODIFICATION OF STAPHYLOCOCCUS AUREUS INDUCED SEPSIS

The following experiment demonstrates the effectiveness of in vivo administration of soluble phosphorylated glucan in modifying the lethal effects of sepsis associated with Staphylococcus aureus.

Twenty ICR/TEX mice were divided into two groups and treated as follows. At 3, 2 and 1 days prior to the induction of sepsis, Group 1 received intravenous injections of soluble phosphorylated glucan at 200 mg/kg; Group 2, designated a control group, received intravenous injections of an equivalent volume of isotonic glucose. One day following the third administration of polysaccharide, both groups received an intravenous injection of 1.0×10^9 cells S. aureus. Survival of experimental and control mice was monitored for 130 days.

Results are illustrated in FIG. 5. As demonstrated therein, at 2 days post-infection with S. aureus, 60% mortality was observed in the glucose-treated mice (Group 2). At the same time, however, 0% mortality was observed in those animals treated with soluble phosphorylated glucan prior to infection. At 8 days post-infection, 27% of the control group survived. In contrast, survival of the animals treated with soluble phosphorylated glucan was 100% at the same time. No further deaths occurred in either groups in 130 days. Thus, pre-treatment with soluble

phosphorylated glucan significantly reduced lethality of a subsequent S. aureus infection.

7.2.2. MODIFICATION OF ESCHERICHIA COLI INDUCED PERITONITIS

7.2.2.1. TIME REQUIRED FOR PROTECTIVE EFFECT

The following experiments demonstrate the effectiveness of intraperitoneal administration of soluble phosphorylated against a subsequent experimentally induced E. coli sepsis.

Seventy nine adult white mice were divided into 8 groups of 8-13 animals each. Group 1, designated control, received 1 ml glucose (5%); Group 2, designated positive control, 3 mg particulate glucan; and Group 3, 12.5 mg soluble phosphorylated glucan at 24 hours prior to challenge with E. coli. Groups 4, 5, 6 and 7 received 12.5 mg soluble phosphorylated glucan at respectively 6, 2, 1, 0 hours prior to challenge with E. coli. Group 8 received 12.5 mg soluble phosphorylated glucan at 2 and 4 hours following challenge with E. coli. All treatments were administered via intraperitoneal injections. E. coli (1.0×10^8 cells) was also injected via an intraperitoneal route. Results are illustrated in Table 5.

TABLE 5

EFFECT OF TIMING OF ADMINISTRATION OF SOLUBLE PHOSPHORYLATED GLUCAN ON MORTALITY DUE TO E. COLI SEPSIS

Group Number[a]	Treatment[b]	Time (Hours)[c]	% Survival Time (Hours) Post-Infection[d] 12	16	24	48
1	Glucose	- 24	40	0	0	0
2	PG	- 24	100	100	88	88
3	SPG	- 24	80	80	70	70
4	SPG	- 6	100	100	100	88
5	SPG	- 2	20	20	20	20
6	SPG	- 1	20	20	20	20
7	SPG	0	30	0	0	0
8	SPG	+2, +4	80	0	0	0

[a] Group number refers to treatment protocol explained in text. The number of animals in each group was 8-13.

[b] PG designates Particulate Glucan; SPG designates Soluble Phosphorylated Glucan

[c] Time at which animals were treated.

[d] No additional mortality was observed in any group after the 48 hour period.

As demonstrated in Table 5, intraperitoneal administration of soluble phosphorylated glucan signficantly enhanced survival of mice with experimentally induce E. coli peritonitis (Groups 3 and 4). As observed, the soluble phosphorylated glucan could effectively be administered as late as 6 hours prior to challenge with E. coli.

Administration of soluble phosphorylated glucan either simultaneously with or subsequent to administration of E. coli was not effective in reversing the lethality of E. coli peritonitis (Groups 7 and 8) due to the fulminant nature of the infection.

7.2.2.2. DOSE-RESPONSE

Another series of experiments was conducted to determine the effect of administration of various doses of soluble phosphorylated glucan on E. coli induced peritonitis and lethality.

One hundred and six white mice were divided into groups of 9-30 mice each. Groups 1-2, designated controls received isovolumetric glucose. Groups 2-7 received soluble phosphorylated glucan at respectively 1, 1, 2, 4, 8, 10, 20, 120, 200 and 260 mg/kg. All injections were administered intraperitoneally at 24 hours prior to the induction of peritonitis by intraperitoneal administration of E. coli (1×10^8 cells). Results are illustrated in Table 6.

TABLE 6

EFFECT OF DOSE OF SOLUBLE PHOSPHORYLATED GLUCAN (SPG) ON LETHALITY OF INTRAPERITONEAL OF ADMINISTRATION OF E. COLI[a]

Group Number	Treatment	Number of Mice	Dose (mg/kg)	% Survival
1	Glucose	30	-	13
2	SPG	22	1	78
3	SPG	12	2	83
4	SPG	12	4	83
5	SPG	12	8	83
6	SPG	9	10	100
7	SPG	9	20	89

[a] Single injection of either glucose or soluble phosphorylated glucan given intraperitoneally 24 hours before challenge with E. coli. Survival was recorded at 24 hours post-challenge.

As demonstrated in Table 6, all doses of soluble phosphorylated glucan ranging from 1 mg/kg to 20 mg/kg were about equally effective in enhancing survival in animals challeged by intraperitoneal infection with E. coli.

7.3. EFFECT OF SOLUBLE PHOSPHORYLATED GLUCAN ON VIRAL INDUCED HEPATITIS

Previous studies have demonstrated that particulate glucan is capable of increasing survival, inhibiting hepatic necrosis, and maintaining an activiated state of phagocytic activity in mice challenged with murine

hepatitis virus (MHV) strain A59 (Williams and Di Luzio, 1980, Science 208:67-69).

The following experiment demonstrates that prior administration of soluble phosphorylated glucan enhanced survival of mice with experimentally induced viral hepatitis.

Twenty male C57BL/6 Tex mice (Timco, Houston, TX) were divided into two groups. Group 1 designated controls, received intravenous injection of glucose (0.5 ml/mouse) and Group 2 received intravenous injection of soluble phosphorylated glucan (5 mg/mouse) at 3, 2 and 1 days before induction of acute viral hepatitis. Hepatitis was induced by intraperitoneal injection of 16 complement fixing units (CFU) of MHV strain A59.

Survival of mice was monitored for 30 days following administration of virus. Results are illustrated in FIG. 6.

As demonstrated in FIG. 6, intravenous administration of soluble phosphorylated glucan significantly enhanced survival in mice with acute viral hepatitis. At 6 days post-induction of hepatitis, 50% survival was observed in the control group. In contrast, at that time 100% survival was observed in the group pre-treated with soluble phosphorylated glucan. No further mortality was observed in either group (day 7-30).

7.4. EFFECT OF ORALLY ADMINISTERED SOLUBLE PHOSPHORYLATED GLUCAN ON CANDIDA ALBICANS-INDUCED SEPSIS

The following experiment demonstrates that orally administered soluble phosphorylated glucan is effective in modifying the lethal effects of sepsis induced by the yeast Candida albicans.

Twenty-five male ICR/Tex mice were divided into two groups. Group 1 (13 animals) were maintained for seven days on drinking water containing 5.0 mg/ml soluble phosphorylated glucan. The mice drink about 1.2-1.5 ml/day, thus treated animals received about 7 mg/day soluble phosphorylated glucan orally. Group 2, designated control group (12 animals), were maintained on tap water throughout the experimental period. On day zero, all animals were injected with Candida albicans (3.0×10^6 cells/mouse) intravenously. Group 1 continued to receive soluble phosphorylated glucan orally, in drinking water, for 5 days post-infection, then these animals were maintained on tap water. The body weight of mice in both groups was monitored. Mice in both groups 1 and 2 gained weight at the same rate. Survival in both groups was also monitored. Results are graphically illustrated in FIG. 7.

As demonstrated in FIG. 7, oral administration of soluble phosphorylated glucan pre-and for 5 days post-infection with C. albicans resulted in a significant, but transient increase in survival of mice. At 25 and 30 days post-infection, the survival in the soluble phosphorylated glucan-treated group was significantly greater (at the $p<.05$ level) than in the control group. (Chi-square test $\lambda < .05 < .01$). The median survival time for the control

Group was 18 days; whereas for the soluble phosphorylated glucan treated group, median survival time was 30 days. With regard to long-term survival, however, the ultimate outcome was not significantly altered. Thus, this experiment suggests that higher dose of soluble phosphorylated glucan may be needed when administered orally.

7.5. ENHANCEMENT OF MACROPHAGE PHAGOCYTIC ACTIVITY

The following experiment demonstrates that administration of soluble phosphorylated glucan significantly enhanced phagocytic function of macrophages.

Twenty male ICR mice were divided into two groups of 10 each. At 3, 2 and 1 day prior to determiniation of phagocytic activity, Group 1, designated control received injections of isovolumetric saline; Group 2, soluble phosphorylated glucan (200 mg/kg). All injections were administered intravenously.

Phagocytic function was evaluated by measuring the rate of intravascular clearance of colloidal carbon (C11/143 (a), Gunther Wagner, Hanover, Germany) according to the method of Wooles et al. (1962, Rad. Res. 16: 546-554). Colloidal carbon was administered (640 mg/kg) intraveneously and serial blood samples were obtained from tail veins. Aliquots were hemolyzed in 4.0 ml of 0.5% sodium carbonate and the concentration of colloidial carbon was determined spectrophotometrically. The half-time (t/2) was taken as the time at which the optical density or concentration was one-half the zero time value as

determined by extrapolation of the clearance curves to zero time. Results are presented in Table 7.

TABLE 7

EFFECT OF SOLUBLE PHOSPHORYLATED GLUCAN (SPG) ON MACROPHAGE PHAGOCYTIC FUNCTION

Treatment[a]	Body Weight (gm)	Liver Weight (gm)	Intravascular Clearance t/2 (minutes)
Saline	24.8 ± 0.82	1.94 ± 0.05	7.6 ± 0.73
SPG	25.2 ± 1.03	1.82 ± 1.03	3.5 ± 0.58*

[a] N = 10 per group.

*$p < 0.001$

As demonstrated in Table 7, administration of soluble phosphorylated glucan significantly enhanced phagocytic function as reflected by a 55% increase in clearance. (Table 7) As previously observed, no increase in liver weight occurred (Table 7).

7.6. ENHANCEMENT OF MACROPHAGE SECRETORY ACTIVITY

A major secretory product of macrophages, particularly in an activated state, is a mediator molecule called Interleukin I. Interleukin I is a polypeptide which induces, both in experimental animals and man, an acute phase protein response. This response includes increased erythrocyte sedimentation rates, leukocytosis, elevated acute phase proteins, and development of fever due to

endogenous pyrogen. Additionally, Interleukin I has the ability to profoundly stimulate T-cell activation and proliferation. Thus, Interleukin I is a lymphocyte activating factor capable of cellular recruitment and, hence, enhances host defense activity.

The following experiment demonstrates that administration of soluble phosphorylated glucan stimulates macrophage secretory activity as assayed by the secretion of Interleukin I.

A number of rats (16) were injected intravenously with soluble phosphorylated glucan (200 mg/kg). Eight control animals received isovolumetric glucose. Plasma samples were obtained at 1, 3, 5, 8, 24, 48, 72 and 168 hours post-injection.

Production of Interleukin I was evaluated employing C-57 BL/6J thymocytes. Cultures of thymocytes (1×10^6 cells) were incubated with media alone, or with 0.1 ml plasma from control or soluble phosphorylated glucan-treated rats. The cell cultures were maintained for 24 hours, at which time 1μ Ci of ^{3}H-thymidine was added, and incubation was carried out for another 24 hour period. At that time, thymidine uptake was measured. Results are presented in FIG. 8.

As illustrated in FIG. 8, serum obtained from soluble phosphorylated glucan-treated rats showed increased Interleukin I activity as reflected by the elevation in thymidine uptake by thymocytes at 1, 24, 48 and 72 hours compared to serum obtained from rats treated with glucose. Thus, soluble phosphorylated glucan rapidly activates

macrophages and increases secretory activity, as reflected by elevated plasma interleukin levels. The nature of the 24-72 hour peak remains to be established.

7.7. ENHANCEMENT OF ANTI-TUMOR CYTOTOXIN PRODUCTION BY MACROPHAGES IN VITRO

The following experiments were conducted to evaluate the production of macrophage cytotoxic/cytostatic factors (MCT) by macrophages under the stimulation of soluble phosphorylated glucan.

Splenic macrophages, obtained from C57BL/6J mice, (5×10^6 cells) were incubated with RPMI 1640 media with 7.5% Fetal Calf Serum, 50 IU/ml penicillin G, 50 µg/ml streptomycin, 50 µg/ml gentamycin sulfate, 10 µg/ml Amphotericin B, and 2 mg/ml $NaHCO_3$. Control cells were incubated with media alone. Experimental cells were incubated in media containing soluble phosphorylated glucan (5 mg/ml). All cell cultures were maintained for 20 hours at 37°C, under 5% CO_2, 95% air in Falcon 2013 culture flasks. After incubation, the culture supernatant was collected by centrifugation and all cells removed by passage through a 0.22 µ filter.

In the assay for the presence of MCT, adenocarcinoma cells (BW10232) were labeled with ^3H-thymidine and washed three times to remove any unincorprated radioactivity. The labeled tumor cells (2 x cells 10^4 in 0.1 ml) were then added to microtiter wells, the supernatants to be tested for MCT were added in 0.1 ml volumes, and the cells were incubated for 24 hours. After incubation the microtiter plates were centrifuged and 0.1 ml aliquots assayed for radioactivity. The released radioactivity, representing an

index of tumor cells lysis, varies directly with the amount of MCT present. Additonally, qualitative evaluation of the degree of cytolysis and cytostasis was obtained by fixing tumor cells with ethanol and staining with giemsa, Results are presented in Table 8.

Supernatant from control or resting macrophages, i.e., non-soluble phosphorylated glucan-treated, contains a cytotoxic factor (MCT) which enhances the release of ^{3}H-thymidine from adenocarcinoma cells when compared with media alone (Table 8). Supernatant from glucan-stimulated macrophages, however, produces substantially more MCT. A significant enhancement in cytotoxicity is manifested. (Table 8).

TABLE 8

ENHANCED CYTOTOXICITY OF SOLUBLE PHOSPHORYLATED GLUCAN-ACTIVATED MACROPHAGE SUPERNATANT AGAINST ADENOCARCINOMA BW10232

% 3H-Thymidine Release [a]		
Media Control	Supernatant Resting Macrophages	Supernatant SPG-Activated Macrophages
27.2 ± 2.8	53.4 ± 6.6*	88.9 ± 3.7**

[a] Values represent mean ± S.E. for 6 replicates per group.

*$p<0.01$

**$p<0.001$

In an effort to demonstrate that the enhanced cytolytic effect of the supernatant fraction was not due to a direct effect of glucan, ^{3}H-thymidine labeled tumor cells were incubated in the presence of 0.5 mg of soluble phosphorylated glucan for 24 hours. Results are presented in Table 9.

TABLE 9

ABSENCE OF DIRECT CYTOTOXIC EFFECT OF SOLUBLE PHOSPHORYLATED GLUCAN ON ADENOCARCINOMA BW10232 IN VITRO

% ^{3}H-Thymidine Release [d]	
Media Control	Soluble Phosphorylated Glucan
27.2 ± 2.8	22.4 ± 1.8

[a] Values represent means ± S.E. for 6 replicates per groups.

As can be observed in Table 9, soluble phosphorylated glucan had no significant effect on the release of thymidine from pre-labeled tumor cells. It can, therefore, be concluded that the enhanced release of thymidine by tumor cells was due to a macrophage produced product in the supernatant from cells cultured with soluble phosphorylated glucan.

Confirmation of the cytotoxic/cytostatic effects of the supernatant fraction was obtained by histological evaluation of the cultures. Excellent growth was apparent

in adenocarcinoma cells (BW 10232) cultured in media alone. In accord with the previously described data relating to ^{3}H-thymidine release, normal growth was also apparent in tumor cells cultured for 24 hours with media containing soluble phosphorylated glucan. This confirms the absence of a direct cytotoxic effect of soluble phosphorylated glucan on the tumor cell line. In marked contrast, significant cell injury and lysis was apparent in tumor cells incubated with the supernatant from macrophage cultures treated with soluble phosphorylated glucan. The degree of cell injury and lysis observed in such tumor cell cultures was considerably greater than that observed when supernatant from normal or control macrophages was added to the culture medium. Thus, soluble phosphorylated glucan induced resting macrophages to increase their production of a tumor cytolytic factor.

Since the cytotoxic/cytostatic factor MCT was found to be a protein, studies were undertaken to define its properties, such as molecular weight(s). Fifty mg of the dried supernatant from macrophage cell cultures was dissolved in 1 ml of sterile water and added to a 1.5 cm x 90 cm glass column (LKB Instruments) packed with Sephacryl S-300 superfine matrix (Pharmacia Fine Chemicals, Piscataway, NJ). The column was operated at a flow rate of 0.2 ml/min using phosphate buffered saline as the eluent. Fractions were collected at 1 ml intervals and tested for cytostatic activity. Results are graphically illustrated in FIG. 9.

As shown in FIG. 9, the column chromatography of soluble phosphorylated glucan-activated macrophage culture supernatant yielded 2 peaks with cytotoxic activity against

adenocarcinoma cells. The peaks elute at volumes indicative of molecular weights of 38,500 and 84,000 daltons.

7.8. MODIFICATION OF METASTATIC LIVER DISEASE

The following experiment demonstates that administration of soluble phosphorylated glucan either alone or in conjunction with an anti-cancer agent, e.g., cyclophosphamide, reduced growth of primary tumor and metastasis of reticulum cell sarcoma in mice.

One hundred twenty C57BL/6J mice (Jackson Laboratories, Bar Harbor, ME) were divided into 4 groups of 30 each. All mice received subcutaneous injection of 1.0×10^4 reticulum cell sarcoma cells M5076. Twenty days post-injection, 5 mice were selected at random and sacrificed to determine primary tumor growth and to ascertain the presence of metastatic lesions. The average primary tumor weight was 1.86 gm or 6.4% of body weight, and all animals examined had organ specific liver micrometasases. The percent change in primary tumor weight was calculated using the tumor weight at 20 days as a reference.

At twenty days post-tumor transplantation and every 3 days until 50 days thereafter, Group 1, designated controls received glucose (0.5 ml) intraveneously; Group 2 received soluble phosphorylated glucan (200 mg/kg body weight) intravenously; Group 3 received cyclophosamide (Cytoxan, Mead Johnson, Evansville, IN) (45 mg/kg body weight); and Group 4 received a combination of soluble phosphorylated

glucan (200 mg/kg body weight) intraveneously and cyclophosphamide (45 mg/kg body weight) intraperitoneally.

Effects of various treatments on the growth of primary tumor are presented in Table 10. Effects on survival are presented in Table 11.

TABLE 10

SOLUBLE PHOSPHORYLATED GLUCAN-CYCLOPHOSPHAMIDE CHEMO-IMMUNOTHERAPY: SYNERGISTIC EFFECT ON PRIMARY TUMOR

Treatment Group Number[a]	Tumor Weight (% of Body Weight)	
	Day 30	Day 36
1	12.6	15.5
2	8.3	11.8
3	8.5	8.7
4	4.4	2.3

[a] All groups of $_4$C57BL/6J mice were subcutaneously injected with 1.0×10^4 reticulum endothelial cells at day 0. At day 20, the mean weight of the primary tumor was 1.86 g or 6.4% body weight. At day 20 day and every 3 days thereafter mice received the appropriate drug treatment. See text for details.

As demonstrated in Table 10, 30 days post-injection of reticulum sarcoma cells, soluble phosphorylated glucan and cyclophosphamide had about equivalent effect on reducing primary tumor growth, i.e., 8.3% and 8.5% as compared to 12.6% body weight in control mice (Group 1). In mice treated with a combination of soluble phosphorylated glucan and cyclophosphamide (Group 4), there was an even greater

reduction in size of the primary tumor, i.e., 4.4% as compared to 12.6% in control (Group 1).

Results were even more remarkable at day 36 (Table 10). While mean tumor weight increased 142% in the sixteen days (day 20-36) in the control group (Group 1), the tumor weight in the group treated with soluble phosphorylated glucan group (Group 2) increased only 84%, and only 36% in the cyclophosphamide (Group 3). For the first time in our studies, actual regression of the primary tumor was manifested under the influence of combined chemotherapy and soluble phosphorylated glucan immunotherapy. With combined therapy, -64% growth was observed, denoting primary tumor regression.

As demonstrated in Table 11, significantly enhanced survival ($p < 0.01$) was observed in mice treated with either soluble phosphorylated glucan (Group 2) or cyclophosphamide alone (Group 3) compared to controls (Group 1). Further, a highly statistically significant ($p < 0.001$) enhanced survival time was observed in those animals treated with a combination of soluble phosphorylated glucan and cyclophosphamide (Group 4).

These studies clearly indicate the effectiveness of combined chemo-and soluble phosphorylated glucan-immunotherapy. Not only did regression of primary tumor growth occur, but also a reduction of metastatic disease as reflected by histopathological observations was noted. Hepatic metastases, which were pronounced in the control group, were essentially absent in the soluble phosphorylated glucan-cyclophosphamide treated group. Additionally, a significant enhancement in survival

(Table 11) was also observed as well as enhancement of the interval before the initial death occurred in the treated group

TABLE 11

SOLUBLE PHOSPHORYLATED GLUCAN-CYCLOPHOSPHAMIDE CHEMOIMM UNOTHERAPY: EFFECT ON SURVIVAL OF MICE WITH ESTABLISHED RETICULUM CELL CARCINOMA M5076

Treatment Group Number[a]	Initial Mortality[b]	Median Survival Time (Days)	Time (Days) 100% Mortality
1	27	34	52
2	32	41*	67
3	43	51*	65
4	52	64**	102

[a] Procedures were identical to those used to obtain data presented in Table 10. All treatments were terminated at day 50.

[b] Mortality in soluble phosphorylated glucan and cyclosphamide group was presumed due to residual splenic tumor cells which subsequently disseminated when therapy was terminated.

*$p<0.01$
**$p<0.001$

7.9. ABILITY OF SOLUBLE PHOSPHORYLATED GLUCAN TO PREVENT CYCLOPHOSPHAMIDE-INDUCED LEUKOPENIA

Among the deleterious effects associated with the administration of almost all antineoplastic agents are the induction of myelosuppression, leukopenia, and the increased susceptibility to infectious disease. (see generally, Klastersky, ed., in Infection in Cancer Patients, Raven Press, NY, 1982, pp. 1-12).

As detailed in Section 7.8., it is possible to induce a syngergistic effect on primary tumors when soluble phosphorylated glucan is combined with cyclophosphamide treatment. One of the disadvantages associated with the use of cyclophosphamide in cancer patients is the development of leukopenia. In view of the demonstrated ability of diverse particulate and soluble polyglycans to enhance hemopoietic recovery in mice when administered either an hour before or one hour after 650 rads of Cobalt radiation (see Patchen, 1983, Surv. Immunol. Res. 2: 237-242; Patchen et al., 1984, J. Biol. Response Modifiers, 3: 627-733) studies were undertaken to determine whether soluble phosphorylated glucan would possess the ability to maintain the peripheral leukocyte level in animals receiving therapeutic and immunosuppressive doses of cyclophosphamide.

Forty mice were subdivided into four groups. Group 1, control mice, received intravenous isotonic glucose. Group 2 received soluble phosphorylated glucan (5 mg per mouse); Group 3, cyclophosphamide (Cytoxan) intraperitoneally (0.6 mg per mouse); and Group 4, combined therapy of cyclophosphamide plus soluble phosphorylated glucan. All injections were given at three day intervals for a total of

four injections per animal. Total leukocyte counts of peripheral blood were made on day 14. The results of this study are presented in Table 12.

TABLE 12

PREVENTION OF CYCLOPHOSPHAMIDE-INDUCED LEUKOPENIA BY SOLUBLE PHOSPHORYLATED GLUCAN

Treatment	Total Leukocytes (in thousand per cu. mm of blood)
Control	13.8 ± 1.6
SPG	10.0 ± 1.8
Cyclophosphamide	6.0 ± 0.8*
SPG + Cyclophosphamide	12.2 ± 1.6**

[a] Soluble phosphorylaged glucan (SPG) (5 mg/mouse) administered intravenously every third day. Cyclophosphamide (0.6 mg/mouse) was administered intraperitoneally every third day. Total leukocytes count were made on day 14 of the experiment.

*$P<0.01$ - control compared with cyclophosphamide treatment.

**$P<0.01$ - SPG + cyclophosphamide compared with cyclophosphamide alone.

As demonstrated, administration of cyclophosphamide produced a characteristic 47% decrease in total number of peripheral leukocytes ($P<0.01$). The administration of soluble phosphorylated glucan together with cyclophosphamide resulted in a 103% increase in total number of leukocytes compared with the cyclophosphamide-treated group ($P<.01$).

This study clearly indicates that the simultaneous administration of soluble phosphorylated glucan with cyclophosphamide was able to prevent the characteristic development of leukopenia following cyclophosphamide adminstration. This should maintain resistance to infectious diseases in the presence of toxic chemotherapeutic agents while exerting a synergistic effect on tumor regression, as demonstrated in Section 7.8., supra.

7.10. CYTOSTATIC EFFECT ON PROLIFERATION OF LYMPHOCYTIC LEUKEMIC CELLS IN VITRO

This study demonstrates the ability of soluble phosphorylated glucan to inhibit the proliferation rate of murine lymphocytic leukemic cells in vitro.

L-1210 lymphocytic leukemic cells, maintained in culture, were plated in microtiter wells at a concentration of 2×10^5 cells/well. Soluble phopsphorylated glucan (500 µg/well) or particulate glucan (100 µg/well) was added and the cells incubated for a period of 24 hours. An equal volume of culture medium (RPMI-1640 supplemented with 7.5% Fetal Calf serum) was added to the control cultures. ^{3}H-thymidine (0.5 µ Ci/well) was added to all cultures and incubations were continued for another period of 24 hours. Cell proliferation was evaluated by determining the incorporaton of ^{3}H-thymidine. Results are illustrated in Table 13.

TABLE 13

COMPARATIVE EFFECT OF SOLUBLE PHOSPHORYLATED GLUCAN (SPG) AND PARTICULATE GLUCAN (PG) ON THE IN VITRO PROLIFERATION OF MURINE LYMPHOCYTIC LEUKEMIA CELLS

Treatment Group[a]	^{3}H-Thymidine Uptake (cmp)	%Inhibition of Tumor Cell Proliferation
Control	3547 ± 310	0
SPG	407 ± 38	88.5 ± 9.3
PG	2269 ± 293	36.0 ± 4.6

[a] L-1210 cells (2×10^5/well) were incubated in the presence of soluble phosphorylated glucan (0.5 mg/well) or particulate glucan (0.1 mg/well) for 24 hours. ^{3}H-thymidine (0.5 µCi/well) was added to measure tumor cell proliferation. N = 24 wells/group.

As shown in Table 13, particulate glucan inhibited of tumor cell proliferation about 36%. In marked contrast, soluble phosphorylated glucan inhibited tumor cell proliferation about 88.5%. Thus, one of the mechanisms by which soluble phosphorylated glucan may inhibit tumor growth and metastases is by its ability, in as yet an undefined manner, to directly inhibit tumor cell proliferation.

8. PREPARATION AND EFFICACY OF SOLUBLE PHOSPHORYLATED GLUCAN FROM CORIOLUS VERISCOLOR

The following experiments demonstrate that a soluble phosphorylated glucan obtained from a basidiomycete,

Coriolus versicolor (Fr. Quel.) also has useful immunobiological activity.

A commercially available polysaccharide-protein preparation termed "Krestin" or "PSK" obtained from Sanyko Corporation, Tokyo, Japan, was used as the starting material for the preparation of soluble phosphorylated glucan from C. versicolor. This commercial preparation is a relatively crude preparation comprising a β- 1,4, β-1,3, β-1,6,- glucan-protein complex. The principal chemical structure of the polyglucose is a main chain of glucose units linked by 1-4 glucosidic bonds, having attached branch or side chains of glucose units linked by β-1,3 and β-1,6 glucosidic bonds. The protein content ranges from 15-38%. (Ehrke et al., 1983, Internat'l J. Immunopharm. 5: 34-42; Yamamura and Azuma, 1982, Adv. Immunopharm. 2: 501-507).

Because the commercially available PSK preparation is a relatively crude preparation and has a relatively high protein content, intravenous administration of this material is not possible. It must be administered orally.

8.1. PREPARATION

The PSK polysaccharide-protein complex from C. versicolor was prepared as a soluble phosphorylated glucan (hereinafter "soluble phosphorylated-PSK") according to the present invention as described in Section 5. The isolated soluble phosphoryated-PSK was lyophilized.

8.2. EFFECTIVENESS AGAINST ESCHERICHIA COLI-INDUCED PERITONITIS

The following experiment demonstrates the effectiveness of intraperitoneal administration of soluble phosphorylated-PSK against a subsequently induced E. coli peritonitis.

Forty eight adult white mice were divided into 3 groups of 16 animals each. Group 1 designated control, received 0.5 ml of isotonic saline solution intravenously; Group 2, 5 mg commercially available PSK (Sankyo Corporation, Tokyo, Japan) intravenously; and Group 3, 5 mg soluble phosphorylated-PSK intravenously. All glucans were administered at 24 hours prior to challenge with E. coli. E. coli (1×10^8 bacteria) was injected via an intraperitoneal route. Results are illustrated in Table 14.

TABLE 14

EFFECT OF ADMINISTRATION OF SOLUBLE PHOSPHORYLATED GLUCAN FROM C. VERSICOLOR ON MORTALITY DUE TO E. COLI SEPSIS

Group[a]	Treatment	% Survival Time (Hours) Post-Infection 24	48	72
1	Saline[b]	6	6	6
2	PSK[c]	63	25	19
3	Soluble Phosphorylated-PSK[b]	100	100	100

[a] N = 16 mice/group

[b] Single injection of either saline or soluble phosphorylated-PSK (5 mg/mouse) was given intraperitoneally 24 hours before challenge with E. coli.

[c] Commercially available PSK (Sankyo Corporation, Tokyo, Japan) was administered intravenously (5 mg/animal) 24 hours before challenge with E. coli.

As illustrated in Table 14, both the commercially available PSK and the soluble phosphorylated-PSK glucans demonstrated significant protective activity against E. coli sepsis at 24 hours post-infection (i.e., 63% and 100% survival as compared to 6% in saline control animals Group 1). In marked contrast to the PSK preparation, however, the soluble phosphorylated glucan-PSK prepared according to the present invention showed greatly enhanced effectiveness against infection on a long term basis. At 72 hours post-infection, no mortality was observed in the group treated with soluble phosphorylated-PSK (Group 3). At the same time, 81% mortality was observed in the group treated with PSK (Group 2).

WHAT IS CLAIMED IS:

1. A soluble glucan, comprising a phosphorylated poly-[β-(1-3)glucopyranose] chain which is characterized by:

(a) the capability of dissolving in water or an aqueous solution;

(b) being non-toxic, non-immunogenic and substantially non-pyrogenic; and

(c) the capability of exerting a pronouced immunobiological response when administered in vivo to an animal or to a human.

2. The soluble glucan according to claim 1, further characterized by the substantially complete absence of triple helical chains as determined by nuclear magnetic resonance spectroscopy.

3. The soluble glucan according to claim 1, further characterized by having a degree of phosphorylation ranging from about 1.4% to about 3.4%.

4. The soluble glucan according to claim 1, further chracterized by having a molecular weight ranging from about 10,000 to about 100,000 daltons.

5. The soluble glucan according to claim 1, further characterized by having a molecular weight ranging from about 100,000 to about 500,000 daltons.

6. The soluble glucan according to claim 1, which is obtained from a microbial source.

7. The soluble glucan according to claim 6, in which the microbial source comprises Saccahromyces cerevisiae.

8. The soluble glucan according to claim 6, in which the microbial source comprises Coriolus versicolor.

9. A composition, comprising a phosphorylated poly-[β-(1-3)glucopyranose] chain which is characterized by:

(a) the capability of dissolving in water or an aqueous solution;

(b) being non-toxic, non-immunogenic and substantially non-pyrogenic; and

(c) the capability of exerting a pronouced immunobiological response when administered in vivo to an animal or to a human in an aqueous solution.

10. The composition according to claim 9, in which the poly-[β-(1-3) glucopyranose] chain is further characterized by the substantially complete absence of triple helical chains as determined by nuclear magnetic resonance spectroscopy.

11. The composition according to claim 9, in which the poly-[β-(1-3) glucopyranose] chain is further characterized by having a degree of phosphorylation ranging from about 1.4% to about 3.4%.

12. The composition according to claim 9, in which the poly-[β-(1-3) glucopyranose] chain is further chracterized by having a molecular weight ranging from about 10,000 to about 100,000 daltons.

13. The composition according to claim 9, in which the poly-[β-(1-3) glucopyranose] chain is further characterized by having a molecular weight ranging from about 100,000 to about 500,000 daltons.

14. The composition according to claim 9, which is obtained from a microbial source.

15. The composition according to claim 14, in which the microbial source comprises Saccharomyces cerevisiae.

16. The composition according to claim 14, in which the microbial source comprises Coriolus versicolor.

17. A pharmaceutical composition for the prevention or treatment of an infection in animals or humans, comprising: a therapeutically or prophylatically effective amount of soluble glucan according to claim 1 and a physiologically acceptable carrier.

18. The composition according to claim 17, further comprising a bioactive agent effective against said infection.

19. A pharmaceutical composition for the treatment of a malignant neoplastic disease in animals or humans, comprising a therapeutically effective amount of soluble glucan according to claim 1 and a physiologically acceptable carrier.

20. The composition according to claim 19, further comprising an anti-cancer agent.

21. The composition according to claim 20, in which the anti-cancer agent comprises cyclophosphamide.

22. A method for preparing a non-toxic, non-immunogenic, substantially non-pyrogenic soluble phosphorylated glucan capable of exerting a profound immunbiological response when administered in vivo in animals or humans, comprising:

(a) dissolving a particulate glucan or a glucan protein complex in a highly polar solvent which contains a strong chaotropic agent;

(b) reacting the resultant dissolved glucan with phosphoric acid to form a soluble phosphorylated glucan; and

(c) recovering the resultant soluble phosphorylated glucan from the reaction mixture.

23. The method according to claim 22, in which the highly polar solvent comprises dimethylsulfoxide.

24. The method according to claim 22, in which the strong chaotropic agent comprises urea.

25. The method according to claim 22, in which the particulate glucan or glucan protein complex is dissolved by a method comprising the sequential steps of:

(a) suspending a particulate glucan or a glucan protein complex in a highly polar solvent which contains a strong chaotropic agent to form a mixture;

(b) heating the mixture to about 50-150 °C;

(c) adding phosphoric acid to the mixture; and

(d) allowing the mixture to react for about 1-12 hours at 50-150 °C.

26. The method according to claim 25, in which the mixture is heated to about 100 °C.

27. The method according to claim 25, in which the mixture comprises about 4-12 M urea in dimethylsulfoxide.

28. The method according to claim 22, in which the glucan is reacted with phosphoric acid for a sufficient period so that phosphorylation of the resultant soluble phosphorylate glucan is substantially complete.

29. The method according to claim 22, in which the soluble phosphorylated glucan is recovered by:

(a) allowing the soluble phosphorylated glucan to precipitate;

(b) adding a sufficient amount of water to resuspend the precipitated soluble phosphorylated glucan; and

(c) removing all components of less than about 10,000 daltons molecular weight.

30. The method according to claim 22, in which the particulate glucan is obtained from Saccharomyces cerevisiae.

31. The method according to claim 22, in which the glucan protein complex is obtained from Coriolus versicolor.

32. The method according to claim 22, in which the particulate glucan is obtained by a method comprising the steps of:

(a) suspending an aliquot of fungal cells in an aqueous solution of hydroxide to form a mixture;

(b) heating the mixture to about 50-150 °C;

(c) removing the supernatant from resulting residue;

(d) suspending the residue in the aqueous solution of hydroxide;

(e) repeating steps b and c , two or three times;

(f) adding hydrochloric acid to the residue to of step e form an acidic mixture;

(g) heating the acidic mixture to about

(h) removing the supernatant;

(i) repeating steps f and g, two times;

(j) washing the residue with water;

(k) repeatedly extracting the residue with ethanol until the supernatant is essentially colorless; and

(l) isolating the non-soluble polyglucose composition formed.

33. A method for treatment of an infection in animals or humans, comprising: administering to an animal or a human a therapeutically effective amount of soluble phosphorylated glucan according to claim 1.

34. The method according to claim 33, in which the infection is caused by a bacterium.

35. The method according to claim 34, in which the bacterium is selected from the group consisting of

Staphylococcus aureus, Streptococcus pneumoniae, Mycobacterium tuberculosis, Hemophilus influenzae, Diplococcus pneumoniae, Escherichia coli, Bacterium enteritis, Francisella tularensis, and Mycobacterium leprae.

36. The method according to claim 33, in which the infection is caused by a virus.

37. The method according to claim 36, in which the virus comprises Herpes simplex or Hepatitis.

38. The method according to claim 33, in which the infection is caused by a fungus.

39. The method according to claim 38, in which the fungus comprises Candida albicans or Sporotrichium schenkii.

40. The method according to claim 33, in which the infection is caused by a parasite.

41. The method according to claim 40, in which the parasite comprises Leishmania donovani or Schistosoma mansoni.

42. A method for the prevention of an infection in animals or humans, comprising: administering to an animal or a human a prophylatically effective amount of soluble phosphorylated glucan according to claim 1.

43. The method according to claim 42, in which the infection is caused by a bacterium.

44. The method according to claim 43, in which the bacterium is selected from the group consisting of Staphylococcus aureus, Streptococcus pneumoniae, Mycobacterium tuberculosis, Hemophilus influenzae, Diplococcus pneumoniae, Escherichia coli, Bacterium enteritis, Francisella tularensis, and Mycobacterium leprae.

45. The method according to claim 42, in which the infection is caused by a virus..

46. The method according to claim 45, in which the virus comprises Herpes simplex or Hepatitis.

47. The method according to claim 42, in which the infection is caused by a fungus.

48. The method according to claim 47, in which the fungus comprises Candida albicans or Sporotrichium schenkii.

49. The method according to claim 42, in which the infection is caused by a parasite.

50. The method according to claim 49, in which the parasite comprises Leishmania donovania or Schistosoma mansoni.

51. The method according to claim 33 or 42, in which the glucan is administered intravenously, intraperitoneally, subcutaneously, orally, topically to nasal linings or by inhalation.

52. A method for treatment of an infection in animals or humans, comprising: administering to an animal or a human a therapeutically effective amount of a composition comprising the soluble phosphorylated glucan of claim 1, in combination with a bioactive agent effective against said infection.

53. The method according to claim 52, in which the composition is administered intravenously, intraperitoneally, subcutaneously, orally, topically to nasal linings or by inhalation.

54. A method for the prevention or treatment of an opportunistic infection in animals or humans which are immunosuppressed, comprising: administering to an immunosuppressed animal or human a prophylatically or therapeutically effective amount of soluble glucan according to claim 1.

55. A method for treatment of a malignant neoplastic disease in animals and humans comprising: administering to an animal or a human a therapeutically effective amount of soluble phosphorylated glucan according to claim 1.

56. The method according to claim 54 or 55, in which the soluble phosphorylated glucan is administered intravenously, intraperitoneally, subcutaneously, orally, topically to nasal linings, or by inhalation.

57. A method for treatment of a malignant neoplastic disease in animals and humans, comprising: administering to an animal or a human, a therapeutically

effective amount of a soluble phosphorylated glucan according to claim 1, in combination with an anti-cancer agent.

58. The method according to claim 57, in which the anti-cancer agent comprises cyclophosphamide.

59. A method for prevention of leukopenia induced by administration of an anti-cancer agent in animals and humans, comprising: administering to an animal or a human a therapeutically effective amount of a soluble phosphorylated glucan according to claim 1, in combination with an anti-cancer agent.

60. The method according to claim 59, in which the anti-cancer agent comprises cyclophophamide.

61. A method for therapeutic or prophylactic treatment of an infection in animals or humans, comprising administering to an animal or a human the composition according to claim 9, 17 or 18.

62. A method for treatment of a malignant neoplastic disease in animals or humans, comprising administering to an animal or a human, a therapeutically effective amount of the composition according to claim 9, 19, 20 or 21.

63. A method for stimulating macrophage cells in vivo to produce and secrete a soluble cytotoxic/cytostatic factor, comprising: administering to an animal or a human the soluble phosphorylated glucan according to claim 1.

64. An in vitro method for producing a soluble cytotoxic/cytostatic factor, comprising: culturing animal or human macrophage cells in vitro in a culture medium containing the soluble phosphorylated glucan according to claim 1; separating a resultant supernatant from the cultured cells; and isolating the soluble cytotoxic/cystostatic factor from the supernatant.

65. The soluble cytotoxic/cytostatic factor produced according to claim 63 or 64.

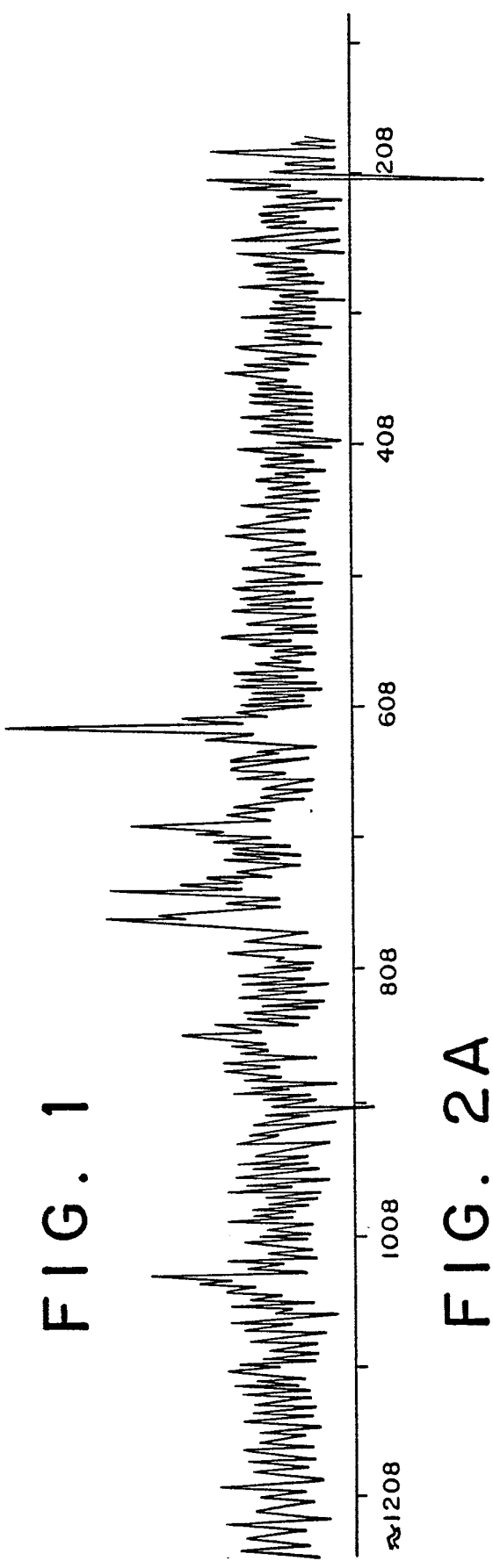


FIG. 1

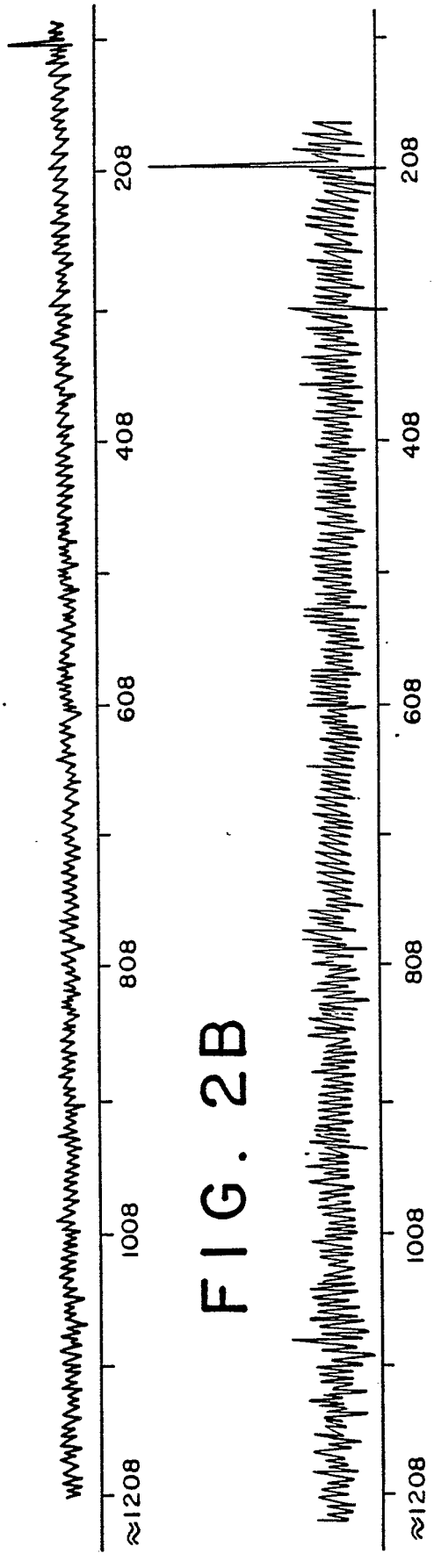
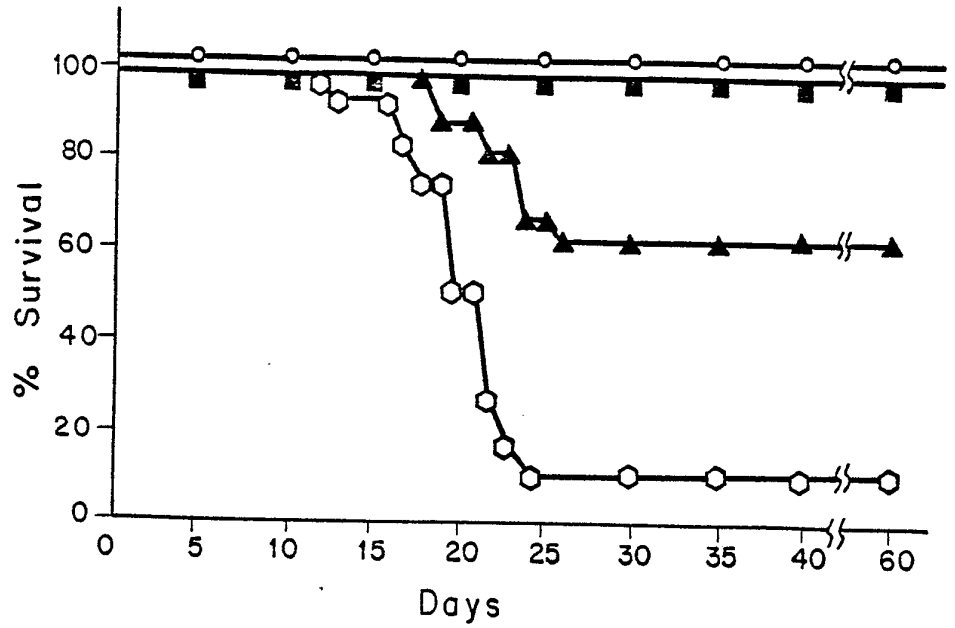


FIG. 2A

FIG. 2B

FIG. 3



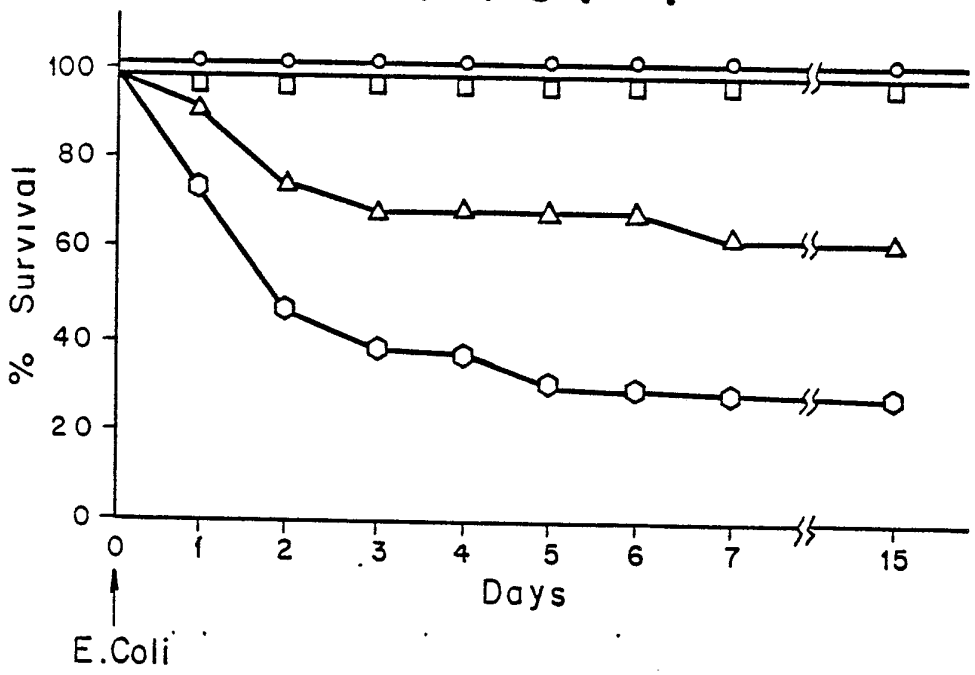
○ = Cortisone

▲ = Cortisone Plug Soluble Glucan

■ = Soluble Glucan

○ = Glucose

FIG. 4



○ = Cortisone

□ = Glucan

△ = Glucose

○ = Cortisone Plus Glucan

FIG. 5

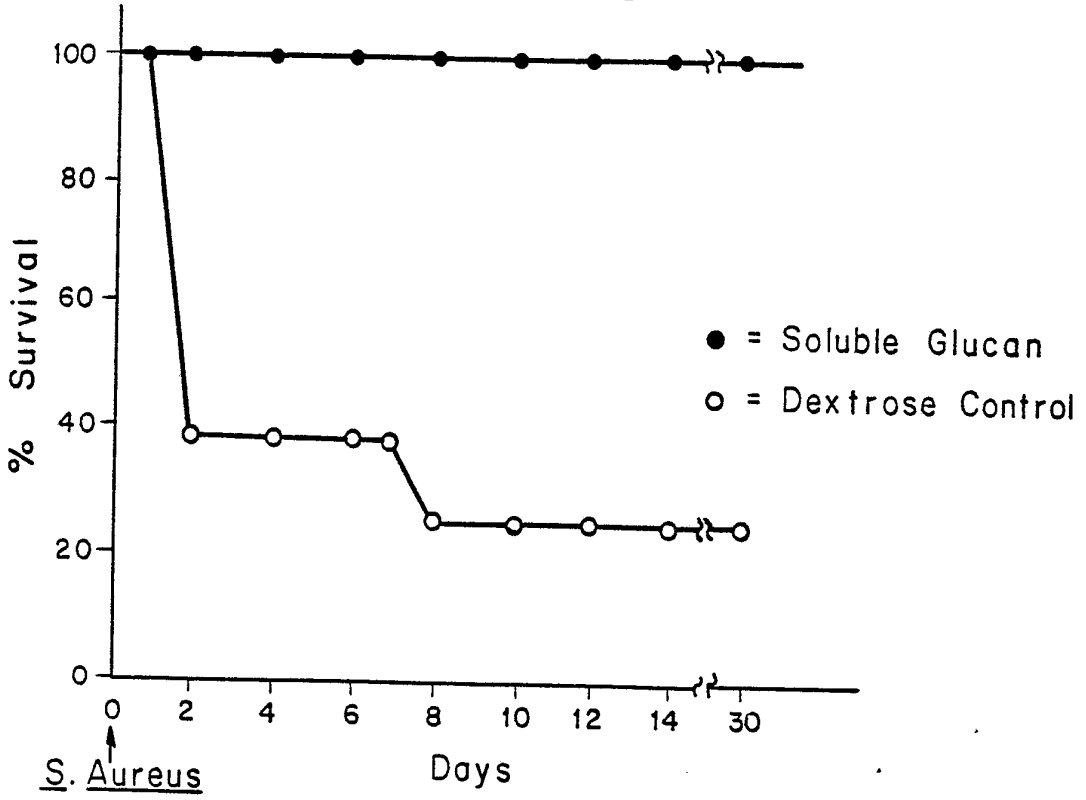

100
80
60
40
20
0
% Survival
0
2
4
6
8
10
12
14
30
Days
S. Aureus
● = Soluble Glucan
○ = Dextrose Control

FIG. 6

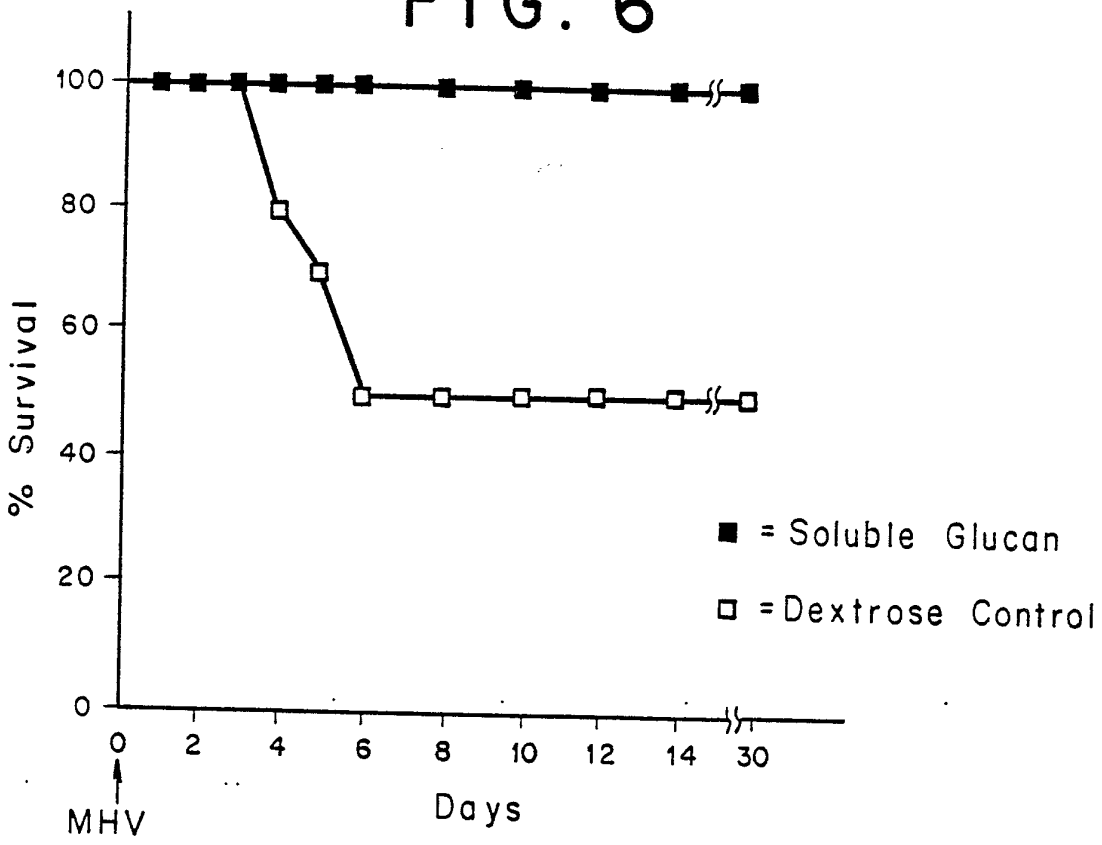

100
80
60
40
20
0
% Survival
0
2
4
6
8
10
12
14
30
Days
MHV
■ = Soluble Glucan
□ = Dextrose Control

FIG. 7

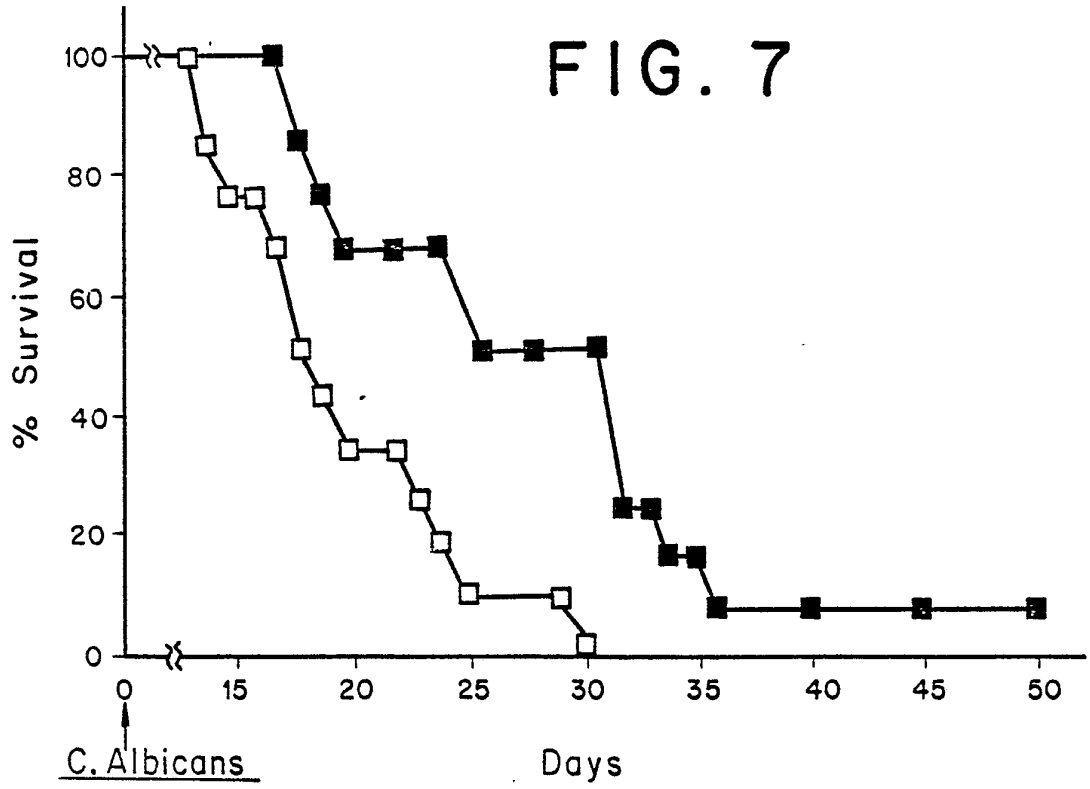

100
80
60
40
20
0
% Survival
0
15
20
25
30
35
40
45
50
C. Albicans
Days
■ = Glucan F
□ = Tap Water Control

FIG. 8

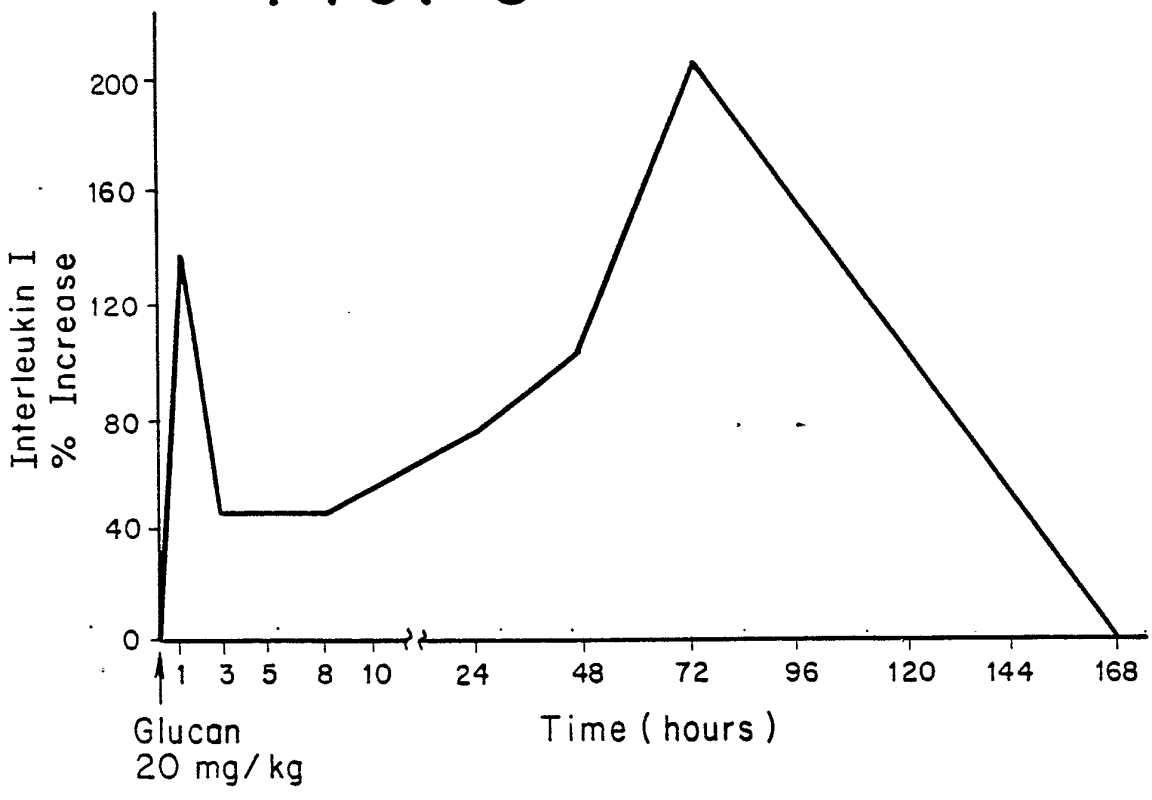
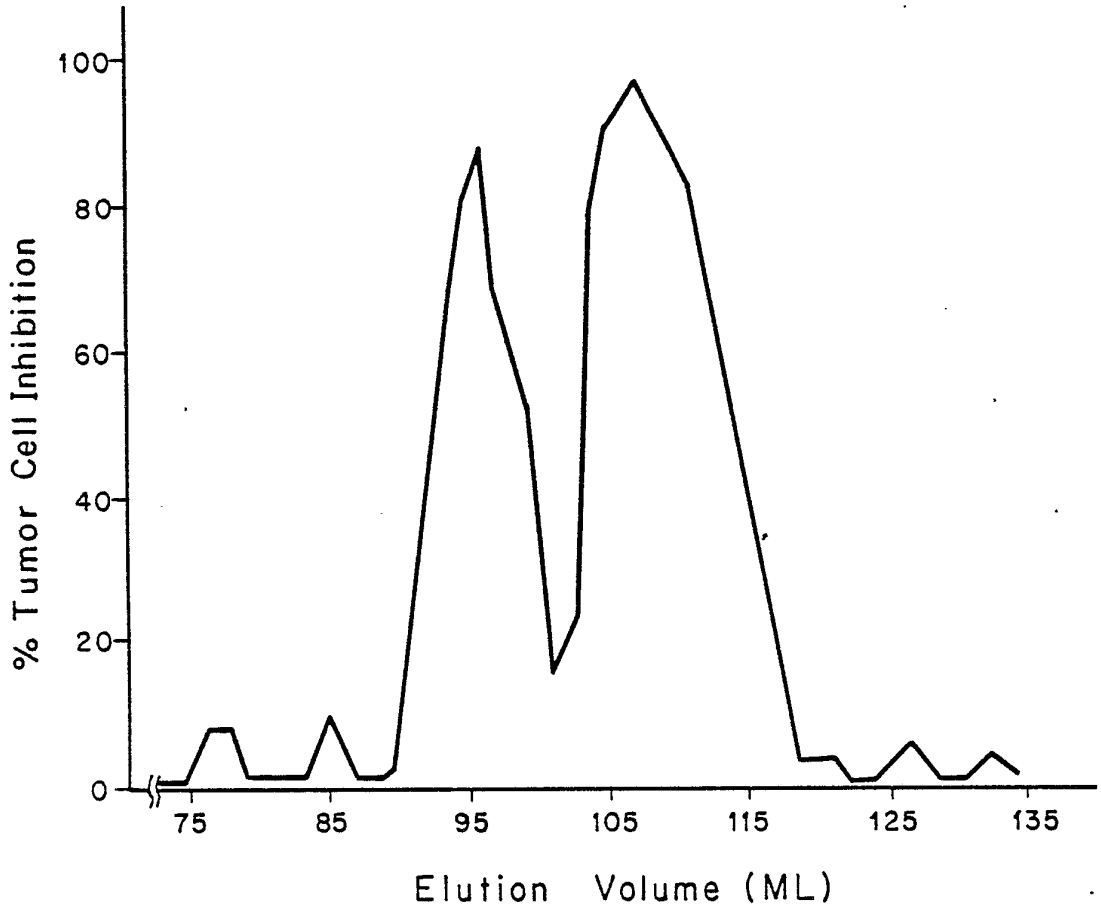

200
160
120
80
40
0
Interleukin I
% Increase
1
3
5
8
10
24
48
72
96
120
144
168
Glucan
20 mg/kg
Time (hours)

FIG. 9


100
80
60
40
20
0
% Tumor Cell Inhibition
75
85
95
105
115
125
135
Elution Volume (ML)

INTERNATIONAL SEARCH REPORT

International Application No PCT/US86/01646

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

INT. CL.,4: A61K 31/715;C07H 3/06; See Attachment

U.S. CL: 514/23;514/54; 435/41;435/101; See Attachment

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
U.S.	435/41; 435/101; 514/23; 514/54; 536/1.1; 536/17.1; 536/117

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

"Chemical Abstracts" Poly 1,3 glucan (phosphorylated) and Uses for Compound

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
A	US,A, 4,237,266, SUGIURA, Published 2 December 1980 (Columns 1-3 and 6).	1-16,19-21,55-58 and 62
A	US,A, 4,225,673 SUGIURA, Published 30 September 1980 (Columbus 1-3 and 6).	1-16,19-21,55-58 and 62
A	US,A, 4,396,611 DUC Published 2 August 1983 (Columns 1-3 and 5-6).	1-21 and 33-58 61 and 64-65
A	US,A, 4,493,894 MIYASHIRO Published 15 January 1985 (Column 1)	1-16 and 65

* Special categories of cited documents: [15]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
03 November 1986	19 NOV 1986
International Searching Authority [1]	**Signature of Authorized Officer [20]**
ISA/US	Johnnie R. Brown Johnnie R. Brown

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

V. ☐ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE [10]

This international search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1. ☐ Claim numbers . . . . . , because they relate to subject matter [12] not required to be searched by this Authority, namely:

2. ☐ Claim numbers . . . . . , because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out [13], specifically:

VI. ☒ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING [11]

This International Searching Authority found multiple inventions in this international application as follows:

See Attachment

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application. Telephone Practice
2. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:

3. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

4. ☐ As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

☐ The additional search fees were accompanied by applicant's protest.

☐ No protest accompanied the payment of additional search fees.

Attachment

I. CLASSIFICATION OF SUBJECT MATTER:

INT. CL^4: C08B 37/00; C12P 19/04

U.S. CL: 536/1.1; 536/17.1; 536/117

Attachment To Form PCT/ISA/210, Part VI.

I. Claims 1-19, 22-54, 61 and 65 are drawn to soluble phosphorylated glucan compounds a process for preparing the phosphorylated glucans, pharmaceutical compositions and a method for the treatment of infections in animals or humans, classified in Classes 514 and 536.

II. Claims 20-21, 55-58 and 62 are drawn to a pharmaceutical compositions containing a phosphorylated glucan compound and an anti-cancer agent and a method for the treatment of malignant neoplastic diseases in animals and humans, classified in Class 514.

III. Claims 59-60 are directed to a method for the prevention of leukopenia, classified in Class 514.

IV. Claim 63 is directed to a method for stimulating macrophage cells, classified in Class 514.

V. Claim 64 is directed to a method of culturing animal or human cells in vitro, classified in Class 435.

Attachment To Form PCT/ISA/210, Part VI. 1

Telephone Approval:

$560.00 payment approved by Mr. Leslie Misrock on 30 October 1986 for Groups I, II, III, IV and V; Charge to Deposit Account No. 16-1150.

Reasons for holding lack of unity of invention:

Group I, is directed to the glucan compounds, process of preparation, pharmaceutical compositions and use of the compounds for the treatment of infections in animals and humans, which is a materially different use from the methods of: Group II, for treating malignant neoplastic diseases; Groups III, for the prevention of leukopenia; Group IV, for stimulating macrophage cells and Group V, for culturing animal or human cells in vitro.

The search burden involved for each additional invention is undue, not only insofar as the additional parent search indicated by the separate classifications, but also insofar as considerable additional literature searches covering the entire classes noted above.

Time Limit for Filing a Protest

Applicant is hereby given 15 days from the mailing date of this Search Report in which to file a protest of the holding of lack of unity of invention. In accordance with PCT Rule 40.2 applicant may protest the holding of lack of unity only with respect to the group(s) paid for.