

EXPRESSING HEPATITIS B VIRUS SURFACE ANTIGEN FOR VACCINE PREPARATION

All documents cited herein are incorporated by reference in their entirety.

TECHNICAL FIELD

This invention is in the field of protein expression, in particular for expressing hepatitis B virus surface antigen (HBsAg) for use in preparing vaccines.

BACKGROUND ART

Hepatitis B vaccines have been available for many years (*e.g.* see chapter 16 of reference 1), and their active ingredient is the surface antigen (HBsAg) from hepatitis B virus (HBV). The original HBV vaccines used HBsAg that had been purified from human blood, but vaccines based on recombinantly-expressed HBsAg became widely available in the 1990s. Since then, HBsAg has also been incorporated as a component in multivalent vaccines *i.e.* vaccines containing a mixture of immunogens from more than one pathogen, such that administration of the vaccine can simultaneously immunize a subject against more than one pathogen. These multivalent vaccines typically include HBsAg plus at least 'DTP' (diphtheria, tetanus and pertussis) antigens.

The original monovalent recombinant HBV vaccine, ENGERIX B™, includes an aluminum hydroxide adjuvant. More recently, monovalent HBV vaccines based on more modern adjuvants have become available *e.g.* using the 'AS04' adjuvant [2] in the FENDRIX™ product from GSK, the RC-529 adjuvant in the SUPERVAX™ product from Berna Biotech, or CpG oligonucleotide adjuvants such as CPG7909 [3] from Coley Pharmaceuticals.

For recombinant expression of HBsAg a variety of systems have been described. Expression hosts that have been used include bacteria, yeasts (including *Saccharomyces*, *Hanensula* and *Pichia* species), mammalian cell culture (including CHO cells, COS cells, Bu3 cells), insect cells (using baculovirus vectors), and plant cells (*e.g.* for 'edible vaccines').

It is an object of the invention to provide further and improved systems for recombinant expression of HBsAg, particularly for preparing HBsAg to be used in combination vaccines (such as those containing DTP antigens) or in new monovalent HBV vaccines.

DISCLOSURE OF THE INVENTION

Early reports of recombinant HBsAg expression focused on *E.coli* [4-6], mouse cells [7], human cells [8], monkey cells [9] and yeasts [10-12]. More recently, however, expression in recombinant plants has received extensive attention [13-24], as has expression in *Pichia pastoris* [25,26] and *Hanensula polymorpha* [27,28] yeasts.

Despite the move towards these modern expression systems, according to the invention HBsAg is expressed in a *Saccharomyces cerevisiae* host. Various options are available for yeast-based expression of HBsAg, including choices of yeast species and strain, culture conditions, the promoter used to control expression, gene termination sequences, codon usage, *etc.* According to the invention,

HBsAg is expressed in a *Saccharomyces cerevisiae* host carrying a plasmid having a HBsAg coding sequence, wherein the plasmid includes: (1) an upstream promoter from a glyceraldehyde-3-phosphate dehydrogenase gene, for controlling expression of the HBsAg coding sequence; and (2) an ARG3 transcription terminator downstream of the HBsAg coding sequence. The plasmids will also typically include: (3) a LEU2 selection marker; (4) a 2 μ plasmid sequence; and (5) an origin of replication functional in *Escherichia coli*.

HBsAg can be expressed in this *Saccharomyces cerevisiae* host, and can be purified for use in the manufacture of vaccines, and in particular for the manufacture of combination vaccines and in new monovalent HBV vaccines. This yeast-expressed material is suitable for use in these complex vaccines despite the reports in reference 29 that *S.cerevisiae*-expressed HBsAg can have immunosuppressive potential.

Multivalent vaccines

Thus the invention provides a process for preparing a multivalent immunogenic composition, comprising the steps of: (a) preparing a HBV component by purifying HBsAg after expression in a *S.cerevisiae* host of the invention; (b) preparing at least one non-HBV component; and (c) mixing the HBV and non-HBV components to give the multivalent composition.

The invention also provides a multivalent immunogenic composition comprising: (a) a HBV component comprising HBsAg expressed in a *S.cerevisiae* host of the invention; and (b) at least one non-HBV component. The composition typically also includes one or more adjuvant(s).

These multivalent compositions are particularly useful for simultaneously protecting against infection by HBV and non-HBV pathogens in children. A typical patient will be in the first year of life, and will receive a first dose of the composition between 6 and 9 weeks after birth. Two or three further doses will typically be administered, given at intervals of about 6 to 8 weeks. The composition may also be used to complete the primary immunization schedule of a different vaccine. The composition may also be used as a booster *e.g.* in children aged 1-16 years.

Monovalent vaccines

The invention also provides a process for preparing a monovalent immunogenic composition, comprising the steps of: (a) preparing a HBV component by purifying HBsAg after expression in a *S.cerevisiae* host of the invention; (b) combining the HBsAg with an adjuvant to give the immunogenic composition. The adjuvant is preferably not an aluminum hydroxide adjuvant, and is more preferably not solely an aluminum salt adjuvant.

The invention also provides a monovalent immunogenic composition comprising: (a) a HBV component comprising HBsAg expressed in a *S.cerevisiae* host of the invention; and (b) an adjuvant.

These monovalent compositions are particularly useful for protecting against and/or treating hepatitis B virus infections in patients for whom existing adjuvanted vaccines (such as the ENGERIX B™

product) are ineffective. Sub-groups of patients for whom the compositions are particularly suitable include: immunocompromised patients; hemodialysis patients; pre-hemodialysis patients; patients with renal insufficiency; patients with renal failure; patients with early renal failure before they require hemodialysis; patients awaiting liver transplantation *e.g.* on waiting lists; patients with end-stage renal failure; patients who have received an organ transplant (particularly a liver transplant) *e.g.* in the 6 month period preceding a first dose of the vaccine of the invention; patients who are receiving (or have been receiving *e.g.* in the 6 month period preceding a first dose of the vaccine of the invention) hepatitis B immunoglobulin (HBIG) treatment; patients with a HLA DQ2 haplotype [30]; patients with a HLA DR3 haplotype [30]; patients with a HLA DR7 haplotype [30]; patients with the with the HLA allele DQB1*0202 [31]; patients infected with HIV; chronic HBV carriers; patients who have recently received a blood transfusion; patients receiving immunosuppressive drugs; patients suffering from AIDS; patients with ascites; patients with cirrhosis; patients with encephalopathy; patients receiving interferon therapy, and in particular ifn- α ; patients who smoke cigarettes; patients who smoke cigars; patients with a body mass index ≥ 30 kg/m²; and patients who have received a HBsAg vaccine but who have not seroconverted (*e.g.* they have a serum anti-HBsAg titer of <10 mIU/ml after a standard primary dosing schedule, such as 3 doses of ENGERIX B™).

These patients may have a creatinine clearance rate of less than 30ml/min (the normal healthy range being ~100-140 ml/min in males and 90-130 ml/min in females). Patients are preferably at least 15 years old *e.g.* between 15-40 years, between 15-60 years, between 40-60 years, or even over 60. Patients aged over 55 can usefully be treated regardless of any underlying illness.

The hepatitis B surface antigen

The HBV virion consists of an inner core surrounded by an outer protein coat or capsid. The major component of the capsid is a protein referred to as 'HBsAg'. All existing hepatitis B vaccines contain HBsAg, and when this antigen is administered to a normal vaccinee it stimulates the production of anti-HBsAg antibodies which protect against HBV infection.

For vaccine manufacture, HBsAg can be made in two ways. The first method involves purifying the antigen in particulate form from the plasma of chronic hepatitis B carriers, as large quantities of HBsAg are synthesized in the liver and released into the blood stream during an HBV infection. The second way involves expressing the protein by recombinant DNA methods. HBsAg for use with the present invention is recombinantly expressed in a *Saccharomyces cerevisiae* yeast.

Unlike native HBsAg (*i.e.* as in the plasma-purified product), HBsAg used with the invention is non-glycosylated. This form of HBsAg is preferred because it is highly immunogenic and can be prepared without the risk of blood product contamination.

The yeast-expressed HBsAg is advantageously in the form of substantially-spherical particles (average diameter of about 20nm), including a lipid matrix comprising phospholipids. Unlike

plasma-derived HBsAg particles, the yeast-expressed particles may include phosphatidylinositol. Moreover, the lipid matrix may include a non-ionic surfactant, such as polysorbate 20, which may be incorporated into the matrix during purification of the antigen from a yeast expression host. Using polysorbate 20 during disruption of recombinant yeast cells at the start of HBsAg purification is one way in which it can be introduced into the HBsAg particles. The polysorbate 20 will typically be present at a weight ratio of at least 5 μ g per 100 μ g of HBsAg.

All known HBV subtypes contain the common determinant 'a'. Combined with other determinants and subdeterminants, nine subtypes have been identified: ayw1, ayw2, ayw3, ayw4, ayr, adw2, adw4, adr_q- and adr_q+. Besides these subtypes, other variants have emerged, such as HBV mutants that have been detected in immunised individuals ("escape mutants"). Whereas some studies have found that the majority of sera in non-responders (*e.g.* in hemodialysis patients) are infected with adw4 or ayw3 subtypes (*e.g.* see reference 32, where 75% of sera were adw4, rising to 88% in a subset of hemodialysis patients; and reference 33, where 58% of subtyped samples from hemodialysis patients were ayw3), the most preferred HBV subtype for use with the invention is subtype adw2. This subtype was found in a single hemodialysis patient in reference 32, and in only a small number of outbreaks of HBV infection among hemodialysis patients in California & Nebraska during 1994 [34] and later in Brazil [35,36], but it highly immunogenic and effective in more than 98% of hemodialysis patients.

A preferred HBsAg has the following 226-mer amino acid sequence (SEQ ID NO: 3):

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MENITSGFLGPLLVLQAGFFLLTRILTIQSLDSWWTSLNFLGGSPVCLGQNSQSPTSNSHPTSCPPICPGYR
WMCLRRFIIIFLLFILLLLCLIFLLVLLDYQGMLPVCPLIPGSTTTNTGPKCTCTTPAQGNSMFPSCCCTKPTDGN
CTCIPIPSWAFAYKYLWEWASVRFSWLSLLVPFVQWFVGLSPTVWLSAIWMMWYWGPSLYSIVSPFIPLLPFI
FCLWVYI
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The invention can use SEQ ID NO: 3, or a sequence differing from SEQ ID NO: 3 by up to 10 (*i.e.* 1, 2, 3, 4, 5, 6, 7, 8, 9 or 10) single amino acid substitutions.

The HBsAg-coding sequence can be the following 678-mer nucleotide sequence (SEQ ID NO: 4):

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atggagaacatcacatcaggattcctaggacccctgctcgtgttacaggcgggggtttttcttgttgacaagaa
tcctcacaataaccgcagagtctagactcgtgggtggacttctctcaattttctagggggatcacccgtgtgtct
tggccaaaattcgcagtcaccaaacctccaatcactcaccaaacctcctgtcctccaatttgcctgttggtatcgc
tggatgtgtctcgcggcggtttatcatattcctcttcacacctgctgtgtatgcctcatcttcttatttggttcttc
tggattatcaagggtatgttgcgcgtttgtcctcctaattccaggatcaacaacaaccaatacgggaccatgcaa
aacctgcacgactcctgctcaaggcaactctatgtttccctcatgttgctgtacaaaacctacggatggaaat
tgcacctgtattcccatcccatcgctcctgggctttcgcaaaaatacctatgggagtgggcctcagtcggttctc
cttggctcagtttactagtgccatttgttcagtggttcgtagggctttccccccactggttggctttcagctat
atggatgatgtggtatttgggggccaagtctgtacagcatcgtgagtcctttataccgctgttaccattttc
ttttgtctctgggtatacatt
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The final codon of the HBsAg-coding sequence is preferably followed by a TAA stop codon (ochre).

In addition to the 'S' sequence, a surface antigen may include all or part of a pre-S sequence, such as all or part of a pre-S1 and/or pre-S2 sequence. It is preferred, however, to use only the S sequence, as shown above.

The GAPDH promoter

According to the invention, HBsAg is expressed in a *Saccharomyces cerevisiae* host carrying a plasmid having an upstream promoter from a glyceraldehyde-3-phosphate dehydrogenase (GAPDH) gene, and in particular from a yeast GAPDH [37-40]. The promoter is linked to the HBsAg-coding sequence in order to regulate its transcription.

Glyceraldehyde-3-phosphate dehydrogenase is a glycolytic enzyme, and its promoter has been found to be particularly suitable for controlling expression of HBsAg in *S.cerevisiae* [41]. The GAPDH promoter disclosed in reference 41 has the following 1061-mer sequence (SEQ ID NO: 5):

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aagcttaccagttctcacacggaacaccactaatggacacaaattcgaaatactttgaccctattttcgagga
ccttggtcaccttgagcccaagagagccaagattttaaattttcctatgacttgatgcaaattcccaaagcta
aacatgcaagacacgtacgggtcaagaagacatatattgacctcttaactgggttcagacgcgactgcctcatcag
taagaccggttgaaaagaacttacctgaaaaaacgaatatatactagcgttgatggttagcgtcaacaacaa
gaagtttaattgacgcggaggccaaggcaaaaagattccttgattacgtaagggagttagaatcattttgaata
aaaaacacgctttttcagttcgagtttatcattatcaatactgccatttcaagaatacgtaaataattaata
gtagtgtattttcctaactttatttagtcaaaaaattagccttttaattctgctgtaaccggtacatgccccaaa
tagggggcggttacacagaatatataacatcgtaggtgtctgggtgaacagtttatccctggcatccactaa
atataatggagctcgcttttaagctggcatccagaaaaaaaagaatcccagcaccaaaatattgttttcttc
accaaccatcagttcataggtccattctcttagcgcaactacagagaacaggggcacaaacaggcaaaaaacg
ggcacaacctcaatggagtgatgcaacctgcctggagtaaatgatgacacaaggcaattgaccacgcgatgta
tctatctcattttcttacaccttctattaccttctgctctctctgatttggaaaaagctgaaaaaaaagggtg
aaaccagttccctgaaattattcccctacttgactaataagtatataaagacggtaggtattgattgtaattc
tgtaaatctattttcttaaacttcttaaattctacttttatagtttagtcttttttttagtttttaaacaccaag
aacttagtttcgaataaacacacataaacaacaagcctt

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This promoter can be used according to the invention, but it is preferred to use a promoter comprising the following 1060-mer nucleotide sequence (SEQ ID NO: 1):

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aagcttaccagttctcacacggaacaccactaatggacacacattcgaaatactttgaccctattttcgagga
ccttggtcaccttgagcccaagagagccaagattttaaattttcctatgacttgatgcaaattcccaaagcta
aacatgcaagacacgtacgggtcaagaagacatatattgacctcttaacagggttcagacgcgactgcctcatcag
taagaccggttgaaaagaacttacctgaaaaaacgaatatatactagcgttgatggttagcgtcaacaacaa
gaagtttactgacgcggaggccaaggcaaaaagattccttgattacgtaagggagttagaatcattttgaata
aaaaacacgctttttcagttcgagtttatcattatcaatactgccatttcaagaatacgtaaataattaata
gtagtgtattttcctaactttatttagtcaaaaaattagccttttaattctgctgtaaccggtacatgccccaaa
atagggggcggttacacagaatatataacatcgtaggtgtctgggtgaacagtttatctctggcatccacta
aatataatggagcccgcttttaagctggcatccagaaaaaaaagaatcccagcaccaaaatattgttttctt
tcaccaaccatcagttcataggtccattctcttagcgcaactacagagaacaggggcacaaacaggcaaaaaa
cgggcacaacctcaatggagtgatgcaacctgcctggagtaaatgatgacacaaggcaattgaccacgcgatg
tatctatctcattttcttacaccttctattaccttctgctctctctgatttggaaaaagctgaaaaaaaagggt
tgaaaccagttccctgaaattattcccctacttgactaataagtatataaagacggtaggtattgattgtaatt
tctgtaaatctattttcttaaacttcttaaattctacttttatagtttagtcttttttttagtttttaaacacca
agaacttagtttcgaataaacacacataaacaacaaa

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This sequence differs from SEQ ID NO: 5 as follows: (1) A/C substitution at nucleotide 42; (2) T/A substitution at nucleotide 194; (3) C/A mutation at nucleotide 301; (4) A insertion at nucleotide 471; (5) C/T substitution at residue 569; (6) T/C substitution at residue 597; (7) T insertion at nucleotide 604 (penta-T instead of tetra-T); and (8) replacement of 3' GCTT sequence with a single A:

The invention can use the SEQ ID NO: 1 promoter sequence, or a sequence differing from SEQ ID NO: 1 by up to 20 (*i.e.* 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19 or 20) point mutations, each point mutation being the deletion, substitution or insertion of a single nucleotide.

The 1060-mer sequence is preferably immediately upstream of the ATG start codon encoding the N-terminus of the HBsAg (SEQ ID NO: 2) *e.g.*:

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aagcttaccagttctcacacggaacaccactaatggacacacattcgaaatactttgaccctatctttcgagga
ccttggtcaccttgagcccaagagagccaagatttttaattttcctatgacttgatgcaaattcccaaagctaatt
5 aacatgcaagacacgtacgggtcaagaagacatatattgacctcttaacagggttcagacgcgactgcctcatcag
taagaccgcgttgaaaagaacttacctgaaaaaaacgaatatatactagcgttgatgttagcgtcaacaacaa
gaagtttactgacgcggaggccaaggcaaaaagattccttgattacgtaagggttagaatcattttgaata
aaaaacacgcctttttcagttcgagtttatcattatcaatactgccatttcaaagaatacgtaaataattaata
10 gtagtgatttttctaactttatcttagtcaaaaaattagccttttaattctgctgtaaccgcgtacatgcccaaa
ataggggggagggttacacagaatatataacatcgtaggtgtctgggtgaacagtttattcctggcatccacta
aatataatggagcccgcttttttaagctggcatccagaaaaaaaagaatcccagcaccaaaatattgttttct
tcaccaaccatcagttcataggtccattctcttagcgcgaactacagagaacaggggcacaaacaggcaaaaaa
cgggcacaaacctcaatggagtgatgcaacctgcctggagtaaatgatgacacaaggcaattgaccacgcgatg
15 tatctatctcatttttcttacaccttctattaccttctgctctctctgatttggaaaaagctgaaaaaaaagg
tgaaaccagttccctgaaattattcccctacttgactaataagtatataaagacggtaggtattgattgtaatt
tctgtaaatctatcttcttaacttcttaaatctacttttatagtttagtcttttttttagtttttaaacacca
agaacttagtttctgaataaacacacataaaacaaacaaaATG...

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The ARG3 terminator

According to the invention, HBsAg is expressed in a *Saccharomyces cerevisiae* host carrying a plasmid having an downstream transcription terminator from ARG3. The terminator is linked to the HBsAg-coding sequence in order to regulate its transcription.

The ARG3 gene in yeast encodes the ornithine carbamoyltransferase enzyme [42] and its transcription termination sequence has been used in several yeast recombinant expression systems [43-45]. It is useful for controlling HBsAg expression in yeast, particularly in combination with a GAPDH promoter.

The sequence immediately downstream of the ARG3 stop codon, as disclosed in GenBank entry GI:171076, is the following 450-mer (SEQ ID NO: 6):

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tccttctttctgtgttcttaataactaatatataaaatcacagatatagatgcatgaataatgatatacattgatt
atcttgcaatgtcaattaaaaaaaaaaaaatgttagtataaaactatgttacattccaagcaataaagcacttgg
30 ttaaacgaaattaacgttttttaagacagccagaccgcggtctaaaaatttaaatatacactgccacaaattc
cttcgagttgtccaattttcaccacttttatattttcatcaacttcagcagattcaaccttctcatatagaaca
ttggaataaacagccttaacaccactttcaagtttgcacagcgtaatatgaggaaattttgttttgacaacaca
accctttaattttctcattgttttcatcaattatgcatccatctttatcttttagacagttccactacaatagc
aatagtttttttc

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Extending 250 nucleotides further backwards into the coding sequence, the ARG3 gene includes the following 700-mer sequence (SEQ ID NO: 7):

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agaatttgcgaaacaggccaagctgaaacaattcaaagggttttcaaatacaatcaagaacttgtctctgtggct
gatccaaactacaaatttatgcatgtgtctgccaagacatcaagaagaagtttagtgatgatgtcttttatggag
40 agcattccatagtcctttgaagaagcagaaaaacagattatatgcagctatgtctgccattgatatctttgttaa
taataaaggtaattttcaaggacttgaaaTAAtccttctttcgtgttcttaataactaatatataaaatcacagat
atagatgcatgaataatgatatacattgattattttgcaatgtcaattaaaaaaaaaaaaatgttagtataaaact
atgttacattccaagcaataaagcacttgggttaaacgaaattaacgtttttaagacagccagaccgcggtct
45 aaaaatttaaatatacactgccacaaattccttcgagttgtccaattttcaccacttttatattttcatcaac
ttcagcagattcaaccttctcatatagaacattggaataaacagccttaacaccactttcaagtttgcacagc
gtaatatgaggaaattttgttttgacaacacacaccttttaattttctcattgttttcatcaattatgcatccat
ctttatcttttagacagttccactacaatagcaatagtttttttc

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Transcription termination in SEQ ID NO: 7 takes place in the region of the underlined *SacII* site.

A preferred terminator for use with the invention includes a portion of both the coding and downstream sequences from this ARG3 region, and in particular comprises the following 689-mer nucleotide sequence (SEQ ID NO: 8), which has the same 3' terminus as SEQ ID NO: 7:

5 cgaattccaagctgaaacaattcaaagggttttcaaatcaatcaagaacttgtctctgtggctgatccaaacta
 caaatttatgcattgtctgccaagacatcaagaagaagttagtgtatgtcttttatggagagcattccata
 gtctttgaagaagcagaaaaacagattatatgcagctatgtctgcccattgatatactttgttaataataaaggta
 atttcaaggacttgaaataatccttctttcgtgttcttaataactaatatataaaatacagatatagatgcatg
 aataatgatatacattgattattttgcagtgtcaattaaaaaaaaaaaatgtagtaaaactatgttacattc
 10 caagcaaataaagcacttggttaaacgaaattaacgtttttaagacagccagaccgcggtctaaaaatttaa
 tatacactgccacaattccttcgagttgtccaatttcaccacttttatattttcatcaacttcagcagatt
 caaccttctcacatagaacattggaataaacagccttaacaccactttcaagtttgcacagcgtaatatgagg
 aatttggtttggacaacacaaccctttaattttctcattgttttcatcaattatgcatccatctttatcttta
 gacagttccactacaatatagcaatagtttttttc

15 This sequence usefully includes an *Eco*RI site near the 5' end (underlined), which facilitates insertion of the terminator into a desired position.

Further downstream terminator sequence from ARG3 can also be present. Up to 1500 nucleotides from ARG3 can be included (*i.e.* up to a further 800 nucleotides downstream of SEQ ID NO: 7) *e.g.* up to 1200 nucleotides, or about 1150 nucleotides.

20 The invention can use the SEQ ID NO: 8 terminator sequence, or a sequence differing from SEQ ID NO: 8 by up to 30 (*i.e.* 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39 or 40) point mutations, each point mutation being the deletion, substitution or insertion of a single nucleotide.

25 The 689-mer sequence is preferably immediately downstream of the stop codon at the C-terminus of the HBsAg (SEQ ID NO: 9) *e.g.*:

 ...TAAcgaattccaagctgaaacaattcaaagggttttcaaatcaatcaagaacttgtctctgtggctgatcc
 aaactacaaatttatgcattgtctgccaagacatcaagaagaagttagtgtatgtcttttatggagagcat
 tccatagtctttgaagaagcagaaaaacagattatatgcagctatgtctgcccattgatatactttgttaataata
 30 aaggtaatttcaaggacttgaaataatccttctttcgtgttcttaataactaatatataaaatacagatataga
 tgcatgaataatgatatacattgattattttgcagtgtcaattaaaaaaaaaaaatgtagtaaaactatgtt
 acattccaagcaaataaagcacttggttaaacgaaattaacgtttttaagacagccagaccgcggtctaaaaa
 tttaaatatacactgccacaattccttcgagttgtccaatttcaccacttttatattttcatcaacttcag
 cagattcaaccttctcacatagaacattggaataaacagccttaacaccactttcaagtttgcacagcgtaaat
 35 atgaggaattttgttttgacaacacaaccctttaattttctcattgttttcatcaattatgcatccatcttta
 tcttttagacagttccactacaatatagcaatagtttttttc

The plasmid

40 The gene encoding HBsAg, the GAPDH promoter and the ARG3 terminator are all operatively linked as part of the same plasmid. Plasmids of the invention will also typically include 1, 2 or (preferably) all 3 of the following elements: a LEU2 selection marker; a 2μ plasmid sequence; and an origin of replication functional in *E.coli*. These three components have previously been described in plasmids used for HBsAg expression [45].

The LEU2 selection marker is frequently used in yeast genetics. LEU2 encodes 3-isopropylmalate dehydrogenase, which is the third enzyme in the leucine biosynthesis pathway. The LEU2 marker on

the plasmid confers the ability to synthesize leucine from metabolic precursors, and is used in host cells that are leucine auxotrophs *e.g.* LEU2 null mutants. Thus the LEU2 marker permits a leucine auxotroph, which cannot normally grow without a leucine supply, to grow in the absence of leucine.

5 The 2μ plasmid sequence is also familiar in yeast genetics [46] and has been used to increase plasmid copy number. Any suitable 2μ plasmid sequence can be used in the plasmids of the invention. The plasmid includes a yeast origin of replication, and this is typically provided by the 2μ sequence.

By including an origin of replication that functions in *E.coli*, plasmids can act as shuttle vectors between yeast and *E.coli*, thereby permitting manipulation of the plasmid in the convenience of *E.coli* systems.

10 Thus invention provides a plasmid comprising the following elements: (1) a HBsAg coding sequence; (2) a promoter from a glyceraldehyde-3-phosphate dehydrogenase gene, upstream of and for controlling expression of the HBsAg coding sequence; and (3) an ARG3 transcription terminator downstream of the HBsAg coding sequence. The plasmid may also include the following elements: (4) a LEU2 selection marker; (5) a 2μ plasmid sequence; and (6) an origin of replication functional in
15 *E.coli*. The HBsAg coding sequence preferably encodes HBsAg with amino acid sequence SEQ ID NO: 3, or a sequence differing from SEQ ID NO: 3 by up to 10 (*i.e.* 1, 2, 3, 4, 5, 6, 7, 8, 9 or 10) single amino acid substitutions. The GAPDH promoter sequence preferably comprises SEQ ID NO: 1, or a sequence differing from SEQ ID NO: 1 by up to 20 (*i.e.* 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19 or 20) point mutations. The ARG3 terminator preferably comprises SEQ ID
20 NO: 8, or a sequence differing from SEQ ID NO: 8 by up to 20 (*i.e.* 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19 or 20) point mutations. The plasmid can be maintained in a *S.cerevisiae* host and can be used for expression of HBsAg.

Plasmids with between 14500 and 15000 bp are preferred *e.g.* between 14600 and 14700 bp.

The S.cerevisiae host

25 *Saccharomyces cerevisiae* is a widely-used yeast host for recombinant expression. Any suitable *S.cerevisiae* host can be used with the invention. It is preferred, however, to use a host that is auxotrophic for leucine, such that a LEU2 selection marker can be used in the plasmid. The host cell may be a *leu2-3 leu2-112* mutant.

Further characteristics of preferred yeast hosts are *his3* and/or *can1-11*. A most preferred yeast host
30 is *leu2-3 leu2-112 his3 can1-11*, such as the DC5 strain.

The invention provides a yeast carrying a plasmid of the invention. The invention also provides the use of this yeast in the manufacture of a composition of the invention.

HBsAg expression and purification

Techniques for yeast culture for recombinant protein expression are well known in the art. Yeast may
35 be cultured in a synthetic medium *e.g.* containing purified amino acids (typically omitting leucine

where a LEU2 marker is being used), vitamins, salts, *etc.* HBsAg can then be purified by a process involving steps such as precipitation, ion exchange chromatography, and ultrafiltration. Other steps that may be used during its purification include gel permeation chromatography, and cesium chloride ultracentrifugation.

- 5 A particularly preferred step for inclusion in the overall purification process is a step of cell disruption in the presence of a non-ionic detergent, such as Triton-X100 or a fatty acid esters of polyoxyethylene sorbitan, such as polyoxyethylene sorbitan monooleate (also known as polysorbate 80) or, more preferably, polyoxyethylene sorbitan monolaurate (also known as polysorbate 20). The disrupted cells can then be centrifuged to give a supernatant in which the HBsAg is found. The
10 protein can then be purified from the supernatant *e.g.* using the process disclosed in reference 47.

After purification HBsAg may be subjected to dialysis (*e.g.* with cysteine), which can be used to remove any mercurial preservatives such as thimerosal that may have been used during HBsAg preparation [48].

- HBsAg expressed and purified according to the invention can be combined with further non-HBV
15 antigens to prepare multivalent vaccines, or can be combined with new adjuvants to prepare improved monovalent vaccines.

Monovalent immunogenic compositions

- HBsAg expressed and purified according to the invention can be combined with new adjuvants to prepare improved monovalent vaccines. Three specific adjuvants of interest for use in monovalent
20 HBV vaccines are: CpG oligonucleotides; aminoalkyl glucosaminide phosphate derivatives; and mixtures of 3d-MPL with aluminum salts.

- CpG oligonucleotide adjuvants are immunostimulatory oligonucleotides that include nucleotide sequences containing a CpG motif (a dinucleotide sequence containing an unmethylated cytosine followed by guanosine). Bacterial double stranded RNA or oligonucleotides containing palindromic
25 or poly(dG) sequences have also been shown to be immunostimulatory. The CpG's can include nucleotide modifications/analogues such as phosphorothioate modifications and can be double-stranded or single-stranded. Optionally, the guanosine may be replaced with an analog such as 2'-deoxy-7-deazaguanosine. References 49-51 give examples of possible analog substitutions. The adjuvant effect of CpG oligonucleotides is further discussed in references 52-57.

- 30 The CpG sequence may be directed to TLR9, such as the motif GTCGTT (SEQ ID NO: 11) or TTCGTT (SEQ ID NO: 12) [58]. The CpG sequence may be specific for inducing a Th1 immune response, such as a CpG-A ODN, or it may be more specific for inducing a B cell response, such as a CpG-B ODN. CpG-A and CpG-B ODNs are discussed in refs. 59-61. Preferably, the CpG is a CpG-A ODN.

Preferably, the CpG oligonucleotide is constructed so that the 5' end is accessible for receptor recognition. Preferably, the CpG oligonucleotide is constructed so that the 5' end is accessible for receptor recognition. Optionally, two CpG oligonucleotide sequences may be attached at their 3' ends to form "immunomers". See, for example, refs. 58 & 62-64.

- 5 Aminoalkyl glucosaminide phosphate (AGP) derivatives include RC-529 [65-68], which is an aminoalkyl glucosaminide 4-phosphate sold by Corixa Corporation.

AS04 is a mixture of an aluminum salt adjuvant and a 3D-MPL adjuvant [69]. When using AS04, the HBsAg is preferably adsorbed onto the aluminum salt *e.g.* as described in ref. 70. It is preferred that the aluminum salt is a phosphate, and that at least 50% (by weight) of the total HBsAg is adsorbed to the aluminum phosphate *e.g.* $\geq 60\%$, $\geq 70\%$, $\geq 80\%$, $\geq 90\%$, $\geq 95\%$, $\geq 98\%$ or more. The percentage that is adsorbed can conveniently be measured by separating the adsorbed material from the non-adsorbed material *e.g.* by centrifugation, in which the aluminum-adsorbed antigen will readily form a pellet, whereas the unadsorbed antigen will remain in the supernatant. The amount of HBsAg in the supernatant (*e.g.* measured by anti-HBsAg ELISA) can be subtracted from the total amount of HBsAg in the composition, and then the adsorbed percentage can be calculated. It is preferred that the HBsAg is totally adsorbed *i.e.* none is detectable in supernatant.

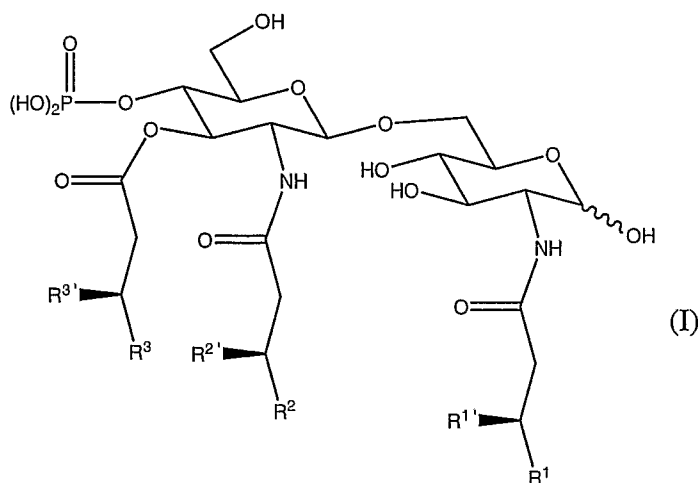
The 3D-MPL adjuvant can also be adsorbed onto the aluminum phosphate. Preferably at least 50% (by weight) of the 3D-MPL is adsorbed *e.g.* $\geq 60\%$, $\geq 70\%$, $\geq 80\%$, $\geq 90\%$, $\geq 95\%$, $\geq 98\%$ or more. The percentage that is adsorbed can be measured in the same way as for HBsAg. In a composition having a total 3D-MPL concentration of 50 $\mu\text{g/ml}$ then the concentration of unadsorbed 3D-MPL should be less than 25 $\mu\text{g/ml}$ *e.g.* $\leq 20 \mu\text{g/ml}$, $\leq 15 \mu\text{g/ml}$, $\leq 10 \mu\text{g/ml}$, $\leq 5 \mu\text{g/ml}$, $\leq 20 \mu\text{g/ml}$, $\leq 1 \mu\text{g/ml}$, *etc.*

Aluminum phosphate adjuvants are described below in more detail.

3-O-deacylated monophosphoryl lipid A (3D-MPL) has also been referred to as 3 de-O-acylated monophosphoryl lipid A or as 3-O-desacyl-4'-monophosphoryl lipid A. The name indicates that position 3 of the reducing end glucosamine in monophosphoryl lipid A is de-acylated. It has been prepared from a heptoseless mutant of *Salmonella minnesota*, and is chemically similar to lipid A but lacks an acid-labile phosphoryl group and a base-labile acyl group. It activates cells of the monocyte/macrophage lineage and stimulates release of several cytokines, including IL-1, IL-12, TNF- α and GM-CSF. Preparation of 3D-MPL was originally described in reference 71, and the product has been manufactured and sold by Corixa Corporation under the trade name MPLTM. Further details can be found in references 72 to 75. The 3D-MPL can be included in combination with a triethanolamine, triethylammonium or triethylamine ion.

3D-MPL can take the form of a mixture of related molecules, varying by their acylation (*e.g.* having 3, 4, 5 or 6 acyl chains, which may be of different lengths). The two 2-deoxy-2-amino-glucose monosaccharides are N-acylated at their 2-position carbons (*i.e.* at positions 2 and 2'), and there is also O-acylation at the 3' position. The group attached to carbon 2 has formula -NH-CO-CH₂-CR¹R^{1'}.

The group attached to carbon 2' has formula $-\text{NH}-\text{CO}-\text{CH}_2-\text{CR}^2\text{R}^{2'}$. The group attached to carbon 3' has formula $-\text{O}-\text{CO}-\text{CH}_2-\text{CR}^3\text{R}^{3'}$. A representative structure is shown below:



Groups R^1 , R^2 and R^3 are each independently $-(\text{CH}_2)_n-\text{CH}_3$. The value of n is preferably between 8 and 16, more preferably between 9 and 12, and is most preferably 10.

Groups $\text{R}^{1'}$, $\text{R}^{2'}$ and $\text{R}^{3'}$ can each independently be: (a) $-\text{H}$; (b) $-\text{OH}$; or (c) $-\text{O}-\text{CO}-\text{R}^4$, where R^4 is either $-\text{H}$ or $-(\text{CH}_2)_m-\text{CH}_3$, wherein the value of m is preferably between 8 and 16, and is more preferably 10, 12 or 14. At the 2 position, m is preferably 14. At the 2' position, m is preferably 10. At the 3' position, m is preferably 12. Groups R^1 , R^2 and R^3 are thus preferably $-\text{O}$ -acyl groups from dodecanoic acid, tetradecanoic acid or hexadecanoic acid.

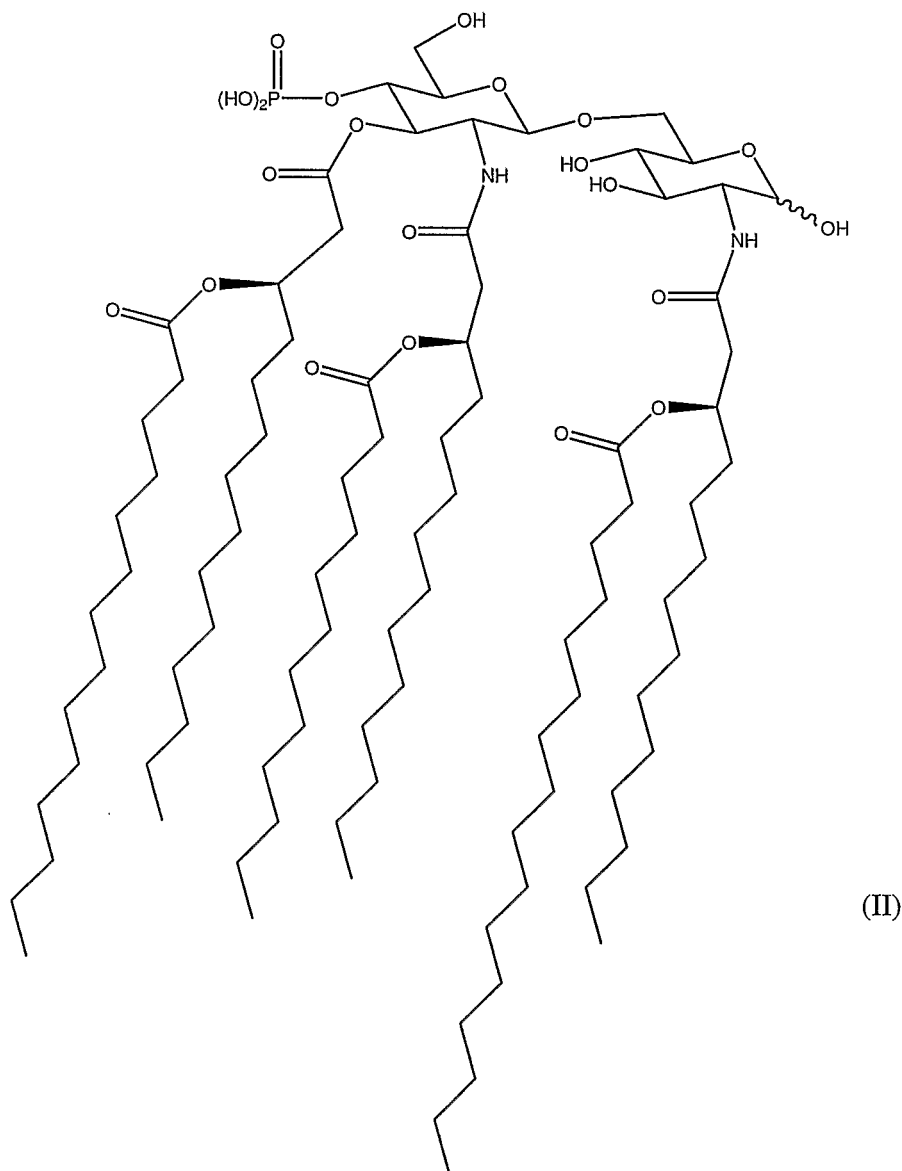
When all of $\text{R}^{1'}$, $\text{R}^{2'}$ and $\text{R}^{3'}$ are $-\text{H}$ then the 3D-MPL has only 3 acyl chains (one on each of positions 2, 2' and 3'). When only two of $\text{R}^{1'}$, $\text{R}^{2'}$ and $\text{R}^{3'}$ are $-\text{H}$ then the 3D-MPL can have 4 acyl chains. When only one of $\text{R}^{1'}$, $\text{R}^{2'}$ and $\text{R}^{3'}$ is $-\text{H}$ then the 3D-MPL can have 5 acyl chains. When none of $\text{R}^{1'}$, $\text{R}^{2'}$ and $\text{R}^{3'}$ are $-\text{H}$ then the 3D-MPL can have 6 acyl chains. The 3D-MPL adjuvant used according to the invention can be a mixture of these forms, with from 3 to 6 acyl chains, but it is preferred to include 3D-MPL with 6 acyl chains in the mixture, and in particular to ensure that the 6 acyl chain form makes up at least 10% by weight of the total 3D-MPL *e.g.* $\geq 20\%$, $\geq 30\%$, $\geq 40\%$, $\geq 50\%$ or more. 3D-MPL with 6 acyl chains has been found to be the most adjuvant-active form.

Thus the most preferred form of 3D-MPL for inclusion in compositions of the invention has formula (II), shown below.

In aqueous conditions, 3D-MPL can form micellar aggregates or particles with different sizes *e.g.* with a diameter $<150\text{nm}$ or $>500\text{nm}$. Either or both of these can be used with the invention, and the better particles can be selected by routine assay. Smaller particles (*e.g.* small enough to give a clear aqueous suspension of 3D-MPL) have been reported to be superior [76] and are preferred for use according to the invention. Preferred particles have a mean diameter less than 220nm , more preferably less than 200nm , less than 150nm , or less than 120nm . They can even have a mean diameter less than 100nm . In most cases, however, the mean diameter will not be lower than 50nm .

Where 3D-MPL is adsorbed to aluminum phosphate then it may not be possible to measure the 3D-MPL particle size directly, but particle size can be measured before adsorption takes place.

Particle diameter can be assessed by the routine technique of dynamic light scattering, which reveals a mean particle diameter. Where a particle is said to have a mean diameter of x nm, there will generally be a distribution of particles about this mean, but at least 50% by number (*e.g.* $\geq 60\%$, $\geq 70\%$, $\geq 80\%$, $\geq 90\%$, or more) of the particles will have a diameter within the range $x \pm 20\%$.



(II)

Multivalent immunogenic compositions

HBsAg expressed and purified according to the invention can be combined with one or more non-HBV antigens to prepare multivalent vaccines. The non-HBV antigens can include bacterial and/or viral antigens. Typical non-HBV components for use according to the invention include, but are not limited to:

- a diphtheria toxoid ('D')
- a tetanus toxoid ('T')

- a pertussis antigen ('P'), which may be either cellular ('wP') or acellular ('aP')
- a hepatitis A virus (HAV) antigen
- a conjugated *Haemophilus influenzae* type b capsular saccharide ('Hib')
- inactivated polio virus (IPV)
- 5 • a conjugated *Neisseria meningitidis* serogroup C capsular saccharide ('MenC')
- a conjugated *Neisseria meningitidis* serogroup A capsular saccharide ('MenA')
- a conjugated *Neisseria meningitidis* serogroup W135 capsular saccharide ('MenW135')
- a conjugated *Neisseria meningitidis* serogroup Y capsular saccharide ('MenY')
- a conjugated *Streptococcus pneumoniae* capsular saccharide
- 10 • a measles virus antigen
- a mumps virus antigen
- a rubella virus antigen
- a varicella zoster virus antigen
- an influenza virus antigen
- 15 More than one of these non-HBV antigens can be used. The following combinations of antigens are particularly preferred:
 - Bivalent vaccines: HBV-HAV; HBV-Hib.
 - Trivalent vaccines: HBV-D-T.
 - Tetravalent vaccines: HBV-D-T-P.
 - 20 • Pentavalent vaccines: HBV-D-T-P-Hib; HBV-D-T-P-IPV.
 - Hexavalent vaccines: HBV-D-T-P-Hib-IPV.
 - Heptavalent vaccines: HBV-D-T-P-Hib-MenA-MenC; HBV-D-T-P-Hib-IPV-MenC.

Diphtheria toxoid ('D') is disclosed in more detail in chapter 13 of reference 1. Preferred diphtheria toxoids are those prepared by formaldehyde treatment. The diphtheria toxoid can be obtained by

25 growing *C.diphtheriae* in growth medium (e.g. Fenton medium, or Linggoud & Fenton medium), which may be supplemented with bovine extract, followed by formaldehyde treatment, ultrafiltration and precipitation. The toxoided material may then be treated by a process comprising sterile filtration and/or dialysis. Quantities of diphtheria toxoid can be expressed in international units (IU). For example, the NIBSC supplies the 'Diphtheria Toxoid Adsorbed Third International Standard 1999'

30 [77,78], which contains 160 IU per ampoule. As an alternative to the IU system, the 'Lf' unit ("flocculating units" or the "limes flocculating dose") is defined as the amount of toxoid which, when mixed with one International Unit of antitoxin, produces an optimally flocculating mixture [79]. For example, the NIBSC supplies 'Diphtheria Toxoid, Plain' [80], which contains 300 LF per ampoule, and also supplies 'The 1st International Reference Reagent For Diphtheria Toxoid For

35 Flocculation Test' [81] which contains 900 Lf per ampoule.

Tetanus toxoid ('T') is disclosed in more detail in chapter 27 of reference 1. Preferred tetanus toxoids are those prepared by formaldehyde treatment. The tetanus toxoid can be obtained by growing

C.tetani in growth medium (e.g. a Latham medium derived from bovine casein), followed by formaldehyde treatment, ultrafiltration and precipitation. The material may then be treated by a process comprising sterile filtration and/or dialysis. Quantities of tetanus toxoid can be expressed in international units (IU). For example, the NIBSC supplies the 'Tetanus Toxoid Adsorbed Third International Standard 2000' [82,83], which contains 469 IU per ampoule. As an alternative to the IU system, the 'Lf' unit ("flocculating units" or the "limes flocculating dose") is defined as the amount of toxoid which, when mixed with one International Unit of antitoxin, produces an optimally flocculating mixture [79]. For example, the NIBSC supplies 'The 1st International Reference Reagent for Tetanus Toxoid For Flocculation Test' [84] which contains 1000 Lf per ampoule.

Pertussis antigen ('P') can be either cellular ('wP') or acellular ('aP'). *Cellular* pertussis antigens typically take the form of inactivated *B.pertussis* cells. Preparation of cellular pertussis antigens is well documented (e.g. see chapter 21 of reference 1) e.g. it may be obtained by heat inactivation of phase I culture of *B.pertussis*. Quantities of wP antigens can be expressed in international units (IU). For example, the NIBSC supplies the 'Third International Standard For Pertussis Vaccine' [85], which contains 46 IU per ampoule. Each ampoule contains the freeze-dried residue of 2.0 ml aliquots of an aqueous solution which contained 10 liters of bacterial suspension (equivalent to 180 opacity units in terms of the U.S. Opacity Standard) diluted with eight litres of M/15 Sorensen's buffer pH 7.0. As an alternative to the IU system, the 'OU' unit ("opacity units") is also used (e.g. 4 OU may be about 1 IU). *Acellular* pertussis antigens currently used in vaccines include pertussis toxoid (PT), filamentous haemagglutinin (FHA), pertactin (also known as the '69 kiloDalton outer membrane protein'), and fimbriae (e.g. agglutinogens 2 and 3). The invention preferably uses at least two of, and preferably all three of, PT, FHA and pertactin (i.e. without using fimbriae). These three antigens are preferably prepared by isolation from *B.pertussis* culture grown in modified Stainer-Scholte liquid medium. PT and FHA can be isolated from the fermentation broth (e.g. by adsorption on hydroxyapatite gel), whereas pertactin can be extracted from the cells by heat treatment and flocculation (e.g. using barium chloride). The antigens can be purified in successive chromatographic and/or precipitation steps. PT and FHA can be purified by hydrophobic chromatography, affinity chromatography and size exclusion chromatography. Pertactin can be purified by ion exchange chromatography, hydrophobic chromatography and size exclusion chromatography. FHA and pertactin may be treated with formaldehyde prior to use according to the invention. PT is preferably detoxified by treatment with formaldehyde and/or glutaraldehyde. As an alternative to this chemical detoxification procedure the PT may be a mutant PT in which enzymatic activity has been reduced by mutagenesis [86], but detoxification by chemical treatment is preferred. Quantities of acellular pertussis antigens are typically expressed in micrograms.

Hepatitis A virus (HAV) vaccines are disclosed in chapter 15 of reference 1. A preferred HAV component is based on inactivated virus, and inactivation can be achieved by formalin treatment. Virus can be grown on human embryonic lung diploid fibroblasts, such as MRC-5 cells. A preferred

HAV strain is HM175, although CR326F can also be used. The cells can be grown under conditions that permit viral growth. The cells are lysed, and the resulting suspension can be purified by ultrafiltration and gel permeation chromatography.

H.influenzae type b capsular saccharide ('Hib') conjugates are disclosed in more detail in chapter 14 of reference 1. The Hib capsular saccharide is conjugated to a carrier protein in order to enhance its immunogenicity, especially in children. Various carrier proteins can be used, including diphtheria toxoid, CRM197, an outer membrane protein complex from serogroup B meningococcus, *H.influenzae* protein D or tetanus toxoid. Tetanus toxoid is the preferred carrier, as used in the product commonly referred to as 'PRP-T'. PRP-T can be made by activating a Hib capsular polysaccharide using cyanogen bromide, coupling the activated saccharide to an adipic acid linker (such as (1-ethyl-3-(3-dimethylaminopropyl)carbodiimide), typically the hydrochloride salt), and then reacting the linker-saccharide entity with a tetanus toxoid carrier protein. The saccharide moiety of a Hib conjugate may comprise full-length polyribosylribitol phosphate (PRP) as prepared from Hib bacteria, and/or it may comprise fragments of full-length PRP. Conjugates with a saccharide:protein ratio (w/w) of between 1:5 (*i.e.* excess protein) and 5:1 (*i.e.* excess saccharide) may be used *e.g.* ratios between 1:2 and 5:1 and ratios between 1:1.25 and 1:2.5. In preferred conjugates, the weight ratio of saccharide to carrier protein is between 1:2.5 and 1:3.5. In vaccines where tetanus toxoid is present both as an antigen and as a carrier protein then the weight ratio of saccharide to carrier protein in the conjugate may be between 1:0.3 and 1:2 [87]. Administration of the Hib conjugate preferably results in an anti-PRP antibody concentration of $\geq 0.15 \mu\text{g/ml}$, and more preferably $\geq 1 \mu\text{g/ml}$, and these are the standard acceptable response thresholds.

Inactivated polio virus vaccine (IPV) is disclosed in more detail in chapter 24 of reference 1. Polioviruses may be grown in cell culture, and a preferred culture uses a Vero cell line, derived from monkey kidney. Vero cells can conveniently be cultured microcarriers. After growth, virions may be purified using techniques such as ultrafiltration, diafiltration, and chromatography. Prior to administration to patients, polioviruses must be inactivated, and this can be achieved by treatment with formaldehyde. Poliomyelitis can be caused by one of three types of poliovirus. The three types are similar and cause identical symptoms, but they are antigenically very different and infection by one type does not protect against infection by others. It is therefore preferred to use three poliovirus antigens in the invention: poliovirus Type 1 (*e.g.* Mahoney strain), poliovirus Type 2 (*e.g.* MEF-1 strain), and poliovirus Type 3 (*e.g.* Saukett strain). The viruses are preferably grown, purified and inactivated individually, and are then combined to give a bulk trivalent mixture for use with the invention. Quantities of IPV are typically expressed in the 'DU' unit (the "D-antigen unit" [88]).

Conjugated meningococcal antigens comprise capsular saccharide antigens from *N.meningitidis* conjugated to carrier proteins. Conjugate vaccines against serogroup C have been approved for human use, and include MENJUGATE™ [89], MENINGITEC™ and NEISVAC-C™. Mixtures of conjugates from serogroups A+C are known [90, 91] and mixtures of conjugates from serogroups

A+C+W135+Y have been reported [92-95] and were approved in 2005 as the MENACTRA™ product. The meningococcal saccharide(s) used in the invention can be from one or more of serogroups A, C, W135 and Y *e.g.* A+C, A+W135, A+Y, C+W135, C+Y, W135+Y, A+C+W135, A+C+Y, C+W135+Y, A+C+W135+Y. It is preferred to use at least the serogroup C saccharide, and preferably to use the saccharides from both of serogroups A and C. The MENJUGATE™ and MENINGITEC™ products use a CRM197 carrier protein, and this carrier can also be used according to the invention. The NEISVAC-C™ product uses a tetanus toxoid carrier protein, and this carrier can also be used according to the invention, as can diphtheria toxoid. A particularly preferred carrier protein for the meningococcal conjugates is protein D from *H.influenzae*, which is not present in any existing approved conjugate vaccines. The saccharide moiety of the conjugate may comprise full-length saccharides as prepared from meningococci, and/or it may comprise fragments of full-length saccharides. Serogroup C saccharides may be prepared from either OAc+ or OAc- strains. For serogroup A saccharides, preferably at least 50% (*e.g.* at least 60%, 70%, 80%, 90%, 95% or more) of the mannosamine residues are O-acetylated at the C-3 position. Meningococcal conjugates with a saccharide:protein ratio (w/w) of between 1:10 (*i.e.* excess protein) and 10:1 (*i.e.* excess saccharide) may be used *e.g.* ratios between 1:5 and 5:1, between 1:2.5 and 2.5:1, or between 1:1.25 and 1.25:1. Administration of a conjugate preferably results in an increase in serum bactericidal assay (SBA) titre for the relevant serogroup of at least 4-fold, and preferably at least 8-fold. SBA titres can be measured using baby rabbit complement or human complement [96].

Conjugated pneumococcal antigens comprise capsular saccharide antigens from *S.pneumoniae* conjugated to carrier proteins [*e.g.* refs. 97 to 99]. It is preferred to include saccharides from more than one serotype of *S.pneumoniae*: mixtures of polysaccharides from 23 different serotype are widely used, as are conjugate vaccines with polysaccharides from between 5 and 11 different serotypes [100]. For example, Prevnar™ [101] contains antigens from seven serotypes (4, 6B, 9V, 14, 18C, 19F, and 23F) with each saccharide individually conjugated to CRM₁₉₇ by reductive amination, with 2µg of each saccharide per 0.5ml dose (4µg of serotype 6B), and with conjugates adsorbed on an aluminum phosphate adjuvant. Compositions of the invention preferably include at least serotypes 6B, 14, 19F and 23F. Further serotypes are preferably selected from: 1, 3, 4, 5, 7F, 9V and 18C.

Antigens for protecting against measles, mumps and rubella viruses are typically live viruses, as found in known monovalent and trivalent ('MMR') vaccines. Measles virus vaccines are described in more detail in chapter 19 of reference 1. Mumps virus vaccines are described in more detail in chapter 20 of reference 1. Rubella virus vaccines are described in more detail in chapter 26 of reference 1. Typical measles virus strains include: Moraten; Connaught; Schwarz; Edmonston-Zagreb; CAM-70; AIK-C; TD97; Leningrad-16; Shanghai-191; *etc.* The Schwarz and Moraten strains are most common for use in USA and Europe. Typical mumps virus strains include: Jeryl Lynn; RIT 4385; Urabe; Hoshino; Rubini; Leningrad-3; Leningrad-Zagreb; Miyahara; Torii; NK

M-46; S-12; *etc.* The Jeryl Lynn, RIT 4385, Urabe and Leningrad-Zagreb strains are the most common worldwide strains. Typical rubella virus strains include: RA27/3; Matsuba; TCRB 19; Takahashi; Matsuura; TP-336; *etc.* The RA27/3 strain is the most common strain used in the western world.

- 5 VZV antigens for protecting against chickenpox are typically live viruses, based on the Oka strain of the virus. VZV vaccines are described in more detail in chapter 28 of reference 1.

Influenza virus antigens are described in more detail in chapters 17 & 18 of reference 1. Broadly, influenza virus vaccines can be based on live virus or inactivated virus, and inactivated vaccines can be based on whole virus, 'split' virus or on purified surface antigens (including hemagglutinin and neuraminidase). The viruses used to prepare the vaccines can be grown either on eggs or on cell culture. Vaccine strains for influenza virus change from season to season. In the current inter-pandemic period, vaccines typically include two influenza A strains (H1N1 and H3N2) and one influenza B strain, and trivalent vaccines are typical. The invention may also use viruses from pandemic strains (*i.e.* strains to which the vaccine recipient and the general human population are immunologically naïve), such as H2, H5, H7 or H9 subtype strains (in particular of influenza A virus), and influenza vaccines for pandemic strains may be monovalent or may be based on a normal trivalent vaccine supplemented by a pandemic strain. The influenza virus may be a reassortant strain, and may have been obtained by reverse genetics techniques. The virus may be attenuated. The virus may be temperature-sensitive. The virus may be cold-adapted.

- 20 When making multivalent combinations, antigens can be combined individually in series, or they can be pre-mixed and added together. For example, a 4-valent DTP-HBsAg vaccine can be made by a process involving serial addition of HBsAg, D, T and P antigens to a vessel, or by pre-mixing D, T and P antigens and then combining the HBsAg and the DTP mixture.

Antigenic components can be combined in any suitable order.

- 25 Where diphtheria and tetanus toxoids are included in a composition of the invention, they are preferably pre-mixed before being combined with HBsAg. Thus the process of the invention involves combining a first component comprising HBsAg with a second component comprising both D and T antigens. Thus it is preferred to use a pre-mixed D-T component. This bivalent component can be used in the processes of the invention *e.g.* it can be combined with HBsAg to make a trivalent D-T-HBV component. As an alternative, the pre-mixed D-T component can be combined with further non-HBV antigens (*e.g.* with acellular pertussis antigens), and that component can then be combined with HBsAg, *etc.*

- 35 Similarly, where diphtheria toxoid, tetanus toxoid and whole cell pertussis antigens are included in a composition, they are preferably pre-mixed, and so the process of the invention involves combining a first component comprising HBsAg with a second component comprising D, T and Pw antigens.

Thus it is preferred to use a pre-mixed D-T-Pw component, and then to use this component during the processes of the invention.

When an adjuvant is included in the compositions of the invention, this also can be added at various stages. Typically, antigens will have been combined with adjuvants before being used in the processes of the invention (*e.g.* a bivalent D-T mixture will have been adsorbed to aluminum salt adjuvant(s) before being used in the processes of the invention), but it is also possible to add adjuvant after the antigens have been mixed, or to add the antigens to an adjuvant (*e.g.* to start with an aqueous adjuvant, then to add antigens, either individually or pre-mixed). As described below, the HBsAg component is preferably adsorbed to an aluminum phosphate adjuvant before being combined with the non-HBV antigenic components.

HBsAg fusion proteins

As well as being used to express HBsAg, the invention can be used to express hybrid antigens that include a HBsAg sequence and a non-HBsAg sequence within the same polypeptide. The non-HBsAg sequence may be inserted into the HBsAg sequence, or may be fused to the N-terminus or C-terminus of the HBsAg sequence.

It is known to fuse the HBsAg sequence to heterologous antigens to exploit HBsAg's ability to assemble into particles. For example, reference 102 reports fusions of HIV-1 gp120 to HBsAg to give a protein that spontaneously assembled into particles that resemble native HBsAg particles in size and density, consistent with a lipid composition of about 25% and a gp120 content of about 100 per particle. The gp120 was able to fold into its native conformation in the fusion, and retained its biological activity. Similarly, HIV gp41 epitopes have been improved by making internal fusions with HBsAg, and the fusion protein self-assembled in yeast into 22nm lipoprotein particles [103].

This approach has also been used for malaria vaccines. Reference 104 reports that epitopes of up to 61aa from the malaria gp190 antigen were inserted into the HBsAg sequence, and that the expressed hybrid particles could elicit an anti-gp190 immune response in animals. Reference 105 report a protein having 16 repeats of a 4-mer sequence of the circumsporozoite protein expressed as a fusion protein with HBsAg. Reference 106 reports the production in yeast of virus-like particles composed of Pfs16 fused to HBsAg. Reference 107 discloses a hybrid antigen in which the circumsporozoite protein is fused to HBsAg. Reference 108 discloses a fusion of the C-terminal region of the merozoite surface 1 protein of *P.vivax*, which formed immunogenic particles of 20-45 nm size. The use of HBsAg for presenting malarial antigens in self-assembling particulate form is therefore well known in the art.

This approach is particularly suitable for fusing HBsAg sequences with antigens from HIV, *Plasmodium falciparum*, *Plasmodium vivax*, *Plasmodium malariae* or *Plasmodium ovale*. Suitable HIV antigens for making HBsAg hybrids include envelope glycoprotein gp120 or antigenic fragments thereof [102]. Suitable *P.falciparum* antigens for making HBsAg hybrids may be based on

the NF54 or 7G8 isolate of *P.falciparum* (amino acids 210 to 398, which includes 19 NANP repeats and the T cell epitope region at amino acids 367 to 390), fused to the N-terminus of HBsAg by four amino acids of the preS2 portion of HBsAg. When expressed in yeast, RTS forms particles that include lipids (primarily phospholipid) in addition to protein. The sequence of RTS can thus, as in SEQ ID NO: 15 herein, contain: (i) a N-terminus methionine residue; (ii) Met-Ala-Pro; (iii) 189 amino acids corresponding either to amino acids 210-398 of CS protein from *P.falciparum* 7G8 or to amino acids 207-395 of CS protein from *P.falciparum* NF54; (iv) Arg or Gly; (v) Pro-Val-Thr-Asn from hepatitis B Pre-S2 protein; and (vi) HBsAg. From the 7G8 isolate, full-length RTS has the sequence given as SEQ ID NO: 1 in reference 109 (see also Figure 5 of reference 110):

15 PNANPNANPNKNNQGGNGQGHNMPNDPNRNVDENNANNNAVKNNNNEEPSDKHIEQYLKKIKNSISTEWSPCSVT
CGNGIQVRIKPGSANKPKDEL DYENDIEKKICKMEKCSSVFNVVNSRPVTNMENTISGFLGPLLVLQAGFFLL
TRILTIQPSLDSWWTISNFLGLSPVCLGQNSQSPTSNNHSPSTCPPICPGYRWMCLRRFIIFLFIILLCLIFLL
VLLDYQGMLPVCPLTIPGSTTTGTSPCKTCTTPAQGNSMYPSCCCTKPTDGNCTCIPISSSWAFAKYLWEWASV
RFSWLSLLVPFVOWFVGLSPTVWLSAIWMMWYWGPSLSYIVSPFIPLPIFFCLWVYI

This hybrid antigen can be expressed in yeast, using a sequence encoding SEQ ID NO:15. It is preferred to co-express the hybrid protein in yeast with normal HBsAg. This approach has previously been used with RTS, and the product of co-expression is referred to as “RTS,S”. A RTS:S ratio of about 1:4 is useful.

25 Thus a useful aspect of the present invention is to co-express (i) HBsAg and (ii) RTS. One or both of these antigens may be expressed using the plasmids described hereinabove. The co-expressed proteins form a particulate antigen that can be used as an active ingredient in a malaria vaccine.

Adjuvants for use in multivalent vaccines

30 ‘Modern’ adjuvants including CpG, AGPs and AS04 are described above. While these can be used in multivalent compositions of the invention, it is preferred instead to use aluminum salts. These include the adjuvants known as aluminum hydroxide and aluminum phosphate. These names are conventional, but are used for convenience only, as neither is a precise description of the actual chemical compound which is present [*e.g.* see chapter 9 of reference 111]. The invention can use any of the “hydroxide” or “phosphate” adjuvants that are in general use as adjuvants.

35 The adjuvants known as “aluminum hydroxide” are typically aluminum oxyhydroxide salts, which are usually at least partially crystalline. Aluminum oxyhydroxide, which can be represented by the formula $\text{AlO}(\text{OH})$, can be distinguished from other aluminum compounds, such as aluminum hydroxide $\text{Al}(\text{OH})_3$, by infrared (IR) spectroscopy, in particular by the presence of an adsorption band at 1070cm^{-1} and a strong shoulder at $3090\text{--}3100\text{cm}^{-1}$ [chapter 9 of ref. 111].

The adjuvants known as “aluminum phosphate” are typically aluminum hydroxyphosphates, often also containing a small amount of sulfate (*i.e.* aluminum hydroxyphosphate sulfate). They may be obtained by precipitation, and the reaction conditions and concentrations during precipitation influence the degree of substitution of phosphate for hydroxyl in the salt. Hydroxyphosphates generally have a PO_4/Al molar ratio between 0.3 and 1.2. Hydroxyphosphates can be distinguished from strict AlPO_4 by the presence of hydroxyl groups. For example, an IR spectrum band at 3164cm^{-1} (*e.g.* when heated to 200°C) indicates the presence of structural hydroxyls [ch. 9 of ref. 111].

The $\text{PO}_4/\text{Al}^{3+}$ molar ratio of an aluminum phosphate adjuvant will generally be between 0.3 and 1.2, preferably between 0.8 and 1.2, and more preferably 0.95 ± 0.1 . The aluminum phosphate will generally be amorphous, particularly for hydroxyphosphate salts. A typical adjuvant is amorphous aluminum hydroxyphosphate with PO_4/Al molar ratio between 0.84 and 0.92, included at $0.6\text{mg Al}^{3+}/\text{ml}$. The aluminum phosphate will generally be particulate. Typical diameters of the particles are in the range $0.5\text{-}20\mu\text{m}$ (*e.g.* about $5\text{-}10\mu\text{m}$) after any antigen adsorption.

The PZC of aluminum phosphate is inversely related to the degree of substitution of phosphate for hydroxyl, and this degree of substitution can vary depending on reaction conditions and concentration of reactants used for preparing the salt by precipitation. PZC is also altered by changing the concentration of free phosphate ions in solution (more phosphate = more acidic PZC) or by adding a buffer such as a histidine buffer (makes PZC more basic). Aluminum phosphates used according to the invention will generally have a PZC of between 4.0 and 7.0, more preferably between 5.0 and 6.5 *e.g.* about 5.7.

An aluminum phosphate solution used to prepare a composition of the invention may contain a buffer (*e.g.* a phosphate or a histidine or a Tris buffer), but this is not always necessary. The aluminum phosphate solution is preferably sterile and pyrogen-free. The aluminum phosphate solution may include free aqueous phosphate ions *e.g.* present at a concentration between 1.0 and 20 mM, preferably between 5 and 15 mM, and more preferably about 10 mM. The aluminum phosphate solution may also comprise sodium chloride. The concentration of sodium chloride is preferably in the range of 0.1 to 100 mg/ml (*e.g.* 0.5-50 mg/ml, 1-20 mg/ml, 2-10 mg/ml) and is more preferably about 3 ± 1 mg/ml. The presence of NaCl facilitates the correct measurement of pH prior to adsorption of antigens.

Aluminum salts can be used for adsorption of any of the HBV and non-HBV antigens. HBsAg is preferably adsorbed to an aluminum phosphate adjuvant [70]. Diphtheria toxoid is preferably adsorbed to an aluminum hydroxide adjuvant. Tetanus toxoid is preferably adsorbed to an aluminum hydroxide adjuvant, but this is not necessary (*e.g.* adsorption of between 0-10% of tetanus toxoid can be used). Acellular pertussis antigens, and particularly the 69kDa antigen, are preferably adsorbed to an aluminum hydroxide adjuvant. Conjugated Hib antigens can be adsorbed to aluminum phosphate [112,113] or can be unadsorbed. Hib adsorption in this way is particularly useful in vaccines

comprising D-T-Pw-Hib-HBsAg antigens. Other conjugated antigens (*e.g.* meningococcus, pneumococcus) can similarly be adsorbed to an aluminum salt (*e.g.* a phosphate) or can be unadsorbed [114]. IPV antigens are typically not adsorbed to any adjuvant before being used in a process of the invention, but they can become adsorbed onto aluminum adjuvant(s) originating with other components.

For HBsAg adsorption, an aluminum phosphate adjuvant is preferably used in the form of an aqueous solution to which HBsAg is added (NB: it is standard to refer to aqueous aluminum phosphate as a "solution" although, on a strict physicochemical view, the salt is insoluble and forms a suspension). It is preferred to dilute the aluminum phosphate to the required concentration and to ensure a homogenous solution before the addition of the HBsAg. The concentration of Al^{3+} prior to addition of HBsAg is generally between 0 and 10 mg/ml. A preferred Al^{3+} concentration is between 2 and 6 mg/ml.

Two preferred components for use in the processes of the invention are: (1) a bivalent D-T component, comprising an aluminum hydroxide adjuvant; and (2) a trivalent D-T-Pw component, comprising both aluminum hydroxide and aluminum phosphate adjuvants.

Pharmaceutical compositions

In addition to the adjuvant and antigen components, compositions of the invention may include further components. These components may have various sources. For example, they may be present in one of the antigen or adjuvant components that is used during manufacture or may be added separately from the antigenic components.

Preferred compositions of the invention include one or more pharmaceutical carrier(s) and/or excipient(s).

To control tonicity, it is preferred to include a physiological salt, such as a sodium salt. Sodium chloride (NaCl) is preferred, which may be present at between 1 and 20 mg/ml.

Compositions will generally have an osmolality of between 200 mOsm/kg and 400 mOsm/kg, preferably between 240-360 mOsm/kg, and will more preferably fall within the range of 290-300 mOsm/kg. Osmolality has previously been reported not to have an impact on pain caused by vaccination [115], but keeping osmolality in this range is nevertheless preferred.

Compositions of the invention may include one or more buffers. Typical buffers include: a phosphate buffer; a Tris buffer; a borate buffer; a succinate buffer; a histidine buffer; or a citrate buffer. Buffers will typically be included in the 5-20mM range.

The pH of a composition of the invention will generally be between 5.0 and 7.5, and more typically between 5.0 and 6.0 for optimum stability, or between 6.0 and 7.0. The process of the invention may therefore include a step of adjusting the pH of the bulk vaccine prior to packaging.

Compositions of the invention are preferably sterile.

Compositions of the invention are preferably non-pyrogenic *e.g.* containing <1 EU (endotoxin unit, a standard measure) per dose, and preferably <0.1 EU per dose.

Compositions of the invention are preferably gluten free.

5 The pH of any aqueous packaged vaccine materials is preferably between 5 and 8 *e.g.* between 5.5 and 6.5.

Due to the adsorbed nature of the HBsAg, the final vaccine product may be a suspension with a cloudy appearance. This appearance means that microbial contamination is not readily visible, and so the vaccine preferably contains an antimicrobial agent. This is particularly important when the vaccine is packaged in multidose containers. Preferred antimicrobials for inclusion are
10 2-phenoxyethanol and thimerosal. It is preferred, however, not to use mercurial preservatives (*e.g.* thimerosal) during the process of the invention. However, the presence of trace amounts may be unavoidable if the HBsAg was treated with such a preservative before being used to prepare the composition of the invention. For safety, however, it is preferred that the final composition contains less than about 25 ng/ml mercury. More preferably, the final vaccine product contains no detectable
15 thimerosal. This will generally be achieved by removing the mercurial preservative from an antigen preparation prior to its addition in the process of the invention or by avoiding the use of thimerosal during the preparation of the components used to make the composition.

Where a bivalent D-T mixture is used during a process of the invention, it should be free from thimerosal. In some embodiments, the D-T mixture may include 2-phenoxyethanol, but in others it is
20 free from both thimerosal and 2-phenoxyethanol. Where a trivalent D-T-Pw mixture is used during a process of the invention, it can be free from 2-phenoxyethanol, but may include thimerosal.

During manufacture, dilution of components to give desired final concentrations will usually be performed with WFI (water for injection).

The concentration of aluminum phosphate in a composition of the invention, expressed in terms of
25 Al^{3+} , is preferably less than 5 mg/ml *e.g.* ≤ 4 mg/ml, ≤ 3 mg/ml, ≤ 2 mg/ml, ≤ 1 mg/ml, *etc.*

The concentration of any 3D-MPL in a composition of the invention is preferably less than 200 μ g/ml *e.g.* ≤ 150 μ g/ml, ≤ 125 μ g/ml, ≤ 110 μ g/ml, ≤ 100 μ g/ml, *etc.*

The concentration of HBsAg in a composition of the invention is preferably less than 60 μ g/ml *e.g.* ≤ 55 μ g/ml, ≤ 50 μ g/ml, ≤ 45 μ g/ml, ≤ 40 μ g/ml, *etc.* A concentration of about 20 μ g/ml is typical.

30 The concentration of diphtheria toxoid in a composition of invention is typically at least 50 IU/ml.

The concentration of tetanus toxoid in a composition of the invention is typically at least 100 IU/ml.

The ratio of diphtheria toxoid to tetanus toxoid in compositions of the invention is usually between 2:1 and 3:1 (measured in Lf units), preferably between 2.4:1 and 2.6:1, and is more preferably 2.5:1.

Where cellular pertussis antigen is used, there will typically be at least 8 IU/ml; where acellular antigens are used, there will typically be between 25-75 μ g PT, about 25-75 μ g FHA and about 10-20 μ g pertactin per dose.

5 The amount of Hib conjugate, measured as saccharide, in compositions of the invention is typically between 10 and 30 μ g/ml.

The amount of HAV antigen, measured in EU (Elisa Units), is typically at least 600EU/ml.

The amount of IPV antigen depends on the strain serotype. For a type 1 virus, a composition typically contains about 80 DU/ml. For a type 2 virus, a composition typically contains about 16 DU/ml. For a type 3 virus, a composition typically contains about 65 DU/ml.

10 The amount of a meningococcal conjugate, measured as saccharide, in compositions of the invention is typically between 5 and 25 μ g/ml for each serogroup.

The amount of a pneumococcal conjugate, measured as saccharide, in compositions of the invention is typically between 2 and 20 μ g/ml for each serotype.

15 Compositions of the invention are preferably administered to patients in 0.5ml doses. References to 0.5ml doses will be understood to include normal variance e.g. 0.5ml $\pm$ 0.05ml.

The invention can provide bulk material which is suitable for packaging into individual doses, which can then be distributed for administration to patients. Concentrations mentioned above are typically concentrations in final packaged dose, and so concentrations in bulk vaccine may be higher (e.g. to be reduced to final concentrations by dilution).

20 Compositions of the invention will generally be in aqueous form.

Packaging compositions of the invention

After combining the HBsAg and the adjuvants, the processes of the invention may comprise a step of extracting and packaging a 0.5ml sample of the mixture into a container. For multidose situations, multiple dose amounts will be extracted and packaged together in a single container.

25 The processes of the invention may comprise the further step of packaging the vaccine into containers for use. Suitable containers include vials and disposable syringes (preferably sterile ones).

30 Where a composition of the invention is packaged into vials, these are preferably made of a glass or plastic material. The vial is preferably sterilized before the composition is added to it. To avoid problems with latex-sensitive patients, vials are preferably sealed with a latex-free stopper. The vial may include a single dose of vaccine, or it may include more than one dose (a 'multidose' vial) e.g. 10 doses. When using a multidose vial, each dose should be withdrawn with a sterile needle and syringe under strict aseptic conditions, taking care to avoid contaminating the vial contents. Preferred vials are made of colorless glass.

A vial can have a cap (*e.g.* a Luer lock) adapted such that a pre-filled syringe can be inserted into the cap, the contents of the syringe can be expelled into the vial (*e.g.* to reconstitute lyophilised material therein), and the contents of the vial can be removed back into the syringe. After removal of the syringe from the vial, a needle can then be attached and the composition can be administered to a patient. The cap is preferably located inside a seal or cover, such that the seal or cover has to be removed before the cap can be accessed.

Where the composition is packaged into a syringe, the syringe will not normally have a needle attached to it, although a separate needle may be supplied with the syringe for assembly and use. Safety needles are preferred. 1-inch 23-gauge, 1-inch 25-gauge and 5/8-inch 25-gauge needles are typical. Syringes may be provided with peel-off labels on which the lot number and expiration date of the contents may be printed, to facilitate record keeping. The plunger in the syringe preferably has a stopper to prevent the plunger from being accidentally removed during aspiration. The syringes may have a latex rubber cap and/or plunger. Disposable syringes contain a single dose of vaccine. The syringe will generally have a tip cap to seal the tip prior to attachment of a needle, and the tip cap is preferably made of butyl rubber. If the syringe and needle are packaged separately then the needle is preferably fitted with a butyl rubber shield. Grey butyl rubber is preferred. Preferred syringes are those marketed under the trade name "Tip-Lok"TM.

Where a glass container (*e.g.* a syringe or a vial) is used, then it is preferred to use a container made from a borosilicate glass rather than from a soda lime glass.

After a composition is packaged into a container, the container can then be enclosed within a box for distribution *e.g.* inside a cardboard box, and the box will be labeled with details of the vaccine *e.g.* its trade name, a list of the antigens in the vaccine (*e.g.* 'hepatitis B recombinant', *etc.*), the presentation container (*e.g.* 'Disposable Prefilled Tip-Lok Syringes' or '10 x 0.5 ml Single-Dose Vials'), its dose (*e.g.* 'each containing one 0.5ml dose'), warnings (*e.g.* 'For Adult Use Only' or 'For Pediatric Use Only'), an expiration date, an indication (*e.g.* 'active immunisation against hepatitis B virus (HBV) infection caused by all known subtypes for patients with renal insufficiency (including pre-haemodialysis and haemodialysis) patients, from the age of 15 years onwards', *etc.*), a patent number, *etc.* Each box might contain more than one packaged vaccine *e.g.* five or ten packaged vaccines (particularly for vials). If the vaccine is contained in a syringe then the package may show a picture of the syringe.

The vaccine may be packaged together (*e.g.* in the same box) with a leaflet including details of the vaccine *e.g.* instructions for administration, details of the antigens within the vaccine, *etc.* The instructions may also contain warnings *e.g.* to keep a solution of adrenaline readily available in case of anaphylactic reaction following vaccination, *etc.*

The packaged vaccine is preferably stored at between 2°C and 8°C. It should not be frozen.

Vaccines can be provided in full-liquid form (*i.e.* where all antigenic components are in aqueous solution or suspension) during manufacture, or they can be prepared in a form where some components are in liquid form and others are in a lyophilized form. Thus a final vaccine can be prepared extemporaneously at the time of use by mixing together two components: (a) a first component comprising aqueous antigens; and (b) a second component comprising lyophilized antigens. The two components are preferably in separate containers (*e.g.* vials and/or syringes), and the invention provides a kit comprising components (a) and (b). This format is particularly useful for vaccines that include a conjugate component, particularly Hib and/or meningococcal conjugates, as these may be more stable in lyophilized form. Thus conjugates may be lyophilised prior to their use with the invention. Further components may also be added prior to freeze-drying *e.g.* as stabilizers. Preferred stabilizers for inclusion are lactose, sucrose and mannitol, as well as mixtures thereof *e.g.* lactose/sucrose mixtures, sucrose/mannitol mixtures, *etc.* The final vaccine may thus contain lactose and/or sucrose. Using a sucrose/mannitol mixture can speed up the drying process.

Thus the invention provides a process for preparing a two-container combination vaccine, comprising the following steps:

- preparing an aqueous combination vaccine as described above, but wherein the said one or more antigens does not include a conjugated capsular saccharide antigen;
- packaging said combination vaccine in a first container (*e.g.* a syringe);
- preparing a conjugated capsular saccharide antigen in lyophilised form;
- packaging said lyophilised antigen in a second container (*e.g.* a vial); and
- packaging the first container and second container together in a kit.

The kit can then be distributed to physicians.

D, T, P and HBsAg components are preferably in liquid form.

Methods of treatment and Administration of the vaccine

Compositions of the invention are suitable for administration to human patients, and the invention provides a method of raising an immune response in a patient, comprising the step of administering a composition of the invention to the patient.

The invention also provides a composition of the invention for use in medicine.

The invention also provides the use of (i) HBsAg expressed according to the invention and (ii) one or more non-HBV antigens, in the manufacture of a medicament for administering to a patient.

The invention also provides the use of (i) HBsAg expressed according to the invention and (ii) an adjuvant other than an aluminum hydroxide, in the manufacture of a medicament for administering to a patient. The medicament is preferably a monovalent vaccine. Preferred patient groups for receiving this vaccine are mentioned above.

Immunogenic compositions of the invention are preferably vaccines, for use in the prevention and/or treatment of at least hepatitis B virus infection. Patients who have received compositions of the invention preferably have a serum anti-HBsAg GM titer of ≥ 500 mIU/ml, measured 6 weeks after the first immunisation. More preferably, the titer is ≥ 500 mIU/ml, when measured after 12 months.

- 5 In order to have full efficacy, a typical immunization schedule for a child may involve administering more than one dose. For example, doses may be at: 0 & 6 months (time 0 being the first dose); at 0, 1, 2 & 6 months; at day 0, day 21 and then a third dose between 6 & 12 months; or at 0, 1, 2, 6 & 12 months.

Compositions of the invention can be administered by intramuscular injection *e.g.* into the arm or leg

- 10 Vaccines produced by the invention may be administered to patients at the same time as a separate pneumococcal conjugate vaccine, such as Prevnar™.

Where compositions of the invention include an aluminum-based adjuvant, settling of components may occur during storage. The composition should therefore be shaken prior to administration to a patient. The shaken composition will be a turbid white suspension.

15 ***Preferred vaccines***

Specific multivalent immunogenic compositions of the invention include:

- A bivalent composition comprising HBsAg and HAV. The vaccine is in aqueous form. It includes both aluminum hydroxide and aluminum phosphate adjuvants. HBsAg is adsorbed to aluminum phosphate. HAV is adsorbed to aluminum hydroxide. Amounts per ml: about 720 ELISA units HAV; about 20 μ g HBsAg. Dose: about 1 ml. May be presented in pre-filled syringe.
- A pentavalent composition comprising HBsAg, D, T, Pa and IPV. The vaccine is in aqueous form. It includes both aluminum hydroxide and aluminum phosphate adjuvants. HBsAg is adsorbed to aluminum phosphate. D, T and Pa are adsorbed to aluminum hydroxide. Amounts per ml: about 50 Lf diphtheria toxoid; about 20 Lf tetanus toxoid; about 50 μ g PT; about 50 μ g FHA; about 16 μ g pertactin; about 20 μ g HBsAg; about 80 DU type 1 poliovirus; about 16 DU type 2 poliovirus; about 64 DU type 3 poliovirus. Dose: about 0.5ml. May be presented in pre-filled syringe.
- A pentavalent composition comprising HBsAg, D, T, Pa and IPV. The vaccine is in aqueous form. It includes both aluminum hydroxide and aluminum phosphate adjuvants. HBsAg is adsorbed to aluminum phosphate. D, T and Pa are adsorbed to aluminum hydroxide. Amounts per ml: at least 60 IU diphtheria toxoid; at least 80 IU tetanus toxoid; about 50 μ g PT; about 50 μ g FHA; about 16 μ g pertactin; about 20 μ g HBsAg; about 80 DU type 1 poliovirus; about 16 DU type 2 poliovirus; about 64 DU type 3 poliovirus. Dose: about 0.5ml. May be presented in pre-filled syringe.

- 5 • A tetravalent composition comprising HBsAg, D, T and Pw. The components are in aqueous form. It includes both aluminum hydroxide and aluminum phosphate adjuvants. HBsAg is adsorbed to aluminum phosphate. D and T are adsorbed to aluminum hydroxide. The composition includes thimerosal, but preferably does not contain 2-phenoxyethanol. Amounts per ml: at least 60 IU diphtheria toxoid; at least 120 IU tetanus toxoid; at least 8 IU Pw; about 20 μ g HBsAg. Dose: about 0.5ml.
- 10 • A pentavalent composition comprising HBsAg, D, T, Pw and a Hib-T conjugate. The HBsAg, D, T and Pw components are in aqueous form; the Hib-T is lyophilized. It includes both aluminum hydroxide and aluminum phosphate adjuvants. D and T are adsorbed to aluminum hydroxide. HBsAg and Hib-T are adsorbed to aluminum phosphate. The lyophilized Hib-T includes lactose. The aqueous component may include thimerosal. Amounts per ml: at least 60 IU diphtheria toxoid; at least 120 IU tetanus toxoid (plus between 5-25 μ g tetanus toxoid as carrier in Hib-T); at least 8 IU Pw; about 20 μ g HBsAg; about 5 μ g Hib-T, measured as saccharide. Dose: about 0.5ml.
- 15 These compositions can be used separately, or as components of further vaccines. For example, the invention provides a hexavalent composition comprising the pentavalent HBsAg-D-T-Pa-IPV composition described above, plus a lyophilized Hib-T conjugate. The lyophilized Hib-T is preferably not adsorbed to an aluminum salt. The invention also provides a pentavalent composition comprising the tetravalent HBsAg-D-T-Pw composition described above, plus a lyophilized Hib-T

20 conjugate. The invention also provides a heptavalent composition comprising the tetravalent HBsAg-D-T-Pw composition described above, plus a lyophilized mixture of Hib-T conjugate, MenA conjugate and MenC conjugate. The final vaccines can be prepared by reconstituting the lyophilized materials with the aqueous HBsAg-containing materials at the time of use, and the lyophilized and aqueous components are preferably packaged together in a kit, as described above.
- 25 A specific monovalent immunogenic composition of the invention is:

 - HBsAg in combination with an aluminum phosphate adjuvant and a 3D-MPL adjuvant, where the HBsAg and 3D-MPL are both adsorbed to the aluminum phosphate. Amounts per dose: about 20 μ g HBsAg, about 50 μ g 3D-MPL, about 0.5mg Al³⁺.

Specific processes of the invention include those comprising the following steps:

- 30 • Purify HBsAg after expression according to invention; adsorb HBsAg to aluminum phosphate adjuvant; obtain thimerosal-free bivalent D-T mixture with aluminum hydroxide adjuvant; obtain PT, FHA and pertactin for Pa component; obtain IPV antigens, as pooled types 1, 2 and 3, preferably without aluminum salt adjuvant; combine D-T, Pa, IPV and HBsAg, in any order, to give final pentavalent combination; optionally, package into syringe.
- 35 • Purify HBsAg after expression according to invention; adsorb HBsAg to aluminum phosphate adjuvant; obtain 2-phenoxyethanol-free, thimerosal-containing trivalent D-T-Pw

mixture with aluminum hydroxide and aluminum phosphate adjuvants; combine D-T-Pw and HBsAg to give final tetravalent combination; optionally, package into syringe; optionally, package in combination with lyophilized conjugate component(s) *e.g.* Hib-T, MenA, MenC.

- 5 • Purify HBsAg after expression according to invention; adsorb HBsAg to aluminum phosphate adjuvant; obtain 2-phenoxyethanol-free, thimerosal-containing trivalent D-T-Pw mixture with aluminum hydroxide and aluminum phosphate adjuvants; obtain lyophilized Hib-T conjugate; combine D-T-Pw and HBsAg to give aqueous tetravalent component; package aqueous tetravalent component into glass vial; package lyophilized Hib-T into glass vial; combine the two vials to be presented in a single kit for reconstitution to give a

10 pentavalent combination vaccine. The glass vials can be type I glass and have rubber butyl stoppers.
- 15 • Purify HBsAg after expression according to invention; adsorb HBsAg to aluminum phosphate adjuvant; obtain 2-phenoxyethanol-free, thimerosal-containing trivalent D-T-Pw mixture with aluminum hydroxide and aluminum phosphate adjuvants; obtain IPV antigens, as pooled types 1, 2 and 3, preferably without aluminum salt adjuvant; combine D-T-Pw, IPV and HBsAg in any order to give final pentavalent combination; optionally, package into syringe; optionally, package in combination with lyophilized conjugate component(s) *e.g.* Hib-T, MenA, MenC.

Further components may be added at any stage *e.g.* sodium chloride, adjuvants, preservatives, *etc.*

20 These processes can be used *e.g.* to prepare the vaccines described above.

The different process steps may be performed at substantially the same time, or may be performed separately. They can be performed in the same location or in different locations, even in different countries *e.g.* HBsAg expression may take place in a different place from lyophilisation of Hib-T conjugate.

25 ***Carrier proteins for conjugates***

Conjugated saccharide antigens include a carrier protein, to which the saccharide is covalently attached, either directly or via a linker. General information on conjugation techniques can be found in reference 116.

Various proteins are known for use as carriers, and preferred carrier proteins are bacterial toxins or toxoids, such as diphtheria toxoid or tetanus toxoid. Other suitable carrier proteins include, but are not limited to, the CRM197 mutant of diphtheria toxin [117-119], the *N.meningitidis* outer membrane protein [120], synthetic peptides [121, 122], heat shock proteins [123, 124], pertussis proteins [125, 126], cytokines [127], lymphokines [127], hormones [127], growth factors [127], artificial proteins comprising multiple human CD4⁺ T cell epitopes from various pathogen-derived antigens

35 [128] such as N19 [129], protein D from *H.influenzae* [130, 131], pneumococcal surface protein PspA

[132], pneumolysin [133], iron-uptake proteins [134], toxin A or B from *C.difficile* [135], *S.agalactiae* proteins [136], etc.

Attachment of a saccharide to a carrier is preferably via a -NH₂ group *e.g.* in the side chain of a lysine residue in a carrier protein, or of an arginine residue. Attachment to -SH groups (*e.g.* in the side chain of a cysteine) is also possible.

Conjugates with a saccharide:protein ratio (w/w) of between 1:5 (*i.e.* excess protein) and 5:1 (*i.e.* excess saccharide) are preferred.

Compositions may include a small amount of free carrier. Ignoring any carrier included as a separate antigen, unconjugated carrier is preferably no more than 5% of the total amount of the carrier protein in the composition as a whole, and more preferably present at less than 2% by weight.

It is possible to include more than one type of carrier protein in a composition *e.g.* to reduce the risk of carrier suppression.

The carrier protein used for *N.meningitidis* conjugates may be protein D from *H.influenzae*. This protein is described in detail in references 137 & 138, and its use as a carrier protein in conjugates is described in reference 139. The term "protein D" includes fragments of the native full-length protein, as disclosed in reference 139, and also fusion proteins comprising either full-length protein D or these fragments (*e.g.* a fusion of a fragment of influenza virus NS1 protein and a fragment of protein D). The fragments will retain the ability to convert a T-independent saccharide antigens into a T-dependent antigen when conjugated thereto. Typical fragments will include at least the N-terminal 1/3 of protein D. The protein can conveniently be expressed in *E.coli* [138], and this recombinant material is preferred for use with the invention [139].

General

The term "comprising" encompasses "including" as well as "consisting" *e.g.* a composition "comprising" X may consist exclusively of X or may include something additional *e.g.* X + Y.

The word "substantially" does not exclude "completely" *e.g.* a composition which is "substantially free" from Y may be completely free from Y. Where necessary, the word "substantially" may be omitted from the definition of the invention.

The term "about" in relation to a numerical value *x* means, for example, $x \pm 10\%$.

Unless specifically stated, a process comprising a step of mixing two or more components does not require any specific order of mixing. Thus components can be mixed in any order. Where there are three components then two components can be combined with each other, and then the combination may be combined with the third component, *etc.*

Where an antigen is described as being "adsorbed" to an adjuvant, it is preferred that at least 50% (by weight) of that antigen is adsorbed *e.g.* 50%, 60%, 70%, 80%, 90%, 95%, 98% or more. It is

preferred that diphtheria toxoid and tetanus toxoid are both totally adsorbed *i.e.* none is detectable in supernatant. Total adsorption of HBsAg is also preferred.

It will be appreciated that ionisable groups may exist in the neutral form shown in formulae herein, or may exist in charged form *e.g.* depending on pH. Thus a phosphate group may be shown as -P-O-(OH)₂, this formula is merely representative of the neutral phosphate group, and other charged forms are encompassed by the invention. Similarly, sugar rings can exist in open and closed form and, while closed forms are shown in structural formulae herein, open forms are also encompassed by the invention.

Where animal (and particularly bovine) materials are used in the culture of cells, they should be obtained from sources that are free from transmissible spongiform encephalopathies (TSEs), and in particular free from bovine spongiform encephalopathy (BSE).

SEQUENCE LISTING DETAILS

ID NO:	DETAILS
1	Preferred GAPDH promoter nucleotide sequence
2	SEQ ID NO: 1, followed by a start codon.
3	Preferred HBsAg amino acid sequence
4	Preferred HBsAg nucleotide sequence
5	Known 1061-mer promoter sequence [41]
6	Known nucleotides downstream of ARG3 stop codon (GI:171076.)
7	SEQ ID NO: 6, extending 250 nucleotides further back into the coding sequence
8	Preferred sequence for use downstream of HBsAg coding sequence
9	SEQ ID NO: 8 with upstream ochre stop codon
10	Known HBsAg amino acid sequence (CAA84792.1)
11	TLR adjuvant
12	TLR adjuvant
13	Combined sequence with promoter, HBsAg coding and terminator sequences

MODES FOR CARRYING OUT THE INVENTION

Plasmid preparation

A plasmid is constructed comprising various elements in the following order: a yeast GAPDH promoter; a HBsAg-coding sequence; a region including a yeast ARG3 transcription terminator; DNA from *E.coli* vector pBR327; yeast DNA with a LEU2 marker; DNA from *E.coli* vector pBR327; yeast 2μ plasmid sequence; DNA from *E.coli* vector pBR327. The pBR327 sequences include an *ori* functional in *E.coli*. The plasmid is between 14600 and 14700 bp long in total.

The GAPDH promoter sequence includes the following 1060-mer (SEQ ID NO: 1):

```
aagcttaccagttctcacacggaacaccactaatggacacacattcgaaatactttgaccctattttcgagga
ccttggtcaccttgagcccaagagagccaagattttaattttcctatgacttgatgcaaattcccaaagcta
aacatgcaagacacgtacgggtcaagaagacataatttgacctcttaacagggttcagacgcgactgcctcatcag
taagaccggttgaaaagaacttacctgaaaaaaacgaatatatactagcgttgatgttagcgtcaacaacaa
gaagtttactgacgcggaggccaaggcaaaaagattccttgattacgtaagggttagaatcattttgaata
```

5 aaaaacacgctttttcagttcaggtttatcattatcaatactgccatttcaaagaatacgtaaataattaata
 gtagtgatttttccctaactttatattagtcacaaaaatttagccttttaattctgctgtaacccgtacatgcccaaa
 atagggggcggttacacagaatatataacatcgtaggtgtctgggtgaacagtttattcctggcatccacta
 10 aatataatggagcccgcctttttaagctggcatccagaaaaaaaagaatcccagcaccacaaatattgttttct
 tcaccaaccatcagttcataggtccattctcttagcgcaactacagagaacaggggcacaaacaggcaaaaaa
 cgggcacaacctcaatggagtgatgcaacctgcctggagtaaatgatgacacaaggcaattgacccacgcatg
 tatctatctcattttcttacaccttctattaccttctgctctctctgatttggaaaaagctgaaaaaaaggt
 tgaaaccagttccctgaaattattcccctacttgactaataagtatataaagacggtaggtattgattgtaaat
 tctgtaaatctattttcttaaaacttcttaaaattctacttttatagtttagtcttttttttagttttaaacacca
 15 agaacttagtttcgaataaacacacataaacaacaaaaa

The HBsAg-coding sequence is as follows (SEQ ID NO: 4), followed by an ochre stop codon:

15 atggagaacatcacatcaggattcctaggacccctgctcgtgttacaggcggttttttctgttgacaagaa
 tcctcacaataccgcagagtctagactcgtgggtgacttctctcaattttctagggggatcacccgtgtgtct
 20 tggccaaaattcgcagtcaccaacctccaatcactcaccaacctcctgtcctccaatttgtcctgggtatcgc
 tggatgtgtctgctggcggttttatcatattcctcttcatcctgctgctatgcctcatcttcttattggttcttc
 tggattatcaaggtatgttgcccggttctcctctaattccaggatcaacaacaaccaatagcgggaccatgcaa
 aacctgcacgactcctgctcaaggcaactctatgtttccctcatgttgctgtacaaaacctacggatggaaat
 tgcacctgtattcccacccatcgtcctgggctttcgcaaaatacctatgggagtgggcctcagtcctgtttct
 25 cttggctcagtttactagtgccatttgttcagtggttcgtagggctttccccactgtttggctttcagctat
 atggatgatgtggtattgggggccaagtctgtacagcatcgtgagtccttttataccgctgtttaccaattttc
 ttttgtctctgggtatacatt

This sequence encodes a polypeptide with the following amino acid sequence SEQ ID NO: 3:

25 MENITSGFLGPLLVLQAGFLLTRILTIPQSLDSWWTSLNFLGGSPVCLGQNSQSPTSNSHPTSCPPICPGYR
 WMCLRRFIIFLFILLCLIFLLVLLDYQGMPLVCPPIPGSTTTNTGPCKTCTTPAQGNSMFPSCCCTKPTDGN
 CTCIPIPSWAFAYKLWEWASVRFWSLSLLVPFVQWVGLSPTVWLSAIWMMWYWGPSLYSIVSPFIPLLPF
 FCLWVYI

30 The ARG3 sequence includes the following 689-mer sequence (SEQ ID NO: 8), together with
 additional sequence from the region downstream of ARG3:

35 cgaattccaagctgaaacaattcaaaggttttcaaataaatcaagaacttgctctctgtggctgatccaaacta
 caaatttatgcattgtctgccagacatcaagaagaagtttagtgatgatgtcttttatggagagcattccata
 gtctttgaagaagcagaaaaacagattatatgcagctatgtctgccattgatattctttgttaataataaaggta
 40 atttcaaggacttgaaataatccttctttcgtgttcttaataactaatatataataacagatatagatgcatg
 aataatgatatacattgattattttgcaatgtcaattaaaaaaaaaaatgttagtaaaactatgtttacattc
 caagcaataaagcacttggttaaacgaaattaacgtttttaagacagccagaccgcggtctaaaaatttaaa
 tatactgccaacaaattccttcgagttgtccaatttccaccacttttatattttcatcaacttcagcagatt
 caaccttctcatatagaacattggaataaacagccttaacaccactttcaagtttgcacagcgtaatatgagg
 aatttgttttgacaacacaaccttttaattttctcattgttttcatcaattatgcatccatctttatcttta
 45 cagagttccactacaatatagcaatagtttttttc

Thus the plasmid includes the following 2430-mer in an expression cassette (SEQ ID NO: 13):

45 aagcttaccagttctcacacggaacaccactaatggacacacattcgaaatactttgaccctattttcgagga
 ccttgtcaccttgagcccaagagagccaagattttaattttcctatgacttgatgcaaatcccaaagctaata
 aacatgcaagacacgtacgggtcaagaagacatatattgacctcttaacaggttcagacgcgactgcctcatcag
 50 taagaccggttgaaaagaacttacctgaaaaaaacgaatatatactagcgttgatgttagcgtcaacaacaa
 gaagtttactgacgcggaggccaaggcaaaaagattccttgattacgtaaggagttagaatcattttgaata
 aaaaacacgctttttcagttcaggtttatcattatcaatactgccatttcaaagaatacgtaaataattaata
 55 gtagtgatttttccctaactttatattagtcacaaaaatttagccttttaattctgctgtaacccgtacatgcccaaa
 atagggggcggttacacagaatatataacatcgtaggtgtctgggtgaacagtttattcctggcatccacta
 aatataatggagcccgcctttttaagctggcatccagaaaaaaaagaatcccagcaccacaaatattgttttct
 tcaccaaccatcagttcataggtccattctcttagcgcaactacagagaacaggggcacaaacaggcaaaaaa
 cgggcacaacctcaatggagtgatgcaacctgcctggagtaaatgatgacacaaggcaattgacccacgcatg
 60 tatctatctcattttcttacaccttctattaccttctgctctctctgatttggaaaaagctgaaaaaaaggt
 tgaaaccagttccctgaaattattcccctacttgactaataagtatataaagacggtaggtattgattgtaaat
 tctgtaaatctattttcttaaaacttcttaaaattctacttttatagtttagtcttttttttagttttaaacacca
 65 agaacttagtttcgaataaacacacataaacaacaaaATGgagaacatcacatcaggattcctaggacccct

gctcgtgttacaggcggggttttttcttgggtgacaagaatcctcacaataccgcagagtctagactcgtgggtgg
 acttctctcaatttttctaggggatcacccgtgtgtcttggccaaaattcgcagtcaccaacacctccaactact
 caccaacctcctgtcctccaatttgcctgggtatcgctggatgtgtctgcggcggttttatcatattcctctt
 5 catcctgctgctatgcctcatcttcttattgggtcttctggattatcaaggatgttgcccgtttgtcctcta
 attccaggatcaacaacaaccaatacgggaccatgcaaaacctgcacgactcctgctcaaggcaactctatgt
 ttcctcatgttgctgtacaaaacctacggatggaaattgcacctgtattcccacccatcgtcctgggcttt
 cgcaaaatacctatgggagtgggcctcagtcggttctcttggctcagtttactagtgcatttgttcagtgg
 ttcgtagggctttccccactgtttggctttcagctatatggatgatgtggtattggggggccaagtctgtaca
 10 gcatcgtgagtccttttataccgctgttaccaattttcttttgtctctgggtatacattTAACgaattccaag
 ctgaaacaattcaaagggttttcaaatacaagaacttgtctctgtggctgatccaaactacaaatttatgc
 attgtctgccagacatcaagaagaagttagtgatgatgtcttttatggagagcattccatagtctttgaaga
 agcagaaaaacagattatatgcagctatgtctgccattgatatctttgttaataataaaggtaatttcaaggac
 ttgaaataatccttcttctgtgttcttaataactaatatataaatacagatatagatgcatgaataatgatat
 15 acattgattattttgcaatgtcaattaaaaaaaaaaaaatgtagtaaaactatgttacattccaagcaataa
 agcacttggttaaacgaaattaacgtttttaagacagccagaccggtctaaaaatttaaatatacactgcc
 aacaaattccttcgagttgtccaatttcaccacttttataattttcatcaacttcagcagattcaaccttctca
 catagaacattggaataaacagccttaacaccactttcaagtttgacagcgtaatatgaggaattttgtttt
 gacaacacaaccctttaattttctcattgttttcatcaattatgcatccatctttatcttttagacagttccac
 20 tacaatagcaatagttttttc

Sequence analysis of plasmid elements

The GAPDH promoter sequence (SEQ ID NO: 1) was differs from the GAPDH promoter sequence disclosed in reference 41 (SEQ ID NO: 5) at several positions:

25	0	[AAGCTTACCAGTTCTCACACGGAACACCACTAATGGACACA]	a	[ATTCGAAATACT
	0	[AAGCTTACCAGTTCTCACACGGAACACCACTAATGGACACA]	c	[ATTCGAAATACT
	54	TTGACCCATATTTTCGAGGACCTTGTCACCTTGAGCCCAAGAGAGCCAAGATTTAAATTTT		
	54	TTGACCCATATTTTCGAGGACCTTGTCACCTTGAGCCCAAGAGAGCCAAGATTTAAATTTT		
30	114	CCTATGACTTGATGCAAATTCCCAAAGCTAATAACATGCAAGACACGTACGGTCAAGAAG		
	114	CCTATGACTTGATGCAAATTCCCAAAGCTAATAACATGCAAGACACGTACGGTCAAGAAG		
	174	ACATATTTGACCTCTTAAC]	t	[GGTTCAGACGCGACTGCCTCATCAGTAAGACCCGTT
35	174	ACATATTTGACCTCTTAAC]	a	[GGTTCAGACGCGACTGCCTCATCAGTAAGACCCGTT
	230	GAAAAGAACCTTACCTGAAAAAACGAATATATACTAGCGTTGAATGTTAGCGTCAACAAC		
	230	GAAAAGAACCTTACCTGAAAAAACGAATATATACTAGCGTTGAATGTTAGCGTCAACAAC		
40	290	AAGAAGTTTA]	a	[TGACGCGGAGGCCAAGGCCAAAAAGATTTCCTTGATTACGTAAGGGA
	290	AAGAAGTTTA]	c	[TGACGCGGAGGCCAAGGCCAAAAAGATTTCCTTGATTACGTAAGGGA
	346	GTTAGAATCATTTTGAATAAAAAACACGCTTTTTCAGTTCGAGTTTATCATTTATCAATAC		
	346	GTTAGAATCATTTTGAATAAAAAACACGCTTTTTCAGTTCGAGTTTATCATTTATCAATAC		
45	406	TGCCATTTCAAAGAATACGTAAATAATTAATAGTAGTGATTTTCCTAACTTTATTTAGTC		
	406	TGCCATTTCAAAGAATACGTAAATAATTAATAGTAGTGATTTTCCTAACTTTATTTAGTC		
	466	] . [AAAAATTAGCCTTTTAATTCTGCTGTAACCCGTACATGCCCAAAATAGGGGGCGG		
50	466	] a [AAAAATTAGCCTTTTAATTCTGCTGTAACCCGTACATGCCCAAAATAGGGGGCGG		
	521	GTTACACAGAATATATAACATCGTAGGTGTCTGGGTGAACAGTTTAT]	c	[CCTGGCAT
	522	GTTACACAGAATATATAACATCGTAGGTGTCTGGGTGAACAGTTTAT]	t	[CCTGGCAT
55	577	CCACTAAATATAATGGAGC]	tcgc.	[TTTTAAGCTGGCATCCAGAAAAAAAAGAATC
	578	CCACTAAATATAATGGAGC]	ccgct	[TTTTAAGCTGGCATCCAGAAAAAAAAGAATC
	632	CCAGCACCAAAATATTGTTTTCTTACCAACCATCAGTTCATAGGTCCATTCTCTTAGCG		
	634	CCAGCACCAAAATATTGTTTTCTTACCAACCATCAGTTCATAGGTCCATTCTCTTAGCG		

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692    CAACTACAGAGAACAGGGGCACAAACAGGCAAAAAACGGGCACAACCTCAATGGAGTGAT
694    CAACTACAGAGAACAGGGGCACAAACAGGCAAAAAACGGGCACAACCTCAATGGAGTGAT

5      752    GCAACCTGCCTGGAGTAAATGATGACACAAGGCAATTGACCCACGCATGTATCTATCTCA
754    GCAACCTGCCTGGAGTAAATGATGACACAAGGCAATTGACCCACGCATGTATCTATCTCA

      812    TTTTCTTACACCTTCTATTACCTTCTGCTCTCTCTGATTTGGAAAAAGCTGAAAAAAAAG
814    TTTTCTTACACCTTCTATTACCTTCTGCTCTCTCTGATTTGGAAAAAGCTGAAAAAAAAG

10     872    GTTGAACCAGTTCCTGAAATTATTCCCCTACTTGACTAATAAGTATATAAAGACGGTA
874    GTTGAACCAGTTCCTGAAATTATTCCCCTACTTGACTAATAAGTATATAAAGACGGTA

      932    GGTATTGATTGTAATTCTGTAAATCTATTTCTTAACTTCTTAAATCTACTTTTATAGT
934    GGTATTGATTGTAATTCTGTAAATCTATTTCTTAACTTCTTAAATCTACTTTTATAGT

15     992    TAGTCTTTTTTTTTTAGTTTTTAAACACCAAGAACTTAGTTTCGAATAAACACACATAAACA
994    TAGTCTTTTTTTTTTAGTTTTTAAACACCAAGAACTTAGTTTCGAATAAACACACATAAACA

      1052   AACAA] gctt
20     1054   AACAA] a...

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SEQ ID NO: 1 was queried against "All GenBank+EMBL+DDBJ+PDB sequences (but no EST, STS, GSS, environmental samples or phase 0, 1 or 2 HTGS sequences)" on 7th April 2005, with no filtering. The top hit in this search aligns with SEQ ID NO: 1 as follows:

```

25     >gi|1323342|emb|Z72978.1|SCYGR193C   S.cerevisiae chromosome VII reading frame ORF YGR193c
      Length = 2262

      Score = 2085 bits (1052), Expect = 0.0
      Identities = 1058/1060 (99%)
30     Strand = Plus / Minus

Query: 1      aagcttaccagttctcacacggaacaccactaatggacacaattcgaaatactttgacc 60
      |||
Sbjct: 1060   aagcttaccagttctcacacggaacaccactaatggacacaattcgaaatactttgacc 1001

35     Query: 61      ctattttcgaggaccttgctcaccttgagcccaagagagccaagattttaattttcctatg 120
      |||
Sbjct: 1000   ctattttcgaggaccttgctcaccttgagcccaagagagccaagattttaattttcctatg 941

40     Query: 121     acttgatgcaaattcccaaagctaataacatgcaagacacgtacggtaagaagacatat 180
      |||
Sbjct: 940      acttgatgcaaattcccaaagctaataacatgcaagacacgtacggtaagaagacatat 881

45     Query: 181     ttgacctcttaacaggttcagacgcgactgcctcatcagtaagaccggtgaaaagaact 240
      |||
Sbjct: 880      ttgacctcttaacaggttcagacgcgactgcctcatcagtaagaccggtgaaaagaact 821

      Query: 241     tacctgaaaaaaacgaatatatactagcggttgatgttagcgtaacaacaagaagttaa 300
      |||
50     Sbjct: 820     tacctgaaaaaaacgaatatatactagcggttgatgttagcgtaacaacaagaagttaa 761

      Query: 301     atgacgcggaggccaaggcaaaaagattccttgattacgtaaggaggttagaatcatttt 360
      |||
55     Sbjct: 760     atgacgcggaggccaaggcaaaaagattccttgattacgtaaggaggttagaatcatttt 701

      Query: 361     gaataaaaaaacacgctttttcagttcgagtttatcattatcaatactgccatttcaaaga 420
      |||
Sbjct: 700      gaataaaaaaacacgctttttcagttcgagtttatcattatcaatactgccatttcaaaga 641

60     Query: 421     atacgtaaataattaatagtagtgattttcctaactttatttagtcaaaaaattagcctt 480
      |||
Sbjct: 640      atacgtaaataattaatagtagtgattttcctaactttatttagtcaaaaaattagcctt 581

65     Query: 481     ttaattctgctgtaaccggtacatgccccaaatagggggcggttacacagaatatataa 540
      |||
Sbjct: 580      ttaattctgctgtaaccggtacatgccccaaatagggggcggttacacagaatatataa 521

Query: 541     catcgtagggtgctctgggtgaacagtttattcctggcatccactaaatataatggagcccg 600

```

Thus SEQ ID NO: 1 differs at two nucleotides compared to the reverse complement of the nearest match.

The encoded sequence (SEQ ID NO: 3) was analyzed by BLASTP on 4th April 2005, using the “non-redundant GenBank CDS translations+PDB+SwissProt+PIR+PRF excluding environmental samples” database with no filtering. SEQ ID NO: 3 differs from the closest database matches at amino acid 117, having an Asn residue rather than Ser. The top hit was entry CAA84792.1 (SEQ ID NO: 10):

-34-

Query: 121 CKTCTTPAQNSMFPSCCCTKPTDGNCTCIPIPSSWAFACYLWEWASVRFSWLSLLVPFV 180
 CKTCTTPAQNSMFPSCCCTKPTDGNCTCIPIPSSWAFACYLWEWASVRFSWLSLLVPFV
 Sbjct: 295 CKTCTTPAQNSMFPSCCCTKPTDGNCTCIPIPSSWAFACYLWEWASVRFSWLSLLVPFV 354

5 Query: 181 QWFVGLSPTVWLSAIWMMWYWGPSLYSIVSPFIPLLPFIFFCLWVYI 226 SEQ ID NO: 3
 QWFVGLSPTVWLSAIWMMWYWGPSLYSIVSPFIPLLPFIFFCLWVYI
 Sbjct: 355 QWFVGLSPTVWLSAIWMMWYWGPSLYSIVSPFIPLLPFIFFCLWVYI 400 SEQ ID NO: 10

BLASTN analysis of the downstream sequence from ARG3 (SEQ ID NO: 8) reveals a 100% match
 10 with database entry M28301.1, but only over a 683-mer overlap starting at nucleotide 7 of SEQ ID
 NO: 8. A CLUSTALW alignment of these two sequences, including the 7 nucleotides at the 5' end of
 SEQ ID NO: 8, is given below:

		10	20	30	40	50	60	70
15	SEQID7	AGAATTTGCGAAACAGGCCAAGCTGAAACAATTCAAAGGTTTCAAATCAATCAAGAACTGTCTCTGTG						
	SEQID8	CGAATT-----CCAAGCTGAAACAATTCAAAGGTTTCAAATCAATCAAGAACTGTCTCTGTG						

20		80	90	100	110	120	130	140
	SEQID7	GCTGATCCAAACTACAAATTTATGCATTGTCTGCCAAGACATCAAGAAGAAGTTAGTGATGATGTCCTTTT						
	SEQID8	GCTGATCCAAACTACAAATTTATGCATTGTCTGCCAAGACATCAAGAAGAAGTTAGTGATGATGTCCTTTT						

25		150	160	170	180	190	200	210
	SEQID7	ATGGAGAGCATTCATAGTCTTTGAAGAAGCAGAAAACAGATTATATGCAGCTATGTCTGCCATTGATAT						
	SEQID8	ATGGAGAGCATTCATAGTCTTTGAAGAAGCAGAAAACAGATTATATGCAGCTATGTCTGCCATTGATAT						

30		220	230	240	250	260	270	280
	SEQID7	CTTTGTTAATAATAAAGGTAATTTCAAGGACTTGAAATAATCCTTCTTCGTGTTCTTAATAACTAATAT						
	SEQID8	CTTTGTTAATAATAAAGGTAATTTCAAGGACTTGAAATAATCCTTCTTCGTGTTCTTAATAACTAATAT						

35		290	300	310	320	330	340	350
	SEQID7	ATAAATACAGATATAGATGCATGAATAATGATATACATTGATTATTTTGCAATGTCAATTAATAAAAAAAAA						
40	SEQID8	ATAAATACAGATATAGATGCATGAATAATGATATACATTGATTATTTTGCAATGTCAATTAATAAAAAAAAA						

45		360	370	380	390	400	410	420
	SEQID7	AATGTTAGTAAACTATGTTACATTCCAAGCAAATAAAGCACTTGGTTAAACGAAATTAACGTTTTTAAG						
	SEQID8	AATGTTAGTAAACTATGTTACATTCCAAGCAAATAAAGCACTTGGTTAAACGAAATTAACGTTTTTAAG						

50		430	440	450	460	470	480	490
	SEQID7	ACAGCCAGACCGCGGTCTAAAAATTTAAATATACACTGCCAACAAATTCCTTCGAGTTGTCCAATTTTCAC						
	SEQID8	ACAGCCAGACCGCGGTCTAAAAATTTAAATATACACTGCCAACAAATTCCTTCGAGTTGTCCAATTTTCAC						

55		500	510	520	530	540	550	560
	SEQID7	CACTTTTATATTTTCATCAACTTCAGCAGATTCAACCTTCTCACATAGAACATTGGAATAAACAGCCTTA						
	SEQID8	CACTTTTATATTTTCATCAACTTCAGCAGATTCAACCTTCTCACATAGAACATTGGAATAAACAGCCTTA						

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      570      580      590      600      610      620      630
      |       |       |       |       |       |       |
5  SEQID7    ACACCACTTTCAAGTTTGCACAGCGTAATATGAGGAATTTGTTTGGACAACACAACCCTTAATTTTCT
   SEQID8    ACACCACTTTCAAGTTTGCACAGCGTAATATGAGGAATTTGTTTGGACAACACAACCCTTAATTTTCT
               *****

      640      650      660      670      680      690      700
      |       |       |       |       |       |       |
10  SEQID7    CATTGTTTTCATCAATTATGCATCCATCTTTATCTTTAGACAGTTCCACTACAATAGCAATAGTTTTTTC
   SEQID8    CATTGTTTTCATCAATTATGCATCCATCTTTATCTTTAGACAGTTCCACTACAATAGCAATAGTTTTTTC
               *****

```

HBsAg expression and adsorption

15 The plasmid is used to transform a *leu2-3 leu2-112 his3 can1-11* strain of *S.cerevisiae* yeast (DC5). The yeast are grown in a synthetic medium containing purified amino acids (but omitting leucine), vitamins, and suitable salts. Expressed HBsAg is purified by a process involving cell recovery, precipitation, ultrafiltration, gel permeation, ion exchange, ultracentrifugation and desalting.

20 The purified antigen is non-glycosylated and can be seen in the form of substantially-spherical particles (average diameter ~20nm).

A suspension of aluminum phosphate in isotonic saline is mixed with the purified HBsAg concentrate. After adjusting the pH to between 5.2 and 6.0, the mixture is left at room temperature for a day, with stirring. Adsorption of antigen to adjuvant takes place over this time.

Monovalent vaccine

25 For making a monovalent vaccine, 3D-MPL is added to the adsorbed HBsAg, and dilution to give a final HBsAg concentration of 20µg/ml is achieved using water for injection and sterile saline. This bulk vaccine is then packaged into individual doses, either in vials or into disposable syringes.

Multivalent vaccine

30 For making a combination vaccine, a DTPw antigen mixture is obtained from Chiron Behring in Marburg, Germany. This mixture is mixed with adsorbed HBsAg to give a tetravalent vaccine product. The tetravalent product can be used on its own, or can be used to reconstitute either (a) a lyophilized Hib-T conjugate that is adsorbed to an aluminum phosphate adjuvant, or (b) a trivalent mixture of lyophilized conjugates from Hib, MenA and MenC.

35 It will be understood that the invention has been described by way of example only and modifications may be made whilst remaining within the scope and spirit of the invention.

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CLAIMS

1. A process for preparing a multivalent immunogenic composition, comprising the steps of:
 - (a) preparing a HBV component by purifying HBsAg after expression in a *S.cerevisiae* host carrying a plasmid having a HBsAg coding sequence, wherein the plasmid includes:
 - (1) an upstream promoter from a glyceraldehyde-3-phosphate dehydrogenase gene, for controlling expression of the HBsAg coding sequence; and (2) an ARG3 transcription terminator downstream of the HBsAg coding sequence;
 - (b) preparing at least one non-HBV component; and
 - (c) mixing the HBV and non-HBV components to give the multivalent composition.
2. A multivalent immunogenic composition comprising:
 - (a) a HBV component comprising HBsAg expressed in a *S.cerevisiae* host carrying a plasmid having a HBsAg coding sequence, wherein the plasmid includes: (1) an upstream promoter from a glyceraldehyde-3-phosphate dehydrogenase gene, for controlling expression of the HBsAg coding sequence; and (2) an ARG3 transcription terminator downstream of the HBsAg coding sequence;
 - (b) at least one non-HBV component.
3. The composition of claim 2, wherein the composition also includes one or more adjuvant(s).
4. The process or composition of any preceding claim, wherein the non-HBV component comprises a diphtheria toxoid.
5. The process or composition of any preceding claim, wherein the non-HBV component comprises a tetanus toxoid.
6. The process or composition of any preceding claim, wherein the non-HBV component comprises a cellular pertussis antigen.
7. The process or composition of any one of claims 1 to 5, wherein the non-HBV component comprises an acellular pertussis antigen.
8. The process or composition of any preceding claim, wherein the non-HBV component comprises a hepatitis A virus antigen.
9. The process or composition of any preceding claim, wherein the non-HBV component comprises a conjugated *Haemophilus influenzae* type b capsular saccharide.
10. The process or composition of any preceding claim, wherein the non-HBV component comprises an inactivated poliovirus.

11. The process or composition of any preceding claim, wherein the non-HBV component comprises a conjugated *Neisseria meningitidis* serogroup C capsular saccharide.
12. The process or composition of any preceding claim, wherein the non-HBV component comprises a conjugated *Neisseria meningitidis* serogroup A capsular saccharide.
- 5 13. The process or composition of any preceding claim, wherein the non-HBV component comprises a conjugated *Neisseria meningitidis* serogroup W135 capsular saccharide.
14. The process or composition of any preceding claim, wherein the non-HBV component comprises a conjugated *Neisseria meningitidis* serogroup Y capsular saccharide.
- 10 15. The process or composition of any preceding claim, wherein the composition is a bivalent HBV-HAV composition.
16. The process or composition of any preceding claim, wherein the composition is a bivalent HBV-Hib composition.
17. The process or composition of any preceding claim, wherein the composition is a trivalent HBV-D-T composition.
- 15 18. The process or composition of any preceding claim, wherein the composition is a tetravalent HBV-D-T-Pa composition.
19. The process or composition of any preceding claim, wherein the composition is a tetravalent HBV-D-T-Pw composition.
- 20 20. The process or composition of any preceding claim, wherein the composition is a tetravalent HBV-HAV composition.
21. The process or composition of any preceding claim, wherein the composition is a pentavalent HBV-D-T-Pa-IPV composition.
22. The process or composition of any preceding claim, wherein the composition is a pentavalent HBV-D-T-Pw-Hib composition.
- 25 23. The process or composition of any preceding claim, wherein the composition is a pentavalent HBV-D-T-Pa-Hib composition.
24. The process or composition of any preceding claim, wherein the composition is a hexavalent HBV-D-T-Pa-Hib-IPV composition.
- 30 25. The process or composition of any preceding claim, wherein the composition is a heptavalent HBV-D-T-Pw-Hib-MenA-MenC composition.

26. The process or composition of any preceding claim, wherein the composition is a heptavalent HBV-D-T-Pa-Hib-IPV-MenC composition.

27. The process or composition of any preceding claim, wherein the composition includes both an aluminum hydroxide adjuvant and an aluminum phosphate adjuvant.

5 28. The process or composition of any preceding claim, wherein the HBsAg includes polysorbate 20.

29. The process or composition of any preceding claim, wherein the HBsAg includes phosphatidylinositol.

30. A process for preparing a monovalent immunogenic composition, comprising the steps of:

10 (a) preparing a HBV component by purifying HBsAg after expression in a *S.cerevisiae* host carrying a plasmid having a HBsAg coding sequence, wherein the plasmid includes: (1) an upstream promoter from a glyceraldehyde-3-phosphate dehydrogenase gene, for controlling expression of the HBsAg coding sequence; and (2) an ARG3 transcription terminator downstream of the HBsAg coding sequence; and

15 (b) combining the HBsAg with an adjuvant to give the immunogenic composition, provided that the adjuvant is not an aluminum hydroxide adjuvant.

31. A process for preparing a monovalent immunogenic composition, comprising the steps of:

20 (a) preparing a HBV component by purifying HBsAg after expression in a *S.cerevisiae* host carrying a plasmid having a HBsAg coding sequence, wherein the plasmid includes: (1) an upstream promoter from a glyceraldehyde-3-phosphate dehydrogenase gene, for controlling expression of the HBsAg coding sequence; and (2) an ARG3 transcription terminator downstream of the HBsAg coding sequence; and

(b) combining the HBsAg with an adjuvant to give the immunogenic composition, provided that the adjuvant does not consist solely of an aluminum salt.

32. A monovalent immunogenic composition comprising:

25 (a) a HBV component comprising HBsAg expressed in a *S.cerevisiae* host carrying a plasmid having a HBsAg coding sequence, wherein the plasmid includes: (1) an upstream promoter from a glyceraldehyde-3-phosphate dehydrogenase gene, for controlling expression of the HBsAg coding sequence; and (2) an ARG3 transcription terminator downstream of the HBsAg coding sequence; and

30 (b) an adjuvant that is not aluminum hydroxide.

33. A monovalent immunogenic composition comprising:

(a) a HBV component comprising HBsAg expressed in a *S.cerevisiae* host carrying a plasmid having a HBsAg coding sequence, wherein the plasmid includes: (1) an upstream

promoter from a glyceraldehyde-3-phosphate dehydrogenase gene, for controlling expression of the HBsAg coding sequence; and (2) an ARG3 transcription terminator downstream of the HBsAg coding sequence; and

(b) an adjuvant that does not consist solely of an aluminum salt.

- 5 34. The process of claim 30 or claim 31, or the composition of claim 32 or claim 33, wherein the adjuvant comprises a mixture of an aluminum phosphate adjuvant and a 3D-MPL adjuvant.
35. The process or composition of claim 34, wherein the 3D-MPL and the HBsAg are both adsorbed to the aluminum phosphate.
36. The process or composition of any one of claims 30 to 35, wherein the HBsAg includes
10 polysorbate 20.
37. The process or composition of any one of claims 30 to 36, wherein the HBsAg includes phosphatidylinositol.
38. The process or composition of any of claims 30 to 37, wherein the composition is for use in hemodialysis patients or pre-hemodialysis patients.
- 15 39. The process or composition of any preceding claim, wherein the plasmid also includes: (3) a LEU2 selection marker; (4) a 2 μ plasmid sequence; and (5) an origin of replication functional in *Escherichia coli*;
40. The process or composition of claim 39, wherein the *S.cerevisiae* host is auxotrophic for leucine, but wherein the plasmid LEU2 marker allows the host to grow in the absence of a leucine source.
- 20 41. The process or composition of any preceding claim, wherein the upstream promoter comprises nucleotide sequence SEQ ID NO: 1.
42. The process or composition of claim 41, wherein SEQ ID NO: 1 is followed directly by a start codon for the HBsAg.
43. The process or composition of any preceding claim, wherein the HBsAg has amino acid
25 sequence SEQ ID NO: 3.
44. The process or composition of any preceding claim, wherein the HBsAg is encoded in the plasmid by nucleotide sequence SEQ ID NO: 4.
45. The process or composition of claim 44, wherein SEQ ID NO: 4 is followed directly by an ochre stop codon.
- 30 46. The process or composition of any preceding claim, wherein the ARG3 terminator comprises nucleotide sequence SEQ ID NO: 8.

47. The process or composition of claim 46, wherein SEQ ID NO: 8 is immediately downstream of the stop codon of the HBsAg coding sequence.
48. The process or composition of any preceding claim, wherein the composition has an osmolality of between 200 mOsm/kg and 400 mOsm/kg.
- 5 49. A method of raising an immune response in a patient, comprising the step of administering a composition of any preceding claim to the patient.
50. The use of (i) HBsAg expressed in a *S.cerevisiae* host carrying a plasmid having a HBsAg coding sequence, wherein the plasmid includes: (1) an upstream promoter from a glyceraldehyde-3-phosphate dehydrogenase gene, for controlling expression of the HBsAg coding sequence; and (2) an ARG3 transcription terminator downstream of the HBsAg coding sequence; and (ii) one or more non-HBV antigens, in the manufacture of a medicament for administering to a patient.
- 10
51. The use of (i) HBsAg expressed in a *S.cerevisiae* host carrying a plasmid having a HBsAg coding sequence, wherein the plasmid includes: (1) an upstream promoter from a glyceraldehyde-3-phosphate dehydrogenase gene, for controlling expression of the HBsAg coding sequence; and (2) an ARG3 transcription terminator downstream of the HBsAg coding sequence; and (ii) an adjuvant other than an aluminum hydroxide, in the manufacture of a medicament for administering to a patient.
- 15
52. A plasmid comprising:
- 20 (1) a HBsAg coding sequence encoding amino acid sequence SEQ ID NO: 3;
- (2) a promoter from a glyceraldehyde-3-phosphate dehydrogenase gene, upstream of and for controlling expression of the HBsAg coding sequence, wherein the promoter comprises nucleotide sequence SEQ ID NO: 1; and
- (3) an ARG3 transcription terminator downstream of the HBsAg coding sequence, wherein the terminator comprises SEQ ID NO: 8.
- 25
53. The plasmid of claim 52, having between 14500 and 15000 base pairs.
54. A yeast carrying the plasmid of claim 52 or claim 53.