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(54) **Title:** TREPONEMA PALLIDUM TRIPLET ANTIGEN

(57) **Abstract:** A Treponema pallidum triplet antigen construct is disclosed which includes three Treponema pallidum antigens (TP15, TP17, and TP47), as well as a ten amino acid leader sequence (tag 261) and human copper zinc superoxide dismutase (hSOD). This construct is optimized for in vitro diagnosis of syphilis infection. Plasmids containing DNA encoding the triplet antigen, host cells, production methods, detection methods, and kits are also disclosed.

TREPONEMA PALLIDUM TRIPLET ANTIGEN**CROSS-REFERENCE TO RELATED APPLICATIONS**

[0001] This application claims the benefit of U.S. Provisional Application No. 61/432,570, filed January 13, 2011.

**STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR
DEVELOPMENT**

[0002] Not applicable.

FIELD OF THE INVENTION

[0003] The invention relates to the field of recombinant antigens, and more particularly to a *Treponema pallidum* triplet antigen construct and its use in immunoassays for the detection of syphilis.

BACKGROUND OF THE INVENTION

[0004] Over the past half century, effective antibiotic treatment programs have made syphilis relatively uncommon in the United States, with less than 7,100 primary and secondary cases diagnosed in 2003. However, recent data indicates that reported cases are again increasing in subsets of the population, and periodic epidemics of syphilis have occurred for decades. In 1995, the number of new cases of syphilis worldwide was estimated to be 12 million per year. If untreated, syphilis can evolve from localized primary lesions (chancres) to disseminated, chronic infections, including secondary, latent, and tertiary forms.

[0005] As a syphilitic infection can produce a variable range of symptoms in humans, laboratory tests are often required to definitively diagnose an infection. Due to the inability to culture the causative organism, *Treponema pallidum* (*T. pallidum*)(TP), in vitro, a need exists for the development and optimization of in vitro methods for the detection of *T. pallidum* in diverse clinical specimens [Morse, *Salud Publica Mex* 5(Suppl 45):S698-S708, 2003]. While enzyme-linked immunosorbent assays (ELISAs) for *Treponema* are commercially available, they exhibit varying efficiencies at different disease stages [Schmidt et al., *J Clin Microbiol* 38:1279-1282 (2000)]. Several ELISAs

based on whole cell lysate were developed which presented sensitivity of 93.3% to 100% and specificity of 95.5% to 99.8% [Castro et al., J Clin Microbiol 41:250-253 (2003)].

[0006] In recent years, several immunodominant and putatively pathogen-specific membrane lipoproteins of *T. pallidum* have been identified in patients with syphilis and in infants with congenital syphilis. These patients and infants developed antigen specific antibodies which could be detected by immunoblot and by enzyme immunoassay.

Therefore, recent methods of detection use recombinant antigens, mainly the membrane-integrated proteins 47kDa, 17kDa and 15kDa (TP47, TP17, and TP15, respectively), in treponemal ELISA tests. Although TP47 was the earliest identified, as well as the most abundant and highly immunogenic [Norgard et al., Infect Immun 54:500-506 (1986)], the later identified TP15 and TP17, present in lower amounts, are also strongly immunogenic [Purcell et al., Infect Immun 57:3708-3714 (1989); Akins et al., Infect Immun 61:1202-1210 (1993)].

[0007] Given the increase in reported cases of syphilis and the periodic epidemics, as well as the severity of the disease, a need continues to exist for sensitive and specific immunoassays for detection of *Treponema pallidum*.

BRIEF SUMMARY OF THE INVENTION

[0008] To this end, the invention provides a recombinant plasmid encoding a *Treponema pallidum* triplet antigen. The plasmid comprises nucleic acid encoding an amino acid sequence selected from the group consisting of SEQ ID NO:7, SEQ ID NO:8, SEQ ID NO:9, SEQ ID NO:10, SEQ ID NO:11, and SEQ ID NO:12.

[0009] The invention further provides a recombinant plasmid encoding a *Treponema pallidum* triplet antigen, the recombinant plasmid selected from the group consisting of: the plasmid designated p261nS-TP17-15-47 and deposited with the American Type Culture Collection ("ATCC") as ATCC Accession No. PTA-11590 on January 12, 2011; the plasmid designated p261nS-TP47-17-15 and deposited with the American Type Culture Collection as ATCC Accession No. PTA-11589 on January 12, 2011; the plasmid designated p261nS-TP17-47-15; the plasmid designated p261nS-TP47-15-17; the plasmid designated p261nS-TP15-17-47; and the plasmid designated p261nS-TP15-47-17.

[0010] Vectors, host cells, and triplet antigen production methods using the host cells are also provided.

[0011] Additionally, the invention provides the *Treponema pallidum* triplet antigen having an amino acid sequence selected from the group consisting of SEQ ID NO:7, SEQ ID NO:8, SEQ ID NO:9, SEQ ID NO:10, SEQ ID NO:11, and SEQ ID NO:12. A method of detecting the presence of *Treponema pallidum* antibodies in a sample is further provided, which uses the *Treponema pallidum* triplet antigen, as well as kits for such detection.

[0012] Additional features and advantages of the subject invention will be apparent from the description which follows when considered in conjunction with the attached figures.

BRIEF DESCRIPTION OF THE DRAWINGS

- [0013] Fig. 1 illustrates the reaction scheme for the VITROS[®] Syphilis TPA test;
- [0014] Fig. 2 shows the plasmid map of pUC57-TP15;
- [0015] Fig. 3 shows the plasmid map of pUC57-TP17;
- [0016] Fig. 4 shows the plasmid map of pUC57-TP47;
- [0017] Fig. 5 shows the plasmid map of pUC57-hSOD;
- [0018] Fig. 6 shows the TP construct for cloning into pB10G;
- [0019] Fig. 7 shows the hSOD construct for cloning into a pB10G triplet plasmid;
- [0020] Fig. 8 shows the plasmid map of pB10G;
- [0021] Fig. 9 shows the plasmid map of pB10G-TP(1);
- [0022] Fig. 10 shows the plasmid map of pB10G-TP(2);
- [0023] Fig. 11 shows the plasmid map of pB10G-TP(3);
- [0024] Fig. 12 shows the TP(1) construct for cloning into pB10G-TP(2);
- [0025] Fig. 13 shows the plasmid map of pB10G-TP(1-2);
- [0026] Fig. 14 shows the TP(3) construct for cloning into pB10G-TP(1-2);
- [0027] Fig. 15 shows the plasmid map of pB10G-TP(1-2-3);
- [0028] Fig. 16 shows the plasmid map of pB10G-TP(1-2-3) with the unique restriction enzyme site;
- [0029] Fig. 17 shows the plasmid map of p261nS-TP(1-2-3);

[0030] Fig. 18 illustrates the direct assay format according to the subject invention; and

[0031] Fig. 19 illustrates the indirect assay format according to the subject invention.

DETAILED DESCRIPTION OF THE INVENTION

[0032] The assay (detection method) of the subject invention uses recombinant *Treponema pallidum* (TP)(the causative agent of Syphilis) outer membrane protein antigens to detect patient sample anti-IgG, anti-IgM, and anti-IgA antibodies. The recombinant protein antigens of interest are a 15 kilodalton antigen (TP15), a 17 kilodalton antigen (TP17), and a 47 kilodalton antigen (TP47). A fused recombinant antigen construct has been developed which incorporates the three antigens of interest as well as human copper zinc superoxide dismutase (hSOD). In addition to the *Treponema pallidum* antigenic sequences and the hSOD, a 10 amino acid tag (the "261sequence") is present at the N-terminus of the fused antigen construct to facilitate evaluation by Western blot and ELISA, and to provide a means for affinity purification if desired. The assay of the subject invention uses this fused recombinant antigen construct.

[0033] In one embodiment, the assay is the VITROS[®] Syphilis TPA test and the assay is performed using the VITROS[®] ECi/ECiQ Immunodiagnostic Systems, VITROS[®] 3600 Immunodiagnostic System, or VITROS[®] 5600 Integrated System using Intellicheck[®] Technology. Each of these analyzers is available from Ortho-Clinical Diagnostics, Inc., 100 Indigo Creek Drive, Rochester, NY 14626. An immunometric immunoassay technique is used, which involves the reaction of IgG, IgM or IgA antibodies present in the sample with a biotinylated recombinant TP antigen and a horseradish peroxidase (HRP)-labeled recombinant TP antigen conjugate. The antibody-antigen complex is captured by streptavidin on the wells (SAC wells). Unbound materials are removed by washing. The bound HRP conjugate is measured by a luminescent reaction. A reagent containing luminogenic substrate (a luminol derivative and a peracid salt) and an electron transfer agent is added to the wells. The HRP in the bound conjugate catalyzes the oxidation of the luminol derivative, producing light. The electron transfer agent (a substituted acetanilide) increases the level of light produced and prolongs its emission. The light signals are read by the analyzer system. The bound HRP

conjugate is directly proportional to the concentration of anti-TP antibody present. This reaction scheme is illustrated in Fig. 1, where 10 represents the streptavidin coated well, 12 represents the biotinylated TP antigen, 14 represents the antibodies to TP antigens present in a sample, 16 represents HRP labeled TP antigen, 18 represents signal reagent with enhancer, and 20 represents luminescence. Superoxide dismutase is present in the assay biotin reagent formulation to block binding of anti-SOD antibodies that may be present in the patient sample. This prevents a false reactive signal from being generated.

[0034] The invention provides a recombinant plasmid encoding a *Treponema pallidum* triplet antigen. The plasmid comprises nucleic acid encoding an amino acid sequence selected from the group consisting of SEQ ID NO:7, SEQ ID NO:8, SEQ ID NO:9, SEQ ID NO:10, SEQ ID NO:11, and SEQ ID NO:12.

[0035] In one embodiment, the plasmid is designated p261nS-TP17-15-47 and is deposited with the American Type Culture Collection ("ATCC") as ATCC Accession No. PTA-11590. Plasmid p261nS-TP17-15-47 includes nucleic acid having the nucleotide sequence as shown in SEQ ID NO:3, encoding the triplet antigen construct having the amino acid sequence as shown in SEQ ID NO:9. In this particular embodiment, amino acids 5-14 encode the 261 tag, amino acids 17-150 encode TP17, amino acids 155-277 encode TP15, amino acids 282-695 encode TP47, and amino acids 697-849 encode hSOD.

[0036] In another embodiment, the plasmid is designated p261nS-TP47-17-15 and is deposited with the American Type Culture Collection as ATCC Accession No. PTA-11589. Plasmid p261nS-TP47-17-15 includes nucleic acid having the nucleotide sequence as shown in SEQ ID NO:6, encoding the triplet antigen construct having the amino acid sequence as shown in SEQ ID NO:12. In this particular embodiment, amino acids 5-14 encode the 261 tag, amino acids 17-430 encode TP47, amino acids 435-568 encode TP17, amino acids 573-695 encode TP15, and amino acids 697-849 encode hSOD.

[0037] In a further embodiment, the plasmid is designated p261nS-TP17-47-15. Plasmid p261nS-TP17-47-15 includes nucleic acid having the nucleotide sequence as shown in SEQ ID NO:4, encoding the triplet antigen construct having the amino acid sequence as shown in SEQ ID NO:10. In this particular embodiment, amino acids 5-14

encode the 261 tag, amino acids 17-150 encode TP17, amino acids 155-568 encode TP47, amino acids 571-693 encode TP15, and amino acids 695-847 encode hSOD.

[0038] In yet another embodiment, the plasmid is designated p261nS-TP47-15-17. Plasmid p261nS-TP47-15-17 includes nucleic acid having the nucleotide sequence as shown in SEQ ID NO:5, encoding the triplet antigen construct having the amino acid sequence as shown in SEQ ID NO:11. In this particular embodiment, amino acids 5-14 encode the 261 tag, amino acids 17-430 encode TP47, amino acids 435-557 encode TP15, amino acids 560-693 encode TP17, and amino acids 695-847 encode hSOD.

[0039] In an additional embodiment, the plasmid is designated p261nS-TP15-17-47. Plasmid p261nS-TP15-17-47 includes nucleic acid having the nucleotide sequence as shown in SEQ ID NO:1, encoding the triplet antigen construct having the amino acid sequence as shown in SEQ ID NO:7. In this particular embodiment, amino acids 5-14 encode the 261 tag, amino acids 17-139 encode TP15, amino acids 143-276 encode TP17, amino acids 281-694 encode TP47, and amino acids 696-848 encode hSOD.

[0040] In another additional embodiment, the plasmid is designated p261nS-TP15-47-17. Plasmid p261nS-TP15-47-17 includes nucleic acid having the nucleotide sequence as shown in SEQ ID NO:2, encoding the triplet antigen construct having the amino acid sequence as shown in SEQ ID NO:8. In this particular embodiment, amino acids 5-14 encode the 261 tag, amino acids 17-139 encode TP15, amino acids 143-556 encode TP47, amino acids 559-692 encode TP17, and amino acids 694-846 encode hSOD.

[0041] The ATCC is located at 10801 University Boulevard, Manassas, Virginia 20110-2209 USA, and each of the above deposits was made on January 12, 2011 under the Budapest Treaty on the International Recognition of the Deposit of Microorganisms for the Purposes of Patent Procedure (the "Budapest Treaty").

[0042] Each *Treponema pallidum* triplet antigen construct includes three *Treponema pallidum* antigens (TP15, TP17, and TP47). While each has been defined by its amino acid sequence as well as a nucleotide sequence, it should be readily apparent that nucleotide additions, deletions, and/or substitutions, such as those which do not affect the translation of the DNA molecule, are within the scope of a particular nucleotide sequence (i.e. the amino acid sequence encoded thereby remains the same). Such

additions, deletions, and/or substitutions can be, for example, the result of point mutations made according to methods known to those skilled in the art. It is also possible to substitute a nucleotide which alters the amino acid sequence encoded thereby, where the amino acid substituted is a conservative substitution or where amino acid homology is conserved. It is also possible to have minor nucleotide additions, deletions, and/or substitutions which do not alter the function of the resulting triplet (i.e. its ability to detect anti-TP15, anti-TP17, and/or anti-TP47 antibodies).

[0043] Amino acid additions, deletions, and/or substitutions which do not negate the ability of the resulting triplet to detect anti-TP15, anti-TP17, and/or anti-TP47 antibodies are thus within the scope of a particular amino acid sequence. Such additions, deletions, and/or substitutions can be, for example, the result of point mutations in the DNA encoding the amino acid sequence, such point mutations made according to methods known to those skilled in the art. Substitutions may be conservative substitutions of amino acids. Two amino acid residues are conservative substitutions of one another, for example, where the two residues are of the same type. In this regard, proline, alanine, glycine, serine, and threonine, all of which are neutral, weakly hydrophobic residues, are of the same type. Glutamine, glutamic acid, asparagine, and aspartic acid, all of which are acidic, hydrophilic residues, are of the same type. Another type of residue is the basic, hydrophilic amino acid residue, which includes histidine, lysine, and arginine. Leucine, isoleucine, valine, and methionine, all of which are hydrophobic, aliphatic amino acid residues, form yet another type of residue. Yet another type of residue consists of phenylalanine, tyrosine, and tryptophan, all of which are hydrophobic, aromatic residues. Further descriptions of the concept of conservative substitutions are given by French and Robson [J Molecular Evolution 19:171-175 (1983)], Taylor [J Theor Biol 119:205-218 (1986)], and Bordo and Argos [J Mol Biol 217:721-729 (1991)].

[0044] While the presently preferred vector system for provision of the nucleic acid encoding the triplet antigen construct is a plasmid vector, other vector systems can also be used. Furthermore, while the presently preferred host cell for expression of the triplet antigen construct is the bacterial host cell *Escherichia coli*, any suitable host and/or vector system can be used to express the triplet antigen construct. Other suitable bacterial hosts, yeasts hosts (such as *Saccharomyces cerevisiae*), as well as mammalian (for

example, HeLa cells, Cv-1 cells, COS cells) and insect hosts (such as *Drosophila* cell lines), can be used.

[0045] Techniques for introducing the nucleic acid molecules into the host cells may involve the use of expression vectors which comprise the nucleic acid molecules. These expression vectors (such as plasmids and viruses; viruses including bacteriophage) can then be used to introduce the nucleic acid molecules into the suitable host cells. For example, DNA encoding the triplet antigen can be injected into the nucleus of a host cell or transformed into the host cell using a suitable vector, or mRNA encoding the triplet antigen can be injected directly into the host cell, in order to obtain expression of triplet antigen in the host cell.

[0046] Various methods are known in the art for introducing nucleic acid molecules into host cells. One method is microinjection, in which DNA is injected directly into the nucleus of cells through fine glass needles (or RNA is injected directly into the cytoplasm of cells). Alternatively, DNA can be incubated with an inert carbohydrate polymer (dextran) to which a positively charged chemical group (DEAE, for diethylaminoethyl) has been coupled. The DNA sticks to the DEAE-dextran via its negatively charged phosphate groups. These large DNA-containing particles stick in turn to the surfaces of cells, which are thought to take them in by a process known as endocytosis. Some of the DNA evades destruction in the cytoplasm of the cell and escapes to the nucleus, where it can be transcribed into RNA like any other gene in the cell. In another method, cells efficiently take in DNA in the form of a precipitate with calcium phosphate. In electroporation, cells are placed in a solution containing DNA and subjected to a brief electrical pulse that causes holes to open transiently in their membranes. DNA enters through the holes directly into the cytoplasm, bypassing the endocytotic vesicles through which they pass in the DEAE-dextran and calcium phosphate procedures (passage through these vesicles may sometimes destroy or damage DNA). DNA can also be incorporated into artificial lipid vesicles, liposomes, which fuse with the cell membrane, delivering their contents directly into the cytoplasm. In an even more direct approach, used primarily with plant cells and tissues, DNA is absorbed to the surface of tungsten microprojectiles and fired into cells with a device resembling a shotgun.

[0047] Further methods for introducing nucleic acid molecules into cells involve the use of viral vectors. Since viral growth depends on the ability to get the viral genome into cells, viruses have devised clever and efficient methods for doing it. One such virus widely used for protein production is an insect virus, baculovirus. Baculovirus attracted the attention of researchers because during infection, it produces one of its structural proteins (the coat protein) to spectacular levels. If a foreign gene were to be substituted for this viral gene, it too ought to be produced at high level. Baculovirus, like vaccinia, is very large, and therefore foreign genes must be placed in the viral genome by recombination. To express a foreign gene in baculovirus, the gene of interest is cloned in place of the viral coat protein gene in a plasmid carrying a small portion of the viral genome. The recombinant plasmid is cotransfected into insect cells with wild-type baculovirus DNA. At a low frequency, the plasmid and viral DNAs recombine through homologous sequences, resulting in the insertion of the foreign gene into the viral genome. Virus plaques develop, and the plaques containing recombinant virus look different because they lack the coat protein. The plaques with recombinant virus are picked and expanded. This virus stock is then used to infect a fresh culture of insect cells, resulting in high expression of the foreign protein. For a review of baculovirus vectors, see Miller [Bioessays 11:91-95 (1989)]. Various viral vectors have also been used to transform mammalian cells, such as bacteriophage, vaccinia virus, adenovirus, and retrovirus.

[0048] As indicated, some of these methods of transforming a cell require the use of an intermediate plasmid vector. U.S. Pat. No. 4,237,224 to Cohen and Boyer describes the production of expression systems in the form of recombinant plasmids using restriction enzyme cleavage and ligation with DNA ligase. These recombinant plasmids are then introduced by means of transformation and replicated in unicellular cultures including procaryotic organisms and eucaryotic cells grown in tissue culture. The DNA sequences are cloned into the plasmid vector using standard cloning procedures known in the art, as described by Sambrook et al. [Molecular Cloning: A Laboratory Manual, 2d Edition, Cold Spring Harbor Laboratory Press, Cold Spring Harbor, NY (1989)].

[0049] Host cells into which the nucleic acid encoding the triplet antigen has been introduced can be used to produce (i.e. to functionally express) the triplet antigen.

[0050] The subject invention further provides a *Treponema pallidum* triplet antigen having an amino acid sequence selected from the group consisting of SEQ ID NO:7, SEQ ID NO:8, SEQ ID NO:9, SEQ ID NO:10, SEQ ID NO:11, and SEQ ID NO:12. Presently preferred embodiments of the triplet antigen are those represented by SEQ ID NO:9 and SEQ ID NO:12. These embodiments present the TP17 portion of the triplet before the TP15 portion of the triplet, and higher antibody detection sensitivity is achieved with these constructs. All constructs include a leader sequence (presently preferred is a ten amino acid leader sequence (tag 261), though other suitable leaders could be substituted). All constructs further include human copper zinc superoxide dismutase (hSOD), a low immunogenic protein, at the carboxy terminus. Eleven lysine residues in the hSOD provide sites for biotin attachment and HRP conjugation, and two cysteine residues are mutated to serine (Cys 4 and Cys 112) to prevent interchain protein polymerization [Hallewel et al., J Biol Chem 264:5260-5268 (1989)]. This construct is thus optimized for in vitro diagnosis of syphilis infection. Other suitable low immunogenic proteins which provide similar sites for biotin attachment and HRP conjugation could be substituted. In the presently preferred plasmid construction, the triplet antigen is under the control of the T5 promoter.

[0051] While the specific details of an assay for detecting the presence of *Treponema pallidum* antibodies in a sample are disclosed below, generally the method comprises: contacting a sample with the *Treponema pallidum* triplet antigen of the subject invention, wherein *Treponema pallidum* antibodies present in the sample bind to the *Treponema pallidum* triplet antigen forming an antibody/antigen complex; and detecting the antibody/antigen complex, thereby detecting the presence of the *Treponema pallidum* antibodies. For use in an assay format for the detection of antibodies to *Treponema pallidum*, the antigen triplet may be labeled with a detectable marker. Suitable markers include, for example, enzymatic labels such as horseradish peroxidase or alkaline phosphatase, as well as fluorescent labels (such as fluorescein, rhodamine, and green fluorescent protein).

[0052] The assay format may also utilize biotin/avidin/streptavidin in the provision of the triplet antigen bound to a solid phase. Suitable solid phases include, for example, any non-aqueous matrix to which the triplet antigen can be bound. Such solid

phases are well known in the immunoassay arts, and include, for example, polystyrene plates, polyacrylamides, glass, polysaccharides, polyvinyl alcohol and silicones.

Microslides, microwells, and microtips are all used as solid phases in immunoassays.

[0053] The assay format may involve direct detection of the antibody/antigen complex (see Fig. 18), which can comprise: contacting the antibody/antigen complex with a second *Treponema pallidum* triplet antigen of the subject invention, wherein the second *Treponema pallidum* triplet antigen is labeled with a detectable marker (HRP as shown). The second *Treponema pallidum* triplet antigen binds to the antibody present in the antibody/antigen complex forming an antigen/antibody/labeled antigen complex, which is then detected thereby detecting the presence of *Treponema pallidum* antibodies in the sample.

[0054] The assay format may involve indirect detection of the antibody/antigen complex (see Fig. 19), which can comprise: contacting the antibody/antigen complex with labeled anti-human antibody (monoclonal mouse anti-human antibody as shown). The labeled anti-human antibody binds to the antibody present in the antibody/antigen complex forming an antigen/antibody/labeled anti-antibody complex, which is then detected thereby detecting the presence of *Treponema pallidum* antibodies in the sample.

[0055] For all assays of the subject invention, the sample can be any suitable sample (for example, serum, plasma, and EDTA or heparin plasma) but is preferably a serum sample.

[0056] The *Treponema pallidum* triplet antigen construct of the subject invention can thus be utilized as a component of a kit for detection of *Treponema pallidum* antibodies. A kit is provided which comprises the *Treponema pallidum* triplet antigen construct, and additionally a second *Treponema pallidum* triplet antigen construct labeled with a detectable marker (an "enzyme conjugate" such as HRP-labeled *Treponema pallidum* triplet antigen)(see above discussion of markers). The kit can also comprise suitable positive and/or negative controls, calibration samples, enzyme conjugates, substrate for enzyme conjugates (such as O-phenylenediamine), buffer solution, and washing solution.

[0057] The details of the construction of the triplet antigen and its use in an assay for detection of *Treponema pallidum* antibodies in a patient sample are described below.

[0058] Synthetic Genes. *T. pallidum* outer membrane protein genes TP15, TP17, and TP47 were each synthesized based on amino acid sequence P16055 (amino acid 19-141), P29722 (amino acid 23-156) and P29723 (amino acid 21-434), respectively, published in the central database UniProt (<http://www.uniprot.org>). Human copper zinc superoxide dismutase (hSOD) gene was synthesized based on amino acid sequence P00441 (amino acid 2-154), except two Cystein residues (amino acid 7 and 112) were mutated to Serine to prevent polymerization. All four synthesized gene codons were optimized for bacterial expression and each was inserted at the EcoR V site on host plasmid pUC57. The resulting plasmids, pUC57-15, pUC57-17, pUC57-45, and pUC57-hSOD, are shown in Figs. 2-5, respectively.

[0059] The four synthetic genes do not bear stop codons and any internal Apa I, BamH I, Bgl II, EcoR I and Hind III sites that were used in subsequent subcloning described below. Restriction enzyme sites, with or without tag gene (261 sequence), were incorporated into the four synthetic genes.

[0060] Expression Vector and TP Doublet Construction. Each of the TP genes from pUC57 was digested by Bgl II and Apa I (see Fig. 6 for resulting TP construct) and separately cloned into BamH I and Apa I sites of a previously constructed expression vector, pB10G (see Fig. 8), which contained a T5 promoter, an ATG start site, and unique restriction sites EcoR I, BamH I, Apa I and Hind III. This generated three expressional vectors, pB10G-TP15, pB10G-TP17 and pB10G-TP47 (shown generically as pB10G-TP(1), pB10G-TP(2), and pB10G-TP(3) in Figs. 9-11, respectively). Ligation of the compatible Bgl II ends of the gene fragments and the BamH I ends on the plasmids eliminated the Bgl II/BamH I restriction enzyme sites in all three constructs. The TP doublet was created by subcloning. To construct a TP doublet subclone (see Fig. 13), a DNA gene insert was produced by PCR reaction using the second antigen expression vector as template and a pair of forward and reverse primers. The forward primer covered the EcoR I site, located in the T5 promoter region, upstream of the TP gene. The reverse primer matched the end of the TP gene and converted the Apa I site to a Bgl II site. This PCR product was then digested with EcoR I/Bgl II (see Fig. 12 for resulting TP-1 construct) and cloned into another antigen expression vector which was cut open with

EcoR I and BamH I. Likewise, ligation of the compatible Bgl II on the insert and the BamH I on the host eliminated both restriction enzyme sites.

[0061] TP Triplet Construction. To produce six final triplet fusion genes, four TP doublet vectors, pB10G-TP17-TP47, pB10G-TP15-TP47, pB10G-TP47-TP15 and pB10G-TP17-TP15, were used as the host and the third TP gene was either added at the 5' end of the TP doublet or added at the 3' end of the TP doublet. The TP(1-2) double vector is shown generically in Fig. 13 and the TP(3) construct for insertion into the doublet vector is shown in Fig. 14. To add the insert at the 3' end, a DNA gene insert was produced by PCR reaction using the third antigen expression vector as template and a pair of forward and reverse primers. The forward primer matched the 5' end of TP gene and contained a Apa I site. The reverse primer matched the 3' end of TP gene and contained a Hind III site. This PCR product was then digested with Apa I/Hind III and cloned into the doublet expression vector which was cut open with the appropriate restriction enzymes. Triplets pB10G-TP15-TP17-TP47, pB10G-TP17-TP15-TP47 and pB10G-TP47-TP17-TP15 were made by adding the third TP gene at the doublet 5' end, while triplets pB10G-TP15-TP47-TP17, pB10G-TP47-TP15-TP17 and pB10G-TP17-TP47-TP15 were made by adding the third TP gene at the doublet 3' end. PCR primers used in creating the doublets and triplets are listed in Table 4, PCR Primers, Group A. This triplet construct is shown generically in Fig. 15.

[0062] TP Triplet with SOD fusion Construction. The TP triplet with a C-terminal SOD fusion tag (shown generically in Fig. 17) was created through "two-round" PCR and cloning. "Two-round PCR" was performed to link the C-terminal TP3 with SOD (see Fig. 7 for SOD construct) and to introduce restriction enzyme sites for cloning. The first round of PCR was composed of two separate PCR reactions, with the reverse primer (Table 4, PCR Primers, Group B) in one PCR reaction complementing the forward primer (Table 4, PCR Primers, Group C) in the other PCR reaction. In the second round of PCR, the two products from the first round PCR were combined and amplified with a third set of nested primers (Table 4, PCR Primers, Group D). The forward primer matched the TP3 sequence and contained a unique restriction enzyme (RE) site. The reverse primer matched the 3' end SOD. Two stop codons and a Hind III site created a new DNA insert (see Fig. 16). To fuse the SOD gene to the existing *T. pallidum* triplet, the new PCR product was digested and

directly cloned into a pB10G-TP triplet plasmid digested at the designed unique restriction site and the Hind III site to yield pB10G-TP(1-2-3)-SOD (see Fig. 17). As used herein, TP1, TP2, and TP3 represent the three *T. pallidum* antigens, TP15, TP17, and TP47, in any order. Thus, TP1 could be TP15, TP2 could be TP17, and TP3 could be TP47. Other combinations include: TP1 could be TP15, TP2 could be TP47, and TP3 could be TP17; TP1 could be TP17, TP2 could be TP15, and TP3 could be TP47; TP1 could be TP17, TP2 could be TP47, and TP3 could be TP15; TP1 could be TP47, TP2 could be TP15, and TP3 could be TP17; and TP1 could be TP47, TP2 could be TP17, and TP3 could be TP15.

[0063] All PCR amplifications were performed with *Taq* polymerase using a standard sequence of 35 PCR cycles: 95°C (15 sec), 55°C (20 sec), 72°C (30 sec). Nucleotide sequences of the PCR primers are listed in Table 4. Usage of each primer in creating particular triplets is indicated. All PCR products were purified following a Qiagen PCR kit protocol. All restriction enzymes were purchased from New England Biolabs. Plasmids were prepared using Qiagen DNA Miniprep kits. All six triplet coding regions were DNA sequenced (SEQ ID NOS:1-6) and amino acid sequences translated (SEQ ID NOS:7-12).

[0064] The assay of the subject invention provides for the measurement of antibodies to three *T. pallidum* antigens, TP15, TP17 and TP47. The assay is performed on antigen precoated microtiter plates. Samples are added to the microtiter plate wells and incubated. *T. pallidum* IgG/IgM specific antibodies, if present, will bind to and become immobilized by the antigen pre-coated on the wells. The bound antibodies were detected either in a direct conjugated antigen sandwich format (see Fig. 18), or in an indirect format detected by conjugated anti-human IgG and IgM (see Fig. 19).

[0065] More particularly, recombinant TP triplets were coated passively on an ELISA high-binding plate well surface as capture antigen. The plate was then blocked with 1% BSA/PBS to cover all unbound well surfaces. Syphilis infected patient's serum or plasma was added in wells and incubated for a first incubation period, enabling *T. pallidum* antibody (IgG, IgM, and IgA) in the sample to react with the precoated triplet antigens. Unbound materials were washed away after the first incubation. For the direct assay, HRP conjugated recombinant TP triplet was the detector and was added into the wells and incubated for a second incubation period. After the second incubation, unbound

triplet conjugates were washed away. The formed antigen - human T. pallidum antibody (IgG/IgM) - antigen complex was measured by adding peroxidase substrate solution, then the reaction was stopped after 30 minutes and optical density was recorded for analysis. For the indirect assay, an HRP conjugated mouse monoclonal anti-human IgG and HRP conjugated mouse monoclonal anti-human IgM mixture was the detector and was added into the wells and incubated for the second incubation period. After the second incubation, unbound conjugates were washed away. The formed anti-human IgG/IgM - human T. pallidum antibody (IgG/IgM) - antigen complex was measured by adding peroxidase substrate solution, then the reaction was stopped after 30 minutes and optical density was recorded for analysis.

[0066] The engineered recombinant T. pallidum triplet has a 10 amino acid leader sequence (tag 261) at the N-terminus and two to four amino acid linkers between each TP antigen. The tag 261 sequence was derived from human placenta growth factor (PlGF). The human copper zinc superoxide dismutase (hSOD) is incorporated at the C-terminus of the T. pallidum antigen triplet to form a fusion protein.

[0067] hSOD has been used previously in various recombinant antigen fusions in diagnostic assays for infectious pathogens such as HCV, HIV etc. hSOD is a small size, low immunogenic human endogenous protein, which has 153 amino acids with a molecular weight of about 16kD. The 11 lysine residues in hSOD provide extra conjugation site for biotinylation and HRP conjugation.

EXAMPLE I

ELISA Assay Reagents, Format, and Protocol

[0068] Assay Reagents:

- 96 well microtiter high-binding plate (Costar)
- Coating buffer (10mM phosphate, 2mM EDTA, pH 7.0), blocking buffer (1% BSA in PBS, pH 7.0), washing solution (PBS with 0.05% twenn-20), sample buffer (Blocker Casein in PBS with 0.05% tween-20, Pierce)
- ELISA specimen and conjugate diluent: Blocker Casein in PBS from Pierce. Tween 20 was added to a final of 0.05% before use. In the direct assay, hSOD lysate was added together with HRP conjugated TP triplet.

- Purified recombinant TP triplet fusions, their sequences were validated by DNA sequencing (see SEQ ID NOs:1-6). Proteins were expressed in prokaryotic E.coli cell. Protein purity was validated to be greater than 87% by SDS PAGE.
- HRP (horseradish peroxidase) conjugated recombinant TP triplet.
150ng/mL, Phosphate, pH= 7.2, Molarity = 50 mM
HRP conjugate reagent buffer contains: H₂O, K₂HPO₄ (anhydrous), KH₂PO₄ (anhydrous), NaCl, BSA liquid, KFeCN, ANS, Tween-20, Anti-foam 204, ProClin 950
- HRP (horseradish peroxidase) conjugated mouse monoclonal anti-261 tag
- HRP (horseradish peroxidase) conjugated mouse monoclonal anti-human IgG
- HRP (horseradish peroxidase) conjugated mouse monoclonal anti-human IgM
- HRP (horseradish peroxidase) substrate tablet (O-Phenylenediamine-2HCl) and solution and stop solution are components from Ortho-Clinical Diagnostics general ELISA products.
- Specimens : Syphilis Positive plasma, Syphilis Negative plasma, SeraCare Syphilis mixed titer panel (PS C202) and Zeptomatrix Syphilis mixed titer panel (K-ZMC002)

[0069] The ELISA Assay Format is shown in Figs. 18 and 19, both a direct assay format and an indirect assay format.

[0070] ELISA Assay Protocol: Plate coating: 1) add 100uL/well coating solution containing 2ug/mL of TP triplet fusion at 25°C for 18hrs. 2) Wells were washed once with washing buffer and 290uL/well blocking buffer were added for 1hr/25°C blocking. 3) After blocking buffer aspirated, plates were dried greater than 4 hrs in a low humidity incubator. 4) Plate was pouched in an air-proof sealed bag until use.

[0071] Direct Assay Protocol: Assay: 1) Add 50uL Casein (PBS) specimen diluent and 50uL specimen (or control) to each well. Plate was incubated for 30 min at 37°C with shaking. 2) After 6 times wash with washing solution; add 100uL HRP conjugated TP triplet fusion diluted in Casein (PBS) to each well. Plate was incubated for 30 min at 37°C with shaking. 3) After 6 times wash, add 100uL OPD substrate and incubate in dark for 30 min at 25°C. 4) Add 25uL stop solution and read optical density (OD) at 492nm.

[0072] Indirect Assay Protocol: Assay: 1) Add 90uL Casein (PBS) specimen diluent and 10uL specimen (or control) to each well. Plate was incubated for 15 min at

37°C with shaking. 2) After 6 times wash with washing solution; add 100uL HRP conjugate mixture containing HRP-mouse monoclonal anti-human IgG and HRP-mouse monoclonal anti-human IgM diluted in casein (PBS) to each well. Plate was incubated for 15 min at 37°C with shaking. 3) After 6 times wash, add 100uL OPD substrate and incubate in dark for 30 min at 25°C. 4) Add 25uL stop solution and read optical density (OD) at 492nm.

EXAMPLE II

Evaluation of Triplet Constructs

[0073] ELISA Reaction: (1) Wells were coated with a serial dilution of six TP triplets and post-coated with 1% BSA in PBS. (2) Add 100ul HRP conjugated mouse monoclonal anti-261 tag diluted in Casein (PBS) to antigen precoated wells, and incubate at 37°C for 15 minutes with shaking. (2) Wash 6 times, add 100uL OPD substrate solution, and incubate at RT for 15 min in dark. (4) Add 25uL 4N sulfuric acid stop solution and read at 490nm.

[0074] Results shown in Table 1 were ODs. Proposed TP Triplet coating concentrations were derived from calculation to calibrate antigen quantity immobilized on the plate and used in plate coating in the antibody assay evaluation.

[0075] ELISA Reaction: (1) Wells were coated with six TP triplets at a concentration defined in Table-1, and post-coated with 1% BSA in PBS. (2) Add 50ul Casein (PBS) and 50ul panel specimens to antigen precoated wells, and incubate at 37°C for 15 minutes with shaking. (3) Wash 6 times, add 100 ul HRP conjugated TP triplet antigens, and incubate at 37°C for 15 minutes with shaking. HRP conjugated antigen is the antigen coated on the plates. (4) Wash 6 times, add 100uL OPD substrate solution, and incubate at RT for 15 min in dark. (4) Add 25uL 4N sulfuric acid stop solution and read at 490nm.

[0076] Results shown in Table 2 were S/C values. S is OD signal, C is cut-off, equals 5 times of an average OD given by three negative controls.

[0077] ELISA Reaction: (1) Add 90ul Casein and 10ul panel sample (2 fold serial diluted in normal human plasma) to antigen precoated wells, and incubate at 37°C for 15 minutes with shaking. (2) Wash 6 times, add 100 ul conjugate mixture containing HRP

mouse monoclonal anti-human IgG and monoclonal anti-human IgM, and incubate at 37°C for 15 minutes with shaking. (3) Wash 6 times, add 100uL OPD substrate solution, and incubate at RT for 15 minutes in dark. (4) Add 25uL 4N sulfuric acid stop solution and read at 490nm.

[0078] Results shown in Table 3 were final dilution of ZeptoMetrix panel specimen with normal human plasma (1:X, X =), at which dilution the specimens were determined to be positive (signal over cut-off >1). The cut-off is 5 times of an average OD given by three negative controls.

EXAMPLE III

Details of VITROS[®] Syphilis TPA Test

[0079] The principles of the VITROS[®] Syphilis TPA test using the TP15-TP17-TP47 triplet construct are as described above and as shown in Fig. 1. A kit is provided which includes a reagent pack and a calibrator. The reagent pack contains: 100 coated wells (streptavidin, bacterial; binds ≥ 2 ng biotin/well); 13.1 mL biotinylated antigen reagent (biotin-recombinant TP antigens 0.15 ug/mL) in buffer with bovine gamma globulin, bovine serum albumin, and antimicrobial agent; and 20.4 mL conjugate reagent (HRP-recombinant TP antigens, 0.15 ug/mL) in buffer with bovine serum albumin and antimicrobial agent). The calibrator contains VITROS[®] Syphilis TPA Calibrator (human syphilis IgG positive plasma, 2.2 mL) with antimicrobial agent. The test uses 25 uL of calibrator for each determination.

[0080] Suitable specimens for use with the test are serum, heparin plasma, EDTA plasma, and citrate plasma. The test uses 25 uL of sample (specimen) for each determination.

[0081] The test also uses signal reagent (such as VITROS[®] Immunodiagnostic Products Signal Reagent), wash reagent (such as VITROS[®] Immunodiagnostic Products Universal Wash Reagent), and quality control materials (such as VITROS[®] Immunodiagnostic Products Syphilis TPA Controls).

[0082] The test uses a 16-minute first incubation period, and an 8-minute second incubation period, with a time for first result of 34 minutes. The test is performed at 37°C.

[0083] Results are automatically calculated by the VITROS[®] Immunodiagnostic and VITROS[®] Integrated Systems, and represent "signal for test sample"/"signal at cutoff (cutoff value)". Samples with results of <0.80 will be flagged as "negative", samples with results ≥ 0.80 and <1.20 will be flagged as "borderline", and samples with results ≥ 1.20 will be flagged as "reactive". Negative indicates no active or previous infection with *Treponema pallidum*; borderline indicates the test is unable to determine if *Treponema pallidum* infection has occurred, and the sample should be re-tested; and reactive indicates active or previous infection with *Treponema pallidum*.

EXAMPLE IV

Performance Characteristics of the VITROS[®] Syphilis TPA Test

[0084] Referring to Table 5, initial sensitivity and specificity was assessed on a population of 4290 samples using the VITROS[®] Syphilis TPA test and a commercially available immunoassay ("IA 1") for antibodies to *Treponema pallidum*. An initial analysis in the VITROS[®] Syphilis TPA test gave an initial specificity, including borderline samples (4015/4016) of 99.98% (exact 95% CI 99.9-100.0%). Initial sensitivity, including borderline samples (266/274) was 97.08% (exact 95% CI 94.3-98.7%). One (0.025%) sample was borderline in the VITROS[®] Syphilis TPA test. The commercially available test did not have a borderline region.

[0085] Referring to Table 6, relative specificity and sensitivity after resolution of uninterpretable samples was assessed. This included samples where there was a difference in classification from the commercial test (reactive/negative)(defined as "discordant"). Samples that resulted in discordant or borderline results (either in the VITROS[®] or IA 1 test) were further tested to determine relative sensitivity and specificity. A total of 9 discordant and borderline samples were further tested by first repeating the VITROS[®] Syphilis TPA test in duplicate. A total of 9 discordant and borderline samples remained discordant with IA 1 after repeat testing in the VITROS[®] Syphilis TPA test. The 9 samples were also tested in up to 4 additional commercially available assays for antibodies to *Treponema pallidum*. The median VITROS[®] Syphilis TPA result was then compared to the consensus classification of the other 4 commercially available tests. Using this algorithm, 8 samples were resolved as syphilis

antibody negative and one sample remained borderline in the VITROS[®] Syphilis TPA test. After resolution of discordant results, the relative specificity of the VITROS[®] Syphilis TPA test to the IA 1 test was calculated (4023/4024) as 99.98% (exact CI 99.9-100.0%) and relative sensitivity (266/266) as 100% (exact CI 98.6-100.0%).

[0086] Referring to Table 7, 149 samples containing potentially cross-reacting sub-groups were tested in the VITROS[®] Syphilis TPA test and in a commercially available test (EIA 1). The sub-groups included: HAV IgG and IgM, HBV IgG and IgM, HCV IgG and IgM, EBV IgG and IgM, anti-HSV IgG and IgM, anti-HIV 1/2 IgG and IgM, CMV IgG and IgM, Rubella IgG and IgM, ANA/SLE, Borrelia burgdorferi infection (European and US strain), Toxoplasma gondii infections IgG and IgM, heterophilic antibodies/HAMA and Rheumatoid factor. The specificity (137/137) was 100.0% (95% CI 97.3-100.0%) and sensitivity (12/12) was 100.0% (95% CI 73.5%-100.0%). No discordant samples were observed and all results were in line with the expected clinical performance in the commercially available test. Thus, none of the samples was found to cross react with the VITROS[®] Syphilis TPA assay to cause any mis-classification of results.

[0087] Precision on the VITROS[®] ECi/ECiQ Immunodiagnostic System was evaluated. Two replicates each of 4 patient sample pools and 4 control samples were tested on 2 separate occasions per day on at least 20 different days. The experiment was performed using 2 reagent lots on two different systems. Precision on the VITROS[®] 3600 Immunodiagnostic System and the VITROS[®] 5600 Integrated System was also evaluated. Two replicates each of 4 patient sample pools and 4 control samples were tested on 2 separate occasions per day on at least 20 different days. The experiment was performed using 1 reagent lot on each system. Results showed precision for samples at the cut off up to strong positives averaged 1.6 % (range 0.9 - 3.2%) within run, 4.8% (range 2.7 - 9.0%) within calibration, and 4.6% (range 2.1 - 9.0%) within lab. The VITROS[®] Syphilis TPA test thus gives excellent precision across the borderline and reactive ranges, on all VITROS[®] systems.

[0088] Referring to Table 8, the VITROS[®] Syphilis TPA test was evaluated for interference. Of the compounds tested, none was found to interference with the clinical interpretation of the test at the concentration indicated.

[0089] The VITROS[®] Syphilis TPA test was also evaluated with two sets of proficiency samples from CAP and NEQAS and two commercially available performance panels (Zeptometrix and BBI-Seracare). 100% agreement was obtained with these proficiency samples and performance panels.

[0090] Samples types were also evaluation on the VITROS[®] Syphilis TPA test. Five normal donor samples were collected as serum (SST, clot activator and on the clot glass tubes), as heparin plasma (lithium and sodium), EDTA plasma and citrate plasma. From five other donors, 50 mL of whole blood was collected. This was spiked with a syphilis reactive plasma and dispensed into the same type of tubes as mentioned above to mimic syphilis reactive donors. Bias between sample type was assessed. No large differences were observed between sample types compared to serum. For citrate samples, the recovery compared to serum was lower due to the dilutional effect of the citrate. A stability study using these samples demonstrated that samples can be stored for 7 days at 2-8°C and 4 weeks at -20°C without significant loss of dose results or change in clinical classification.

[0091] Taking all performance characteristics into account, the VITROS[®] Syphilis TPA test combines good analytical and clinical performance with the operational simplicity of a rapid automated continuous random access immunoassay.

[0092] While particular embodiments of the invention have been shown, it will be understood, of course, that the invention is not limited thereto, since modifications may be made by those skilled in the art, particularly in light of the foregoing teachings. Reasonable variation and modification are possible within the scope of the foregoing disclosure of the invention without departing from the spirit of the invention.

Table -1 Calibration Coated Six TP Triplet Antigens on Plate

Plate coated TP Triplet [ug/ml]	OD signal probed by HRP anti-261 (2 ng/mL)						Proposed TP Triplet coating [ug/mL]
	4.00	2.00	1.00	0.50	0.25	0.13	
TP15-17-47-SOD	over	3.006	2.372	1.490	0.914	0.613	1.00
TP15-47-17-SOD	over	2.916	2.106	1.356	0.843	0.566	1.20
TP17-15-47-SOD	over	3.144	3.193	2.508	1.494	0.891	0.50
TP17-47-15-SOD	over	1.454	0.914	0.580	0.346	0.263	2.80
TP47-15-17-SOD	over	3.310	2.481	1.950	1.209	0.713	0.65
TP47-17-15-SOD	over	3.523	3.626	3.489	2.434	1.426	0.25

Table -2 Evaluation of Syphilis Reactive Specimens by Direct ELISA

Plate: TP Triplet Coated		SeraCare Syphilis mixed titer panel (PS C202) -- (S/C Values)									
ID	[ug/ml]	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10
TP15-17-47-SOD	1.00	3.0	5.4	1.1	0.0	2.6	2.6	8.0	1.3	7.7	4.0
TP15-47-17-SOD	1.20	4.5	7.2	2.7	0.0	1.8	4.5	14	4.0	7.8	6.1
TP17-15-47-SOD	0.50	4.9	10	3.4	0.0	3.0	4.9	15	6.7	15	6.7
TP17-47-15-SOD	2.80	3.1	8.8	3.0	0.0	2.6	4.9	4.7	5.6	15	6.7
TP47-15-17-SOD	0.65	4.4	9.7	1.9	0.0	3.1	4.9	17	3.4	15	5.4
TP47-17-15-SOD	0.25	4.9	10	3.3	0.0	4.2	4.9	15	6.0	15	6.7

Table -2 (continued)

Plate: TP Triplet Coated											
ID	[ug/ml]	#11	#12	#13	#14	#15	#16	#17	#18	#19	#20
TP15-17-47-SOD	1.00	2.1	3.3	3.2	2.9	5.3	0.0	3.1	2.6	2.8	3.9
TP15-47-17-SOD	1.20	3.0	6.1	6.9	8.1	6.9	0.0	3.2	7.0	4.0	2.8
TP17-15-47-SOD	0.50	6.3	6.7	11	7.5	10	0.0	4.6	16	4.5	10
TP17-47-15-SOD	2.80	5.6	4.0	14	6.2	10	0.0	3.6	10	4.2	5.3
TP47-15-17-SOD	0.65	4.9	6.1	11	6.6	10	0.0	2.5	5.0	5.8	5.6
TP47-17-15-SOD	0.25	7.0	6.7	11	9.7	13	0.0	3.5	12	3.9	9.0

Table -3 Evaluation of Plate Coating Antigen Sequence Combination

Plate: TP Triplet Coated		ZeptoMetrix Mixed Titer Syphilis Panel (K-ZMC002)							
ID	[ug/ml]	#1	#2	#3	#4	#5	#6	#7	#8
TP15-17-47-SOD	1.00	2	2	2	4	8	8	8	2
TP15-47-17-SOD	1.20	4	2	2	8	4	16	8	2
TP17-15-47-SOD	0.50	16	4	2	256	32	64	256	8
TP17-47-15-SOD	2.80	8	2	2	32	4	8	64	2
TP47-15-17-SOD	0.65	16	2	4	64	32	16	256	8
TP47-17-15-SOD	0.25	32	4	4	256	16	64	256	8

Table -3 (continued)

Plate: TP Triplet Coated								
ID	[ug/ml]	#9	#10	#11	#12	#13	#14	#15
TP15-17-47-SOD	1.00	2	32	2	2	4	256	8
TP15-47-17-SOD	1.20	2	16	2	2	4	32	8
TP17-15-47-SOD	0.50	32	256	8	64	32	256	32
TP17-47-15-SOD	2.80	2	256	2	8	8	256	16
TP47-15-17-SOD	0.65	16	256	4	16	16	256	32
TP47-17-15-SOD	0.25	16	256	8	32	16	256	64

Table -4 PCR Primers

Group	Name	Primer Direction	Primers used in creating triplet of						Comments
			15-17-47	17-15-47	15-47-17	47-15-17	17-47-15	47-17-15	
A	F4-ER	Forward	yes	yes	yes	yes	yes	yes	<u>EcoR I</u> , vector sequence
	Apa-TP15	Forward					yes		<u>Apa</u> -(TP15)...
	Apa-TP17	Forward			yes	yes			<u>Apa</u> -(TP17)...
	TP15-BG	Reverse		yes					...TP15-gly-pro- <u>Bgl II</u>
	TP15-BG2	Reverse	yes		yes				...TP15-gly- <u>Bgl II</u>
	TP17-BG	Reverse	yes	yes			yes	yes	...TP17-gly-pro- <u>Bgl II</u>
	TP47-BG2	Reverse				yes		yes	...TP47-gly-pro- <u>Bgl II</u>
B	F-15	Forward					yes	yes	50bp before <u>SacI</u> in TP15
	R-15S	Reverse					yes	yes	<u>TP15(3')-SOD(5')</u>
	T17-BH	Forward			yes	yes			95bp before <u>Eag I</u> in TP17
	R-17S	Reverse			yes	yes			<u>TP17(3')-SOD(5')</u>
	F-47b	Forward	yes	yes					50bp before <u>Xma</u> in TP47
	R-47S	Reverse	yes	yes					<u>TP47(3')-SOD(5')</u>
C	F-15S	Forward					yes	yes	<u>TP15(3')-SOD(5')</u>
	F-17S	Forward			yes	yes			<u>TP17(3')-SOD(5')</u>
	F-47S	Forward	yes	yes					<u>TP47(3')-SOD(5')</u>
	RS	Reverse	yes	yes	yes	yes	yes	yes	downstream of SOD gene
D	T15-Sac	Forward					yes	yes	(TP15)... <u>SacI</u> ...
	TP17-EAG	Forward			yes	yes			(TP17)... <u>EagI</u> ...
	T47-XMA	Forward	yes	yes					(TP47)... <u>XmaI</u> ...
	RS-H3	Reverse	yes	yes	yes	yes	yes	yes	<u>SOD(3')-StopStop-Hind III</u>

Table -4 (continued)

Group	Name	Primer Sequence (5'-3')
A	F4-ER	SEQ ID NO:13: cacaGAATTCATTAAAGAGGAGAAATTAAC
	Apa-TP15	SEQ ID NO:14: tgtctGGGCCCAGCTTTTCTAGTATTCCGA
	Apa-TP17	SEQ ID NO:15: tgtctGGGCCCCTGAGCTGCACCACGGT
	TP15-BG	SEQ ID NO:16: agctggAGATCTCGGGCCGCGAGAGATAATGGCTTCTT
	TP15-BG2	SEQ ID NO:17: gctggAGATCTACCGCGAGAGATAATGGCTTCTT
	TP17-BG	SEQ ID NO:18: agctggAGATCTCGGGCCTTTCTTGGTTTTCTTCAGAACGTA
	TP47-BG2	SEQ ID NO:19: agctggAGATCTTGGACCCTGCGCCACCACTTTTCGCG
B	F-15	SEQ ID NO:20: CGCGACCGTGAGCTCTCAGAGTTTT
	R-15S	SEQ ID NO:21: <u>CAGCACGCTGACGGCTTTGGTCGCgagGCGAGAGATAATGGCTTCTTTTTTCGCC</u>
	T17-BH	SEQ ID NO:22: GTGAGCTGCACCACGGT
	R-17S	SEQ ID NO:23: <u>CAGCACGCTGACGGCTTTGGTCGCgagTTTCTTGGTTTTCTTCAGAACGTAAA</u>
	F-47b	SEQ ID NO:24: GGTTAGCGATCAGGCCGT
	R-47S	SEQ ID NO:25: <u>CAGCACGCTGACGGCTTTGGTCGCgagCTGCGCCACCACTTTTCGCGCGC</u>
C	F-15S	SEQ ID NO:26: <u>GGCGAAAAAGAAGCCATTATCTCTCGCctcGCGACCAAAGCCGTCAGCGTGCTG</u>
	F-17S	SEQ ID NO:27: <u>TTTACGTTCTGAAGAAAACCAAGAAActcGCGACCAAAGCCGTCAGCGTGCTG</u>
	F-47S	SEQ ID NO:28: <u>GCGCGCGAAAGTGGTGGCGCAGctcGCGACCAAAGCCGTCAGCGTGCTG</u>
	RS	SEQ ID NO:29: TGCAGTCGACGGGCCCGGGAT
D	T15-Sac	SEQ ID NO:30: CGCGACCGTGAGCTCTCAGAGTTTT
	TP17-EAG	SEQ ID NO:31: CCCTGCCGGCCGCAGATTGT
	T47-XMA	SEQ ID NO:32: GGATTTACCCCGGGTACCGAATATA
	RS-H3	SEQ ID NO:33: agccAAGCTTcattaCTGGGCGATACCAATAACGCCA

Table 5

		VITROS Syphilis TPA Test			Total
		Reactive	Borderline	Negative	
IA 1	Reactive	266	0	8	274
	Negative	0	1	4015	4016
	Totals	266	1	4023	4290

Table 6

		VITROS Syphilis TPA Test			Total
		Reactive	Borderline	Negative	
IA 1	Reactive	266	0	0	266
	Negative	0	1	4023	4024
	Totals	266	1	4023	4290

Table 7

		VITROS Syphilis TPA Test			Total
		Reactive	Borderline	Negative	
EIA 1	Reactive	12	0	0	12
	Negative	0	0	137	137
	Totals	12	0	137	149

Table 8

Compound	Concentration	
Azide (sodium)	20 mg/dL	3.06 mmol/L
Bilirubin	20 mg/dL	0.342 mmol/L
Biotin	1000 ng/dL	40.8 nmol/L
BSA (High Protein)	5g/dL (total ~12 g/dL)	N/A
Cholesterol	250 mg/dL	N/A
Hemoglobin (hemolysate)	500 mg/dL	0.155 mmol/L
Intralipid	850 mg/dL	N/A
Triolein	3000 mg/dL	33.96 mmol/L

CLAIMS

1. A recombinant plasmid encoding a *Treponema pallidum* triplet antigen, wherein the plasmid comprises nucleic acid encoding an amino acid sequence selected from the group consisting of SEQ ID NO:7, SEQ ID NO:8, SEQ ID NO:9, SEQ ID NO:10, SEQ ID NO:11, and SEQ ID NO:12.

2. The recombinant plasmid of claim 1 wherein the amino acid sequence is SEQ ID NO:7.

3. The recombinant plasmid of claim 1 wherein the amino acid sequence is SEQ ID NO:8.

4. The recombinant plasmid of claim 1 wherein the amino acid sequence is SEQ ID NO:9.

5. The recombinant plasmid of claim 1 wherein the amino acid sequence is SEQ ID NO:10.

6. The recombinant plasmid of claim 1 wherein the amino acid sequence is SEQ ID NO:11.

7. The recombinant plasmid of claim 1 wherein the amino acid sequence is SEQ ID NO:12.

8. The recombinant plasmid of claim 1, wherein the nucleic acid has a nucleotide sequence selected from the group consisting of SEQ ID NO:1, SEQ ID NO:2, SEQ ID NO:3, SEQ ID NO:4, SEQ ID NO:5, and SEQ ID NO:6.

9. The recombinant plasmid of claim 1 wherein the nucleic acid has a nucleotide sequence as shown in SEQ ID NO:1.

10. The recombinant plasmid of claim 1 wherein the nucleic acid has a nucleotide sequence as shown in SEQ ID NO:2.
11. The recombinant plasmid of claim 1 wherein the nucleic acid has a nucleotide sequence as shown in SEQ ID NO:3.
12. The recombinant plasmid of claim 1 wherein the nucleic acid has a nucleotide sequence as shown in SEQ ID NO:4.
13. The recombinant plasmid of claim 1 wherein the nucleic acid has a nucleotide sequence as shown in SEQ ID NO:5.
14. The recombinant plasmid of claim 1 wherein the nucleic acid has a nucleotide sequence as shown in SEQ ID NO:6.
15. A host cell comprising the recombinant plasmid of claim 1.
16. The host cell of claim 15 wherein the host cell is *Escherichia coli*.
17. A method of producing a *Treponema pallidum* triplet antigen which comprises culturing the host cell of claim 15 under conditions suitable for expression of the *Treponema pallidum* triplet antigen, and recovering the *Treponema pallidum* triplet antigen from the cell culture.
18. A recombinant plasmid encoding a *Treponema pallidum* triplet antigen, the recombinant plasmid selected from the group consisting of:
 - the plasmid designated p261nS-TP17-15-47 and deposited with the American Type Culture Collection as ATCC Accession No. PTA-11590;
 - the plasmid designated p261nS-TP47-17-15 and deposited with the American Type Culture Collection as ATCC Accession No. PTA-11589;

the plasmid designated p261nS-TP17-47-15;
the plasmid designated p261nS-TP47-15-17;
the plasmid designated p261nS-TP15-17-47; and
the plasmid designated p261nS-TP15-47-17.

19. The recombinant plasmid of claim 18 designated p261nS-TP17-15-47 and deposited with the American Type Culture Collection as ATCC Accession No. PTA-11590.

20. The recombinant plasmid of claim 18 designated p261nS-TP47-17-15 and deposited with the American Type Culture Collection as ATCC Accession No. PTA-11589.

21. The recombinant plasmid of claim 18 designated p261nS-TP17-47-15.

22. The recombinant plasmid of claim 18 designated p261nS-TP47-15-17.

23. The recombinant plasmid of claim 18 designated p261nS-TP15-17-47.

24. The recombinant plasmid of claim 18 designated p261nS-TP15-47-17.

25. A host cell comprising the recombinant plasmid of claim 18.

26. The host cell of claim 25 wherein the host cell is *Escherichia coli*.

27. A method of producing a *Treponema pallidum* triplet antigen which comprising culturing the host cell of claim 25 under conditions suitable for expression of the *Treponema pallidum* triplet antigen, and recovering the *Treponema pallidum* triplet antigen from the cell culture.

28. A *Treponema pallidum* triplet antigen having an amino acid sequence selected from the group consisting of SEQ ID NO:7, SEQ ID NO:8, SEQ ID NO:9, SEQ ID NO:10, SEQ ID NO:11, and SEQ ID NO:12.

29. The *Treponema pallidum* triplet antigen of claim 28 having an amino acid sequence as shown in SEQ ID NO:7.

30. The *Treponema pallidum* triplet antigen of claim 28 having an amino acid sequence as shown in SEQ ID NO:8.

31. The *Treponema pallidum* triplet antigen of claim 28 having an amino acid sequence as shown in SEQ ID NO:9.

32. The *Treponema pallidum* triplet antigen of claim 28 having an amino acid sequence as shown in SEQ ID NO:10.

33. The *Treponema pallidum* triplet antigen of claim 28 having an amino acid sequence as shown in SEQ ID NO:11.

34. The *Treponema pallidum* triplet antigen of claim 28 having an amino acid sequence as shown in SEQ ID NO:12.

35. The *Treponema pallidum* triplet antigen of claim 28 labeled with a detectable marker.

36. The *Treponema pallidum* triplet antigen of claim 35 wherein the detectable marker is horseradish peroxidase.

37. A method of detecting the presence of *Treponema pallidum* antibodies in a sample, the method comprising:

contacting the sample with the *Treponema pallidum* triplet antigen of claim 28, wherein *Treponema pallidum* antibodies present in the sample bind to the *Treponema pallidum* triplet antigen forming an antibody/antigen complex; and

detecting the antibody/antigen complex, thereby detecting the presence of *Treponema pallidum* antibodies.

38. The method of claim 37 wherein the *Treponema pallidum* triplet antigen is immobilized on a solid support.

39. The method of claim 37 wherein detecting the antibody/antigen complex comprises:

contacting the antibody/antigen complex with a second *Treponema pallidum* triplet antigen of claim 28, the second *Treponema pallidum* triplet antigen labeled with a detectable marker, wherein the second *Treponema pallidum* triplet antigen binds to the antibody present in the antibody/antigen complex forming an antigen/antibody/labeled antigen complex; and

detecting the antigen/antibody/labeled antigen complex, thereby detecting the presence of *Treponema pallidum* antibodies.

40. The method of claim 37 wherein detecting the antibody/antigen complex comprises:

contacting the antibody/antigen complex with labeled anti-human antibody, wherein the labeled anti-human antibody binds to the antibody present in the antibody/antigen complex forming an antigen/antibody/labeled anti-antibody complex; and

detecting the antigen/antibody/labeled anti-antibody complex, thereby detecting the presence of *Treponema pallidum* antibodies.

41. A component of a kit for detection of *Treponema pallidum* antibodies, the component comprising the *Treponema pallidum* triplet antigen of claim 28.

42. A kit for detection of *Treponema pallidum* antibodies, the kit comprising: the *Treponema pallidum* triplet antigen of claim 28; and a second *Treponema pallidum* triplet antigen of claim 28, the second *Treponema pallidum* triplet antigen labeled with a detectable marker.

43. The kit of claim 42 further comprising positive or negative controls.

44. The kit of claim 42 further comprising calibration samples.

45. The kit of claim 42 further comprising one or more of enzyme conjugate, substrate for enzyme conjugate, buffer solution, and washing solution.

Fig. 1

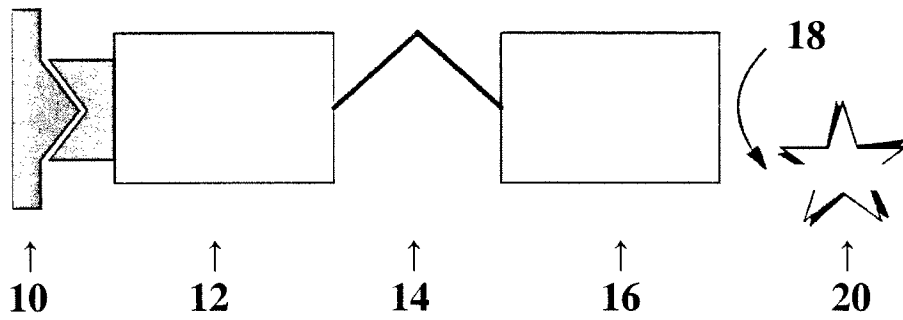


Fig. 2

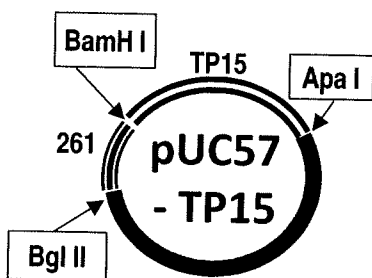


Fig. 3

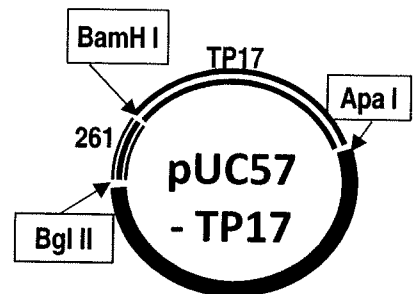


Fig. 4

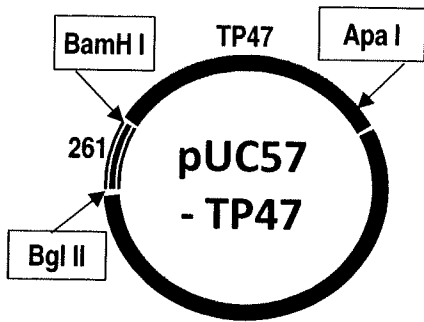


Fig. 5

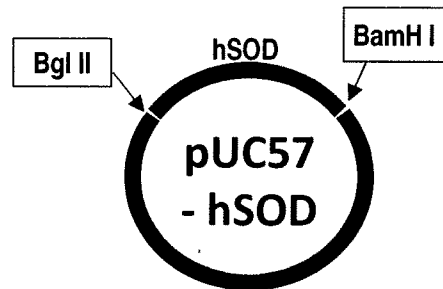


Fig. 6

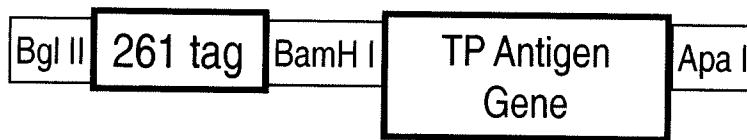
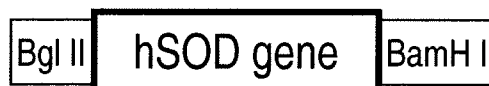


Fig. 7



3/9

Fig. 8

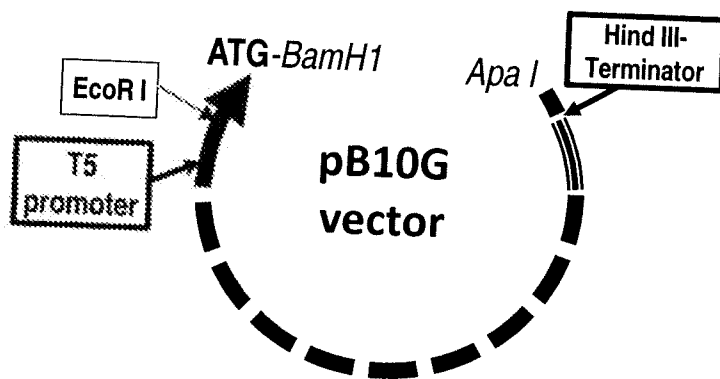


Fig. 9

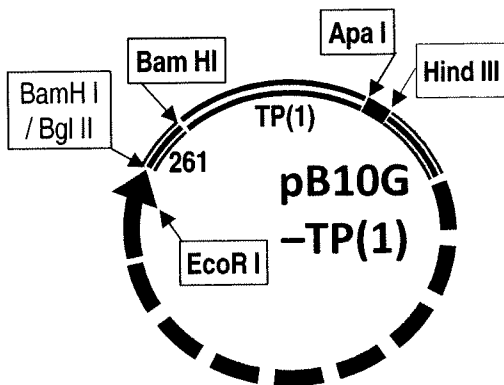
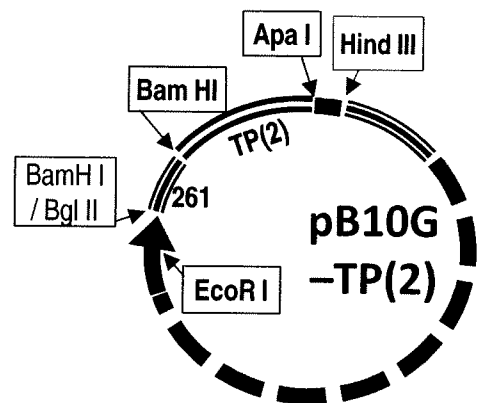


Fig. 10



4/9

Fig. 11

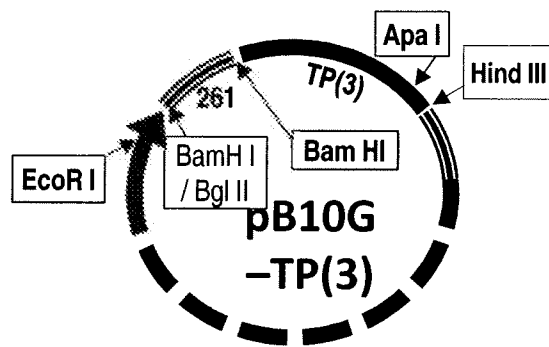


Fig. 12



5/9

Fig. 13

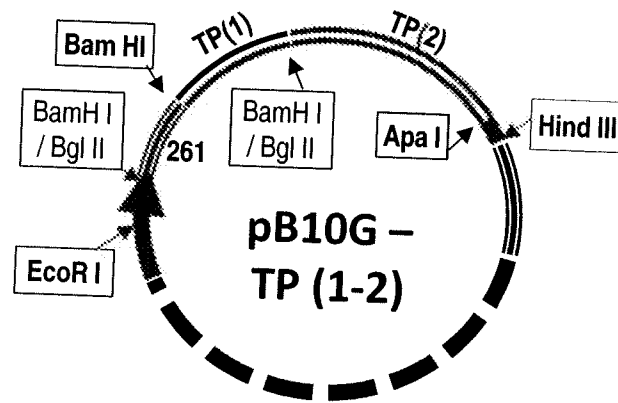
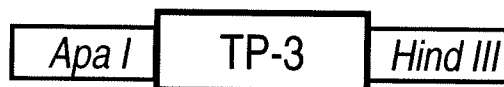


Fig. 14



6/9

Fig. 15

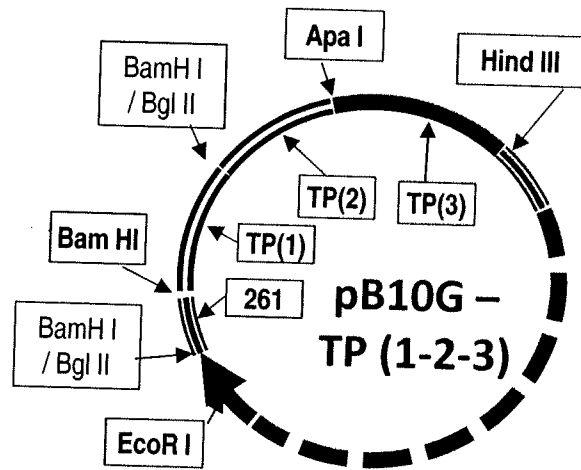
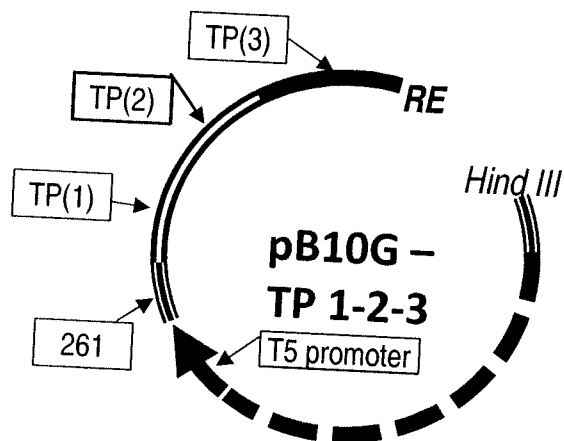
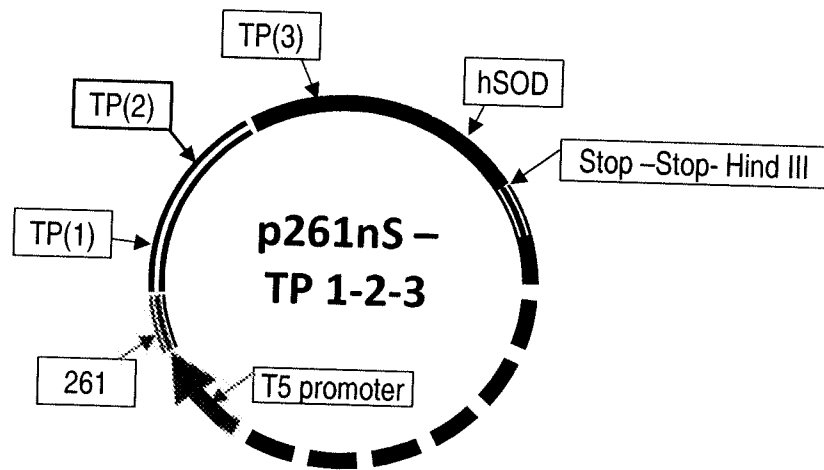


Fig. 16



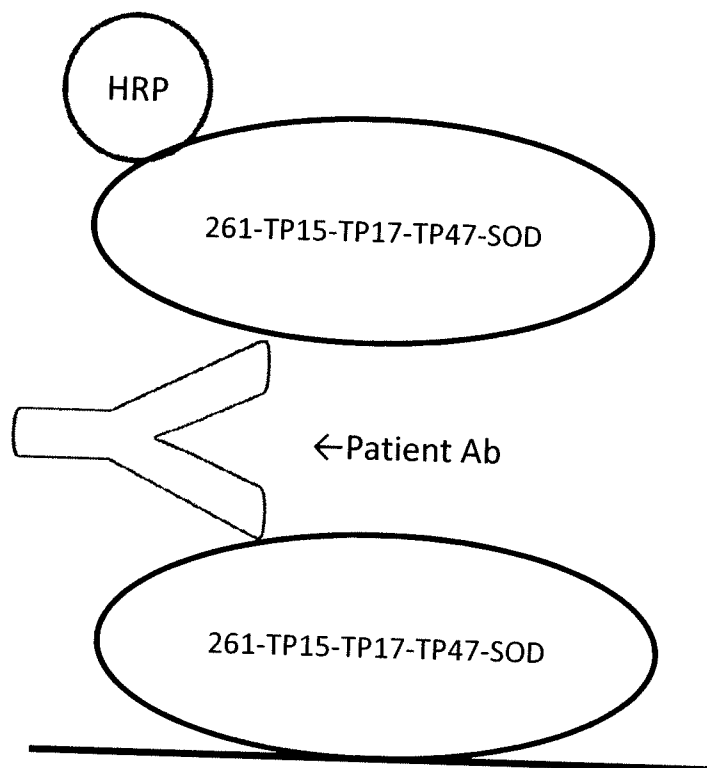
7/9

Fig. 17



8/9

Fig. 18



9/9

Fig. 19

