

IMMUNOGENIC COMPOSITIONS FOR *CHLAMYDIA TRACHOMATIS*

This application claims the benefit of U.S. Provisional Application 60/680,725, filed May 12, 2005, which is incorporated herein in its entirety.

This application incorporates by reference the contents of each of two duplicate CD-ROMs. Each CD-ROM contains an identical 95 kB file labeled "Sequence Listing for 2441_199.txt" and containing the sequence listing for this application. The CD-ROMs were created on May 3, 2006.

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

TECHNICAL FIELD

This invention is in the fields of immunology and vaccinology. In particular, it relates to antigens derived from *Chlamydia trachomatis* and their use in immunisation.

BACKGROUND ART

The *Chlamydiae* are obligate intracellular parasites of eukaryotic cells which are responsible for endemic sexually transmitted infections and various other disease syndromes. They occupy an exclusive eubacterial phylogenic branch, having no close relationship to any other known organisms. A particular characteristic of the *Chlamydiae* is their unique life cycle, in which the bacterium alternates between two morphologically distinct forms: an extracellular infective form (elementary bodies, EB) and an intracellular non-infective form (reticulate bodies, RB). The life cycle is completed with the re-organization of RB into EB, which leave the disrupted host cell ready to infect further cells.

Historically, the *Chlamydiae* have been classified in their own order (*Chlamydiales*) made up of a single family (*Chlamydiaceae*) which in turn contains a single genus (*Chlamydia* also referred to as *Chlamydophila*). More recently, this order has been divided into at least four families including *Chlamydia trachomatisceae*, *ParaChlamydia trachomatisceae*, *Waddiaceae* and *Simkaniaceae*. In this more recent classification, the *Chlamydiaceae* family includes genres of *Chlamydophila* and *Chlamydia trachomatis*, *Chlamydia trachomatis* being a species within the *Chlamydia* genus. See Ref. 1.

The genome sequences of at least five *Chlamydia trachomatis* or chlamydothila species are currently known – *C.trachomatis*, *C.pneumoniae*, *C.muridarum*, *C.pecorum* and *C.psittaci* (See Refs. 2, 8). The various *C. trachomatis* strains, of which there are currently at least 18 serovars, may be classified according to their serological reactivities with polyclonal or monoclonal antisera (i.e., “serovars”). These serological differences are typically detected due to differences in the MOMP (Major Outer Membrane Protein) of *C. trachomatis*.

The human serovariants (“serovars”) of *C.trachomatis* are divided into two biovariants (“biovars”). Serovars L1, L2 and L3 are the agents of invasive lymphogranuloma venereum (LGV) which is a sexually transmitted systemic infection. LGV is uncommon in industrialised countries but frequent in Africa, Asia, Australian and South America. It predominantly affects lymphatic tissue but may also occur as an acute symptomatic infection without apparent lymph node involvement or tissue reaction at the point of infection. Acute LGV is reported over five times more frequent in men than in women. Other biotypes of *C. trachomatis* include serovars A, B, Ba, and C which are associated with trachoma, a transmissible condition of the eye.

Serovars A-K (D, E, F, G, H, I, J, and K) are typically associated with genital tract disease. In particular, Serovars D, E, F, H and K account for nearly 85% of genital tract infections (see for example, WO 02/065129) Serovars A-K elicit epithelial infections primarily in the ocular tissue (A-C) or urogenital tract (D-K). Research to date also indicates that the 4 Serovars (or serotypes) responsible for Sexually Transmitted Infections or Diseases (STIs or STDs) in the US and Europe are D-K, preferably D, E, F and I.

More than 4 million new cases of *Chlamydia* sexually transmitted infections are diagnosed each year in the United States alone (8) and the cost of their treatment has been estimated in 4 billion dollars annually, with 80% attributed to infection and disease of women (9).

Although *Chlamydia* infection itself causes disease, it is thought that the severity of symptoms in some patients is actually due to an aberrant or an altered host immune response which may arise from either (i) the nature of the invading *Chlamydia* organism which may vary from serovar to serovar or (ii) the nature of the subject invaded (for example, the nature of the patient profile). The failure to clear the infection results in persistent immune stimulation and, rather than helping

the host, this results in chronic infection with severe consequences, including sterility and blindness. See, e.g., Ref. 9. In addition, the protection conferred by natural *Chlamydial* infection is usually incomplete, transient, and strain-specific.

Although *Chlamydia* infections can be treated with several antibiotics, a majority of the female infections are asymptomatic, and antimicrobial therapy may be delayed or inadequate to prevent long term sequelae, especially in countries with poor hygienic conditions. Multiple-antibiotic-resistant strains of *Chlamydia* have also been reported (Somani, *et al.*, 2000). Furthermore it has been suggested that antibiotic treatment could lead to the formation of aberrant or altered forms of *C. trachomatis* that may be reactivated later on (Hammerschlag M.R. 2002. The intracellular life of *Chlamydia trachomatis* Semin.Pediatr.Infect.Dis.13:239-248).

Unfortunately the major determinants of *Chlamydia* pathogenesis are complicated and at present still unclear, mostly due to the intrinsic difficulty in working with this pathogen and the lack of adequate methods for its genetic manipulation. In particular very little is known about the antigenic composition of elementary body surface, that is an essential compartment in pathogen-host interactions, and likely to carry antigens able to elicit a protective immune response.

Due to the serious nature of the disease, there is a desire to provide suitable immunogenic compositions, such as vaccines to deal with an aberrant or altered host cell immune response which may result from, for example, allelic variation in the invading *Chlamydia* strain and/or aberrant or altered forms of *Chlamydia* invading strain. These immunogenic compositions may be useful (a) for immunisation against *Chlamydial* infection or against *Chlamydia*-induced disease (prophylactic vaccination) or (b) for the eradication of an established chronic *Chlamydia* infection (therapeutic vaccination). Being an intracellular parasite, however, the bacterium can generally evade antibody-mediated immune responses.

Various antigenic proteins have been described for *C.trachomatis*, and the cell surface in particular has been the target of detailed research. See, e.g., Ref. 10. These include, for instance, Pgp3 (Refs. 11, 12, and 13), MOMP (Ref. 14), Hsp60 (GroEL) (Ref. 15) and Hsp70 (DnaK-like) (Ref. 16). Not all of these have proved to be effective vaccines, however, and further candidates have been identified. See Ref. 17.

Vaccines against pathogens such as hepatitis B virus, diphtheria and tetanus typically contain a single protein antigen (e.g. the HBV surface antigen, or a tetanus toxoid). In contrast, acellular whooping cough vaccines typically have at least three *B.pertussis* proteins, and the Prevnar™ pneumococcal vaccine contains seven separate conjugated saccharide antigens. Other vaccines such as cellular pertussis vaccines, the measles vaccine, the inactivated polio vaccine (IPV) and meningococcal OMV vaccines are by their very nature complex mixtures of a large number of antigens. Whether protection can be elicited by a single antigen, a small number of defined antigens, or a complex mixture of undefined antigens, therefore depends on the pathogen in question.

It is an object of the invention to provide further and improved immunogenic compositions for providing immunity against *Chlamydial* disease and/or infection. In particular, it is an object of the invention to provide improved immunogenic compositions for providing immunity against aberrant or altered *Chlamydia* serovar strains (eg strains such as allelic variant strains).

The immunogenic compositions of the present invention are based on a combination of one or more (e.g. two or more) *C.trachomatis* antigens. The immunogenic compositions may include one or more of the same *Chlamydia trachomatis* antigens from different *Chlamydia trachomatis* serovars and/or one or more of the same or different *Chlamydia trachomatis* antigen from the different *Chlamydia trachomatis* serovars.

SUMMARY OF THE INVENTION

Within the ~900 proteins described for the *C.trachomatis* genome of reference 5, the Applicants were the first to show that the Low Calcium Response Element (LcrE) protein is present and accessible to antibodies on the surface of the infectious EB form thus marking this protein a possible vaccine candidate. The Applicants hypothesised at the time that an efficient block of the Type Three Secretion or TTS organelle (of which LcrE is a part) may in turn inhibit the infection process by “freezing” the LcrE negative regulator (see Montigiani *et al* Infection and Immunity (2002) 70(1); 368-379). Applicants have subsequently demonstrated that the LcrE protein is indeed capable of inducing a significantly protective immune response in a hamster model of *C. trachomatis* infection (see Sambri *et al* (2004) 22(9-10) 1131-7). These immunoprotective results for LcrE have also been confirmed by others (see for example,

Example 9 in WO 03/41560) and point towards the value of LcrE as a good candidate for the prevention and/or treatment and/or diagnosis of a *C. trachomatis* infection.

In the course of evaluating the allelic variation for the LcrE gene in 14 *C. trachomatis* clinical isolates representative of 8 different *C. trachomatis* serovars, the Applicants established that a higher than expected number of single amino acid substitutions across the *C. trachomatis* serovars was observed for the LcrE antigen relative to (i) a reference *Chlamydia trachomatis* LcrE sequence from Serovar D and (ii) those found for other immunogenic *Chlamydia trachomatis* antigens.

This highly unexpected and surprising finding suggests that:

- (i) the LcrE protein may be subjected to a greater immunological pressure than other immunogenic *Chlamydia trachomatis* antigens; and
- (ii) the peptides surrounding the amino acid substitutions are likely to be epitopic regions (either B-cell epitopes involved in antibody-antigen (Ab-Ag) interactions and/or T-cell epitopes capable of eliciting *Chlamydia* specific cell mediated responses).

Applicants finding is all the more surprising because the *Chlamydia* isolates used for these genotyping studies came from two very divergent immunological sources which were isolated from two different Continents (North America and Europe) and over different time periods (minimum of 30 years ago versus 5- 8 years ago).

Given that it is surprising that an LcrE sequence from a not so recently isolated ATCC Serovar E can have the same number of mutations as an LcrE sequence from a recently isolated Italian Serovar E, it is even highly surprising and unexpected that the nature of the eight mutations is the same in both LcrE sequences from both sources. The fact that both LcrE Serovar E mutant sequences are the same points towards a finding that these eight mutations are true and real mutations as opposed to random or arbitrary mutations. These mutations may be used to tailor LcrE immunogenic compositions to specific target groups.

Applicants have also identified two high frequency mutation points or hypervariable regions at amino acid residues 64 and 162 in the LcrE sequence across the serovars. At amino acid residue 64, there are seven mutations from Glycine (G) to Glutamic (E) acid across the 14 different *Chlamydia* isolates while at point 162, there are also seven mutations from Threonine (T) to Alanine (A) across the 14 *Chlamydia* isolates. The existence of two high frequency mutation points or hypervariable regions (eg at residues 64 and 162 of the LcrE sequence) is surprising and

unexpected and is likely to be associated with the presence of T and/or B cell epitopic regions capable of eliciting an immunogenic response in a subject. These high frequency mutations may be used to tailor LcrE immunogenic compositions to specific target groups.

Applicants have also identified other variant *Chlamydia* antigen sequences and/or combinations of variant *Chlamydia* antigen sequences across the *Chlamydia trachomatis* serovars. These *Chlamydia* antigens include but are not limited to OmpH-like (CT242), ArtJ (CT381), DnaK (CT396), Hypothetical (CT398) and PepA (CT045) antigens. The amino acid changes observed in these *Chlamydia* antigen genotypes across the *Chlamydia trachomatis* serovars are likely to correspond with changes in the *Chlamydia* antigen phenotypes, in particular, with changes in immunogenicity. The peptides surrounding or associated with the amino acid substitutions, in particular, peptides surrounding or associated with high frequency mutated amino acid positions or hypervariable regions, are likely to be epitopic regions which are either B-cell epitopes involved in antibody-antigen (Ab-Ag) interactions and/or T-cell epitopes capable of eliciting *Chlamydia* specific immunogenic responses, in particular, cell mediated immune responses.

Brief Description of the Sequences

The following Table provides a brief Description of the *Chlamydia trachomatis* LcrE sequences (SEQ ID Nos 1-13) found across the 13 isolated *Chlamydia trachomatis* serovars. Of these Serovars, seven serovars were obtained from the ATCC, and 6 serovars were obtained from an Italian (Cevenini) collection. There is also provided 14 x 30mer consensus sequences for the LcrE sequences (SEQ ID Nos 14-SEQ ID Nos 27). SEQ ID No 28 corresponds to an LcrE sequence with all 10 mutations points (64, 126, 157, 162, 179, 207, 217, 220, 275 and 420) found across the *Chlamydia trachomatis* LcrE Serovars. SEQ ID Nos 29-45 correspond to the identified epitope regions found around the mutant sequences. SEQ ID No 46 is the reference LcrE Serovar D sequence from Serovar D/UW-3/CX against which comparisons with the other sequences were made. SEQ ID Nos 181, 182, 183 and 184 correspond with epitopic regions associated with the high frequency mutation points at residues 64 and 162.

Table 1

Antigen	Serovar	Sequence ID No
LcrE reference sequence from Serovar D/UW-3/CX (gi: 15604717) (Stephens <i>et al</i> (1998) Science 282 (5389) 754-759)	LcrE reference sequence from Serovar D	SEQ ID No 46
LcrE	ATCC Serovar E	SEQ ID No 1
LcrE	ATCC Serovar F	SEQ ID No 2
LcrE	ATCC Serovar G	SEQ ID No 3
LcrE	ATCC Serovar H	SEQ ID No 4
LcrE	ATCC Serovar I	SEQ ID No 5
LcrE	ATCC Serovar J	SEQ ID No 6
LcrE	ATCC Serovar K	SEQ ID No 7
LcrE	Cev 1 = Serovar J	SEQ ID No 8
LcrE	Cev 2= Serovar G	SEQ ID No 9
LcrE	Cev 4= Serovar H	SEQ ID No 10
LcrE	Cev 5= Serovar E	SEQ ID No 11
LcrE	Cev 8= Serovar D	SEQ ID No 12
LcrE	G086= Serovar D	SEQ ID No 13
LcrE	30 mer consensus sequences I-14	SEQ ID No 14-27
LcrE	LcrE Serovar D reference sequence from D/UW-3/CX with identified 10 mutation points	SEQ ID No 28
LcrE	Epitope peptide sequences 1-17	SEQ ID Nos 29-45
	Peptides comprising epitope sequences	SEQ ID Nos 47-98 and 99-180
LcrE	Epitope sequence associated with two high frequency mutation points 64 and 162 in the LcrE sequence	SEQ ID Nos 181, 182, 183 and 184
LcrE	LcrE Serovar D reference sequence from D/UW-3/CX with identified 10 mutation points listed as X1-X10	SEQ ID No 185

Table 7

LcrE Amino acid residue	Reference amino acid	Mutated amino acid
X1 = 64	Glycine (G)	Glutamic acid (E)
X2 = 126	Aspartic acid (D)	Glutamic acid (E) or Asparagine (N)
X3 = 157	Glycine (G)	Arginine ®
X4 = 162	Threonine (T)	Alanine (A)
X5 = 179	Valine (V)	Isoleucine (I)
X6 = 207	Phenylalanine (F)	Leucine (L)
X7 = 217	Alanine (A)	Aspartic Acid (D)
X8 = 220	Histidine (H)	Arginine ®
X9 = 275	Asparagine (N)	Aspartic acid (D)
X10 = 420	Serine (S)	Proline (P)

Summary Aspects of the Invention

The present invention relates to the variations in the *Chlamydia trachomatis* LcrE sequence found across the *Chlamydia trachomatis* serovars. The variations in the *Chlamydia trachomatis* LcrE sequence across the *Chlamydia trachomatis* serovars are measured relative to the *Chlamydia trachomatis* LcrE Serovar D/UW-3/CX sequence (SEQ ID No 46). The following paragraphs (para(s)) are provided which set out various aspects of the invention. Further details are provided in the accompanying disclosure:

In the present invention, there is provided:

1. A protein consisting of an amino acid sequence of SEQ ID NO: 46, except that the amino acid sequence contains one or more mutations, wherein the one or more mutation(s) involves an amino acid residue(s) selected from the group consisting of 64, 126, 157, 162, 179, 207, 217, 220, 275 and/or 420.
2. The protein according to para 1 wherein the mutation is independently a substitution, an insertion or a deletion, preferably comprising one or more of the mutations listed in Table 7.
3. The protein of para 1 or para 2 wherein the one or more mutation(s) alter the immunogenicity of the protein.
4. The protein of any one of paras 1 to 3 wherein the protein comprises one or more mutated sequences selected from the group of sequences consisting of SEQ ID Nos 1, 4, 6, 8, 11, 12, 13, 16, 18, 19, 20, 21, 23 and/or 27.
5. The protein of para 4 comprising SEQ ID No 11, 4 or 6.
6. The protein of para 4 comprising SEQ ID No 13 or 8.
7. The protein of para 4 comprising SEQ ID No 12 or 1.
8. The protein of para 2 comprising a mutation at amino acid residue 64 and/or 162.
9. The protein of para 4 comprising SEQ ID No 16, 18, 19, 20, 21, 22, 23 or 27.
10. A protein comprising the amino acid sequence of a protein according to any one of the preceding paras or one or more fragment(s) of at least 7 consecutive amino acids of a protein according to any one of the preceding paras.
11. The protein of para 10 wherein the one or more fragment(s) comprises one or more mutations involving an amino acid residue(s) selected from the group consisting of 64, 126, 157, 162, 179, 207, 217, 220, 275 and/or 420.

12. An antibody which binds to a protein of any one of paras 1-11.
13. A nucleic acid encoding the protein of any one of paras 1-11.
14. A vector comprising a nucleic acid according to para 13.
15. A host cell transformed with a vector according to para 14.
16. The protein of any one of paras 1-11, an antibody according to para 12 or a nucleic acid according to para 13 for use as a medicament.
17. The protein or nucleic acid of para 16 for use as an immunogen.
18. The protein of any one of paras 1-11, an antibody according to para 12 or a nucleic acid according to para 13 for use as a diagnostic reagent.
19. The use of the protein as defined in any one of paras 1-11, the antibody according to para 12 or the nucleic acid according to para 13 in the manufacture of a medicament for preventing or treating a *Chlamydia trachomatis* infection.
20. The use of the protein as defined in any one of paras 1-11, the antibody according to para 12 or the nucleic acid according to para 13 in the manufacture of a diagnostic reagent for detecting the presence of *Chlamydia trachomatis* or of antibodies raised against *Chlamydia trachomatis*.
21. The use of the protein as defined in any one of paras 1-11, the antibody according to para 12 or the nucleic acid according to para 13 in the manufacture of a reagent which can raise antibodies against *Chlamydia trachomatis*.
22. A method of treating a subject comprising administering to the subject a therapeutically effective amount of a protein according to any one of paras 1-11, an antibody according to para 12 or a nucleic acid according to para 13.

23. A process for producing a protein according to any one of paras 1-11, the antibody according to para 12 or the nucleic acid according to para 13 comprising the step of culturing a host cell according to para 15 under conditions which induce protein expression.

24. A process for producing a protein according to any one of paras 1-11, the antibody according to para 12 or the nucleic acid according to para 13 wherein the protein or nucleic acid is synthesised in part or in whole using chemical means.

25. A process for detecting a nucleic acid according to para 13 comprising the steps of (a) contacting a nucleic acid probe with a biological sample under hybridising conditions to form duplexes and (b) detecting said duplexes.

26. A process for detecting a protein according to any one of paras 1-11 comprising the steps of (a) contacting an antibody according to para 12 with a biological sample under conditions suitable for the formation of antibody-antigen complexes and (b) detecting said complexes.

27. A process for detecting an antibody according to para 12 comprising the steps of: contacting a protein according to any one of paras 1-11 with a biological sample under conditions suitable for the formation of an antibody-antigen complexes and (b) detecting said complexes.

28. A kit comprising reagents suitable for use in a process according to any one of paras 25-28.

29. An immunogenic composition comprising the protein of any one of paras 1-11, the antibody of example 12 or the nucleic acid of example 13 and an immunologically acceptable excipient.

30. The composition of para 29 further comprising one or more antigen(s).

31. The composition of para 29 or 30 further comprising one or more adjuvant(s).

32. The composition of any one of paras 29-31 for use as a medicament.

33. Use of a composition of any one of paras 29-31 in the manufacture of a medicament for preventing or treating or diagnosing a bacterial infection.

34. The use according to para 33 wherein the bacterial infection is a *Chlamydia trachomatis* infection.
35. An immunogenic composition comprising at least two proteins selected from the group of sequences consisting of SEQ ID Nos 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, 40, 41, 42, 43, 44, and 45, 49-98, 99-180, 181, 182, 183 and/or 184.
36. The composition according to para 35 wherein the composition comprises SEQ ID No 1 and SEQ ID No 12.
37. The composition according to para 36 wherein the composition comprises SEQ ID No 13 and SEQ ID No 46.
38. The composition according to any one of paras 35-37 comprising (a) one or more further antigen(s) and/or (d) one or more further adjuvant(s).
39. The composition of any one of paras 35-38 for use as a medicament.
40. Use of a composition of any one of paras 35-38 in the manufacture of a medicament for preventing or treating or diagnosing a bacterial infection.
41. The use according to example 40 wherein the bacterial infection is a *Chlamydia trachomatis* infection.
42. A method of eliciting an immune response in a subject wherein the method comprises administering to a subject a composition according to any one of paras 29-31 or 35-38.
43. A polypeptide comprising one or more fragment(s) of at least 7 consecutive amino acids, preferably at least 9 consecutive amino acids, selected from the group consisting of SEQ 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44 and 45, 47-98, 99-180, 55, 66, 109, 110, 111, 181, 182, 183 and/or 184.

44. The composition according to para 35 having proteins comprising SEQ ID NOS: 1, 12, 13, 45, and 7.
46. An immunogenic composition comprising one of more peptides selected from the group consisting of SEQ ID Nos 54, 66, 109, 110, 111, 181, 182, 183 and 184.
47. An immunogenic composition comprising one of more peptides selected from the group consisting of SEQ ID Nos 181, 182, 183 and/or 184.
48. The polypeptide according to para 43 or the composition according to paras 46 or 47 for use as an immunogen.
49. The polypeptide according to para 48 wherein the use is as an immunogen for raising a humoural and/or a cytotoxic T cell lymphocyte response which is sufficient to protect or treat a disease and/or infection caused by *Chlamydia*.
50. A method of raising an immune response in a mammal comprising the step of administering to the mammal a polypeptide according to para 43 or an immunogenic composition according to para 46 or 47.
51. The method of claim 50 wherein the immune response protects or treats a disease and/or an infection caused by *Chlamydia*.
52. The polypeptide according to para 43 or the composition according to paras 46 or 47 for use as a diagnostic.
53. A method of diagnosing a *Chlamydia* infection in a patient comprising incubating T cell from the patient with a polypeptide as defined in para 43 or 46 or 47 and detecting the subsequent presence or absence of T-cell proliferation.

54. Use of a polypeptide according to para 43 or the composition according to paras 46 or 47 in the preparation of a medicament for use in the prevention or treatment of a bacterial infection, preferably a *Chlamydia* infection.
55. An protein or an immunogenic composition comprising SEQ ID Nos 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26 and 27.
56. A protein or an immunogenic composition comprising SEQ ID No 185 wherein amino amino acid residue at position X1 is selected from the group consisting of Glycine (G) or Glutamic acid (E); amino acid at residue X2 is selected from the group consisting of Aspartic acid (D) or Glutamic acid (E) or Asparagine (N); amino acid at residue X3 is selected from the group consisting of Glycine (G) or Arginine (R); amino acid at residue X4 is selected from the group consisting of Threonine (T) or Alanine (A); amino acid at residue X5 is selected from the group consisting of Valine (V) or Isoleucine (I); amino acid at residue X6 is selected from the group consisting of Phenylalanine (F) or Leucine (L); amino acid at residue X7 is selected from the group consisting of Alanine (A) or Aspartic acid (D); amino acid at residue X8 is selected from the group consisting of Histidine (H) or Arginine ®; amino acid at residue X9 is selected from the group consisting of Asparagine (N) or Aspartic acid (D) and amino acid residue at position X10 is selected from the group consisting of Serine (S) or Proline (P) wherein the protein is not SEQ ID No 46.
57. The protein or the immunogenic composition according to para 56 for use according to any one of paras 16-27.

BRIEF DESCRIPTION OF THE DRAWINGS

The following invention will now be further described only by way of example in which reference is made to the following Figures. The following examples are presented only to illustrate the present invention and to assist one of ordinary skill in making and using the same. The examples are not intended in any way to otherwise limit the scope of the invention. Efforts have been made to ensure accuracy with respect to numbers used (*e.g.*, amounts, temperatures, etc.), but some experimental error and deviation should, of course, be allowed for.

Figure 1 shows the Amino acid sequence of LcrE alleles found in different clinical isolates of *C. trachomatis*. Sequences are compared to the reference sequence as reported in the fully sequenced genome of the serovar-D strain UW-3/Cx. Amino acid changes are therefore intended as compared to the reference serovar D sequence, arbitrarily identified as allele-1.

Figure 2 shows the Alignment of the LcrE sequence from 14 *Chlamydia* isolates corresponding to 8 different *Chlamydia* serovars relative to the reference Chlamydia LcrE Serovar D (D/UW-3/CX) serovar. The "Majority" sequence at the top of each 30mer alignment corresponds to a "consensus" sequence. In the event there are hypervariable regions with an equal number of substitutions (eg 7/14 substitutions at amino acid residues 64 and 162), then, this high frequency mutation point is indicated as an "asterisk = *" rather than an "either or" substitution.

Table 3 shows the Allelic variation of 6 genes in 14 *Chlamydia trachomatis* clinical isolates comprising 8 different serovars

Detailed Description of the LcrE sequence variants

Each of SEQ ID Nos 1-46 is described in more detail below:

SEQ ID No 46 = *Chlamydia trachomatis* trachomatis LcrE (CT089) reference sequence from Serovar D (D-UW-3/CX)

The non-mutated LcrE protein is disclosed as SEQ ID NO^s: 61 & 62 in reference 17 {GenBank accession number: AAC67680, GI:3328485; 'CT089'; SEQ ID NO: 46 below}.

SEQ ID NO: 46

MTASGGAGGLGSTQTVTDVARAQAAAATQDAQEVIGSQEASEASMLKGCEDLINPAAATRIKKKGEKFESLEARRKPT
ADKAEEKSESTEEKGDTPLEDRFTEDLSEVSGEDFRGLKNSFDDSSPDEILDALTSKFSPTIKDLALDYLIQTAP
SDGKLKSTLIQAKHQLMSQNPQAIVGGRNVLLASETFASRANTSPSSLRSLYFQVTSSPSNCANLHQLASYPSEK
TAVMEFLVNGMVADLKSEGPSIPPAKLQVYMTLSNLQALHSVNSFFDRNIGNLENSLKHEGHAPIPSLTGNTLTKT
FLQLVEDKFPSSSKAQKALNELVGPDTPQTEVLNLFRRALNGCSPRIFSGAEKKQQLASVITNTLDAINADNEDYP
KPGDFPRSSFSSSTPPHAPVPQSEIPTSTSTQPPSP

(SEQ ID No 1) Genome: ATCC-E (8 mutations: allele-5)

The Genome ATCC-E (Serovar E) LcrE sequence (SEQ ID No 1) has 8 mutations relative to the Serovar D LcrE reference sequence (SEQ ID No 46). Genome ATCC-E is associated with Serovar E. The sequence of Genome ATCC-E is disclosed as SEQ ID NO: 1 (see below).

SEQ ID NO: 1:

```

MTASGGAGGLGSTQTVVARAQAAAATQDAQEVIGSQEASEASMLKGCED
LINPAAATRIKKKEKFESLEARRKPTADKAEKKSESTEKGDTPLEDRF
TEDLSEVSGEDFRGLKNSFDDSSPEEILDALTSKFSDPTIKDLALDYLI
QTAPSDRKLKSTLIQAKHQLMSQNPQAIVGGRNVLLASETFASRANTSPS
SLRSLYLQVTSSPSNCDNIQMLASYLPSEKTAVMEFLVNGMVADLKSEG
PSIPPAKLQVYMTLSNLQALHSVDSFFDRNIGNLENLKHGHAIPISL
TTGNLTKTFLQLVEDKFPSSSKAQKALNELVGPDTGPGQTEVLNLFFRALN
GCSPRIFSGAEKKQQLASVITNTLDAINADNEDYKPGDFPRSSFSSTPP
HAPVPQSEIPTSPSTQPPSP*

```

The alignment of Genome ATCC-E with the LcrE *Chlamydia trachomatis* antigen is as follows:

```

MTASGGAGGLGSTQTVVARAQAAAATQDAQEVIGSQEASEASMLKGCED
LINPAAATRIKKKEKFESLEARRKPTADKAEKKSESTEKGDTPLEDRF
.....E
TEDLSEVSGEDFRGLKNSFDDSSPEEILDALTSKFSDPTIKDLALDYLI
.....E
QTAPSDGKLKSTLIQAKHQLMSQNPQAIVGGRNVLLASETFASRANTSPS
.....R....A
SLRSLYLQVTSSPSNCDNIQMLASYLPSEKTAVMEFLVNGMVADLKSEG
.....L.....D..R
PSIPPAKLQVYMTLSNLQALHSVDSFFDRNIGNLENLKHGHAIPISL
.....D
TTGNLTKTFLQLVEDKFPSSSKAQKALNELVGPDTGPGQTEVLNLFFRALN
GCSPRIFSGAEKKQQLASVITNTLDAINADNEDYKPGDFPRSSFSSTPP
HAPVPQSEIPTSPSTQPPSP*

```

(2) Genome: ATCC-F (no mutations: allele-1)

The Genome ATCC-F (Serovar F) LcrE sequence (SEQ ID No 2) has no mutations relative to the Serovar D LcrE reference sequence (SEQ ID No 46).

Genome ATCC-F is associated with Serovar F. The sequence of Genome ATCC-F is disclosed as SEQ ID NO: 2 (see below).

SEQ ID NO: 2:

```

MTASGGAGGLGSTQTVVARAQAAAATQDAQEVIGSQEASEASMLKGCED
LINPAAATRIKKKEKFESLEARRKPTADKAEKKSESTEKGDTPLEDRF
TEDLSEVSGEDFRGLKNSFDDSSPEEILDALTSKFSDPTIKDLALDYLI
QTAPSDGKLKSTLIQAKHQLMSQNPQAIVGGRNVLLASETFASRANTSPS
SLRSLYLQVTSSPSNCDNIQMLASYLPSEKTAVMEFLVNGMVADLKSEG
PSIPPAKLQVYMTLSNLQALHSVDSFFDRNIGNLENLKHGHAIPISL
TTGNLTKTFLQLVEDKFPSSSKAQKALNELVGPDTGPGQTEVLNLFFRALN
GCSPRIFSGAEKKQQLASVITNTLDAINADNEDYKPGDFPRSSFSSTPP
HAPVPQSEIPTSPSTQPPSP*

```

(3) Genome: ATCC-G (no mutations: allele-1)

The Genome ATCC-G (Serovar G) LcrE has no mutations relative to the Serovar D LcrE reference sequence (SEQ ID No 46).

Genome ATCC-G is associated with Serovar G. The sequence of Genome ATCC-G is disclosed as SEQ ID NO: 3 (see below).

SEQ ID NO: 3:

```
MTASGGAGGLGSTQTVDDVARAQAAAATQDAQEVIGSQEASEASMLKGCED
LINPAAATRIKKKGEKFESLEARRKPTADKAEKKSESTEKGDTPLEDRF
TEDLSEVSGEDFRGLKNSFDDDDSSPDEILDALTSKFS DPTIKDLALDYLI
QTAPSDGKLKSTLIQAKHQLMSQNPQAI VGG RNVLLASETFASRANTSPS
SLRSLYFQVTSSPSNCANLHQMLASYLPSEKTAVMEFLVNGMVADLKSEG
PSIPPAKLQVYMTLSNLQALHSVNSFFDRNIGNLENSLKHEGHAPIPSL
TTGNLTKTFLQLVEDKFPSSSKAQKALNELVGPDTGPGQTEVLNLFRRALN
GCSPRIFSGAEKKQQLASVITNTLDAINADNEDYPKPGDFPRSSFSSTPP
HAPVPQSEIPTSTSTQPPSP*
```

(4) Genome: ATCC-H (3 mutations: allele-4)

The Genome ATCC-H LcrE sequence has 3 mutations relative to the Serovar D LcrE reference sequence (SEQ ID No 46). Genome ATCC-H is associated with Serovar H. The sequence of Genome ATCC-H is disclosed as SEQ ID NO: 4 (see below).

SEQ ID NO: 4:

```
MTASGGAGGLGSTQTVDDVARAQAAAATQDAQEVIGSQEASEASMLKGCED
LINPAAATRIKKKGEKFESLEARRKPTADKAEKKSESTEKGDTPLEDRF
TEDLSEVSGEDFRGLKNSFDDDDSSPDEILDALTSKFS DPTIKDLALDYLI
QTAPSDGKLKSTLIQAKHQLMSQNPQAI VGG RNVLLASETFASRANTSPS
SLRSLYFQVTSSPSNCANLHQMLASYLPSEKTAVMEFLVNGMVADLKSEG
PSIPPAKLQVYMTLSNLQALHSVNSFFDRNIGNLENSLKHEGHAPIPSL
TTGNLTKTFLQLVEDKFPSSSKAQKALNELVGPDTGPGQTEVLNLFRRALN
GCSPRIFSGAEKKQQLASVITNTLDAINADNEDYPKPGDFPRSSFSSTPP
HAPVPQSEIPTSTSTQPPSP*
```

The alignment of Genome ATCC-H with the LcrE *Chlamydia trachomatis* antigen is as follows:

```
MTASGGAGGLGSTQTVDDVARAQAAAATQDAQEVIGSQEASEASMLKGCED
LINPAAATRIKKKGEKFESLEARRKPTADKAEKKSESTEKGDTPLEDRF
.....E
TEDLSEVSGEDFRGLKNSFDDDDSSPDEILDALTSKFS DPTIKDLALDYLI
QTAPSDGKLKSTLIQAKHQLMSQNPQAI VGG RNVLLASETFASRANTSPS
.....A
SLRSLYFQVTSSPSNCANLHQMLASYLPSEKTAVMEFLVNGMVADLKSEG
PSIPPAKLQVYMTLSNLQALHSVNSFFDRNIGNLENSLKHEGHAPIPSL
TTGNLTKTFLQLVEDKFPSSSKAQKALNELVGPDTGPGQTEVLNLFRRALN
GCSPRIFSGAEKKQQLASVITNTLDAINADNEDYPKPGDFPRSSFSSTPP
HAPVPQSEIPTSTSTQPPSP*
.....P
```

(5) Genome: ATCC-I (no mutations: allele-1)

The Genome ATCC-I LcrE sequence has no mutations relative to the Serovar D LcrE reference sequence (SEQ ID No 46).

Genome ATCC-I is associated with Serovar I. The sequence of Genome ATCC-I is disclosed as SEQ ID NO: 5 (see below).

SEQ ID NO: 5:

```
MTASGGAGGLGSTQTVDFVARAQAAAATQDAQEVIGSQEASEASMLKGCED
LINPAAATRIKKKGKGFESLEARRKPTADKAEEKSESTEKGDTPLEDRF
TEDLSEVSGEDFRGLKNSFDDDDSSPDEILDALTSKFSDPTIKDLALDYLI
QTAPSDGKLKSTLIQAKHQLMSQNPQAIVGGRNVLLASETFASRANTSPS
SLRSLYFQVTSSPSNCANLHQM LASYL PSEKTAVMEFLVNGMVADLKSEG
PSIPPAKLQVYMTLSNLQALHSVNSFFDRNIGNLENSLKHEGHAPIPSL
TTGNLTKTFLQLVEDKFPSSSKAQKALNELVGPDTGPGQTEVLNLFFRALN
GCSPRIFSGAEKKQQLASVITNTLD AINADNEDYPKPGDFPRSSFSSTPP
HAPVPQSEIPTSTSTQPPSP*
```

(6) Genome: ATCC-J (3 mutations: allele-4, as Cev-5)

The Genome ATCC-J LcrE sequence has 3 mutations relative to the Serovar D LcrE reference sequence (SEQ ID No 46).

Genome ATCC-J is associated with Serovar J. The sequence of Genome ATCC-J is disclosed as SEQ ID NO: 6 (see below).

SEQ ID NO: 6:

```
MTASGGAGGLGSTQTVDFVARAQAAAATQDAQEVIGSQEASEASMLKGCED
LINPAAATRIKKKGKGFESLEARRKPTADKAEEKSESTEKGDTPLEDRF
TEDLSEVSGEDFRGLKNSFDDDDSSPDEILDALTSKFSDPTIKDLALDYLI
QTAPSDGKLKSTLIQAKHQLMSQNPQAIVGGRNVLLASETFASRANTSPS
SLRSLYFQVTSSPSNCANLHQM LASYL PSEKTAVMEFLVNGMVADLKSEG
PSIPPAKLQVYMTLSNLQALHSVNSFFDRNIGNLENSLKHEGHAPIPSL
TTGNLTKTFLQLVEDKFPSSSKAQKALNELVGPDTGPGQTEVLNLFFRALN
GCSPRIFSGAEKKQQLASVITNTLD AINADNEDYPKPGDFPRSSFSSTPP
HAPVPQSEIPTSTSTQPPSP*
```

The alignment of Genome ATCC-J with the LcrE *Chlamydia trachomatis* antigen is as follows:

```
MTASGGAGGLGSTQTVDFVARAQAAAATQDAQEVIGSQEASEASMLKGCED
LINPAAATRIKKKGKGFESLEARRKPTADKAEEKSESTEKGDTPLEDRF
.....E
TEDLSEVSGEDFRGLKNSFDDDDSSPDEILDALTSKFSDPTIKDLALDYLI
QTAPSDGKLKSTLIQAKHQLMSQNPQAIVGGRNVLLASETFASRANTSPS
.....A
SLRSLYFQVTSSPSNCANLHQM LASYL PSEKTAVMEFLVNGMVADLKSEG
PSIPPAKLQVYMTLSNLQALHSVNSFFDRNIGNLENSLKHEGHAPIPSL
TTGNLTKTFLQLVEDKFPSSSKAQKALNELVGPDTGPGQTEVLNLFFRALN
GCSPRIFSGAEKKQQLASVITNTLD AINADNEDYPKPGDFPRSSFSSTPP
HAPVPQSEIPTSTSTQPPSP*
.....P
```

(7) Genome: ATCC-K (no mutations: allele-1)

The Genome ATCC-I LcrE sequence has no mutations relative to the Serovar D LcrE reference sequence (SEQ ID No 46).

Genome ATCC-I is associated with Serovar I. The sequence of Genome ATCC-I is disclosed as SEQ ID NO: 7 (see below).

SEQ ID NO: 7:

```
MTASGGAGGLGSTQTVDVARAQAAAATQDAQEVIGSQEASEASMLKGCED
LINPAAATRIKKKGKGFESLEARRKPTADKAEKKSESTEKGDTPLEDRF
TEDLSEVSGEDFRGLKNSFDDDDSSPDEILDALTSKFSDPTIKDLALDYLI
QTAPSDGKLKSTLIQAKHQLMSQNPQAIVGGRNVLLASETFASRANTSPS
SLRSLYFQVTSSPSNCANLHQLASYLPSEKTAVMEFLVNGMVADLKSEG
PSIPPAKLQVYMTLSNLQALHSVNSFFDRNIGNLENSLKHEGHAPIPSL
TTGNLTKTFLQLVEDKFPSSSKAQKALNELVGPDTGPQTEVLNLFRRALN
GCSPRIFSGAEKKQQLASVITNTLDAINADNEDYPKPGDFPRSSFSSTPP
HAPVPQSEIPTSPTSTQPPSP*
```

(8) Genome: Cev-1, serJ (4 mutations: allele-3)

The Genome Cev-1 (Serovar J) sequence has 4 mutations relative to the Serovar D LcrE reference sequence (SEQ ID No 46).

Genome Cev-1 is associated with Serovar J. The sequence of Genome Cev-1 is disclosed as SEQ ID NO: 8 (see below).

SEQ ID NO: 8:

```
MTASGGAGGLGSTQTVDVARAQAAAATQDAQEVIGSQEASEASMLKGCED
LINPAAATRIKKKGKGFESLEARRKPTADKAEKKSESTEKGDTPLEDRF
TEDLSEVSGEDFRGLKNSFDDDDSSPDEILDALTSKFSDPTIKDLALDYLI
QTAPSDGKLKSTLIQAKHQLMSQNPQAIVGGRNVLLASETFASRANTSPS
SLRSLYFQVTSSPSNCANLHQLASYLPSEKTAVMEFLVNGMVADLKSEG
PSIPPAKLQVYMTLSNLQALHSVNSFFDRNIGNLENSLKHEGHAPIPSL
TTGNLTKTFLQLVEDKFPSSSKAQKALNELVGPDTGPQTEVLNLFRRALN
GCSPRIFSGAEKKQQLASVITNTLDAINADNEDYPKPGDFPRSSFSSTPP
HAPVPQSEIPTSPTSTQPPPP*
```

The alignment of Genome Cev-1 with the LcrE *Chlamydia trachomatis* antigen is as follows:

```
MTASGGAGGLGSTQTVDVARAQAAAATQDAQEVIGSQEASEASMLKGCED
LINPAAATRIKKKGKGFESLEARRKPTADKAEKKSESTEKGDTPLEDRF
.....E
TEDLSEVSGEDFRGLKNSFDDDDSSPDEILDALTSKFSDPTIKDLALDYLI
QTAPSDGKLKSTLIQAKHQLMSQNPQAIVGGRNVLLASETFASRANTSPS
.....A.....I
SLRSLYFQVTSSPSNCANLHQLASYLPSEKTAVMEFLVNGMVADLKSEG
PSIPPAKLQVYMTLSNLQALHSVNSFFDRNIGNLENSLKHEGHAPIPSL
TTGNLTKTFLQLVEDKFPSSSKAQKALNELVGPDTGPQTEVLNLFRRALN
GCSPRIFSGAEKKQQLASVITNTLDAINADNEDYPKPGDFPRSSFSSTPP
HAPVPQSEIPTSPTSTQPPSP*
.....P
```

(9) Genome: Cev-2, serG (no mutations: allele-1)

The Genome Cev-2 (Serovar G) sequence has no mutations relative to the Serovar D LcrE reference sequence (SEQ ID No 46).

Genome Cev-2 is associated with Serovar G. The sequence of Genome Cev-2 is disclosed as SEQ ID NO: 9 (see below).

SEQ ID NO: 9:

MTASGGAGGLGSTQTV DVARAQAAAATQDAQEVIGSQEASEASMLKGCED
 LINPAAATRIKKKG EK FESLEARRKPTADKA EKKSESTE EKGDTPLEDRF
 TEDLSEVSGEDFRGLKNSFDDSSPDEILDALTSKFSDPTIKDLALDYLI
 QTAPSDGKLKSTLIQAKHQLMSQNPQAI VGG RNVLLASETFASRANTSPS
 SLRSLYFQVTSSPSNCANLHQMLASYLPSEKTAVMEFLVNGMVADLKSEG
 PSIPPAKLQVYMTLSNLQALHSVNSFFDRNIGNLENSLKHEGHAPIPSL
 TTGNLTKTFLQLVEDKFPSSSKAQKALNELVGPD TG PQTEVLNLFFRALN
 GCSPRIFSGAEKKQQLASVITNTLD AINADNEDYPKPGDFPRSSFSSTPP
 HAPVPQSEIPTSTPTSTQPPSP*

(10) Genome: Cev-4, serH (no mutations: allele-1)

The Genome Cev-4 LcrE sequence has no mutations relative to the Serovar D LcrE reference sequence (SEQ ID No 46).

Genome Cev-4 is associated with Serovar H. The sequence of Genome Cev-4 is disclosed as SEQ ID NO: 10 (see below).

SEQ ID NO: 10:

MTASGGAGGLGSTQTV DVARAQAAAATQDAQEVIGSQEASEASMLKGCED
 LINPAAATRIKKKG EK FESLEARRKPTADKA EKKSESTE EKGDTPLEDRF
 TEDLSEVSGEDFRGLKNSFDDSSPDEILDALTSKFSDPTIKDLALDYLI
 QTAPSDGKLKSTLIQAKHQLMSQNPQAI VGG RNVLLASETFASRANTSPS
 SLRSLYFQVTSSPSNCANLHQMLASYLPSEKTAVMEFLVNGMVADLKSEG
 PSIPPAKLQVYMTLSNLQALHSVNSFFDRNIGNLENSLKHEGHAPIPSL
 TTGNLTKTFLQLVEDKFPSSSKAQKALNELVGPD TG PQTEVLNLFFRALN
 GCSPRIFSGAEKKQQLASVITNTLD AINADNEDYPKPGDFPRSSFSSTPP
 HAPVPQSEIPTSTPTSTQPPSP*

(11) Genome: Cev-5, serJ (3 mutations: allele-4)

The Genome Cev-5 sequence has 3 mutations relative to the Serovar D LcrE reference sequence (SEQ ID No 46).

Genome Cev-5 is associated with Serovar J. The sequence of Genome Cev-5 is disclosed as SEQ ID NO: 11 (see below).

SEQ ID NO: 11:

```

MTASGGAGGLGSTQTVDFVARAQAAAATQDAQEVIGSQEASEASMLKGCED
LINPAAATRIKKKEEFESLEARRKPTADKAEEKSESTEKGDTPLEDRE
TEDLSEVSGEDFRGLKNSFDDDDSSPDEILDALTSKFSPTIKDLALDYLI
QTAPSDGKLKSAITQAKHQLMSQNPQAIVGGRNVLLASETFASRANTSPS
SLRSLYFQVTSSPSNCANLHQMILASYPSEKTAVMEFLVNGMVADLKSEG
PSIPPAKLQVYMTLSNLQALHSVNSFFDRNIGNLENSLKHEGHAPIPSL
TTGNLTKTFLQLVEDKFPSSSKAQKALNELVGPDTGPQTEVLNLFRRALN
GCSPRIFSGAEKKQQLASVITNTLDAINADNEDYKPGDFPRSSFSSTPP
HAPVPQSEIPTSTSTQPPPP*

```

The alignment of Genome Cev-5 with the LcrE *Chlamydia trachomatis* antigen is as follows:

```

MTASGGAGGLGSTQTVDFVARAQAAAATQDAQEVIGSQEASEASMLKGCED
LINPAAATRIKKKEEFESLEARRKPTADKAEEKSESTEKGDTPLEDRE
.....E
TEDLSEVSGEDFRGLKNSFDDDDSSPDEILDALTSKFSPTIKDLALDYLI
QTAPSDGKLKSTLIQAKHQLMSQNPQAIVGGRNVLLASETFASRANTSPS
.....A
SLRSLYFQVTSSPSNCANLHQMILASYPSEKTAVMEFLVNGMVADLKSEG
PSIPPAKLQVYMTLSNLQALHSVNSFFDRNIGNLENSLKHEGHAPIPSL
TTGNLTKTFLQLVEDKFPSSSKAQKALNELVGPDTGPQTEVLNLFRRALN
GCSPRIFSGAEKKQQLASVITNTLDAINADNEDYKPGDFPRSSFSSTPP
HAPVPQSEIPTSTSTQPPSP*
.....P

```

(12) Genome: Cev-8, serE (8 mutations: allele-5)

The Genome Cev-8 LcrE sequence has 8 mutations relative to the Serovar D LcrE reference sequence (SEQ ID No 46).

Genome Cev-8 is associated with Serovar E. The sequence of Genome Cev-8 is disclosed as SEQ ID NO: 12 (see below).

SEQ ID NO: 12:

```

MTASGGAGGLGSTQTVDFVARAQAAAATQDAQEVIGSQEASEASMLKGCED
LINPAAATRIKKKEEFESLEARRKPTADKAEEKSESTEKGDTPLEDRE
TEDLSEVSGEDFRGLKNSFDDDDSSPEILDALTSKFSPTIKDLALDYLI
QTAPSDRKLKSAITQAKHQLMSQNPQAIVGGRNVLLASETFASRANTSPS
SLRSLYLQVTSSPSNCDNLQMLASYPSEKTAVMEFLVNGMVADLKSEG
PSIPPAKLQVYMTLSNLQALHSVDSFFDRNIGNLENSLKHEGHAPIPSL
TTGNLTKTFLQLVEDKFPSSSKAQKALNELVGPDTGPQTEVLNLFRRALN
GCSPRIFSGAEKKQQLASVITNTLDAINADNEDYKPGDFPRSSFSSTPP
HAPVPQSEIPTSTSTQPPPP*

```

The alignment of Genome Cev-8 with the LcrE *Chlamydia trachomatis* antigen is as follows:

```

MTASGGAGGLGSTQTVDFVARAQAAAATQDAQEVIGSQEASEASMLKGCED
LINPAAATRIKKKEEFESLEARRKPTADKAEEKSESTEKGDTPLEDRE
.....E
TEDLSEVSGEDFRGLKNSFDDDDSSPDEILDALTSKFSPTIKDLALDYLI
.....E

```

```

QTAPSDGKLGKSTLIQAKHQLMSQNPQAI_VGGRNVLLASETFASRANTSPS
.....R....A
SLRSLYFQVTSSPSNCANLHQMLASYLPSEKTAVMEFLVNGMVADLKSEG
.....L.....D..R
PSIPPAKLQVYMTLSNLQALHSVNSFFDRNIGNLENSLKHEGHAPIPSL
.....D
TTGNLTKTFLQLVEDKFPSSSKAQKALNELVGPDTPGPQTEVLNLFFRALN
GCSPRIFSGAEKKQQLASVITNTLDAINADNEDYPKPGDFPRSSFSSTPP
HAPVPQSEIPTSTSTQPPSP*

```

(13) Genome: GO/86 serD (4 mutations: allele-2)

The Genome GO/86 LcrE sequence has 4 mutations (at position 64, 126, 162, and 420) relative to the Serovar D LcrE reference sequence (SEQ ID No 46).

Genome GO/86 is associated with Serovar D. The sequence of Genome GO/86 is disclosed as SEQ ID NO: 13 (see below).

SEQ ID NO: 13:

```

MTASGGAGGLGSTQTVVARAQAAAATQDAQEVIGSQEASEASMLKGCED
LINPAAATRIKKKKEKFESLEARRKPTADKAEKKSESTEKGDTPLEDRE
TEDLSEVSGEDFRGLKNSFDDSSPNEILDALTSKFSDPTIKDLALDYLI
QTAPSDGKLGKSTLIQAKHQLMSQNPQAI_VGGRNVLLASETFASRANTSPS
SLRSLYFQVTSSPSNCANLHQMLASYLPSEKTAVMEFLVNGMVADLKSEG
PSIPPAKLQVYMTLSNLQALHSVNSFFDRNIGNLENSLKHEGHAPIPSL
TTGNLTKTFLQLVEDKFPSSSKAQKALNELVGPDTPGPQTEVLNLFFRALN
GCSPRIFSGAEKKQQLASVITNTLDAINADNEDYPKPGDFPRSSFSSTPP
HAPVPQSEIPTSTSTQPPSP*

```

The alignment of Genome GO/86 with the LcrE *Chlamydia trachomatis* antigen is as follows:

Genome: GO/86 serD (4 mutations: allele-2)

```

MTASGGAGGLGSTQTVVARAQAAAATQDAQEVIGSQEASEASMLKGCED
LINPAAATRIKKKKEKFESLEARRKPTADKAEKKSESTEKGDTPLEDRE
.....E
TEDLSEVSGEDFRGLKNSFDDSSPDEILDALTSKFSDPTIKDLALDYLI
.....N
QTAPSDGKLGKSTLIQAKHQLMSQNPQAI_VGGRNVLLASETFASRANTSPS
.....A
SLRSLYFQVTSSPSNCANLHQMLASYLPSEKTAVMEFLVNGMVADLKSEG
PSIPPAKLQVYMTLSNLQALHSVNSFFDRNIGNLENSLKHEGHAPIPSL
TTGNLTKTFLQLVEDKFPSSSKAQKALNELVGPDTPGPQTEVLNLFFRALN
GCSPRIFSGAEKKQQLASVITNTLDAINADNEDYPKPGDFPRSSFSSTPP
HAPVPQSEIPTSTSTQPPSP*
.....P

```

Consensus sequences (SEQ ID Nos 14-27)

The majority or consensus sequence of the LcrE *Chlamydia trachomatis* antigen was determined in 30 mer peptide segments.

The first segment of 30 amino acid residues of the consensus sequence (*residues 1-30*) is disclosed as SEQ ID NO: 14 as follows:

SEQ ID NO: 14

MTASGGAGGLGSTQTV DVARAQAAAATQDA

The second segment of 30 amino acid residues of the consensus sequence (*residues 31-60*) is disclosed as SEQ ID NO: 15 as follows:

SEQ ID NO: 15

QEVIGSQEASEASMLKGCEDLINPAAATRI

No mutations were identified in either SEQ ID NO: 14 or SEQ ID NO: 15 relative to the Serovar D LcrE reference sequence (SEQ ID No 46).

The third segment of 30 amino acid residues of the consensus sequence (*residues 61-90*) is disclosed as SEQ ID NO: 16 as follows:

SEQ ID NO: 16

KKKXEKFESLEARRKPTADKAEEKKSESTEE

The amino acid residue at position 4 of SEQ ID NO: 16 is glutamic acid (E) in half of the observed isolates and glycine (G) in the other half of the observed isolates. Therefore, the amino acid residue at position 4 of the 61-90 residue segment of the consensus sequence for the LcrE antigen (i.e., *residue 64* of the consensus sequence overall = high frequency mutation point) is marked as X here.

The fourth segment of 30 amino acid residues of the consensus sequence (*residues 91-120*) is disclosed as SEQ ID NO: 17 as follows:

SEQ ID NO: 17

KGDTPLEDRFTEDLSEVSGEDFRGLKNSFD

No mutations were observed in the isolates in the segment of the LcrE *Chlamydia trachomatis* antigen in the portion of the sequence from residue 91-120 relative to the Serovar D LcrE reference sequence (SEQ ID No 46).

The fifth segment of 30 amino acid residues of the consensus sequence (*residues 121-150*) is disclosed as SEQ ID NO: 18 as follows:

SEQ ID NO: 18

DDSSP¹²¹FEILDALTSKFS¹²²DPTIKDLALDYLI

The amino acid residue at position 6 (*overall residue = 126*) of the consensus sequence segment from residue 121-150 was aspartic acid in 10 of 13 of the isolates, glutamic acid in 2 of 13 of the isolates and asparagines in 1 of the 13 isolates.

The sixth segment of 30 amino acid residues of the consensus sequence (*residues 151-180*) is disclosed as SEQ ID NO: 19 as follows:

SEQ ID NO: 19

QTAPSD¹⁵¹QKLKSLI¹⁵²QAKHQLMSQNPQAI¹⁵³VG

The amino acid residue at position 12 (*overall residue = 162 = high frequency mutation point*) of SEQ ID NO: 19 was alanine (A) in half of the observed isolates and threonine (T) in the other half of the observed isolates. Therefore, the amino acid residue at position 12 of the 151-180 residue segment of the consensus sequence for the LcrE *Chlamydia trachomatis* antigen (i.e., residue 162 of the consensus sequence overall) is marked as X here.

The seventh segment of 30 amino acid residues of the consensus sequence (*residues 181-210*) is disclosed as SEQ ID NO: 20 as follows:

SEQ ID NO: 20

GRNVLLASETFASRANTSPSSLRSLY¹⁸¹QVT

The amino acid residue at position 27 (*overall residue = 207*) of the consensus sequence segment from residue 181-210 was phenylalanine (F) in 12 of 14 isolates and leucine (L) in 2 of 14 isolates.

The eighth segment of 30 amino acid residues of the consensus sequence (*residues 211-240*) is disclosed as SEQ ID NO: 21 as follows:

SEQ ID NO: 21

SSPSNC²¹¹ANL²¹²QMLASYLPSEKTAVMEFLVN

Two mutations were observed in the consensus sequence segment (SEQ ID No 21) from residue 211-240 at positions 217 and 220 of the overall consensus sequence.

The ninth segment of 30 amino acid residues of the consensus sequence (*residues 241-270*) is disclosed as SEQ ID NO: 22 as follows:

SEQ ID NO: 22

GMVADLKSEGPSIPPAKLQVYMTLSNLQA

No mutations were identified in SEQ ID NO: 22 relative to the Serovar D LcrE reference sequence (SEQ ID No 46).

The tenth segment of 30 amino acid residues of the consensus sequence (*residues 271-300*) is disclosed as SEQ ID NO: 23 as follows:

SEQ ID NO: 23

LHSVNSFFDRNIGNLENSLKHEGHAPIPSL

The amino acid residue at position 5 (*overall residue* = 275) of the consensus sequence segment from residue 271-300 was asparagines (N) in 12 of 14 of the isolates and aspartic acid (D) in 2 of the 14 isolates.

The eleventh segment of 30 amino acid residues of the consensus sequence (*residues 301-330*) is disclosed as SEQ ID NO: 24 as follows:

SEQ ID NO: 24

TTGNLTKTFLQLVEDKFPSSSKAQKALNEL

The twelfth segment of 30 amino acid residues of the consensus sequence (*residues 331-360*) is disclosed as SEQ ID NO: 25 as follows:

SEQ ID NO: 25

VGPD TG PQTEVLNLFFRALNGCSPRIFSGA

The thirteenth segment of 30 amino acid residues of the consensus sequence (*residues 361-390*) is disclosed as SEQ ID NO: 26 as follows:

SEQ ID NO: 26

EKKQQLASVITNTLDAINADNEDYPKPGDF

No mutations were identified in either SEQ ID NO: 24, 25, or 26 relative to the Serovar D LcrE reference sequence (SEQ ID No 46).

The fourteenth segment of 30 amino acid residues of the consensus sequence (*residues 391-420*) is disclosed as SEQ ID NO: 27 as follows:

SEQ ID NO: 27

PRSSFSSSTPPHAPVPQSEIPTSTSTQPPSP

The amino acid residue at position 30 of the consensus sequence segment from residue 391-420 (i.e., position 420 of the overall consensus sequence) was serine (S) in 9 of 14 isolates and was proline (P) in 5 of 14 isolates.

In all isolates observed, the amino acid residue at position 421 was proline.

The LcrE reference sequence from *Chlamydia trachomatis* Strain D/UW-3/CX is provided as SEQ ID NO: 28 (below) which also shows a summary of the all of the allelic mutation points detected in the various *Chlamydia trachomatis* serovar isolates: The underlined regions in SEQ ID No 28 surrounding the point mutations are likely to correspond with either B and/or T cell epitopic peptide regions.

SEQ ID NO: 28

MTASGGAGGLGSTQTVDVARAQAAAATQDAQEVIGSQEASEASMLKGCED
 LINPAAATRIKKKTEKFESLEARRKPTADKAEEKSESTEKGDTPLEDRF
 TEDLSEVSGEDFRGLKNSFDDSSPTEILDALTSKFSDPTIKDLALDYLI
 QTAPSDGKLKSLIQAQHQLMSONPQAIWGGRNVLASETFASRANTSPS
 SLRSLYQVTSPPSNCANLHOMLASYPSEKTAVMEFLVNGMVADLKSEG
 PSIPPAKLQVYMTLSNLQALHSVNSFFDRNIGNLENSLKHEGHAPIPSL
 TTGNLTKTFLQLVEDKFPSSSKAQKALNELVGPDTGPTQTEVLNLFFRALN
 GCSPRIFSGAEKKQQLASVITNTLDAINADNEDYPKPGDFPRSSFSTPP
 HAPVPQSEIPTSTSTQPPSP

SEQ ID NO: 185

MTASGGAGGLGSTQTVDVARAQAAAATQDAQEVIGSQEASEASMLKGCED
 LINPAAATRIKKKTEKFESLEARRKPTADKAEEKSESTEKGDTPLEDRF
 TEDLSEVSGEDFRGLKNSFDDSSPTEILDALTSKFSDPTIKDLALDYLI
 QTAPSDGKLKSLIQAQHQLMSONPQAIWGGRNVLASETFASRANTSPS
 SLRSLYQVTSPPSNCANLHOMLASYPSEKTAVMEFLVNGMVADLKSEG
 PSIPPAKLQVYMTLSNLQALHSVNSFFDRNIGNLENSLKHEGHAPIPSL
 TTGNLTKTFLQLVEDKFPSSSKAQKALNELVGPDTGPTQTEVLNLFFRALN
 GCSPRIFSGAEKKQQLASVITNTLDAINADNEDYPKPGDFPRSSFSTPP
 HAPVPQSEIPTSTSTQPPSP

Table 2 shows 17 antigenic determinants (or epitopic peptides set out as SEQ ID Nos 29-45) for *Chlamydia trachomatis* trachomatis LcrE protein

n	Start Position	Sequence	End Position	Seq ID NO:
1	14	QTVDVARAQAAAA	26	29
2	29	DAQEVIG	35	30
3	44	MLKGCEDLINP	54	31
4	125	P E EILDALTS	134	32
5	140	TKDLALDYLIQT	152	33
6	159	LKS I LIQAKHQ	169	34
7	180	GGRNVLLASE	189	35
8	198	SPSSLRSLY I QVTSSPSNCA N L I QMLASYLPSE	230	36
9	233	AVMEFLVNGMVAD	245	37
10	250	GPSIPPAKLQVYM	262	38
11	265	LSNLQALHSV S S	276	39
12	293	GHAPIPS	299	40
13	306	TKTFLQLVED	315	41
14	326	ALNELVGP	333	42
15	337	PQTEVLNLFRRALNGCSPRI	356	43
16	362	KKQQLASVIT	371	44
17	395	FSSTPPHAPVPQSEI	409	45

Detailed Description of the Invention

Before describing the present invention in detail, it is to be understood that this invention is not limited to particularly exemplified molecules or process parameters as such may, of course, vary. It is also to be understood that the terminology used herein is for the purpose of describing particular embodiments of the invention only, and is not intended to be limiting. In addition, the practice of the present invention will employ, unless otherwise indicated, conventional methods of virology, microbiology, molecular biology, recombinant DNA techniques and immunology all of which are within the ordinary skill of the art. Such techniques are explained fully in the literature. See, e.g., Sambrook, *et al.*, Molecular Cloning: A Laboratory Manual (2nd Edition, 1989); DNA Cloning: A Practical Approach, vol. I & II (D. Glover, ed.); Oligonucleotide Synthesis (N. Gait, ed., 1984); A Practical Guide to Molecular Cloning (1984); and Fundamental Virology, 2nd Edition, vol. I & II (B.N. Fields and D.M. Knipe, eds.).

All publications, patents and patent applications cited herein, whether *supra* or *infra*, are hereby incorporated by reference in their entirety. It must be noted that, as used in this specification and

the appended claims, the singular forms “a”, “an” and “the” include plural referents unless the content clearly dictates otherwise. All scientific and technical terms used in this application have meanings commonly used in the art unless otherwise specified. As used in this application, the following words or phrases have the meanings specified.

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

References to a percentage sequence identity between two amino acid sequences means that, when aligned, that percentage of amino acids are the same in comparing the two sequences. This alignment and the percent homology or sequence identity can be determined using software programs known in the art, for example those described in section 7.7.18 of *Current Protocols in Molecular Biology* (F.M. Ausubel *et al.*, eds., 1987) Supplement 30. A preferred alignment is determined by the Smith-Waterman homology search algorithm using an affine gap search with a gap open penalty of 12 and a gap extension penalty of 2, BLOSUM matrix of 62. The Smith-Waterman homology search algorithm is disclosed in Smith & Waterman (1981) *Adv. Appl. Math.* 2: 482-489

The one-letter amino acid symbols recommended by the IUPAC-IUB Biochemical Nomenclature Commission are provided below together with the three-letter codes which are also provided for reference purposes.

A	Ala	Alanine
C	Cys	Cysteine
D	Asp	Aspartic acid
E	Glu	Glutamic Acid
F	Phe	Phenylalanine
G	Gly	Glycine
H	His	Histidine
I	Ile	Isoleucine
K	Lys	Lysine
L	Leu	Leucine
M	Met	Methionine
N	Asn	Asparagine
P	Pro	Proline
Q	Gln	Glutamine
R	Arg	Arginine
S	Ser	Serine

T	Thr	Threonine
V	Val	Valine
W	Trp	Tryptophan
Y	Tyr	Tyrosine

Unless otherwise noted, terminology used herein should be given its normal meaning as understood by one of skill in the art. In order to facilitate understanding of the present invention, a number of defined terms are used herein to designate particular elements of the present invention. When so used, the following meanings are intended:

As also noted above, in the course of evaluating the allelic variation for the LcrE gene in 14 *Chlamydia trachomatis* clinical isolates representative of 8 different *Chlamydia trachomatis* serovars, the Applicants established that a higher than expected number of single amino acidic substitutions across the *C. trachomatis* serovars was observed for the LcrE antigen relative to (i) a reference *Chlamydia trachomatis* LcrE sequence from Serovar D and (ii) those found for other immunogenic *Chlamydia trachomatis* antigens.

This highly unexpected and suprising finding suggests that:

- (i) the LcrE protein may be subjected to a greater immunological pressure than other immunogenic *Chlamydia trachomatis* antigens; and
- (ii) the peptides surrounding the amino acid substitutions are likely to be epitopic regions (either B-cell epitopes involved in antibody-antigen (Ab-Ag) interactions and/or T-cell epitopes capable of eliciting *Chlamydia* specific cell mediated responses).

Applicants finding is all the more surprising because the *Chlamydia* isolates used for these genotyping studies came from two very divergent immunological sources which were isolated from two different Continents (North America and Europe) and over different time periods (minimum of 30 years ago versus 5- 8 years ago).

Allelic Variant

As used herein, the term "allelic variant" refers to any one of a series of two or more different genes that occupy the same position (locus) on a chromosome. By way of example, an "allelic variant" of a nucleic acid molecule, or region, for which nucleic acid sequence is provided herein is a nucleic acid molecule, or region, that occurs essentially at the same locus in the genome of another or second isolate, and that, due to natural variation caused by, for example, mutation or recombination, has a similar but not identical nucleic acid sequence. A coding region allelic variant may encode a protein having a similar biological activity but not necessarily the same

immunological activity relative to that of the protein encoded by the gene to which it is being compared. As discussed below, the nature of the mutation or change in genotype may influence the resulting functional effect or change in biological and/or immunological phenotype. An allelic variant can also comprise an alteration in the 5' or 3' untranslated regions of the gene, such as in regulatory control regions (eg see US patent 5,753, 235).

Mutant

As used herein, the term "mutant" refers to a sequence which differs from a reference sequence by having one or more differences (mutations). This may be a substitution, a deletion, or an insertion. The mutant may or may not have a functional effect. By way of example, if one or more of the differences in allelic variants or mutants of the invention, compared to reference SEQ ID No 46 involves a conservative amino acid replacement, such as, for example, replacement of one amino acid with another which has a related side chain, then the mutated sequence may not demonstrate a functional biological effect relative to the reference sequence. In this respect, genetically-encoded amino acids are generally divided into four families: (1) acidic ie. aspartate, glutamate ; (2) basic i. e. lysine, arginine, histidine; (3) non-polar i. e. alanine, valine, leucine, isoleucine, proline, phenylalanine, methionine, tryptophan; and (4) uncharged polar i. e. glycine, asparagine, glutamine, cystine, serine, threonine, tyrosine. Phenylalanine, tryptophan, and tyrosine are sometimes classified jointly as aromatic amino acids. In general, substitution of single amino acids within these families does not have a major effect on the biological or immunological activity.

On the other hand if one or more of the differences in allelic variants or mutants of the invention, compared to reference SEQ ID No 46 involves a non-conservative amino acid replacement, then this replacement may have a functional effect resulting, for example in a change in phenotype, such as an altered immunogenicity for an antigen sequence, such as LcrE. By way of example, analysis of data from experimentally determined antigenic sites on proteins suggests that the hydrophobic residues Cys, Leu and Val, if they occur on the surface of a protein, are more likely to be part of antigenic sites (see Kolaskar and Tongaonkar (1990) FEBS Lett 276(1-2) 172-4). In relation to the ten mutations highlighted in SEQ ID No 28 and SEQ ID No 185 of the present invention, four mutations were viewed as "conservative" and six mutations were viewed as "non-conservative" (see for Example, Table 4 in Example 4). Given that there are conflicting views of the nature of a conservative or a non-conservative mutations (for example, difference in physical or chemical characteristics relative to the nature of the amino

acid side chain versus various evolutionary criteria), Applicants have used the existence of high frequency mutations (eg at points 64 and 162 of the LcrE sequence) as one example of a useful marker for hypervariable regions within a sequence which are likely to be linked to the presence of T and/or B cell epitopic regions capable of eliciting an immunogenic response in a subject, such as a humoral and/or a cell-mediated immune response.

By way of further explanation, Applicants have identified two high frequency mutation points or hypervariable regions at amino acid residues 64 and 162 in the LcrE Sero var sequence. At amino acid residue 64, there are seven mutations from Glycine (G) to Glutamic (E) acid across the 14 *Chlamydia* isolates while at point 162, there are also seven mutations from Threonine (T) to Alanine (A) across the 14 *Chlamydia* isolates. The existence of two high frequency mutation points or hypervariable regions (eg at residues 64 and 162 of the reference sequence) is a highly surprising and unexpected finding and is likely to be associated with the presence of epitopic regions capable of eliciting an altered immunogenic response in a subject.

The LcrE reference sequence from *Chlamydia trachomatis* trachomatis Strain D/UW-3/CX is provided as SEQ ID NO:46 and SEQ ID No 28 and SEQ ID No 185. The latter sequence also provides a summary of the all of the allelic mutation points or allelic variants points detected in the various *Chlamydia trachomatis* serovar isolates: The underlined regions in SEQ ID No 28 and SEQ ID No 185 surrounding the point mutations are likely to correspond with either B and/or T cell epitopic peptide regions.

Epitopes

As used herein, the term "epitope" generally refers to the site on an antigen which is recognised by a T-cell receptor and/or an antibody. Preferably it is a short peptide derived from or as part of a protein antigen. However the term is also intended to include peptides with glycopeptides and carbohydrate epitopes. Several different epitopes may be carried by a single antigenic molecule. The term "epitope" also includes modified sequences of amino acids or carbohydrates which stimulate responses which recognise the whole organism. It is advantageous if the selected epitope is an epitope of an infectious agent, such as a *Chlamydia trachomatis* bacterium, which causes the infectious disease.

The epitope can be generated from knowledge of the amino acid and corresponding DNA sequences of the peptide or polypeptide, as well as from the nature of particular amino acids

(e.g., size, charge, etc.) and the codon dictionary, without undue experimentation. See, e.g., Ivan Roitt, *Essential Immunology*, 1988; Kendrew, *supra*; Janis Kuby, *Immunology*, 1992 e.g., pp. 79-81. Some guidelines in determining whether a protein will stimulate a response, include: Peptide length—preferably the peptide is about 8 or 9 amino acids long to fit into the MHC class I complex and about 13-25 amino acids long to fit into a class II MHC complex. This length is a minimum for the peptide to bind to the MHC complex. It is preferred for the peptides to be longer than these lengths because cells may cut peptides. The peptide may contain an appropriate anchor motif which will enable it to bind to the various class I or class II molecules with high enough specificity to generate an immune response (See Bocchia, M. *et al*, Specific Binding of Leukemia Oncogene Fusion Protein Pentides to HLA Class I Molecules, *Blood* 85:2680-2684; Englehard, VH, Structure of peptides associated with class I and class II MHC molecules *Ann. Rev. Immunol.* 12:181 (1994)). This can be done, without undue experimentation, by comparing the sequence of the protein of interest with published structures of peptides associated with the MHC molecules. Thus, the skilled artisan can ascertain an epitope of interest by comparing the protein sequence with sequences listed in the protein database.

T cell epitopes

Preferably, the antigen of the invention, in particular, the LcrE antigen(s) of the present invention comprises one or more T cell epitopes.

As used herein, the term "T cell epitope" refers generally to those features of a peptide structure which are capable of inducing a T cell response. In this regard, it is accepted in the art that T cell epitopes comprise linear peptide determinants that assume extended conformations within the peptide-binding cleft of MHC molecules (Unanue *et al.* (1987) *Science* 236: 551-557).

As used herein, a T cell epitope is generally a peptide having at least about 3-5 amino acid residues, preferably at least 5-10 or more consecutive amino acid residues, preferably at least 8-10 amino consecutive acid residues, preferably at least 10-14 consecutive amino acid residues, more preferably at least 9 consecutive amino acid residues.

However, as used herein, the term "T cell epitope" encompasses any MHC Class I-or MHC Class II restricted peptide. The ability of a particular T cell epitope to stimulate/enhance or alter a CMI response may be determined by a number of well-known assays, such as by

lymphoproliferation (lymphocyte activation) assays, CD8⁺ T-cell cytotoxic cell assays, or by assaying for T-lymphocytes specific for the epitope in a sensitized subject. See, e. g., Erickson *et al.* (1993) J. Immunol. 151: 4189-4199; and Doe *et al.* (1994) Eur. J. Immunol. 24: 2369-2376 or CD8⁺ T-cell ELISPOT assays for measuring Interferon gamma production (Miyahara *et al* PNAS(USA) (1998) 95: 3954-3959).

CD8⁺ T-cell epitopes.

Preferably the antigen of the invention, in particular the LcrE antigen(s) of the present invention comprise one or more CD8⁺ T-cell inducing epitopes. A CD8⁺ T-cell –inducing epitope is an epitope capable of stimulating the formation, or increasing the activity, or altering the activity of specific CD8⁺ T-cells following its administration to a host subject.

As used herein, a CD8⁺ T cell epitope is generally a peptide having at least about 3-5 amino acid residues, preferably at least 5-10 or more consecutive amino acid residues, preferably at least 8-10 consecutive amino acid residues, preferably at least 10-14 consecutive amino acid residues, more preferably at least 8 or at least 9 consecutive amino acid residues.

The CD8⁺ T-cell epitopes may be provided in a variety of different forms such as a recombinant string of one or two or more epitopes. CD8⁺ T-cell epitopes have been identified and can be found in the literature, for many different diseases. It is possible to design epitope strings to generate CD8⁺ T-cell response against any chosen antigen that contains such CD8⁺ T-cell epitopes. Advantageously, CD8⁺ T-cell inducing epitopes may be provided in a string of multiple epitopes which are linked together without intervening sequences so that unnecessary nucleic acid material is avoided.

T helper epitopes

Preferably the LcrE antigen(s) of the present invention comprise one or more helper T lymphocyte epitopes. Various methods are available to identify T helper cell epitopes suitable for use in accordance herewith. For example, the amphipathicity of a peptide sequence is known to affect its ability to function as a T helper cell inducer. A full discussion of T helper cell-inducing epitopes is given in U.S. Patent 5,128,319, incorporated herein by reference and in further discussion below.

As used herein, a helper (or CD4+) T cell epitope is generally a peptide having at least about 3-5 amino acid residues, preferably at least 5-10 or more consecutive amino acid residues, preferably at least 8-10 amino acid residues, preferably at least 9 consecutive amino acid residues. More preferably at least 10-14 consecutive amino acid residues.

Combination of Epitopes

Preferably the antigen of the invention, in particular, the LcrE antigen(s) of the present invention comprise a mixture of CD8+ T-cell epitopes and B cell epitopes. As used herein, the term "B cell epitope" generally refers to the site on an antigen to which a specific antibody molecule binds.

As used herein, a B cell epitope is generally a peptide having at least about 3-5 consecutive amino acid residues, preferably at least 5-10 or more consecutive amino acid residues, preferably at least 8-10 consecutive amino acid residues, preferably at least 10-14 consecutive amino acid residues, more preferably at least 8 or at least 9 consecutive amino acid residues.

The identification of epitopes which are able to elicit an antibody response is readily accomplished using techniques well known in the art. See, e. g., Geysen *et al.* (1984) Proc. Natl. Acad. Sci. USA 81: 3998-4002 (general method of rapidly synthesizing peptides to determine the location of immunogenic epitopes in a given antigen); U. S. Patent No. 4,708,871 (procedures for identifying and chemically synthesizing epitopes of antigens); and Geysen *et al.* (1986) Molecular Immunology 23: 709-715 (technique for identifying peptides with high affinity for a given antibody)

In a preferred embodiment of the present invention, the antigen of the invention, in particular, the LcrE antigen or LcrE antigen combination of the invention, comprises a mixture of a CD8+ T-cell -inducing epitopes and a T helper cell-inducing epitopes. As is well known in the art, T and B cell inducing epitopes are frequently distinct from each other and can comprise different peptide sequences. Therefore certain regions of a protein's peptide chain can possess either T cell or B cell epitopes. Therefore, in addition to the CD8+ T-cell epitopes, it may be preferable to include one or more epitopes recognised by T helper cells, to augment the immune response generated by the CD8+ T-cell epitopes.

Immunodominant epitope

When an individual is immunized with an antigen or combination of antigens or nucleotide sequence or combinations of nucleotide sequences encoding multiple epitopes of a target antigen, in many instances the majority of responding T lymphocytes will be specific for one or more linear epitopes from that target antigen and/or a majority of the responding B lymphocytes will be specific for one or more linear or conformational epitopes for the antigen or combination of antigens. For the purposes of the present invention, then, such epitopes are referred to as "immunodominant epitopes". In an antigen having several immunodominant epitopes, a single epitope may be the most dominant in terms of commanding a specific T and/or B cell response.

Peptides comprising T-cell and/or B cell epitopes of the invention

The invention provides polypeptides comprising an amino acid sequence selected from the group consisting of SEQ ID Nos 1-184.

The polypeptide is preferably less than 80 amino acids in length (e. g. less than 75, 70, 65, 60, 55, 50, 45, 40, 35, 30, 29, 28, 27, 26, 25, 24, 23, 22, 21, 20, 19, 18, 17, 16, 15, 14, 13, 12, 11, 10 etc.)

Some of the cell epitopes of the invention (eg SEQ ID Nos 181, 182, 183 and 184) have been identified as 9mers, but it is well-known that shorter peptides can interact with HLA molecules with high affinity and so the invention also provides a polypeptide comprising at least a 7 or 8 amino acid fragment of an amino acid sequence selected from the group consisting of SEQ IDs 1-184. The polypeptide is preferably less than 80 amino acids in length (e. g. less than 75, 70, 65, 60, 55, 50, 45, 40, 35, 30, 29, 28, 27, 26, 25, 24, 23, 22, 21, 20, 19, 18, 17, 16, 15, 14, 13, 12, 11 etc.). There are, for example, at least two 7mer fragments and at least one 8mer fragments set out in Table 2.

If desired, these 7mer and 8mer sequences can be used according to the invention.

Similarly, there are at least three 10mer fragments set out in Table 2. If desired, 10mer fragments can be used according to the invention.

Preferably the invention provides polypeptides comprising amino acid sequences selected from the group consisting of SEQ ID Nos 29-45.

Preferably the invention provides polypeptides comprising amino acid sequence selected from the group consisting of SEQ ID Nos 47-98.

Preferably, the invention provides polypeptides comprising amino acid sequence selected from the group consisting of SEQ ID Nos 99-184.

More preferably, the invention provides polypeptides comprising amino acid sequence selected from the group consisting of SEQ ID Nos 54, 109, 110 and 111.

Even more preferably the polypeptide comprises the sequence IKKKGEKFE (SEQ ID No 181) or IKKKEEKFE (SEQ ID No 182).

These 9mer and 15mer polypeptides are particularly advantageous as they comprise the N-terminal segment surrounding or associated with the first high frequency mutation point or hypervariable regions at residues 64 of the LcrE sequence from Serovar D (SEQ ID No 54) and from Serovar E (SEQ ID Nos 109, 110 and 111) and equivalent regions in other Serovar isolates as seen in the Serovar Sequence Alignment in Figure 2.

More preferably, the invention provides polypeptides comprising amino acid sequence selected from the group consisting of SEQ ID Nos 66, 129 and 130.

Even more preferably the polypeptide comprises the sequence KKKSTLIQA (SEQ ID No 183) or KKKSALIQA (SEQ ID No 184).

These 9mer or 15mer polypeptides are particularly advantageous as they comprise the hypervariable regions at residues 162 of the LcrE sequence from Serovar D (SEQ ID No 66) and from Serovar E (SEQ ID Nos 129 and 130) and equivalent regions in other Serovar isolates as seen in the Serovar Sequence Alignment in Figure 2.

Th1Th2 immune responses

As noted above, the peptides surrounding the amino acid substitutions in antigen sequences of the invention, such as the LcrE sequence, are likely to be epitopic regions (either B-cell epitopes

involved in Ab-Ag interactions and/or T-cell epitopes capable of eliciting *Chlamydia trachomatis* specific cell mediated immune responses, such as Th1 or Th2 cellular immune response. Preferably, the B-cell epitopes and/or the T-cell epitopes associated with these regions elicit an enhanced immune response either alone or in combination with other antigens and/or immunoregulatory agents.

As *Chlamydia trachomatis* infection is an intracellular infection, one of the currently accepted paradigms is that effective anti-*Chlamydial* immunisation would require both an adequate T-cell response and high serum levels of neutralising antibodies and that "an ideal vaccine should induce long lasting (neutralising) antibodies and a cell mediated immunity that can quickly respond upon exposure to *Chlamydia trachomatis*". Several sometimes contradictory studies have indicated that both CD4+ and CD 8 positive T cells have a role in *Chlamydia* clearance (Loomis and Starnback (2002) Curr Opin Microbiol 5: 87-91). Indeed, there now appears to be a prevailing consensus that specific CD4+ T cells and B cells are critical to the complete clearance of intracellular *Chlamydia trachomatis* and for mediating recall immunity to *Chlamydia trachomatis* infection (see Igietsme, Black and Caldwell (2002) Biodrugs 16: 19-35 and Igietsme *et al* (1999) Immunology 98: 510-519). However, even more recently, evidence has been advanced that a T cell vaccine could also be feasible, such as, for example, an immunogenic composition comprising one or more T cell epitopes (see for example, Webster *et al* (2005) PNAS 102 (13) 4836-4841).

T cell

The invention provides T cells which can bind to a T-cell epitope of the invention.

As used herein, term "T-cell" refers to lymphocyte cells which mature in the thymus and which express CD3 and a T-cell receptor. It includes naive cells, memory cells and effector cells.

The population of cells generated from T-cells which bind specifically to epitopes of the invention and which are activated by this interaction will be of two types: effector cells and memory cells. Effector cells are activated by epitopes of the invention to produce cytokines and kill infected cells. A proportion of effector cells can survive as memory cells. Memory cells are longer-lived and can be induced to generate new effector cell populations when the epitope is re-encountered, either by re-administration of epitopes of the invention or by infection by *Chlamydia*. The generation of memory and effector T-cell populations specific for epitopes of the invention may require the participation of helper T-cells which provide factors necessary for

their growth and differentiation (e. g. cytokines, such as interleukin-2). The activation of helper T-cells can be achieved through a number of standard approaches. For example the epitope of invention may be joined to one or more helper T-cell epitopes or a helper T-cell epitopes could be co-delivered (e. g. by a nucleic acid vector).

Two types of T cells, helper T cells (or CD4+ cells) and cytotoxic (or CD8+cells), are generally thought necessary to initiate and/or enhance cell mediated immunity and humoral immunity. Cytotoxic T-cells express a CD8 co-receptor and are commonly referred to as Cytotoxic T lymphocytes (CTLs) or CD8+ cells. Cytotoxic T-cells have a T-cell receptor which recognises a T-cell epitope when it is presented by a target cell in the context of a class I MHC protein thus resulting in the the lysis of a target cell which displays a T-cell epitope of the invention within a class I MHC molecule. The cytotoxic T-cell may be located *in vitro* or *in vivo*. Transfer of such a T-cell into a host may be used to transfer immunity ("adoptive immunotherapy"). Various methods can be used for obtaining and/or detecting T-cells of the invention.

CD4 T cells can express a CD4 co-receptor and are commonly referred to as T helper cells. CD4 T cells are able to recognize antigenic peptides bound to MHC class II molecules. Upon interaction with a MHC class II molecule, the CD4 cells can secrete factors such as cytokines. These secreted cytokines can activate B cells, cytotoxic T cells, macrophages, and other cells that participate in an immune response. Helper T cells or CD4+ cells can be further divided into two functionally distinct subsets: TH1 phenotype and TH2 phenotypes which differ in their cytokine and effector function.

Activated TH1 cells enhance cellular immunity (including an increase in antigen-specific CTL production) and are therefore of particular value in responding to intracellular infections. Activated TH1 cells may secrete one or more of IL-2, IFN-gamma, and TNF-beta. A TH1 immune response may result in local inflammatory reactions by activating macrophages, NK (natural killer) cells, and CD8 cytotoxic T cells (CTLs). A TH1 immune response may also act to expand the immune response by stimulating growth of B and T cells with IL-12. TH1 stimulated B cells may secrete IgG2a.

Activated TH2 cells enhance antibody production and are therefore of value in responding to extracellular infections. Activated TH2 cells may secrete one or more of IL-4, IL-5, IL-6, and IL-10. A TH2 immune response may result in the production of IgG1, IgE, IgA and memory B cells for future protection.

An immune response may include one or more of an TH1 immune response and a TH2 immune response.

A TH1 immune response may include one or more of an increase in CTLs, an increase in one or more of the cytokines associated with a TH1 immune response (such as IL-2, IFN-gamma, and TNF-beta), an increase in activated macrophages, an increase in NK activity, or an increase in the production of IgG2a. Preferably, the enhanced TH1 immune response will include an increase in IgG2a production.

A TH2 immune response may include one or more of an increase in one or more of the cytokines associated with a TH2 immune response (such as IL-4, IL-5, IL-6 and IL-10), or an increase in the production of IgG1, IgE, IgA and memory B cells. Preferably, the enhanced TH2 immune response will include an increase in IgG1 production.

The mechanism of eliciting a CD8+ T-cell induced response in vivo by T helper cell inducing agents is not completely clear. However, without being bound by theory, it is likely that the immune activating agent, by virtue of its ability to induce T helper cells, will result in increased levels of necessary cytokines that assist in the clonal expansion and dissemination of specific CD8+ T-cells. Regardless of the underlying mechanism, it is envisioned that the use of mixtures of helper T cell and CD8+ T-cell -inducing antigen combinations of the present invention will assist in eliciting the CMI response. Particularly suitable T helper cell epitopes are those which are active in individuals of different HLA types, for example T helper epitopes from tetanus (against which most individuals will already be primed). It may also be useful to include B cell epitopes for stimulating B cell responses and antibody production. Synthetic nucleotide sequences may also be constructed to produce two types of immune responses: T cell only and T cell combined with a B cell response.

Immunogenic compositions of the invention, in particular, immunogenic composition comprising one or more LcrE antigen(s) of the present invention may be used either alone or in combination with other LcrE antigen(s) and/or other *Chlamydia* antigens or other antigens associated with a sexually transmissible disease (STD) optionally with an immunoregulatory agent capable of eliciting a Th1 and/or Th2 response.

The invention also comprises an immunogenic composition comprising one or more immunoregulatory agent, such as a mineral salt, such as an aluminium salt and an oligonucleotide containing a CpG motif. Most preferably, the immunogenic composition includes both an aluminium salt and an oligonucleotide containing a CpG motif. Alternatively, the immunogenic composition includes an ADP ribosylating toxin, such as a detoxified ADP ribosylating toxin and an oligonucleotide containing a CpG motif. Preferably, one or more of the immunoregulatory agents include an adjuvant. The adjuvant may be selected from one or more of the group consisting of a TH1 adjuvant and TH2 adjuvant, further discussed below. The adjuvant may be selected from the group consisting

The compositions of the invention will preferably elicit both a cell mediated immune response as well as a humoral immune response in order to effectively address a *Chlamydia trachomatis* intracellular infection. This immune response will preferably induce long lasting (eg neutralising) antibodies and a cell mediated immunity that can quickly respond upon exposure to *Chlamydia trachomatis*.

As discussed further in the Examples, the use of the combination of a mineral salt, such as an aluminium salt, and an oligonucleotide containing a CpG motif can provide for an enhanced immune response. The achievement of an improved immune response using such a combination of immunoregulatory agents is wholly unexpected and could not be predicted from the use of either agent alone. The invention therefore includes an oligonucleotide containing a CpG motif, a mineral salt such as an aluminium salt, and an antigen associated with a sexually transmissible disease(STD), such as a *Chlamydia trachomatis* antigen, such as an LcrE antigen. Further examples of *Chlamydia* antigens, such as but not limited to CT242, CT381, CT396, CT398 and/or CT045 and/or an antigen associated with a sexually transmissible disease (STD) are discussed further below and in the Examples.

The invention also provides a composition of the invention for use as a medicament. The medicament is preferably able to raise an immune response in a mammal (*i.e.* it is an immunogenic composition) and is more preferably a vaccine. The invention also provides the use of the compositions of the invention in the manufacture of a medicament for raising an immune response in a mammal. The medicament is preferably a vaccine.

The immune response may be one or both of a TH1 immune response and a TH2 response. Preferably, immune response provides for one or both of an enhanced TH1 response and an enhanced TH2 response.

The immune response may be an improved or an enhanced or an altered immune response.

The immune response may be one or both of a systemic and a mucosal immune response. Preferably, the immune response provides for one or both of an enhanced or altered systemic and an enhanced or altered mucosal immune response. Preferably the mucosal immune response is a TH2 immune response. Preferably, the mucosal immune response includes an increase in the production of IgA.

The invention also provides for a kit comprising a first component comprising a combination of *Chlamydia trachomatis* antigens, in particular an LcrE antigen. The combination of *Chlamydia trachomatis* antigens may be one or more of the immunogenic compositions of the invention. The kit may further include a second component comprising one or more of the following: instructions, syringe or other delivery device, adjuvant, or pharmaceutically acceptable formulating solution.

The invention also provides a delivery device pre-filled with the immunogenic compositions of the invention.

The invention also provides a method for raising an immune response in a mammal comprising the step of administering an effective amount of a composition of the invention. The immune response is preferably protective and preferably involves antibodies and/or cell-mediated immunity. Preferably, the immune response includes one or both of a TH1 immune response and a TH2 immune response. The method may raise a booster response.

The mammal is preferably a human. Where the vaccine is for prophylactic use, the human is preferably a child (*e.g.* a toddler or infant) or a teenager; where the vaccine is for therapeutic use, the human is preferably a teenager or an adult. A vaccine intended for children may also be administered to adults *e.g.* to assess safety, dosage, immunogenicity, *etc.* Preferably, the human is a teenager. More preferably, the human is a pre-adolescent teenager. Even more preferably, the human is a pre-adolescent female or male. Preferably the pre-adolescent male or female is around 9-12 years of age. Preferably the adolescent male or female is around 15-19 years of age. Preferably the male or female is around 20-49 years of age. Preferably the male or female is over 49 years of age. Preferably the target patient profile is selected from the group consisting of homosexuals and sex workers (*eg* prostitutes).

Tests to determine the efficacy of the immune response

One way of assessing the immunogenicity of the component proteins of the immunogenic compositions of the present invention is to express the proteins recombinantly and to screen patient sera or mucosal secretions by immunoblot. A positive reaction between the protein and the patient serum indicates that the patient has previously mounted an immune response to the protein in question- that is, the protein is an immunogen. This method may also be used to identify immunodominant proteins and/or epitopes.

Another way of checking efficacy of therapeutic treatment involves monitoring *C.trachomatis* infection after administration of the compositions of the invention. One way of checking efficacy of prophylactic treatment involves monitoring immune responses both systemically (such as monitoring the level of IgG1 and IgG2a production) and mucosally (such as monitoring the level of IgA production) against the *Chlamydia trachomatis* antigens in the compositions of the invention after administration of the composition. Typically, serum *Chlamydia trachomatis* specific antibody responses are determined post-immunisation but pre-challenge whereas mucosal *Chlamydia trachomatis* specific antibody body responses are determined post-immunisation and post-challenge.

These uses and methods are preferably for the prevention and/or treatment of a disease caused by a *Chlamydia trachomatis* (*e.g.* trachoma, pelvic inflammatory disease, epididymitis, infant pneumonia, *etc.*). The compositions may also be effective against *C.pneumoniae*.

The vaccine compositions of the present invention can be evaluated in *in vitro* and *in vivo* animal models prior to host, e.g., human, administration. For example, *in vitro* neutralization by Peterson *et al* (1988) is suitable for testing vaccine compositions directed toward *Chlamydia trachomatis*.

One example of such an *in vitro* test is described as follows. Hyper-immune antisera is diluted in PBS containing 5% guinea pig serum, as a complement source. *Chlamydia trachomatis* (10^4 IFU; inclusion forming units) are added to the antisera dilutions. The antigen-antibody mixtures are incubated at 37°C for 45 minutes and inoculated into duplicate confluent Hep-2 or HeLa cell monolayers contained in glass vials (e.g., 15 by 45 mm), which have been washed twice with PBS prior to inoculation. The monolayer cells are infected by centrifugation at 1000X g for 1 hour followed by stationary incubation at 37°C for 1 hour. Infected monolayers are incubated for 48 or 72 hours, fixed and stained with *Chlamydia trachomatis* specific antibody, such as anti-MOMP. Inclusion-bearing cells are counted in ten fields at a magnification of 200X. Neutralization titer is assigned on the dilution that gives 50% inhibition as compared to control monolayers/IFU.

The efficacy of immunogenic compositions of the invention can also be determined *in vivo* by challenging animal models of *Chlamydia trachomatis* infection, e.g., guinea pigs or mice, with the immunogenic compositions. The immunogenic compositions may or may not be derived from the same serovars as the challenge serovars. Preferably the immunogenic compositions are derivable from the same serovars as the challenge serovars. More preferably, the immunogenic composition and/or the challenge serovar are derivable from the group of genital tract serovars consisting of D, E, F, H, I and K and/or combinations thereof. Even more preferably, the immunogenic composition and/or the challenge serovar are derivable from the group of genital tract serovars consisting of D, E, F and I. Even more preferably, the immunogenic composition and/or the challenge serovar are derivable from the group of genital tract serovars consisting of D, E and F. In women, the serotypes D and F have been associated with asymptomatic infection while serotype E has been associated with both symptomatic and asymptomatic infection. Other possible serovar generally associated with male infections include LGV serovars. The serovars of the present invention are obtainable from clinical isolates or from culture collections such as the American Tissue Culture Collection (ATCC).

In vivo efficacy models include but are not limited to: (i) A murine infection model using human *Chlamydia trachomatis* serotypes, such as serotypes D, E, F, H, I and K; (ii) a murine disease model which is a murine model using a mouse-adapted *Chlamydia trachomatis* strain, such as the *Chlamydia trachomatis* mouse pneumonitis (MoPn) strain also known as *Chlamydia muridarum*; and (iii) a primate model using human *Chlamydia trachomatis* isolates. The MoPn strain is a mouse pathogen while human *Chlamydia trachomatis* serotypes, such as serotypes D, E, F, H, I and K are human pathogens (see for example, Brunham et al (2000) J Infect Dis 181 (Suppl 3) S538-S543; Murdin et al (2000) J Infect Dis 181 (Suppl 3) S544-S551 and Read et al (2000) NAR 28(6); 1397-1406). As the Examples demonstrate, human *Chlamydia trachomatis* serotypes, such as serovar D can be used in mouse models although they normally require high inocula or pretreatment with progesterone. Progesterone is generally used because it seems to render the genital epithelium more susceptible to chlamydial infection (see Pal et al 2003 Vaccine 21: 1455-1465). On the other hand, MoPn, which was originally isolated from mouse tissues, is thought to be a natural murine pathogen and thus offers an evolutionarily adapted pathogen for analysis of host-pathogen interactions. Although the MoPn serovar is thought to have a high degree of DNA homology to the human *Chlamydia* serovars, it may also have some unique properties (see for example, Pal et al (2002) Infection and Immunity 70(9); 4812-4817).

By way of example, *in vivo* vaccine compositions challenge studies can be performed in the murine model of *Chlamydia trachomatis* (Morrison et al 1995). A description of one example of this type of approach is as follows. Female mice 7 to 12 weeks of age receive 2.5 mg of depoprovera subcutaneously at 10 and 3 days before vaginal infection. Post-vaccination, mice are infected in the genital tract with 1,500 inclusion-forming units of *Chlamydia trachomatis* contained in 5ml of sucrose-phosphate-glutamate buffer, pH 7.4. The course of infection is monitored by determining the percentage of inclusion-bearing cells by indirect immunofluorescence with *Chlamydia trachomatis* specific antisera, or by a Giemsa-stained smear from a scraping from the genital tract of an infected mouse. The presence of antibody titers in the serum of a mouse is determined by an enzyme-linked immunosorbent assay. The immunogenic compositions of the present invention can be administered using a number of different immunization routes such as but not limited to intra-muscularly (i.m.), intra-peritoneal (i.p.), intra-nasal (i.n.), sub-cutaneous (s.c) or transcutaneous (t.c) routes. Generally, any route of administration can be used provided that the desired immune response at the required mucosal

surface or surfaces is achieved. Likewise, the challenge serovars may be administered by a number of different routes. Typically, the challenge serovars are administered mucosally, such as but not limited to genital challenge or intra-nasal (i.n) challenge.

Alternative in-vivo efficacy models include guinea pig models. For example, *in vivo* vaccine composition challenge studies in the guinea pig model of *Chlamydia trachomatis* infection can be performed. A description of one example of this type of approach follows. Female guinea pigs weighing 450 – 500 g are housed in an environmentally controlled room with a 12 hour light-dark cycle and immunized with vaccine compositions via a variety of immunization routes. Post-vaccination, guinea pigs are infected in the genital tract with the agent of guinea pig inclusion conjunctivitis (GPIC), which has been grown in HeLa or McCoy cells (Rank et al. (1988)). Each animal receives approximately 1.4×10^7 inclusion forming units (IFU) contained in 0.05 ml of sucrose-phosphate-glutamate buffer, pH 7.4 (Schacter, 1980). The course of infection monitored by determining the percentage of inclusion-bearing cells by indirect immunofluorescence with GPIC specific antisera, or by Giemsa-stained smear from a scraping from the genital tract (Rank et al 1988). Antibody titers in the serum is determined by an enzyme-linked immunosorbent assay.

Alternatively, *in vivo* vaccine compositions challenge studies can be performed in the murine model of *Chlamydia trachomatis* (Morrison *et al* 1995). A description of one example of this type of approach is as follows. Female mice 7 to 12 weeks of age receive 2.5 mg of depoprovera subcutaneously at 10 and 3 days before vaginal infection. Post-vaccination, mice are infected in the genital tract with 1,500 inclusion-forming units of *Chlamydia trachomatis* contained in 5ml of sucrose-phosphate-glutamate buffer, pH 7.4. The course of infection is monitored by determining the percentage of inclusion-bearing cells by indirect immunofluorescence with *Chlamydia trachomatis* specific antisera, or by a Giemsa-stained smear from a scraping from the genital tract of an infected mouse. The presence of antibody titers in the serum of a mouse is determined by an enzyme-linked immunosorbent assay.

Epitope Mapping

Epitope mapping of serovar variants, such as, but not limited to the LcrE serovar variants is carried out as follows: A mouse model of genital tract infection as described in WO 05/002619 is used. All the serovar variants, such as the LcrE variants, are expressed as recombinant

proteins, methodology for which is also described in WO 05/002619. Mice are immunised with the recombinant LcrE variants (with and without *Chlamydia trachomatis* challenge). The spleen cells from immunised mice (with and without *Chlamydia trachomatis* challenge) are then isolated and pulsed with CT LcrE specific peptides (as set out in SEQ ID Nos 29-45 in Example 2, SEQ ID Nos 47-98 in Example 3 and SEQ ID Nos 99-180, 181, 182, 183 and/or 184 in Example 4). The spleen cell response to each of the CT LcrE specific peptides is then assessed in terms of the presence or absence of spleen cell proliferation, mediator response such as, for eg, Th1 or Th2 cell response as determined by various tests described above.

Compositions of the invention will generally be administered directly to a patient. Direct delivery may be accomplished by parenteral injection (*e.g.* subcutaneously, intraperitoneally, intravenously, intramuscularly, or to the interstitial space of a tissue), or mucosally, such as by rectal, oral (*e.g.* tablet, spray), vaginal, topical, transdermal (*See e.g.* WO99/27961) or transcutaneous (*See e.g.* WO02/074244 and WO02/064162), intranasal (*See e.g.* WO03/028760), ocular, aural, pulmonary or other mucosal administration.

The invention may be used to elicit systemic and/or mucosal immunity, preferably to elicit an enhanced systemic and/or mucosal immunity.

Preferably the enhanced systemic and/or mucosal immunity is reflected in an enhanced TH1 and/or TH2 immune response. Preferably, the enhanced immune response includes an increase in the production of IgG1 and/or IgG2a and/or IgA.

Dosage treatment can be a single dose schedule or a multiple dose schedule. Multiple doses may be used in a primary immunisation schedule and/or in a booster immunisation schedule. In a multiple dose schedule the various doses may be given by the same or different routes *e.g.* a parenteral prime and mucosal boost, a mucosal prime and parenteral boost, *etc.*

Chlamydia infections affect various areas of the body and so the compositions of the invention may be prepared in various forms. For example, the compositions may be prepared as injectables, either as liquid solutions or suspensions. Solid forms suitable for solution in, or suspension in, liquid vehicles prior to injection can also be prepared (*e.g.* a lyophilised composition or a spray-freeze dried composition). The composition may be prepared for topical

administration *e.g.* as an ointment, cream or powder. The composition may be prepared for oral administration *e.g.* as a tablet or capsule, as a spray, or as a syrup (optionally flavoured). The composition may be prepared for pulmonary administration *e.g.* as an inhaler, using a fine powder or a spray. The composition may be prepared as a suppository or pessary. The composition may be prepared for nasal, aural or ocular administration *e.g.* as drops. The composition may be in kit form, designed such that a combined composition is reconstituted just prior to administration to a patient. Such kits may comprise one or more antigens in liquid form and one or more lyophilised antigens.

Immunogenic compositions used as vaccines comprise an immunologically effective amount of antigen(s), as well as any other components, as needed. By 'immunologically effective amount', it is meant that the administration of that amount to an individual, either in a single dose or as part of a series, is effective for treatment or prevention. This amount varies depending upon the health and physical condition of the individual to be treated, age, the taxonomic group of individual to be treated (*e.g.* non-human primate, primate, *etc.*), the capacity of the individual's immune system to synthesise antibodies, the degree of protection desired, the formulation of the vaccine, the treating doctor's assessment of the medical situation, and other relevant factors. It is expected that the amount will fall in a relatively broad range that can be determined through routine trials.

Further components of the composition

The composition of the invention will typically, in addition to the components mentioned above, comprise one or more 'pharmaceutically acceptable carriers', which include any carrier that does not itself induce the production of antibodies harmful to the individual receiving the composition. Suitable carriers are typically large, slowly metabolised macromolecules such as proteins, polysaccharides, polylactic acids, polyglycolic acids, polymeric amino acids, amino acid copolymers, and lipid aggregates (such as oil droplets or liposomes). Such carriers are well known to those of ordinary skill in the art. The vaccines may also contain diluents, such as water, saline, glycerol, *etc.* Additionally, auxiliary substances, such as wetting or emulsifying agents, pH buffering substances, and the like, may be present. A thorough discussion of pharmaceutically acceptable excipients is available in reference 18.

Immunoregulatory Agents

Vaccines of the present invention may be administered in conjunction with other immunoregulatory agents. In particular, compositions will usually include an adjuvant. Adjuvants for use with the invention include, but are not limited to, one or more of the following set forth below:

A. Mineral Containing Compositions

Mineral containing compositions suitable for use as adjuvants in the invention include mineral salts, such as aluminum salts and calcium salts. The invention includes mineral salts such as hydroxides (*e.g.* oxyhydroxides), phosphates (*e.g.* hydroxyphosphates, orthophosphates), sulfates, *etc.* (*e.g.* see chapters 8 & 9 of *Vaccine Design...* (1995) eds. Powell & Newman. ISBN: 030644867X. Plenum.), or mixtures of different mineral compounds (*e.g.* a mixture of a phosphate and a hydroxide adjuvant, optionally with an excess of the phosphate), with the compounds taking any suitable form (*e.g.* gel, crystalline, amorphous, *etc.*), and with adsorption to the salt(s) being preferred. The mineral containing compositions may also be formulated as a particle of metal salt (WO00/23105).

Aluminum salts may be included in vaccines of the invention such that the dose of Al^{3+} is between 0.2 and 1.0 mg per dose.

Preferably the adjuvant is alum, preferably $Al(OH)_3$.

B. Oil-Emulsions

Oil-emulsion compositions suitable for use as adjuvants in the invention include squalene-water emulsions, such as MF59 (5% Squalene, 0.5% Tween 80, and 0.5% Span 85, formulated into submicron particles using a microfluidizer). See WO90/14837. See also, Frey *et al.*, "Comparison of the safety, tolerability, and immunogenicity of a MF59-adjuvanted influenza vaccine and a non-adjuvanted influenza vaccine in non-elderly adults", *Vaccine* (2003) 21:4234-4237. MF59 is used as the adjuvant in the FLUAD™ influenza virus trivalent subunit vaccine.

Particularly preferred adjuvants for use in the compositions are submicron oil-in-water emulsions. Preferred submicron oil-in-water emulsions for use herein are squalene/water emulsions optionally containing varying amounts of MTP-PE, such as a submicron oil-in-water emulsion containing 4-5% w/v squalene, 0.25-1.0% w/v Tween 80™ (polyoxyethylsorbitan monooleate), and/or 0.25-1.0% Span 85™ (sorbitan trioleate), and, optionally, N-acetylmuramyl-

L-alanyl-D-isoglutaminyl-L-alanine-2-(1'-2'-dipalmitoyl-*sn*-glycero-3-hydroxyphosphoryloxy)-ethylamine (MTP-PE), for example, the submicron oil-in-water emulsion known as "MF59" (International Publication No. WO90/14837; US Patent Nos. 6,299,884 and 6,451,325, incorporated herein by reference in their entireties; and Ott *et al.*, "MF59 -- Design and Evaluation of a Safe and Potent Adjuvant for Human Vaccines" in *Vaccine Design: The Subunit and Adjuvant Approach* (Powell, M.F. and Newman, M.J. eds.) Plenum Press, New York, 1995, pp. 277-296). MF59 contains 4-5% w/v Squalene (e.g. 4.3%), 0.25-0.5% w/v Tween 80™, and 0.5% w/v Span 85™ and optionally contains various amounts of MTP-PE, formulated into submicron particles using a microfluidizer such as Model 110Y microfluidizer (Microfluidics, Newton, MA). For example, MTP-PE may be present in an amount of about 0-500 µg/dose, more preferably 0-250 µg/dose and most preferably, 0-100 µg/dose. As used herein, the term "MF59-0" refers to the above submicron oil-in-water emulsion lacking MTP-PE, while the term MF59-MTP denotes a formulation that contains MTP-PE. For instance, "MF59-100" contains 100 µg MTP-PE per dose, and so on. MF69, another submicron oil-in-water emulsion for use herein, contains 4.3% w/v squalene, 0.25% w/v Tween 80™, and 0.75% w/v Span 85™ and optionally MTP-PE. Yet another submicron oil-in-water emulsion is MF75, also known as SAF, containing 10% squalene, 0.4% Tween 80™, 5% pluronic-blocked polymer L121, and thr-MDP, also microfluidized into a submicron emulsion. MF75-MTP denotes an MF75 formulation that includes MTP, such as from 100-400 µg MTP-PE per dose.

Submicron oil-in-water emulsions, methods of making the same and immunostimulating agents, such as muramyl peptides, for use in the compositions, are described in detail in International Publication No. WO90/14837 and US Patent Nos. 6,299,884 and 6,451,325, incorporated herein by reference in their entireties. Complete Freund's adjuvant (CFA) and incomplete Freund's adjuvant (IFA) may also be used as adjuvants in the invention.

C. Saponin Formulations

Saponin formulations, may also be used as adjuvants in the invention. Saponins are a heterologous group of sterol glycosides and triterpenoid glycosides that are found in the bark, leaves, stems, roots and even flowers of a wide range of plant species. Saponin from the bark of the *Quillaia saponaria* Molina tree have been widely studied as adjuvants. Saponin can also be commercially obtained from *Smilax ornata* (sarsapilla), *Gypsophilla paniculata* (brides veil),

and *Saponaria officianalis* (soap root). Saponin adjuvant formulations include purified formulations, such as QS21, as well as lipid formulations, such as ISCOMs.

Saponin compositions have been purified using High Performance Thin Layer Chromatography (HP-LC) and Reversed Phase High Performance Liquid Chromatography (RP-HPLC). Specific purified fractions using these techniques have been identified, including QS7, QS17, QS18, QS21, QH-A, QH-B and QH-C. Preferably, the saponin is QS21. A method of production of QS21 is disclosed in US Patent No. 5,057,540. Saponin formulations may also comprise a sterol, such as cholesterol (see WO96/33739).

Combinations of saponins and cholesterol can be used to form unique particles called Immunostimulating Complexs (ISCOMs). ISCOMs typically also include a phospholipid such as phosphatidylethanolamine or phosphatidylcholine. Any known saponin can be used in ISCOMs. Preferably, the ISCOM includes one or more of Quil A, QHA and QHC. ISCOMs are further described in EP0109942, WO96/11711 and WO96/33739. Optionally, the ISCOMS may be devoid of additional detergent. See WO00/07621.

A review of the development of saponin based adjuvants can be found at Barr, *et al.*, "ISCOMs and other saponin based adjuvants", *Advanced Drug Delivery Reviews* (1998) 32:247-271. See also Sjolander, *et al.*, "Uptake and adjuvant activity of orally delivered saponin and ISCOM vaccines", *Advanced Drug Delivery Reviews* (1998) 32:321-338.

D. *Virosomes and Virus Like Particles (VLPs)*

Virosomes and Virus Like Particles (VLPs) can also be used as adjuvants in the invention. These structures generally contain one or more proteins from a virus optionally combined or formulated with a phospholipid. They are generally non-pathogenic, non-replicating and generally do not contain any of the native viral genome. The viral proteins may be recombinantly produced or isolated from whole viruses. These viral proteins suitable for use in virosomes or VLPs include proteins derived from influenza virus (such as HA or NA), Hepatitis B virus (such as core or capsid proteins), Hepatitis E virus, measles virus, Sindbis virus, Rotavirus, Foot-and-Mouth Disease virus, Retrovirus, Norwalk virus, human Papilloma virus, HIV, RNA-phages, Q β -phage (such as coat proteins), GA-phage, fr-phage, AP205 phage, and Ty (such as retrotransposon Ty protein p1). VLPs are discussed further in WO03/024480, WO03/024481, and Niikura *et al.*, "Chimeric Recombinant Hepatitis E Virus-Like Particles as an Oral Vaccine Vehicle Presenting Foreign Epitopes", *Virology* (2002) 293:273-280; Lenz *et al.*, "Papillomavirus-Like Particles Induce Acute Activation of Dendritic Cells", *Journal of Immunology* (2001) 5246-5355; Pinto,

et al., “Cellular Immune Responses to Human Papillomavirus (HPV)-16 L1 Healthy Volunteers Immunized with Recombinant HPV-16 L1 Virus-Like Particles”, *Journal of Infectious Diseases* (2003) 188:327-338; and Gerber *et al.*, “Human Papillomavirus Virus-Like Particles Are Efficient Oral Immunogens when Coadministered with *Escherichia coli* Heat-Labile Enterotoxin Mutant R192G or CpG”, *Journal of Virology* (2001) 75(10):4752-4760. Virosomes are discussed further in, for example, Gluck *et al.*, “New Technology Platforms in the Development of Vaccines for the Future”, *Vaccine* (2002) 20:B10 –B16. Immunopotentiating reconstituted influenza virosomes (IRIV) are used as the subunit antigen delivery system in the intranasal trivalent INFLEXAL™ product {Mischler & Metcalfe (2002) *Vaccine* 20 Suppl 5:B17-23} and the INFLUVAC PLUS™ product.

E. *Bacterial or Microbial Derivatives*

Adjuvants suitable for use in the invention include bacterial or microbial derivatives such as:

(1) *Non-toxic derivatives of enterobacterial lipopolysaccharide (LPS)*

Such derivatives include Monophosphoryl lipid A (MPL) and 3-O-deacylated MPL (3dMPL). 3dMPL is a mixture of 3 De-O-acylated monophosphoryl lipid A with 4, 5 or 6 acylated chains. A preferred “small particle” form of 3 De-O-acylated monophosphoryl lipid A is disclosed in EP 0 689 454. Such “small particles” of 3dMPL are small enough to be sterile filtered through a 0.22 micron membrane (see EP 0 689 454). Other non-toxic LPS derivatives include monophosphoryl lipid A mimics, such as aminoalkyl glucosaminide phosphate derivatives *e.g.* RC-529. See Johnson *et al.* (1999) *Bioorg Med Chem Lett* 9:2273-2278.

(2) *Lipid A Derivatives*

Lipid A derivatives include derivatives of lipid A from *Escherichia coli* such as OM-174. OM-174 is described for example in Meraldi *et al.*, “OM-174, a New Adjuvant with a Potential for Human Use, Induces a Protective Response with Administered with the Synthetic C-Terminal Fragment 242-310 from the circumsporozoite protein of *Plasmodium berghei*”, *Vaccine* (2003) 21:2485-2491; and Pajak, *et al.*, “The Adjuvant OM-174 induces both the migration and maturation of murine dendritic cells in vivo”, *Vaccine* (2003) 21:836-842.

(3) *Immunostimulatory oligonucleotides*

Immunostimulatory oligonucleotides suitable for use as adjuvants in the invention include nucleotide sequences containing a CpG motif (a sequence containing an unmethylated cytosine followed by guanosine and linked by a phosphate bond). Bacterial double stranded RNA or

oligonucleotides containing palindromic 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 analogue such as 2'-deoxy-7-deazaguanosine. See Kandimalla, *et al.*, "Divergent synthetic nucleotide motif recognition pattern: design and development of potent immunomodulatory oligodeoxyribonucleotide agents with distinct cytokine induction profiles", *Nucleic Acids Research* (2003) 31(9): 2393-2400; WO02/26757 and WO99/62923 for examples of possible analogue substitutions. The adjuvant effect of CpG oligonucleotides is further discussed in Krieg, "CpG motifs: the active ingredient in bacterial extracts?", *Nature Medicine* (2003) 9(7): 831-835; McCluskie, *et al.*, "Parenteral and mucosal prime-boost immunization strategies in mice with hepatitis B surface antigen and CpG DNA", *FEMS Immunology and Medical Microbiology* (2002) 32:179-185; WO98/40100; US Patent No. 6,207,646; US Patent No. 6,239,116 and US Patent No. 6,429,199.

The CpG sequence may be directed to TLR9, such as the motif GTCGTT or TTCGTT. See Kandimalla, *et al.*, "Toll-like receptor 9: modulation of recognition and cytokine induction by novel synthetic CpG DNAs", *Biochemical Society Transactions* (2003) 31 (part 3): 654-658. 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 Blackwell, *et al.*, "CpG-A-Induced Monocyte IFN-gamma-Inducible Protein-10 Production is Regulated by Plasmacytoid Dendritic Cell Derived IFN-alpha", *J. Immunol.* (2003) 170(8):4061-4068; Krieg, "From A to Z on CpG", *TRENDS in Immunology* (2002) 23(2): 64-65 and WO01/95935. Preferably, the CpG is a CpG-A ODN.

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, Kandimalla, *et al.*, "Secondary structures in CpG oligonucleotides affect immunostimulatory activity", *BBRC* (2003) 306:948-953; Kandimalla, *et al.*, "Toll-like receptor 9: modulation of recognition and cytokine induction by novel synthetic CpG DNAs", *Biochemical Society Transactions* (2003) 31(part 3):664-658; Bhagat *et al.*, "CpG penta- and hexadeoxyribonucleotides as potent immunomodulatory agents" *BBRC* (2003) 300:853-861 and WO03/035836.

Preferably the adjuvant is CpG. Even more preferably, the adjuvant is Alum and CpG or AlOH and CpG.

(4) *ADP-ribosylating toxins and detoxified derivatives thereof.*

Bacterial ADP-ribosylating toxins and detoxified derivatives thereof may be used as adjuvants in the invention. Preferably, the protein is derived from *E. coli* (i.e., *E. coli* heat labile enterotoxin "LT), cholera ("CT"), or pertussis ("PT"). The use of detoxified ADP-ribosylating toxins as mucosal adjuvants is described in WO95/17211 and as parenteral adjuvants in WO98/42375. Preferably, the adjuvant is a detoxified LT mutant such as LT-K63, LT-R72, and LTR192G. The use of ADP-ribosylating toxins and detoxified derivatives thereof, particularly LT-K63 and LT-R72, as adjuvants can be found in the following references, each of which is specifically incorporated by reference herein in their entirety: Beignon, *et al.*, "The LTR72 Mutant of Heat-Labile Enterotoxin of Escherichia coli Enhances the Ability of Peptide Antigens to Elicit CD4+ T Cells and Secrete Gamma Interferon after Coapplication onto Bare Skin", *Infection and Immunity* (2002) 70(6):3012-3019; Pizza, *et al.*, "Mucosal vaccines: non toxic derivatives of LT and CT as mucosal adjuvants", *Vaccine* (2001) 19:2534-2541; Pizza, *et al.*, "LTK63 and LTR72, two mucosal adjuvants ready for clinical trials" *Int. J. Med. Microbiol* (2000) 290(4-5):455-461; Scharton-Kersten *et al.*, "Transcutaneous Immunization with Bacterial ADP-Ribosylating Exotoxins, Subunits and Unrelated Adjuvants", *Infection and Immunity* (2000) 68(9):5306-5313; Ryan *et al.*, "Mutants of Escherichia coli Heat-Labile Toxin Act as Effective Mucosal Adjuvants for Nasal Delivery of an Acellular Pertussis Vaccine: Differential Effects of the Nontoxic AB Complex and Enzyme Activity on Th1 and Th2 Cells" *Infection and Immunity* (1999) 67(12):6270-6280; Partidos *et al.*, "Heat-labile enterotoxin of Escherichia coli and its site-directed mutant LTK63 enhance the proliferative and cytotoxic T-cell responses to intranasally co-immunized synthetic peptides", *Immunol. Lett.* (1999) 67(3):209-216; Peppoloni *et al.*, "Mutants of the Escherichia coli heat-labile enterotoxin as safe and strong adjuvants for intranasal delivery of vaccines", *Vaccines* (2003) 2(2):285-293; and Pine *et al.*, (2002) "Intranasal immunization with influenza vaccine and a detoxified mutant of heat labile enterotoxin from Escherichia coli (LTK63)" *J. Control Release* (2002) 85(1-3):263-270. Numerical reference for amino acid substitutions is preferably based on the alignments of the A and B subunits of ADP-ribosylating toxins set forth in Domenighini *et al.*, *Mol. Microbiol* (1995) 15(6):1165-1167, specifically incorporated herein by reference in its entirety.

Preferably the adjuvant is LTK63. Preferably the adjuvant is LTK72.

F. *Bioadhesives and Mucoadhesives*

Bioadhesives and mucoadhesives may also be used as adjuvants in the invention. Suitable bioadhesives include esterified hyaluronic acid microspheres (Singh *et al.* (2001) *J. Cont. Rele.* 70:267-276) or mucoadhesives such as cross-linked derivatives of poly(acrylic acid), polyvinyl alcohol, polyvinyl pyrrolidone, polysaccharides and carboxymethylcellulose. Chitosan and derivatives thereof may also be used as adjuvants in the invention. E.g. WO99/27960.

G. *Microparticles*

Microparticles may also be used as adjuvants in the invention. Microparticles (*i.e.* a particle of ~100nm to ~150µm in diameter, more preferably ~200nm to ~30µm in diameter, and most preferably ~500nm to ~10µm in diameter) formed from materials that are biodegradable and non-toxic (*e.g.* a poly(α-hydroxy acid), a polyhydroxybutyric acid, a polyorthoester, a polyanhydride, a polycaprolactone, *etc.*), with poly(lactide-co-glycolide) are preferred, optionally treated to have a negatively-charged surface (*e.g.* with SDS) or a positively-charged surface (*e.g.* with a cationic detergent, such as CTAB).

H. *Liposomes*

Examples of liposome formulations suitable for use as adjuvants are described in US Patent No. 6,090,406, US Patent No. 5,916,588, and EP 0 626 169.

L. *Polyoxyethylene ether and Polyoxyethylene Ester Formulations*

Adjuvants suitable for use in the invention include polyoxyethylene ethers and polyoxyethylene esters. WO99/52549. Such formulations further include polyoxyethylene sorbitan ester surfactants in combination with an octoxynol (WO01/21207) as well as polyoxyethylene alkyl ethers or ester surfactants in combination with at least one additional non-ionic surfactant such as an octoxynol (WO01/21152).

Preferred polyoxyethylene ethers are selected from the following group: polyoxyethylene-9-lauryl ether (laureth 9), polyoxyethylene-9-stearyl ether, polyoxyethylene-8-stearyl ether, polyoxyethylene-4-lauryl ether, polyoxyethylene-35-lauryl ether, and polyoxyethylene-23-lauryl ether.

J. Polyphosphazene (PCPP)

PCPP formulations are described, for example, in Andrianov *et al.*, "Preparation of hydrogel microspheres by coacervation of aqueous polyphosphazene solutions", *Biomaterials* (1998) 19(1-3):109-115 and Payne *et al.*, "Protein Release from Polyphosphazene Matrices", *Adv. Drug. Delivery Review* (1998) 31(3):185-196.

K. Muramyl peptides

Examples of muramyl peptides suitable for use as adjuvants in the invention include N-acetyl-muramyl-L-threonyl-D-isoglutamine (thr-MDP), N-acetyl-normuramyl-l-alanyl-d-isoglutamine (nor-MDP), and N-acetylmuramyl-l-alanyl-d-isoglutaminyl-l-alanine-2-(1'-2'-dipalmitoyl-sn-glycero-3-hydroxyphosphoryloxy)-ethylamine MTP-PE).

L. Imidazoquinolone Compounds.

Examples of imidazoquinolone compounds suitable for use as adjuvants in the invention include Imiquimod and its homologues, described further in Stanley, "Imiquimod and the imidazoquinolones: mechanism of action and therapeutic potential" *Clin Exp Dermatol* (2002) 27(7):571-577 and Jones, "Resiquimod 3M", *Curr Opin Investig Drugs* (2003) 4(2):214-218.

The invention may also comprise combinations of aspects of one or more of the adjuvants identified above. For example, the following adjuvant compositions may be used in the invention:

- (1) a saponin and an oil-in-water emulsion (WO99/11241);
- (2) a saponin (e.g., QS21) + a non-toxic LPS derivative (e.g. 3dMPL) (see WO94/00153);
- (3) a saponin (e.g., QS21) + a non-toxic LPS derivative (e.g. 3dMPL) + a cholesterol;
- (4) a saponin (e.g. QS21) + 3dMPL + IL-12 (optionally + a sterol) (WO98/57659);
- (5) combinations of 3dMPL with, for example, QS21 and/or oil-in-water emulsions (See European patent applications 0835318, 0735898 and 0761231);
- (6) SAF, containing 10% Squalane, 0.4% Tween 80, 5% pluronic-block polymer L121, and thr-MDP, either microfluidized into a submicron emulsion or vortexed to generate a larger particle size emulsion.
- (7) RibiTM adjuvant system (RAS), (Ribi Immunochem) containing 2% Squalene, 0.2% Tween 80, and one or more bacterial cell wall components from the group consisting of monophosphorylipid A (MPL), trehalose dimycolate (TDM), and cell wall skeleton (CWS), preferably MPL + CWS (DetoxTM); and

(8) one or more mineral salts (such as an aluminum salt) + a non-toxic derivative of LPS (such as 3dPML).

Aluminum salts and MF59 are preferred adjuvants for use with injectable influenza vaccines. Bacterial toxins and bioadhesives are preferred adjuvants for use with mucosally-delivered vaccines, such as nasal vaccines.

M. Human Immunomodulators

Human immunomodulators suitable for use as adjuvants in the invention include cytokines, such as interleukins (*e.g.* IL-1, IL-2, IL-4, IL-5, IL-6, IL-7, IL-12, *etc.*), interferons (*e.g.* interferon- γ), macrophage colony stimulating factor, and tumor necrosis factor.

Fusion proteins

The *Chlamydia trachomatis* antigens used in the invention may be present in the composition as individual separate polypeptides. Generally, the recombinant fusion proteins of the present invention are prepared as a GST-fusion protein and/or a His-tagged fusion protein.

However, preferably, at least two (*i.e.* 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19 or 20) of the antigens are expressed as a single polypeptide chain (a 'hybrid' polypeptide). Hybrid polypeptides offer two principal advantages: first, a polypeptide that may be unstable or poorly expressed on its own can be assisted by adding a suitable hybrid partner that overcomes the problem; second, commercial manufacture is simplified as only one expression and purification need be employed in order to produce two polypeptides which are both antigenically useful.

In the context of the following discussions, reference will be made to Serovar E as a first serovar group, Serovar D as a second serovar group, Serovar K as a third serovar group, Serovar F as a fourth serovar group, Serovar G as a fifth serovar group, Serovar H as a sixth serovar group, Serovar I as a seventh serovar group, and Serovar J as an eighth serovar group.

The hybrid polypeptide may comprise two or more polypeptide sequences from the first serovar group. Accordingly, the invention includes a composition comprising a first amino acid sequence and a second amino acid sequence, wherein said first and second amino acid sequences are selected from a *Chlamydia trachomatis* antigen or a fragment thereof, such as an LcrE antigen, of the first serovar group. Preferably, the first and second amino acid sequences in the hybrid polypeptide comprise different epitopes.

The hybrid polypeptide may comprise two or more polypeptide sequences from the second serovar group. Accordingly, the invention includes a composition comprising a first amino acid sequence and a second amino acid sequence, wherein said first and second amino acid sequences are selected from a *Chlamydia trachomatis* antigen or a fragment thereof, such as the LcrE antigen, of the second serovar group. Preferably, the first and second amino acid sequences in the hybrid polypeptide comprise difference epitopes.

The hybrid polypeptide may comprise one or more polypeptide sequences from the first serovar group and one or more polypeptide sequences from the second serovar group. Accordingly, the invention includes a composition comprising a first amino acid sequence and a second amino acid sequence, said first amino acid sequence selected from a *Chlamydia trachomatis* antigen or a fragment thereof, such as the LcrE antigen, from the first serovar group and said second amino acid sequence selected from a *Chlamydia trachomatis* antigen or a fragment thereof, such as the LcrE antigen, from the second serovar group. Preferably, the first and second amino acid sequences in the hybrid polypeptide comprise difference epitopes.

The hybrid polypeptide may comprise one or more the antigens of the invention, such as the LcrE polypeptide sequence(s) from across the *Chlamydia trachomatis* serovars. Accordingly, the invention includes a composition comprising a first LcrE amino acid sequence and a second LcrE amino acid sequence, said first amino acid sequence selected from an LcrE *Chlamydia trachomatis* antigen or a fragment thereof from the *Chlamydia trachomatis* Serovar E and said second amino acid sequence selected from a *Chlamydia trachomatis* antigen or a fragment thereof from *Chlamydia trachomatis* Serovar D. Preferably, the first and second amino acid sequences in the hybrid polypeptide comprise difference epitopes.

Hybrids consisting of amino acid sequences from two, three, four, five, six, seven, eight, nine, or ten LcrE *Chlamydia trachomatis* antigens are preferred. In particular, hybrids consisting of amino acid sequences from two, three, four, or five LcrE *Chlamydia trachomatis* antigens are preferred.

Different hybrid polypeptides may be mixed together in a single formulation. Within such combinations, a *Chlamydia trachomatis* antigen may be present in more than one hybrid

polypeptide and/or as a non-hybrid polypeptide. It is preferred, however, that an antigen is present either as a hybrid or as a non-hybrid, but not as both.

Hybrid polypeptides can be represented by the formula $\text{NH}_2\text{-A-}\{-\text{X-L-}\}_n\text{-B-COOH}$, wherein: X is an amino acid sequence of a *Chlamydia trachomatis* antigen or a fragment thereof from the first serovar group, the second serovar group or the third serovar group; L is an optional linker amino acid sequence; A is an optional N-terminal amino acid sequence; B is an optional C-terminal amino acid sequence; and n is 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14 or 15.

If a -X- moiety has a leader peptide sequence in its wild-type form, this may be included or omitted in the hybrid protein. In some embodiments, the leader peptides will be deleted except for that of the -X- moiety located at the N-terminus of the hybrid protein *i.e.* the leader peptide of X_1 will be retained, but the leader peptides of $\text{X}_2 \dots \text{X}_n$ will be omitted. This is equivalent to deleting all leader peptides and using the leader peptide of X_1 as moiety -A-.

For each n instances of $\{-\text{X-L-}\}$, linker amino acid sequence -L- may be present or absent. For instance, when $n=2$ the hybrid may be $\text{NH}_2\text{-X}_1\text{-L}_1\text{-X}_2\text{-L}_2\text{-COOH}$, $\text{NH}_2\text{-X}_1\text{-X}_2\text{-COOH}$, $\text{NH}_2\text{-X}_1\text{-L}_1\text{-X}_2\text{-COOH}$, $\text{NH}_2\text{-X}_1\text{-X}_2\text{-L}_2\text{-COOH}$, *etc.* Linker amino acid sequence(s) -L- will typically be short (*e.g.* 20 or fewer amino acids *i.e.* 19, 18, 17, 16, 15, 14, 13, 12, 11, 10, 9, 8, 7, 6, 5, 4, 3, 2, 1). Examples comprise short peptide sequences which facilitate cloning, poly-glycine linkers (*i.e.* comprising Gly_n where $n = 2, 3, 4, 5, 6, 7, 8, 9, 10$ or more), and histidine tags (*i.e.* His_n where $n = 3, 4, 5, 6, 7, 8, 9, 10$ or more). Other suitable linker amino acid sequences will be apparent to those skilled in the art. A useful linker is GSGGGG (SEQ ID 1), with the Gly-Ser dipeptide being formed from a *Bam*HI restriction site, thus aiding cloning and manipulation, and the $(\text{Gly})_4$ tetrapeptide being a typical poly-glycine linker.

-A- is an optional N-terminal amino acid sequence. This will typically be short (*e.g.* 40 or fewer amino acids *i.e.* 39, 38, 37, 36, 35, 34, 33, 32, 31, 30, 29, 28, 27, 26, 25, 24, 23, 22, 21, 20, 19, 18, 17, 16, 15, 14, 13, 12, 11, 10, 9, 8, 7, 6, 5, 4, 3, 2, 1). Examples include leader sequences to direct protein trafficking, or short peptide sequences which facilitate cloning or purification (*e.g.* histidine tags *i.e.* His_n where $n = 3, 4, 5, 6, 7, 8, 9, 10$ or more). Other suitable N-terminal amino acid sequences will be apparent to those skilled in the art. If X_1 lacks its own N-terminus

methionine, -A- is preferably an oligopeptide (*e.g.* with 1, 2, 3, 4, 5, 6, 7 or 8 amino acids) which provides a N-terminus methionine.

-B- is an optional C-terminal amino acid sequence. This will typically be short (*e.g.* 40 or fewer amino acids *i.e.* 39, 38, 37, 36, 35, 34, 33, 32, 31, 30, 29, 28, 27, 26, 25, 24, 23, 22, 21, 20, 19, 18, 17, 16, 15, 14, 13, 12, 11, 10, 9, 8, 7, 6, 5, 4, 3, 2, 1). Examples include sequences to direct protein trafficking, short peptide sequences which facilitate cloning or purification (*e.g.* comprising histidine tags *i.e.* His_{*n*} where *n* = 3, 4, 5, 6, 7, 8, 9, 10 or more), or sequences which enhance protein stability. Other suitable C-terminal amino acid sequences will be apparent to those skilled in the art. Most preferably, *n* is 2 or 3.

The invention also provides nucleic acid encoding hybrid polypeptides of the invention. Furthermore, the invention provides nucleic acid which can hybridise to this nucleic acid, preferably under "high stringency" conditions (*e.g.* 65°C in a 0.1xSSC, 0.5% SDS solution).

Polypeptides of the invention can be prepared by various means (*e.g.* recombinant expression, purification from cell culture, chemical synthesis, *etc.*) and in various forms (*e.g.* native, fusions, non-glycosylated, lipidated, *etc.*). They are preferably prepared in substantially pure form (*i.e.* substantially free from other *Chlamydial* or host cell proteins).

Nucleic acid according to the invention can be prepared in many ways (*e.g.* by chemical synthesis, from genomic or cDNA libraries, from the organism itself, *etc.*) and can take various forms (*e.g.* single stranded, double stranded, vectors, probes, *etc.*). They are preferably prepared in substantially pure form (*i.e.* substantially free from other *Chlamydial* or host cell nucleic acids).

The term "nucleic acid" includes DNA and RNA, and also their analogues, such as those containing modified backbones (*e.g.* phosphorothioates, *etc.*), and also peptide nucleic acids (PNA), *etc.* The invention includes nucleic acid comprising sequences complementary to those described above (*e.g.* for antisense or probing purposes).

Processes for making products of the invention

The invention also provides a process for producing a polypeptide of the invention, comprising the step of culturing a host cell transformed with nucleic acid of the invention under conditions which induce polypeptide expression.

The invention provides a process for producing a polypeptide of the invention, comprising the step of synthesising at least part of the polypeptide by chemical means.

The invention provides a process for producing nucleic acid of the invention, wherein the nucleic acid is prepared (at least in part) by chemical synthesis.

The invention provides a process for producing nucleic acid of the invention, comprising the step of amplifying nucleic acid using a primer-based amplification method (*e.g.* PCR).

The invention provides a process for producing a protein complex of the invention, comprising the step of contacting a class I MHC protein with a polypeptide of the invention, or a fragment thereof.

The invention provides a process for producing a protein complex of the invention, comprising the step administering a polypeptide of the invention, or a fragment thereof, to a subject. The process may comprise the further step of purifying the complex from the subject.

The invention provides a process for producing a composition comprising admixing a polypeptide and/or a nucleic acid of the invention with a pharmaceutically acceptable carrier or diluent.

General features of polypeptides of the invention

Polypeptides of the invention can be prepared in various forms (*e. g.* native, fusions, glycosylated, non-glycosylated *etc.*).

Polypeptides of the invention may be attached to a solid support.

Polypeptides of the invention may comprise a detectable label (*e. g.* a radioactive or fluorescent label, or a biotin label).

polypeptides of the invention may comprise B cell epitopes in addition to T-cell epitopes.

Strains

Preferred polypeptides of the invention comprise an LcrE amino acid sequence found in *C. trachomatis* serovar E, or in one or more of an epidemiologically prevalent serotype.

Preferred polypeptides of the invention comprise an LcrE amino acid sequence found in *C. trachomatis* serovar D, or in one or more of an epidemiologically prevalent serotype

Preferred polypeptides of the invention comprise an LcrE amino acid sequence found in *C. trachomatis* serovar K, or in one or more of an epidemiologically prevalent serotype

Where hybrid polypeptides are used, the individual antigens within the hybrid (*i.e.* individual -X-moieties) may be from one or more strains. Where $n=2$, for instance, X_2 may be from the same strain as X_1 or from a different strain. Where $n=3$, the strains might be (i) $X_1=X_2=X_3$ (ii) $X_1=X_2 \neq X_3$ (iii) $X_1 \neq X_2 = X_3$ (iv) $X_1 \neq X_2 \neq X_3$ or (v) $X_1=X_3 \neq X_2$, *etc.*

Heterologous host

Whilst expression of the polypeptides of the invention may take place in *Chlamydia trachomatis*, the invention preferably utilises a heterologous host. The heterologous host may be prokaryotic (*e.g.* a bacterium) or eukaryotic. It is preferably *E. coli*, but other suitable hosts include *Bacillus subtilis*, *Vibrio cholerae*, *Salmonella typhi*, *Salmonella typhimurium*, *Neisseria lactamica*, *Neisseria cinerea*, *Mycobacteria* (*e.g.* *M. tuberculosis*), yeasts, *etc.*

Immunogenic compositions and medicaments

Compositions of the invention are preferably immunogenic compositions, and are more preferably vaccine compositions. The pH of the composition is preferably between 6 and 8, preferably about 7. The pH may be maintained by the use of a buffer. The composition may be sterile and/or pyrogen-free. The composition may be isotonic with respect to humans.

Vaccines according to the invention may either be prophylactic (*i.e.* to prevent infection) or therapeutic (*i.e.* to treat infection), but will typically be prophylactic. Accordingly, the invention includes a method for the therapeutic or prophylactic treatment of *Chlamydia trachomatis*

infection in an animal susceptible to *Chlamydial* infection comprising administering to said animal a therapeutic or prophylactic amount of the immunogenic compositions of the invention. Preferably, the immunogenic composition comprises a combination of *Chlamydia trachomatis* variant mutations said combination selected from the group consisting of two, three, four, five, six, seven or all eighth *Chlamydia trachomatis* LcrE antigen mutations found across the different *Chlamydia trachomatis* serovars. Still more preferably, the combination consists of all eight *Chlamydia trachomatis* LcrE antigen variant or mutations found across the different *Chlamydia trachomatis* serovars.

By way of example, a composition of the present invention may include a combination of *Chlamydia trachomatis trachomatis* antigens, said combination comprising at least one LcrE antigen selected from the group consisting of: (1) Genome GO/86; (2) Genome Cev-1; (3) Genome Cev2; (4) Genome Cev4; (5) Genome Cev5; (5) Genome Cev8; (6) Genome ATTC-E; (7) Genome ATTC-F; (8) Genome ATTC-G; (9) Genome ATTC-H; (10) Genome ATTC-I, (11) Genome ATTC-J and (12) Genome ATTC-K. The combination may further be combined with an immunoregulatory agent or agents, such as Alum and CpG or AIOH and CpG. The compositions of the invention may further comprise antigens derived from one or more sexually transmitted diseases in addition to *Chlamydia trachomatis trachomatis*. Preferably the antigen is derived from one or more of the following sexually transmitted diseases, for example, *N.gonorrhoeae*, human papilloma virus, *Treponema pallidum*, herpes simplex virus (HSV-1 or HSV-2), HIV (HIV-1 or HIV-2), or *Haemophilus ducreyi*.

In one preferred embodiment, the present invention provides immunogenic compositions that may cover the range of mutations for an antigen, such as *Chlamydia trachomatis* LcrE across the serovars rather than tailoring the immunogenic composition to a specific mutation. For example, a *Chlamydia trachomatis* LcrE Serovar E immunogenic composition may comprise an LcrE sequence comprising all eight mutations across all 5 alleles for Serovar E. Alternatively, a mixture of mutations across different *Chlamydia trachomatis* Serovar alleles could cover the mutations in Serovar E and in Serovars other than Serovar E and thus confer cross-serovar protection. As one example, the 8 amino acid substitutions may include the 4 amino acid substitutions seen in the J serovar.

in one particularly preferred embodiment, the immunogenic composition comprises one or more *Chlamydia* antigen(s) which elicits a neutralising antibody response and one or more *Chlamydia* antigen(s) which elicit a cell mediated immune response. In this way, the neutralising antibody response prevents or inhibits an initial *Chlamydia* infection while the cell-mediated immune response capable of eliciting an enhanced Th1 cellular response which prevents ascending and/or spreading infection. Preferably, the immunogenic composition comprises one or more surface antigens and one or more cytoplasmic antigens. Preferably the immunogenic composition comprises one or more LcrE antigens or the like and one or other antigens, such as a cytoplasmic antigen, such as pgp3 or the like, capable of eliciting a Th1 cellular response.

Further antigens

The compositions of the invention may further comprise antigens derived from one or more sexually transmitted diseases in addition to *Chlamydia trachomatis*. Preferably the antigen is derived from one or more of the following sexually transmitted diseases: *N.gonorrhoeae* {e.g. 19, 20, 21, 22}; human papilloma virus; *Treponema pallidum*; herpes simplex virus (HSV-1 or HSV-2); HIV (HIV-1 or HIV-2); and *Haemophilus ducreyi*. Further antigens for inclusion may be, for example:

- a saccharide antigen from *N.meningitidis* serogroup A, C, W135 and/or Y, such as the oligosaccharide disclosed in ref. 23 from serogroup C {see also ref. 24} or the oligosaccharides of ref. 25.
- antigens from *Helicobacter pylori* such as CagA {26 to 29}, VacA {30, 31}, NAP {32, 33, 34}, HopX {e.g. 35}, HopY {e.g. 35} and/or urease.
- a saccharide antigen from *Streptococcus pneumoniae* {e.g. 36, 37, 38}.
- a protein antigen from *Streptococcus pneumoniae* {e.g. 39}.
- an antigen from hepatitis A virus, such as inactivated virus {e.g. 40, 41}.
- an antigen from hepatitis B virus, such as the surface and/or core antigens {e.g. 41, 42}.
- an antigen from hepatitis C virus {e.g. 43}.
- a diphtheria antigen, such as a diphtheria toxoid {e.g. chapter 3 of ref. 44} e.g. the CRM₁₉₇ mutant {e.g. 45}.
- a tetanus antigen, such as a tetanus toxoid {e.g. chapter 4 of ref. 44}.
- an antigen from *Bordetella pertussis*, such as pertussis holotoxin (PT) and filamentous haemagglutinin (FHA) from *B.pertussis*, optionally also in combination with pertactin and/or agglutinogens 2 and 3 {e.g. refs. 46 & 47}; whole-cell pertussis antigen may also be used.

- a saccharide antigen from *Haemophilus influenzae* B {e.g. 24}.
- polio antigen(s) {e.g. 48, 49} such as OPV or, preferably, IPV.
- an antigen from *N.gonorrhoeae* {e.g. 50, 51, 52, 53} (such as Ng13, Ng576 (PPIase or Mip) or NgpIII)
- (see, for example, WO 99/57280, WO 00/66791, WO 02/79243, and WO 04/112832)
- a protein antigen from *N.meningitidis* serogroup B {e.g. refs. 54 to 65}
- an outer-membrane vesicle (OMV) preparation from *N.meningitidis* serogroup B, such as those disclosed in refs. 66, 67, 68, 69, etc.
- an antigen from *Chlamydia trachomatis* or *Chlamydia pneumoniae* {e.g. refs. 70 to 76}
- (eg Cpn0324 which is the *Chlamydia trachomatis pneumonia* LcrE equivalent)
- an antigen from *Porphyromonas gingivalis* {e.g. 77}.
- an antigen from *Treponema pallidum*.
- rabies antigen(s) {e.g. 78} such as lyophilised inactivated virus {e.g. 79, RabAvert™}.
- measles, mumps and/or rubella antigens {e.g. chapters 9, 10 & 11 of ref. 44}.
- influenza antigen(s) {e.g. chapter 19 of ref. 44}, such as the haemagglutinin and/or neuraminidase surface proteins.
- antigen(s) from a paramyxovirus such as respiratory syncytial virus (RSV {80, 81}) and/or parainfluenza virus (PIV3 {82}).
- an antigen from *Moraxella catarrhalis* {e.g. 83}.
- an antigen from *Streptococcus pyogenes* (group A streptococcus) {e.g. 84, 85, 86}.
- an antigen from *Streptococcus agalactiae* (group B streptococcus) {e.g. 87}.
- an antigen from *Staphylococcus aureus* {e.g. 88}.
- an antigen from *Bacillus anthracis* {e.g. 89, 90, 91}.
- a papillomavirus antigen e.g. from any HPV type.
- a herpes simplex virus antigen e.g. from HSV-1 or HSV-2.
- an antigen from a virus in the flaviviridae family (genus flavivirus), such as from yellow fever virus, Japanese encephalitis virus, four serotypes of Dengue viruses, tick-borne encephalitis virus, West Nile virus.
- an antigen from a HIV e.g. a HIV-1 or HIV-2.
- an antigen from a rotavirus.
- a pestivirus antigen, such as from classical porcine fever virus, bovine viral diarrhoea virus, and/or border disease virus.
- a parvovirus antigen e.g. from parvovirus B19.

- a coronavirus antigen *e.g.* from the SARS coronavirus.
- a cancer antigen, such as those listed in Table 1 of ref. 92 or in tables 3 & 4 of ref. 93.

The composition may comprise one or more of these further antigens. The composition may include at least one further bacterial antigen and/or at least one further viral antigen. It is preferred that combinations of antigens should be based on shared characteristics *e.g.* antigens associated with respiratory diseases, antigens associated with enteric diseases, antigens associated with sexually-transmitted diseases, *etc.*

A preferred composition comprises: (1) at least t of the *Chlamydia trachomatis* antigens from either the first serovar group or the second serovar group, where t is 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 or 13, preferably t is five; (2) one or more antigens from another sexually transmitted disease. Preferably, the sexually transmitted disease is selected from the group consisting of herpes simplex virus, preferably HSV-1 and/or HSV-2; human papillomavirus; *N.gonorrhoeae*; *Treponema pallidum*; and *Haemophilus ducreyi*. These compositions can thus provide protection against the following sexually-transmitted diseases: *Chlamydia trachomatis*, genital herpes, genital warts, gonorrhoea, syphilis and chancroid (See, Ref. 94).

Where a saccharide or carbohydrate antigen is used, it is preferably conjugated to a carrier protein in order to enhance immunogenicity {*e.g.* refs. 95 to 104}. Preferred carrier proteins are bacterial toxins or toxoids, such as diphtheria or tetanus toxoids. The CRM₁₉₇ diphtheria toxoid is particularly preferred {105}. Other carrier polypeptides include the *N.meningitidis* outer membrane protein {106}, synthetic peptides {107, 108}, heat shock proteins {109, 110}, pertussis proteins {111, 112}, protein D from *H.influenzae* {113}, cytokines {114}, lymphokines, hormones, growth factors, toxin A or B from *C.difficile* {115}, iron-uptake proteins {116}, *etc.* Where a mixture comprises capsular saccharides from both serogroups A and C, it may be preferred that the ratio (w/w) of MenA saccharide:MenC saccharide is greater than 1 (*e.g.* 2:1, 3:1, 4:1, 5:1, 10:1 or higher). Different saccharides can be conjugated to the same or different type of carrier protein. Any suitable conjugation reaction can be used, with any suitable linker where necessary.

Toxic protein antigens may be detoxified where necessary *e.g.* detoxification of pertussis toxin by chemical and/or genetic means.

Where a diphtheria antigen is included in the composition it is preferred also to include tetanus antigen and pertussis antigens. Similarly, where a tetanus antigen is included it is preferred also to include diphtheria and pertussis antigens. Similarly, where a pertussis antigen is included it is preferred also to include diphtheria and tetanus antigens.

Antigens in the composition will typically be present at a concentration of at least 1µg/ml each. In general, the concentration of any given antigen will be sufficient to elicit an immune response against that antigen.

As an alternative to using protein antigens in the composition of the invention, nucleic acid encoding the antigen may be used {e.g. refs. 117 to 125}. Protein components of the compositions of the invention may thus be replaced by nucleic acid (preferably DNA e.g. in the form of a plasmid) that encodes the protein.

Combination therapies

The immunogenic compositions of the present invention may be administered in combination with an antibiotic treatment regime. In one embodiment, the antibiotic is administered prior to administration of the antigen of the invention or the composition comprising the antigen of the invention, such as the LcrE immunogenic composition. In another embodiment, the antibiotic is administered subsequent to the administration of the antigen of the invention or the composition comprising the antigen of the invention, such as the LcrE immunogenic composition. Examples of antibiotics suitable for use in the treatment of *Chlamydia trachomatis* include but are not limited to azithromycin or a derivative thereof as set out in WO 98/17280 or cyclosporin as set out in WO 04/047759.

Preferably, the immunogenic composition comprises one or more variant *Chlamydia trachomatis* Type Three Secretion System (TTSS) protein(s).

Preferably, the immunogenic composition comprises one or more variant *Chlamydia trachomatis* Type Three Secretion System (TTSS) protein(s) with an amino acid sequence selected from the group consisting of SEQ ID Nos 29-45 or SEQ ID Nos 1-13 or SEQ ID Nos 17-45 or SEQ ID

Nos 47-180 or SEQ ID No 54, 109, 110 or 111 or SEQ ID No 66, 129 or 130 or SEQ ID Nos 181, 182, 183 and/or 184.

By way of background information, the TTSS is a complex protein secretion and delivery machine or apparatus, which may be located on the Elementary Body (EB) and which allows an organism, such as *Chlamydia*, to maintain its intracellular niche by injecting proteins, such as bacterial effector proteins (which may act as anti-host virulence determinants) into the cytosol of a eukaryotic cell in order to establish the bacterial infection and to modulate the host cellular functions. These injected proteins (the TTSS effector proteins) can have various effects on the host cell which include but are not limited to manipulating actin and other structural proteins and modification of host cell signal transduction systems. The injected (or translocated) proteins or substrates of the TTSS system may also be processed and presented by MHC-class I molecules.

Not all the proteins secreted by a Type III secretion system are delivered into the host cell or have effector function. For example, several Type III proteins are involved in the secretion process itself, its regulation or the translocation of effector proteins through the host cell membrane. By way of example, CT089 also known as Low Calcium Response Element (LcrE) or CoPn – which is the *Chlamydia* outer protein homologue of YopN) is thought to act as a peripherally associated regulator that prevents secretion (of possible pre-synthesised proteins) in the absence of proper signals from the host cell. In effect, it “plugs” the terminal end of the secretion system until an inductive signal is received. Although the Elementary Body (EB) is regarded as “metabolically inert”, it has been postulated that the *Chlamydial* TTS system located on the (EB) is triggered by membrane contact and is capable of releasing pre-formed “payload” proteins. The current hypothesis is that Type Three Secretion System (TTSS) becomes active during the intracellular phase of the chlamydial replicative cycle for the secretion of proteins into the host cell cytoplasm and for the insertion of chlamydial proteins (like the Inc set) into the inclusion membrane that separates the growing chlamydial microcolony from the host cell cytoplasm (see Montigiani et al (2002) *Infection and Immunity* 70(1); 386-379).

By way of example, the LcrE (CT089) protein is thought to act as a kind of “molecular syringe”, injecting effector proteins directly across bacterial and eukaryotic cell membranes into the target cell cytoplasm. As *Chlamydia* bacteria reside in membrane bound vacuoles termed inclusions, it has also been postulated that the *Chlamydia* TTSS probably translocates proteins into, across or

through the vacuolar membrane (ie the inclusion membrane) as well as the plasma membrane (see for example Stephens et al 1998 Science (282); 754-759). Immunoblot analysis indicates that both CopN (CT089) and Scc1 (CT088) are present in both chlamydial developmental forms and whole-culture lysates 20h after infection. Analysis of infected monolayers by indirect immunofluorescence reveals that CopN localised to both bacteria and the inclusion membrane whereas Scc1 was detected only in chlamydiae. Based upon these observations, it appears that, although CopN is directly associated with chlamydiae, it can also be secreted and associate with the inclusion membrane (see Fields and Hackstadt (2000) Molecular Microbiology 38(5); 1048-1060).

EXAMPLES

The present invention will be defined only by way of example. 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.

EXAMPLE 1

Purpose of Example I:

(i) to evaluate the degree of allelic variation of possible *Chlamydia* vaccine candidates in 13 *Chlamydia trachomatis* clinical isolates corresponding to eight different *Chlamydia* serovars; and

(ii) to evaluate the degree of antigenic variation in *Chlamydial* isolates which have, so far, been classified only on the basis of major outer membrane protein (MOMP) variants

Isolates examined

8 isolates were obtained from the ATCC (American Type Culture Collection).

According to the ATCC catalogue these strains were isolated in the USA from patient genital or ocular swabs in the years ranging from 1959 and 1974.

Six Italian isolates belonging to 5 different prevalent *Chlamydia* serovars were also examined.

These *Chlamydial* strains were isolated from patients with inflammation symptoms consistent with *Chlamydia* infection, the patients being examined at the Policlinico St. Orsola, Bologna, Italy in a time period approximately around 1998 to 2001.

These isolates were serotyped by described RFLP (restriction fragment length polymorphism) methods assessing sequence variation within the gene *omp1*, encoding the protein MOMP (major outer membrane protein).

As mentioned earlier, MOMP is a major immunogen in *Chlamydia trachomatis* (CT) infections and provides the basis for serotype or serovar classification of CT strains.

Methodology

Genomic DNA was extracted from EB or CT infected cells, and DNA segments expected to contain the genes to be studied were amplified by PCR. The amplified segments were purified and sequenced in an automatic DNA sequencer, following normal DNA sequencing procedures. A range of specialized software was used, including the GCG package.

Protein sequences encoded by the sequences so obtained were compared to those reported from the only fully sequenced, serovar-D genome (D/UW-3/CX) of *C. trachomatis* available in public databases.

Amino-acid substitutions in the proteins encoded by each gene were scored against the corresponding alleles in the only fully sequenced genome of *C. trachomatis*, i.e. in the reference genome from serotype-D strain UW-3/Cx.

Serotype Assignment

Apart from the use of the RFLP technique, serotyping was mostly carried out by monoclonal antibody typing. As mentioned above, monoclonal antibody typing (ie standard serotype specific monoclonal typing) was the main serotyping procedure used before PCR technology became available.

Results

Table 3 illustrates that allelic variation can also be found for different *Chlamydia trachomatis* antigens across the serovars. For example, Table 3 illustrates the assessment of allelic variation of 6 genes in 14 different CT clinical isolates comprising 8 different serovars. As Table 3 shows, it was found that that most allelic variation was seen for LcrE (CT089) in the E serovar where 5 alleles with a maximum of 8 amino acid substitution points were found over the 421 amino acid sequence. Allele 5 with 8 amino acid substitutions was found to be identical in two isolates

(Cev8 Serovar E and ATCC E) which was a highly surprising and unexpected finding given that these two E serovars (European and American) have significantly divergent origins.

The least allelic variation was seen for OmpH-like (CT242), ArtJ (CT381), DnaK (CT396) and Hypothetical (CT398) antigens where only two alleles with a maximum of 1-2 amino acid substitution points were found. An intermediate allelic variation was seen for PepA (CT045) where 3 alleles with a maximum of 4 amino acid substitution points over a 499 amino acid sequence were found.

Summary Results

Genotyping was carried out from serovars from different collections, the ATCC collection and the Italian (Cevenini) collection. The ATCC and Cevenini collections are not connected in either source or time (ATCC collection approximately 30-40 years old, whereas the Cevenini collection is approximately 5 years old). Given these geographical and temporal differences between the two collections, it was surprising and unexpected to find that the LcrE amino acid sequence from the ATCC Serovar E (SEQ ID NO: 1) has the same eight mutations as that seen in the amino acid sequence from LcrE Italian (Cevenini) Serovar E (cev-8) (SEQ ID NO: 12).

It was wholly unexpected to find that amino acid sequences from different sources and from different time periods and having been exposed to different immunological pressures would result in the same set of 8 mutations in the LcrE Serovar E sequence. It was also discovered that the LcrE from ATCC Serovar J (SEQ ID NO: 6) has the same three mutations as that seen in the LcrE Italian (Cevenini) Serovar J (cev-5) (SEQ ID NO: 11). Similarly, it was discovered that the LcrE from ATCC Serovar H (SEQ ID NO: 4) has the same three mutations as ATCC Serovar J (SEQ ID NO: 6 and SEQ ID NO: 11). These sequences are also from different sources, different time periods, and different immunological pressures, however the mutations are the same in each of the pairings. Even sequences without identical mutations were still similar. For example, GO 86 Serovar D and LcrE from Italian (Cevenini) Serovar J (cev-1) unexpectedly matched in 3 of the four mutations.

No mutations were noted in the LcrE from ATCC Serovar F, G, I, K, Cev-2 (Serovar G), Cev-4 (Serovar H), or consensus sequences SEQ ID NOS: 14, 15, 17, 22, 24, 25, and 26. This was also an unexpected finding in view of the fact that the different sequences were also exposed to

different immunologic pressures in different geographical locations over different periods of time.

Overall Result Summary

Overall, the genotyping results for 6 Chlamydia antigens across 13 isolates corresponding to 8 different *Chlamydia* serovars show a high degree of amino acid sequence conservation, particularly within the same serovar, with allelic variations due to a limited amount of unique single-aminoacid substitutions.

However, in the case of LcrE (CT089), a higher than expected number of single amino acid substitution was observed, indicating the likelihood that the LcrE protein is subjected to a greater immunological pressure than the other Chlamydia antigens assessed (these being CT242, CT381, CT396, CT398 and CT045), and that the peptides surrounding these amino acid substitutions are likely to be epitopic regions (either B-cell epitopes involved in Ab-Ag interactions and/or T-cell epitopes capable of eliciting *Chlamydia trachomatis* specific cell mediated immune responses). In particular, the existence of two high frequency mutation positions at residues 64 and 162 of the LcrE sequence is surprising and unexpected and is likely to be associated with the presence of epitopic regions capable of eliciting immunogenic response in a subject.

Serovar specific alterations in immunogenicity can be utilized to tailor specific diagnostic or therapeutic (eg immunological) treatments for different patient profiles (for example, including but not limited to adolescent girls, sex workers (eg prostitutes), homosexuals, etc.)

EXAMPLE 2: LCRE EPITOPE MAPPING

The LcrE reference sequence from *Chlamydia trachomatis* Strain D/UW-3/CX is provided as SEQ ID NO: 28 (below) which also shows a summary of the all of the allelic mutation points detected in the various *Chlamydia trachomatis* serovar isolates: The underlined regions in SEQ ID No 28 surrounding the point mutations correspond with either B and/or T cell epitopic peptide regions. The first mutation point at residue 64 - underlined in the following epitope region KKKGEK- corresponds with a high frequency mutation point or hypervariable region and is also likely to be associated with a T and/or B-cell epitope region.

SEQ ID NO: 28

MTASGGAGGLGSTQTVDVARAQAAATQDAQEVIGSQEASEASMLKGCED
 LINPAAATRIKKK⁶⁴EKFESLEARRKPTADKA¹²⁶EKKSESTE¹⁵⁷EKGDTPLEDRF
 TEDLSEVSGEDFRGLKNSFDDSSP¹⁶²EILDALTSKFSDPTIKDLALDYLI
 QTAPSD¹⁷⁹EKLKS²⁰⁷LIQAKHQLMSQNPOAI²¹⁷VGGRNVLLASETFASRANTS²⁷⁵SPS
 SLRSLY⁴²⁰QVTS²⁷⁵SPSNC²⁷⁵NL²⁷⁵QMLASYLPSEKTAVMEFLVNGMVADLKSEG
 PSIPPAKLQVYMT²⁷⁵ELSNLQALHSV²⁷⁵NSFFDRNIGNLEN²⁷⁵SLKHEGHAPIPSL
 TTGNLT²⁷⁵TKTFLQLVEDKFPSSSKAQKALNELVGPD²⁷⁵TGPGQTEVLNLF²⁷⁵FRALN
 GCSPRIFSGAEKKQQLASVITNTLD²⁷⁵AINADNEDY²⁷⁵PKPGDFPRSSFSSTPP
 HAPVPQSEIPTSTSTQPP²⁷⁵P

Thus, mutation points detected in the isolates were at position 64, 126, 157, 162, 179, 207, 217, 220, 275, and 420 (see Table 7). Based on the observed mutations in the isolates, antigenic peptides were determined using the method of Kolaskar and Tongaonkar (Kolaskar *et al.*, "A semi-empirical method for prediction of antigenic determinants on protein antigens", FEBS Lett. 1990 Dec 10; 276(1-2): 172-4), incorporated herein in its entirety. Briefly, predictions are based on a table that reflects the occurrence of amino acid residues in experimentally known segmental epitopes. Segments are only reported if they have a minimum size of 8 residues. The reported accuracy of the method is about 75%. Using this method, 17 antigenic determinants in the sequence for LcrE *Chlamydia trachomatis* antigen were determined as summarized in the following Table 2 above.

Table 7

LcrE Amino acid residue	Reference amino acid	Mutated amino acid
X1 = 64	Glycine (G)	Glutamic acid (E)
X2 = 126	Aspartic acid (D)	Glutamic acid (E) or Asparagine (N)
X3 = 157	Glycine (G)	Arginine ®
X4 = 162	Threonine (T)	Alanine (A)
X5 = 179	Valine (V)	Isoleucine (I)
X6 = 207	Phenylalanine (F)	Leucine (L)
X7 = 217	Alanine (A)	Aspartic Acid (D)
X8 = 220	Histidine (H)	Arginine ®
X9 = 275	Asparagine (N)	Aspartic acid (D)
X10 = 420	Serine (S)	Proline (P)

EXAMPLE 3: EPITOPE MAPPING FOR CHLAMYDIA (eg LcrE) ANTIGENS

Epitope mapping of all the LcrE serovar variants is carried out as follows: A mouse model of genital tract infection as described above and in WO 05/002619 is used. All the LcrE variants are expressed as recombinant proteins, methodology for which is also described in WO 05/002619. Mice are immunised with the recombinant LcrE variants (with and without

Chlamydia trachomatis challenge). The spleen cells from immunised mice (with and without *Chlamydia trachomatis* challenge) are then isolated and pulsed with LcrE specific peptides, set out as SEQ ID Nos 47-98 below. The spleen cell response to each of LcrE specific peptides is then assessed in terms of the presence or absence of spleen cell proliferation, mediator response such as, for eg, Th1 or Th2 cell response as determined by various tests described above. A particularly preferred peptide for pulsing spleen cells and for evaluating the humoral and cellular immune response in a subject is set out as SEQ ID No 54 below. This 15mer peptide comprises the region corresponding to the N-terminal segment surrounding the first high frequency (7/14) mutation point or hypervariable region identified at residue 64 in the LcrE amino acid sequence when evaluated across 13 *Chlamydia* serovars. A second particularly preferred peptide for pulsing spleen cells and for evaluating the humoral and cellular immune response in a subject is set out as SEQ ID No 66 below. This 15mer peptide comprises the region corresponding to the segment surrounding the second high frequency (7/14) mutation point or hypervariable region identified at residue 162 in the LcrE amino acid sequence when evaluated across 13 *Chlamydia* serovar isolates. Other particularly preferred peptides include those which comprise the epitopes set out in SEQ ID Nos 29-45 (see Table 2) and SEQ ID Nos 181, 182, 183 and/or 184.

These peptides, in particular SEQ ID No 54 and/or SEQ ID No 66 and/or SEQ ID Nos 181, 182, 183 and/or 184 can be used in the immunisation schedule described in Example 5 to evaluate their prophylactic and therapeutic efficacy and, of course, for diagnostic purposes. Similar methodology can be applied to map epitopes for other *Chlamydia* antigens, such as but not limited to CT242, CT381, CT396, CT398 and CT045.

LcrE peptides for epitope mapping

LcrE serotype D reference strain(allele 1) from Serovar D/UW-3/CX

MTASGGAGGLGSTQTVDDVARAQAAAATQDAQEVIGSQEASEASMLKGCED
 LINPAAATRIKKKGEKFESLEARRKPTADKAEKKSESTEKGDTPLEDRF
 TEDLSEVSGEDFRGLKNSFDDDDSSPDEILDALTSKFSDPTIKDLALDYLI
 QTAPSDGKLKSTLIQAKHQLMSQNPQAIVGGRNVLLASETFASRANTSPS
 SLRSLYFQVTSSPNCANLHQLASYPSEKTAVMEFLVNGMVADLKSEG
 PSIPPAKLQVYMTLSNLQALHSVNSFFDRNIGNLENSLKHEGHAPIPSL
 TTGNLTKTFLQLVEDKFPSSSKAQKALNELVGPDTGPQTEVLNLFRRALN
 GCSPRIFSGAEKKQQLASVITNTLDADNADNEDYPKPGDFPRSSFSSTPP
 HAPVPQSEIPTSTSTQPPSP (421 aa)

Splitting the LcrE sequence into peptide for Epitope mapping can be carried out in several ways by varying the length of individual peptides and changing the extent of overlapping. One

example based on the published reference sequence of CT LcrE, and choosing to use overlapping 15nmers progressively shifted by 8 aminoacid residues is set out as follows:

Split in 51 overlapping 15nmers plus 1 end-14nmer shifted by 8 residues

1. MTASGGAGGLGSTQT (SEQ ID No 47)
2. GLGSTQTVDDVARAQA (SEQ ID No 48)
3. DVARAQAAAATQDAQ (SEQ ID No 49)
4. AATQDAQEVIGSQEA (SEQ ID No 50)
5. VIGSQEASEASMLKG (SEQ ID No 51)
6. EASMLKGCEDLINPA (SEQ ID No 52)
7. EDLINPAAATRIKKK (SEQ ID No 53)
8. ATRIKKKGEKFESLE (SEQ ID No 54)
9. EKFSLEARRKPTAD (SEQ ID No 55)
10. RRKPTADKAEKKSES (SEQ ID No 56)
11. AEKKSESTEKGDTP (SEQ ID No 57)
12. EEKGDTPLEDRTED (SEQ ID No 58)
13. EDRFTEDLSEVSGED (SEQ ID No 59)
14. SEVSGEDFRGLKNSF (SEQ ID No 60)
15. RGLKNSFDDSSPDE (SEQ ID No 61)
16. DDSSPDEILDALTSK (SEQ ID No 62)
17. LDALTSKFSDPTIKD (SEQ ID No 63)
18. SDPTIKDLALDYLIQ (SEQ ID No 64)
19. ALDYLIQTAPSDGKL (SEQ ID No 65)
20. APSDGKLKSTLIQAK (SEQ ID No 66)
21. STLIQAKHQLMSQNP (SEQ ID No 67)
22. QLMSQNPQAIVGGRN (SEQ ID No 68)
23. AIVGGRNVLLASETF (SEQ ID No 69)
24. LLASETFASRANTSP (SEQ ID No 70)
25. SRANTSPSSLSLYF (SEQ ID No 71)
26. SLRSLYFQVTSSPSN (SEQ ID No 72)
27. VTSSPSNCANLHQL (SEQ ID No 73)
28. ANLHQLASYPSEK (SEQ ID No 74)
29. SYLPSEKTA VMEFLV (SEQ ID No 75)
30. AVMEFLVNGMVADLK (SEQ ID No 76)
31. GMVADLKSEGPSIPP (SEQ ID No 77)
32. EGPSIPPAKLQVYMT (SEQ ID No 78)
33. KLQVYMTLSNLQAL (SEQ ID No 79)
34. LSNLQALHSVNSFFD (SEQ ID No 80)
35. SVNSFFDRNIGNLEN (SEQ ID No 81)
36. NIGNLENSLKHEGHA (SEQ ID No 82)
37. LKHEGHAPIPSLTTG (SEQ ID No 83)
38. IPSLTTGNLTKTFLQ (SEQ ID No 84)
39. LTKTFLQLVEDKFPS (SEQ ID No 85)
40. VEDKFPSSSKAQKAL (SEQ ID No 86)
41. SKAQKALNELVGPDT (SEQ ID No 87)
42. ELVGPDTPGPTEVLN (SEQ ID No 88)
43. PQTEVLNLFRRALNG (SEQ ID No 89)
44. FRRALNGCSPRIFSG (SEQ ID No 90)
45. SPRIFSGAEKKQLA (SEQ ID No 91)
46. EKKQLASVITNTLD (SEQ ID No 92)
47. VITNTLDINADNED (SEQ ID No 93)
48. INADNEDYPKPGDFP (SEQ ID No 94)
49. PKPGDFPRSSFSSTP (SEQ ID No 95)
50. SSFSSTPPHAPVPQS (SEQ ID No 96)
51. HAPVPQSEIPTSPTS (SEQ ID No 97)

EXAMPLE 4: EPITOPE MAPPING FOR CHLAMYDIA (eg LcrE) ANTIGENS

Epitope mapping of all the LcrE serovar variants is carried out as follows: A mouse model of genital tract infection as described above and in WO 05/002619 is used. All the LcrE variants are expressed as recombinant proteins, methodology for which is also described in WO 05/002619. Mice are immunised with the recombinant LcrE variants (with and without *Chlamydia trachomatis* challenge). The spleen cells from immunised mice (with and without *Chlamydia trachomatis* challenge) are then isolated and pulsed with LcrE specific peptides, set out as SEQ ID Nos 99-180 below. The spleen cell response to each of LcrE specific peptides is then assessed in terms of the presence or absence of spleen cell proliferation, mediator response such as, for eg, Th1 or Th2 cell response as determined by various tests described above. Three particularly preferred peptides for pulsing spleen cells and for evaluating the humoural and cellular immune response in a subject are set out as SEQ ID No 109, 110 and 111 below. These 15mer peptides comprises the region corresponding to the N-terminal segment surrounding the first high frequency (7/14) mutation point or hypervariable region identified at residue 64 in the LcrE amino acid sequence when evaluated across 13 *Chlamydia* serovars. Other particularly preferred peptide for pulsing spleen cells and for evaluating the humoural and cellular immune response in a subject are set out as SEQ ID No 129 and 130 below. These 15mer peptide comprises the region corresponding to the segment surrounding the second high frequency (7/14) mutation point or hypervariable region identified at residue 162 in the LcrE amino acid sequence when evaluated across 13 *Chlamydia* serovar isolates. Other particularly preferred peptides include those which comprise the epitopes set out in SEQ ID Nos 29-45 (see Table 2) and SEQ ID Nos 181, 182, 183 and/or 184.

These peptides, in particular SEQ ID Nos 109, 110 and 111 and/or SEQ ID No 129, 130 and/or SEQ ID Nos 181, 182, 183 and/or 184 can be used in the immunisation schedule described in Example 5 to evaluate their prophylactic and therapeutic efficacy and, of course, for diagnostic purposes. Similar methodology can be applied to map epitopes for other *Chlamydia* antigens, such as but not limited to CT242, CT381, CT396, CT398 and CT045

LcrE peptides for serE mapping

LcrE found in serotype E strains (LcrE allele 5).

Allele 5 has 8 amino acid changes as compared to the published LcrE of the Serovar D sequenced genome.

Also, 2 of these changes are regarded “conservative” while 6 of the changes are regarded “non-conservative” (see Table 4 below).

LcrE found in serotype E strains (LcrE allele 5).

MTASGGAGGLGSTQTVDVARAQAAAATQDAQEVIGSQEASEASMLKGCEDLINPAAATRIKKKEEFESL
EARRKPTADKAEEKSESTEEKGDTPLEDRFTEDLSEVSGEDFRGLKNSFDDSSPEEILDALTSKFSDPT
IKDLALDYLIQTAPSDRKLKSALIQAKHQLMSQNPQAIVGGRNVLLASETFASRANTSPSSLRSLYLQVT
SSPSNCDNLRQMLASLYLPSEKTAVMEFLVNGMVADLKSEGPSIPPAKLQVYMTLSNLQALHSVDSFFDR
NIGNLENSLKHEGHAPIPSLTGTGNLTKTFLQLVEDKFPSSSKAQKALNELVGPDTGPTQTEVLNLFRRALN
GCSPRIFFSGAEKKQQLASVITNTLDADNADNEDYPKPGDFPRSSFSSTPPHAPVPQSEIPTSTSTQPPS
P (421 aa)

The following example shows the splitting the serovar-E LcrE sequence into peptide for Epitope mapping by choosing to use overlapping 15nmers progressively shifted by 5 aminoacid residues.

Split in 81 overlapping 15nmers plus 1 end-16nmer, shifted by 5 residues

1. MTASGGAGGLGSTQT(SEQ ID No 99)
2. GAGGLGSTQTVDVAR(SEQ ID No 100)
3. GSTQTVDVARAQAAA(SEQ ID No 101)
4. VDVARAQAAAATQDA (SEQ ID No 102)
5. AQAAAATQDAQEVIG(SEQ ID No 103)
6. ATQDAQEVIGSQEAS(SEQ ID No 104)
7. QEVIGSQEASEASML(SEQ ID No 105)
8. SQEASEASMLKGCED(SEQ ID No 106)
9. EASMLKGCEDLINPA(SEQ ID No 107)
10. KGCEDLINPAAATRI(SEQ ID No 108)
11. LINPAAATRIKKKEE(SEQ ID No 109)
12. AATRIKKKEEFESL(SEQ ID No 110)
13. KKKEEFESLEARRK(SEQ ID No 111)
14. KFESLEARRKPTADK(SEQ ID No 112)
15. EARRKPTADKAEEKS(SEQ ID No 113)
16. PTADKAEEKSESTEE(SEQ ID No 114)
17. AEKKSESTEEKGDTP(SEQ ID No 115)
18. ESTEEKGDTPLEDRF(SEQ ID No 116)
19. KGDTPLEDRFTEDLS(SEQ ID No 117)
20. LEDRFTEDLSEVSGE(SEQ ID No 118)
21. TEDLSEVSGEDFRGL(SEQ ID No 119)
22. EVSGEDFRGLKNSFD(SEQ ID No 120)
23. DFRGLKNSFDDSSP(SEQ ID No 121)
24. KNSFDDSSPEEILD(SEQ ID No 122)
25. DDSSPEEILDALTSK(SEQ ID No 123)
26. EEILDALTSKFSDPT(SEQ ID No 124)
27. ALTSKFSDPTIKDLA(SEQ ID No 125)
28. FSDPTIKDLALDYLI(SEQ ID No 126)
29. IKDLALDYLIQTAPS(SEQ ID No 127)
30. LDYLIQTAPSDRKLK(SEQ ID No 128)
31. QTAPSDRKLKSALIQ(SEQ ID No 129)
32. DRKLKSALIQAKHQL(SEQ ID No 130)
33. SALIQAKHQLMSQNP(SEQ ID No 131)

34. AKHQLMSQNPQAIVG(SEQ ID No 132)
35. MSQNPQAIVGGGRNVL(SEQ ID No 133)
36. QAIVGGGRNVLLASET(SEQ ID No 134)
37. GRNVLLASETFASRA(SEQ ID No 135)
38. LASETFASRANTSPS(SEQ ID No 136)
39. FASRANTSPSSLRSL(SEQ ID No 137)
40. NTSPSSLRSLYLQVT(SEQ ID No 138)
41. SLRSLYLQVTSSPSN(SEQ ID No 139)
42. YLQVTSSPSNCDNLR(SEQ ID No 140)
43. SSPSNCDNLRQMLAS(SEQ ID No 141)
44. CDNLRQMLASYLPSE(SEQ ID No 142)
45. QMLASYLPSEKTAVM(SEQ ID No 143)
46. YLPSEKTAVMEFLVN(SEQ ID No 144)
47. KTAVMEFLVNGMVAD(SEQ ID No 145)
48. EFLVNGMVADLKSEG(SEQ ID No 146)
49. GMVADLKSEGPSIPP(SEQ ID No 147)
50. LKSEGPSIPPAKLQV(SEQ ID No 148)
51. PSIPPAKLQVYMTEL(SEQ ID No 149)
52. AKLQVYMTELSNLQA(SEQ ID No 150)
53. YMTELSNLQALHSVD(SEQ ID No 151)
54. SNLQALHSVDSFFDR(SEQ ID No 152)
55. LHSVDSFFDRNIGNL(SEQ ID No 153)
56. SFFDRNIGNLENSLK(SEQ ID No 154)
57. NIGNLENSLKHEGHA(SEQ ID No 155)
58. ENSLKHEGHAPIPSL(SEQ ID No 156)
59. HEGHAPIPSLTTGNL(SEQ ID No 157)
60. PIPSLTTGNLTKTFL(SEQ ID No 158)
61. TTGNLTKTFLQLVED (SEQ ID No 159)
62. TKTFLQLVEDKFPSS(SEQ ID No 160)
63. QLVEDKFPSSSKAQK(SEQ ID No 161)
64. KFPSSSKAQKALNEL(SEQ ID No 162)
65. SKAQKALNELVGPDT(SEQ ID No 163)
66. ALNELVGPDTGPQTE(SEQ ID No 164)
67. VGPDTGPQTEVLNLF(SEQ ID No 165)
68. GPQTEVLNLFALN(SEQ ID No 166)
69. VLNLFFRALNGCSPR(SEQ ID No 167)
70. FRALNGCSPRIFSGA(SEQ ID No 168)
71. GCSPRIFSGAEKKQQ(SEQ ID No 169)
72. IFSGAEKKQQLASVI(SEQ ID No 170)
73. EKKQQLASVITNTLD(SEQ ID No 171)
74. LASVITNTLDAINAD(SEQ ID No 172)
75. TNTLDAINADNEDYP(SEQ ID No 173)
76. AINADNEDYPKPGDF(SEQ ID No 174)
77. NEDYPKPGDFPRSSF(SEQ ID No 175)
78. KPGDFPRSSFSTPP(SEQ ID No 176)
79. PRSSFSTPPHAPVP(SEQ ID No 177)
80. SSTPPHAPVPQSEIP(SEQ ID No 178)
81. HAPVPQSEIPTSPTS(SEQ ID No 179)
82. QSEIPTSPTSTQPPSP(SEQ ID No 180)

IKKKGEKFE (SEQ ID No 181)
IKKKEEKFE (SEQ ID No 182)
KLKSTLIQA (SEQ ID No 183)
KLKSALIQA (SEQ ID No 184)

Table 4

LcrE Amino acid (AA) residue no	AA in LcrE D serovar	AA in LcrE E serovar	Nature of the mutation
64	G	E	Not conserved
126	D	E	Conserved
157	G	R	Not conserved
162	T	A	Not conserved
207	F	L	Not conserved
217	A	D	Not conserved
220	H	R	Not conserved
275	N	D	Conserved

EXAMPLE 5: Immunization with LcrE antigen or Combinations thereof

Immunizations with LcrE alone and in combination with LcrE from different *Chlamydia trachomatis* serovars and/or in combination with other *Chlamydia trachomatis* proteins and/or one or more other STD antigen(s) either alone with or without an immunoregulatory agent.

The following example illustrates immunization with various combinations of CT LcrE antigens in a mouse model. The recombinant CT LcrE antigens are prepared and characterised using, for eg, the procedures described in WO 05/002619 and Finco *et al* (2005) Vaccine 23; 1178-1188 and Sambri *et al* (2004) Vaccine 22 (9-10); 1131-7).

In this Example, immunization is shown with a combination of 1 or 2 or 3 or 4 or 5 LcrE antigens from different *Chlamydia trachomatis* serovars were prepared as described above. The antigens are expressed and purified. Compositions of antigen combinations are then prepared comprising 1 or 2 or 3 or 4 or 5 LcrE antigens per composition (and containing 15 µg of each antigen per composition).

CD1 mice are divided into seven groups (5-6 mice per group for groups 1 through 6; 3 to 4 mice for groups 5, 6, 7, 8 and 9), and immunized as follows:

Table 5: Immunization Schedule for Example 5

Group	Immunizing Composition	Route of Delivery
1	Mixture of 1 or 2 or 3 or 4 or 5 LcrE antigens (15 µg/each) + CFA	Intra-peritoneal or intra-nasal
2	Mixture of 1 or 2 or 3 or 4 or 5 antigens (15 µg/each) + AIOH (200µg)	Intra-peritoneal or intra-nasal
3	Mixture of 1 or 2 or 3 or 4 or 5 antigens (15 µg/each) + CpG (10µg)	Intra-peritoneal or intra-nasal
4	Mixture of 1 or 2 or 3 or 4 or 5 antigens (15 µg/each) + AIOH (200µg) + CpG (10µg)	Intra-peritoneal or intra-nasal
5	Complete Freund's Adjuvant (CFA)	Intra-peritoneal or intra-nasal
6	Mixture of 1 or 2 or 3 or 4 or 5 antigens (5 µg/each) + LTK63 (5µg)	Intra-peritoneal or Intranasal
7	AIOH (200µg) + CpG (10µg)	Intra-peritoneal or intra-nasal
8	CpG (10µg)	Intra-peritoneal or intra-nasal
9	LTK63 (5µg)	Intra-peritoneal or intra-nasal

Mice are immunized at two week intervals. Two weeks after the last immunization, all mice are challenged by intravaginal infection with the appropriate *Chlamydia* serovar, such as but not limited to *Chlamydia trachomatis* serovar D. When mucosal immunization (eg intra-nasal(in)) is used, the animal model is also challenged mucosally to test the protective effect of the mucosal immunogen.

EXAMPLE 6: Immunization with LcrE antigen or Combinations thereof

The following Example shows immunizations with LcrE alone and in combination with LcrE from different *Chlamydia trachomatis* serovars and/or in combination with other *Chlamydia trachomatis* proteins either alone with or without an immunoregulatory agent.

Specifically, in this example, immunization is shown with a combination of 1 or 2 or 3 or 4 or 5 LcrE antigens from different *Chlamydia trachomatis* serovars were prepared as described above. The antigens are expressed and purified. Compositions of antigen combinations are then prepared comprising 1 or 2 or 3 or 4 or 5 antigens per composition (and containing 15 µg of each antigen per composition).

Table 6: Immunization Schedule for Example 6

Group	Immunising Composition	ImmunoRegulatory Agent	Route of Delivery
1 (Test Group)	Combos of 1 or 2 or 3 or 4 or 5 LcrE antigens from different <i>Chlamydia trachomatis</i> serovars were prepared as described above. The antigens are expressed and purified. Compositions of antigen combinations are then prepared comprising five antigens per composition (and containing 15 µg of each antigen per composition). (15ug/each CT antigen)	CFA	Intra-peritoneal (i.p.)
2 (Test Group)	As for test 1 (15ug/each CT antigen)	AlOH (200ug) and CpG (10ug)	Intra-peritoneal (i.p.)
3 (Test Group)	As for test 1 (15ug/each CT antigen)	AlOH (200ug) alone	Intra-peritoneal (i.p.)
4 (Test Group)	As for test 1 (15ug/each CT antigen)	CpG (10ug) alone	Intra-peritoneal (i.p.)
5 (Negative control)	Complete Freund's Adjuvant (CFA) alone		Intra-peritoneal (i.p.)
6 (Negative Control)	AlOH (200µg) + CpG (10µg)		Intra-peritoneal (i.p.)
7 (Positive Control) (Protection control)	Live Elementary Body (EB) from <i>Chlamydia trachomatis</i> (twice – pre-challenge + challenge)		Intra-peritoneal (i.p.)
8 (Infection control)	Live Elementary Body (EB) from <i>Chlamydia trachomatis</i> (once – challenge only)		Intra-peritoneal (i.p.)

Mouse Model for in-vivo screening for CT protective antigens: A Mouse Model of *Chlamydia trachomatis* genital infection for determining *in-vivo* protective effect of CT antigens (resolution of a primary *Chlamydia trachomatis* infection) was used. The model used is described as follows: Balb/c female mice 4-6 weeks old were used. The mice were immunized intra-peritoneally (ip) with a mixture of 1 or 2 or 3 or 4 or 5 recombinant CT antigens, such as but not limited to LcrE, as set out in Table 5 or 6 above. These CT antigens were determined to be FACS positive and/or neutralizing. Three doses of the 1 or 2 or 3 or 4 or 5 LcrE antigen mixture were given at a concentration of 15ug per dose. The mice were given hormonal treatment 5 days prior to challenge with 2.5mg of DepoProvera (medroxyprogesterone acetate).

Test Challenges: The mice were challenged intravaginally with 10^5 IFU of purified EBs (Serovar D), 2 weeks after the last immunization dose. A read out of vaginal swabs every 7 days up to 28 days after challenge. The following assays were also carried out on pre-challenge sera:

Serological analysis: FACS, WB, Neutralization assay and ELISA. The ELISA were performed by coating plates with each recombinant antigen and testing the reaction of pre-challenge immune sera from single mice immunized with the combination of 1 or 2 or 3 or 4 or 5 CT LcrE antigens. The data is expressed as the mean value calculated for each group expressed as mean ELISA units. The *Chlamydia trachomatis* specific antibody type (IgG, IgA etc) and isotype was checked in serum post immunization but pre-challenge. The purpose of the serum studies was to determine how the mice responded to immunization with the CT LcrE antigen combinations. The purpose of the vaginal washes was to determine how the mice responded to the *Chlamydia trachomatis* bacterial challenge. *Chlamydia trachomatis* specific antibody analyses in terms of antibody type (IgG and IgA) and antibody subtype were also carried out on the vaginal washes. *Negative Controls*: The negative control used was the immunoregulatory agent alone (eg CFA or ALOH and/or CpG).

Positive "live" EB controls: The positive control used was an extract from live *Chlamydia trachomatis* Elementary Bodies (EBs). Here the mice were infected with live *Chlamydia trachomatis* EB at the same time that the test CT combination antigens are being administered. The "live" EB positive control animals were infected for about 1.5 months (ie 6 weeks) (because 3 doses of CT antigenic combinations were administered every 2 weeks (ie over a total of 6 weeks). The animals (mice) infected with "live" EB developed a natural immunity and resolved the infection (because *Chlamydia* infection in mice is a transient infection). When the mice were vaccinated with the CT antigenic combinations were then challenged with "live" EB, the positive control "live" EB mice were also re-challenged (ie they were given a second dose of "live" EB). As the "live" EB positive control group developed a natural immunity, they cleared the second re-challenge quickly.

Infection Control: In this group, the mice were only challenged with "live" EB at the same time that the "Positive Live EB controls were re-challenged and the test CT group was challenged. The purpose of this control group was to check for a possible protective effect from the negative control group (ie the group immunized with immunoregulatory agent alone).

EXAMPLE 7: *In vitro* model for the selection of antigens inducing a CD4 Th1 response

Th1-type cytokines, such as IL-12 and IFN- γ , have been proposed to be important for resolution of chlamydial infection. Indeed, mice deficient in IFN- γ are unable to control chlamydial infection in the genital tract as Chlamydia disseminates to systemic sites [126, 127].

Two immunological screening approaches to identify Chlamydia antigens capable of inducing Chlamydia-specific IFN- γ -producing CD4⁺ T cells have been devised: 1) after experimental mouse infection with Chlamydia trachomatis, and 2) following mouse immunization with Chlamydia recombinant proteins. These antigens would be the most promising candidates to confer CD4⁺-mediated protection.

In the first approach: CD4 Th1 stimulation upon EB (Elementary Bodies) infection: LPS-free purified recombinant surface antigens are screened for their capacity to stimulate CD4⁺/IFN- γ -producing T lymphocytes from mice resolving a primary Ct infection and thereby protected against further infections. This approach allows the identification of antigens which could induce a CD4 Th1 response during natural infection.

In the second approach: CD4 Th1 induction upon immunization with CT recombinant antigens: purified recombinant antigens are used to immunize mice and antigen specific CD4 T cell response is analysed ex vivo by stimulating spleen cells with Ct EB and LPS-free antigens. This approach allows the priming of in vivo antigen-specific CD4-Th1 cells that could potentially be involved in recognition of EB.

In the first approach female BALB/c mice 6-7 weeks old were pretreated with 2.5 mg of medroxy-progesterone acetate (Depo-Provera) on day -5 and then infected intravaginally at day 0 by depositing 15ml of SPG (250mM Sucrose, 10mM Sodium Phosphate, 5mM L-Glutamic acid) containing 10⁶ IFU of C.trachomatis serovar D. Seven days post infection the course of infection was monitored by swabbing the vaginal vault and determining the number of recovered IFUs on LL-CMK2 cell monolayers using indirect immunofluorescence.

Splenocytes were prepared from spleens of mice infected with Chlamydia trachomatis (10 days post infection) and non-infected controls. Spleens of each group of mice were pooled and dispersed manually. Splenocytes were cultured in RPMI 1640 medium supplemented with 25

mM HEPES buffer, 100UI/ml penicillin, 100 ug/ml streptomycin, 50 uM 2-mercaptoethanol, 0.15 mM L-glutamine, sodium pyruvate, vitamins, a cocktail of non-essential amino acids and 2.5% heat inactivated fetal calf serum.

Freshly prepared splenocytes from infected mice and non infected controls were stimulated for 4 hours in round-bottom 96 well plates with 20ug/ml of various *Chlamydia trachomatis* recombinant antigens in the presence of 1ug/ml anti-CD28. As positive controls of stimulation 1ug/ml of anti-CD3 and 10ug/ml of heat inactivated whole *C.trachomatis* Elementary Bodies were used. For the analysis of antigen induced intracellular cytokine expression, 2.5 ug/ml Brefeldin-A (Sigma) was added overnight. At the end of the stimulation period cells were fixed with 2% paraformaldehyde and subsequently permeabilized with PBS-1%BSA-0.5% saponin. Fixed cells were stained for 30 min at room temperature with the following antibodies: antiCD4-FITC, antiCD8-PerCp, antiIFN γ -APC and antiIL5-PE (all BD Pharmingen).

Stained cells were analyzed for cytokine production on a LSRII cytometer with a DIVA software.

In the second approach, mice were immunized intramuscularly on days 1, 14 and 28 with a panel of recombinant chlamydial proteins with proper adjuvants. A week after the last immunization, PBMC were isolated and assessed by spleen harvesting as described above, in the presence of syngeneic irradiated APC. Ex vivo stimulation was carried out for 24 hours using whole *Chlamydia trachomatis* EBs and LPS-free antigens. Following stimulation the cells were analysed for cytokine production (IFN- γ and IL-5) as described above.

For the second approach, splenocytes were prepared from spleens of mice immunized with the recombinant antigens (3 doses 20ug, with AIOH +CpG) and adjuvant-immunized mice. Spleens of each group of mice were pooled and dispersed manually. Splenocytes were cultured in RPMI 1640 medium supplemented with 25 mM HEPES buffer, 100UI/ml penicillin, 100 ug/ml streptomycin, 50 uM 2-mercaptoethanol, 0.15 mM L-glutamine, sodium pyruvate, vitamins, a cocktail of non-essential amino acids and 2.5% heat inactivated fetal calf serum.

Flow cytometry analysis of antigen-induced cytokine expression for the second approach was carried out in the same way as the first approach except in this case antigen specific CD4 T cell response is analysed ex vivo by stimulating spleen cells with Ct EB and LPS-free antigens.

Both screening are carried out using multi-parametric FACS analysis to assess the cytokine expression profile of antigen-specific Th1-cells.

Results from the first approach indicated that 13 out of 70 tested antigens were found to be CD4-Th1 inducers (CT681, CT823, CT043, CT587, CT153, CT480, CT016, CT341, CT372, CT396, CT600, CT601, CT711). Noteworthy among these CT4-Th1 inducing antigens is CT396.

Results for the second approach indicated that both CT396 and CT381 are able to induce strong antigen-specific and Chlamydia specific responses.

Results from the first and second approach are expressed in terms of the frequency of EB-specific and antigen-specific CD4-IFN gamma+ T lymphocytes in 10000 CD4+ cells derived from splenocytes of mice immunized with the antigens (formulated with LTK63+CpG as adjuvant), upon stimulation with either EB or the antigen itself as compared to that obtained from adjuvant-immunized mice.

For CT381, the frequency of EB-specific and CT381-specific CD4-IFN gamma+ T lymphocytes is 450 (vs 131 of adjuvant immunized mice) and 109 (vs 17 of adjuvant immunized mice) respectively.

For CT396, the frequency of EB-specific and CT396-specific CD4-IFN gamma+ T lymphocytes is 612 (vs 309 of adjuvant immunized mice) and 488 (vs 17 of adjuvant immunized mice) respectively.

These results indicate that both ArtJ (CT381) and DnaK (CT396) are examples of Chlamydia antigens capable of producing high frequencies of cells that are capable of producing IFN-gamma.

OVERALL SUMMARY

The present invention provides variant LcrE sequences and/or combinations of variant LcrE sequences across the *Chlamydia trachomatis* serovars. Such changes in LcrE genotypes across the *Chlamydia trachomatis* serovars are likely to correspond with changes in LcrE phenotypes, in particular, with changes in immunogenicity. The present invention also provides peptides surrounding or associated with the amino acid substitutions, in particular, peptides surrounding or associated with high frequency mutated amino acid positions or hypervariable regions, which are likely to be B and/or T cell epitopic regions capable of eliciting *Chlamydia* specific cell mediated immune responses. The variant LcrE sequences and/or combinations of the variant LcrE sequences and/or epitope regions associated with the variant LcrE sequences are useful as immunogens and/or in the preparation of immunogenic compositions for preventing and/or treating and/or diagnosing *Chlamydia* infections.

The present invention also provides variant Omp-H-like sequences and/or combinations of variant Omp-H-like sequences across the *Chlamydia trachomatis* serovars. Such changes in Omp-H-like genotypes across the *Chlamydia trachomatis* serovars are likely to correspond with changes in Omp-H-like phenotypes, in particular, with changes in immunogenicity. The present invention also provides peptides surrounding or associated with the amino acid substitutions, in particular, peptides surrounding or associated with high frequency mutated amino acid positions or hypervariable regions, which are likely to be B and/or T cell epitopic regions capable of eliciting *Chlamydia* specific immune responses. The variant Omp-H-like sequences and/or combinations of the variant LcrE sequences and/or epitope regions associated with the variant Omp-H-like sequences are useful as immunogens and/or in the preparation of immunogenic compositions for preventing and/or treating and/or diagnosing *Chlamydia* infections.

The present invention also provides variant PepA sequences and/or combinations of variant PepA sequences across the *Chlamydia trachomatis* serovars. Such changes in PepA genotypes across the *Chlamydia trachomatis* serovars are likely to correspond with changes in PepA phenotypes, in particular, with changes in immunogenicity. The present invention also provides peptides surrounding or associated with the amino acid substitutions, in particular, peptides surrounding or associated with high frequency mutated amino acid positions or hypervariable regions, which are likely to be B and/or T cell epitopic regions capable of eliciting *Chlamydia*

specific immune responses. The variant PepA sequences and/or combinations of the variant PepA sequences and/or epitope regions associated with the variant PepA sequences are useful as immunogens and/or in the preparation of immunogenic compositions for preventing and/or treating and/or diagnosing *Chlamydia* infections.

The present invention also provides variant ArtJ sequences and/or combinations of variant ArtJ sequences across the *Chlamydia trachomatis* serovars. Such changes in ArtJ genotypes across the *Chlamydia trachomatis* serovars are likely to correspond with changes in ArtJ phenotypes, in particular, with changes in immunogenicity. The present invention also provides peptides surrounding or associated with the amino acid substitutions, in particular, peptides surrounding or associated with high frequency mutated amino acid positions or hypervariable regions, which are likely to be B and/or T cell epitopic regions capable of eliciting *Chlamydia* specific immune responses. The variant ArtJ sequences and/or combinations of the variant ArtJ sequences and/or epitope regions associated with the variant ArtJ sequences are useful as immunogens and/or in the preparation of immunogenic compositions for preventing and/or treating and/or diagnosing *Chlamydia* infections.

The present invention also provides variant DnaK sequences and/or combinations of variant DnaK sequences across the *Chlamydia trachomatis* serovars. Such changes in DnaK genotypes across the *Chlamydia trachomatis* serovars are likely to correspond with changes in DnaK phenotypes, in particular, with changes in immunogenicity. The present invention also provides peptides surrounding or associated with the amino acid substitutions, in particular, peptides surrounding or associated with high frequency mutated amino acid positions or hypervariable regions, which are likely to be B and/or T cell epitopic regions capable of eliciting *Chlamydia* specific immune responses. The variant DnaK sequences and/or combinations of the variant DnaK sequences and/or epitope regions associated with the variant DnaK sequences are useful as immunogens and/or in the preparation of immunogenic compositions for preventing and/or treating and/or diagnosing *Chlamydia* infections.

The present invention also provides variant Hypothetical (CT398) sequences and/or combinations of variant DnaK sequences across the *Chlamydia trachomatis* serovars. Such changes in Hypothetical (CT398) genotypes across the *Chlamydia trachomatis* serovars are

likely to correspond with changes in Hypothetical (CT398) phenotypes, in particular, with changes in immunogenicity. The present invention also provides peptides surrounding or associated with the amino acid substitutions, in particular, peptides surrounding or associated with high frequency mutated amino acid positions or hypervariable regions, which are likely to be B and/or T cell epitopic regions capable of eliciting *Chlamydia* specific immune responses. The variant sequences and/or combinations of the variant Hypothetical (CT398) sequences and/or epitope regions associated with the variant Hypothetical (CT398) sequences are useful as immunogens and/or in the preparation of immunogenic compositions for preventing and/or treating and/or diagnosing *Chlamydia* infections.

All publications mentioned in the above specification are herein incorporated by reference. Various modifications and variations of the described methods and system of the invention will be apparent to those skilled in the art without departing from the scope and spirit of the invention. Although the invention has been described in connection with specific preferred embodiments, it should be understood that the invention as claimed should not be unduly limited to such specific embodiments. Indeed, various modifications of the described modes for carrying out the invention which are obvious to those skilled in molecular biology or related fields are intended to be covered by the present invention.

REFERENCES

Moulder JW. 1991. Interaction of *Chlamydia trachomatis* and host cells in vitro. Microbiol Rev. **55**: 143-90.

Stephens RS. 1999. Genomic autobiographies of Chlamidiae. American Society for Microbiology Press. Washington DC, USA. 9-27.

Schachter, J., and Stamm W.E. 1999. *Chlamydia trachomatis*. In P.R. Murray, Baron E.J., Tenover F.C. and Tenover F.C. Manual of Clinical Microbiology. American Society for Microbiology Press. Washington DC, USA. 669-677.

An BB, Adamis AP. 1998. *Chlamydia trachomatis* ocular diseases. Int Ophthalmol Clin. **38**: 221-30.

Schachter J. 1999. Infection and disease epidemiology. American Society for Microbiology Press. Washington DC, USA. 139-170.

Centers for Disease Control and Prevention. 1993. Recommendations for the prevention and management of *Chlamydia trachomatis* trachomatis infections. Morbid.Mortal. Wkly Rep. **42**:1-39.

Washington AE, Johnson RE, Sanders LL Jr. 1987. *Chlamydia trachomatis trachomatis* infections in the United States. What are they costing us? *JAMA*. 257: 2070-2.

Schachter, J., and P. B. Wyrick. 1994. Culture and isolation of *Chlamydia trachomatis trachomatis*. *Methods Enzymol*. 236:377-390.

Stephens RS, Kalman S, Lammel C, Fan J, Marathe R, Aravind L, Mitchell W, Olinger L, Tatusov RL, Zhao Q, Koonin EV, Davis RW. 1998. Genome sequence of an obligate intracellular pathogen of humans: *Chlamydia trachomatis trachomatis*. *Science* 282: 754-9.

Gardy JL, Spencer C, Wang K, Ester M, Tusnady GE, Simon I, Hua S, deFays K, Lambert C, Nakai K, Brinkman FS. PSORT-B: Improving protein subcellular localization prediction for Gram-negative bacteria. *Nucleic Acids Res*. 2003 Jul 1;31(13):3613-7.

Montigiani, S., F. Falugi, M. Scarselli, O. Finco, R. Petracca, G. Galli, M. Mariani, R. Manetti, M. Agnusdei, R. Cevenini, M. Donati, R. Nogarotto, N. Norais, I. Garaguso, S. Nuti, G. Saletti, D. Rosa, G. Ratti, and G. Grandi. 2002. Genomic approach for analysis of surface proteins in *Chlamydia trachomatis pneumoniae*. *Infect Immun* 70:368-79.

Towbin, H., T. Staehelin, and J. Gordon. 1979. Electrophoretic transfer of proteins from polyacrylamide gels to nitrocellulose sheets: procedure and some applications. *Proc. Natl. Acad. Sci. USA* 76:4350-4354.

Laemmli, U. K. 1970. Cleavage of structural proteins during the assembly of the head of bacteriophage T4. *Nature* 227:680-685.

Young, I. T. 1977. Proof without prejudice: use of the Kolmogorov-Smirnov test for the analysis of histograms from flow systems and other sources. *J Histochem Cytochem* 25:935-41.

Bini, L., Sanchez-Campillo, M., Santucci, A., Magi, B., Marzocchi, B., Comanducci, M., Christiansen, G., Birkelund, S., Cevenini, R., Vretou, E., Ratti, G. and Pallini, V. (1996). Mapping of *Chlamydia trachomatis trachomatis* proteins by immobilized-polyacrylamide two-dimensional electrophoresis: spot identification by N-terminal sequencing and immunoblotting. *Electrophoresis* 17, 185-90.

Christiansen, G., Boesen, T., Hjerno, K., Daugaard, L., Mygind, P., Madsen, A. S., Knudsen, K., Falk, E. and Birkelund, S. (1999). Molecular biology of *Chlamydia trachomatis pneumoniae* surface proteins and their role in immunopathogenicity. *Am Heart J* 138, S491-5.

Comanducci, M., Cevenini, R., Moroni, A., Giuliani, M. M., Ricci, S., Scarlato, V. and Ratti, G. (1993). Expression of a plasmid gene of *Chlamydia trachomatis trachomatis* encoding a novel 28 kDa antigen. *J Gen Microbiol* 139, 1083-92.

Gardy, J. L., Spencer, C., Wang, K., Ester, M., Tusnady, G. E., Simon, I., Hua, S., deFays, K., Lambert, C., Nakai, K. and Brinkman, F. S. (2003). PSORT-B: Improving protein subcellular localization prediction for Gram-negative bacteria. *Nucleic Acids Res* 31, 3613-7.

Grandi, G. (2001). Antibacterial vaccine design using genomics and proteomics. *Trends Biotechnol* 19, 181-8.

Grimwood, J., Olinger, L. and Stephens, R. S. (2001). Expression of *Chlamydia trachomatis pneumoniae* polymorphic membrane protein family genes. *Infect Immun* 69, 2383-9.

- Kawa, D. E. and Stephens, R. S. (2002). Antigenic topology of *Chlamydia trachomatis* PorB protein and identification of targets for immune neutralization of infectivity. *J Immunol* **168**, 5184-91.
- Knudsen, K., Madsen, A. S., Mygind, P., Christiansen, G. and Birkelund, S. (1999). Identification of two novel genes encoding 97- to 99-kilodalton outer membrane proteins of *Chlamydia trachomatis* pneumoniae. *Infect Immun* **67**, 375-83.
- Montigiani, S., Falugi, F., Scarselli, M., Finco, O., Petracca, R., Galli, G., Mariani, M., Manetti, R., Agnusdei, M., Cevenini, R., Donati, M., Nogarotto, R., Norais, N., Garaguso, I., Nuti, S., Saletti, G., Rosa, D., Ratti, G. and Grandi, G. (2002). Genomic approach for analysis of surface proteins in *Chlamydia trachomatis* pneumoniae. *Infect Immun* **70**, 368-79.
- Moulder, J. W. (1991). Interaction of *Chlamydia trachomatis* and host cells in vitro. *Microbiol Rev* **55**, 143-90.
- Mygind, P. H., Christiansen, G., Roepstorff, P. and Birkelund, S. (2000). Membrane proteins PmpG and PmpH are major constituents of *Chlamydia trachomatis* trachomatis L2 outer membrane complex. *FEMS Microbiol Lett* **186**, 163-9.
- Pedersen, A. S., Christiansen, G. and Birkelund, S. (2001). Differential expression of Pmp10 in cell culture infected with *Chlamydia trachomatis* pneumoniae CWL029. *FEMS Microbiol Lett* **203**, 153-9.
- Pizza, M., Scarlato, V., Masignani, V., Giuliani, M. M., Arico, B., Comanducci, M., Jennings, G. T., Baldi, L., Bartolini, E., Capecci, B., Galeotti, C. L., Luzzi, E., Manetti, R., Marchetti, E., Mora, M., Nuti, S., Ratti, G., Santini, L., Savino, S., Scarselli, M., Storni, E., Zuo, P., Broeker, M., Hundt, E., Knapp, B., Blair, E., Mason, T., Tettelin, H., Hood, D. W., Jeffries, A. C., Saunders, N. J., Granoff, D. M., Venter, J. C., Moxon, E. R., Grandi, G. and Rappuoli, R. (2000). Identification of vaccine candidates against serogroup B meningococcus by whole-genome sequencing. *Science* **287**, 1816-20.
- Schachter, J. and Wyrick, P. B. (1994). Culture and isolation of *Chlamydia trachomatis* trachomatis. *Methods Enzymol* **236**, 377-90.
- Shaw, A. C., Gevaert, K., Demol, H., Hoorelbeke, B., Vandekerckhove, J., Larsen, M. R., Roepstorff, P., Holm, A., Christiansen, G. and Birkelund, S. (2002). Comparative proteome analysis of *Chlamydia trachomatis* trachomatis serovar A, D and L2. *Proteomics* **2**, 164-86.
- Somani, J., Bhullar, V. B., Workowski, K. A., Farshy, C. E. and Black, C. M. (2000). Multiple drug-resistant *Chlamydia trachomatis* trachomatis associated with clinical treatment failure. *J Infect Dis* **181**, 1421-7.
- Stephens, R. S., Kalman, S., Lammel, C., Fan, J., Marathe, R., Aravind, L., Mitchell, W., Olinger, L., Tatusov, R. L., Zhao, Q., Koonin, E. V. and Davis, R. W. (1998). Genome sequence of an obligate intracellular pathogen of humans: *Chlamydia trachomatis* trachomatis. *Science* **282**, 754-9.
- Taraktchoglou, M., Pacey, A. A., Turnbull, J. E. and Eley, A. (2001). Infectivity of *Chlamydia trachomatis* trachomatis serovar LGV but not E is dependent on host cell heparan sulfate. *Infect Immun* **69**, 968-76.
- Vandahl, B. B., Pedersen, A. S., Gevaert, K., Holm, A., Vandekerckhove, J., Christiansen, G. and Birkelund, S. (2002). The expression, processing and localization of polymorphic membrane proteins in *Chlamydia trachomatis* pneumoniae strain CWL029. *BMC Microbiol* **2**, 36.
- Waldman, F. M., Hadley, W. K., Fulwyler, M. J. and Schachter, J. (1987). Flow cytometric analysis of *Chlamydia trachomatis* trachomatis interaction with L cells. *Cytometry* **8**, 55-9.

ENDNOTE CITATIONS USED IN SPECIFICATION

1. Bush, R.M. and Everett, K.D.E. (2001) Molecular Evolution of the *C. trachomatis trachomatis*ceae. *Int. J. Syst. Evol. Microbiol.* 51:203 – 220.
2. Kalman *et al.* (1999) *Nature Genetics* 21:385-389
3. Read *et al.* (2000) *Nucleic Acids Res* 28:1397-1406
4. Shirai *et al.* (2000) *Nucleic Acids Res* 28:2311-2314
5. Stephens *et al.* (1998) *Science* 282:754-759
6. WO99/27105
7. WO00/27994
8. WO99/28475
9. Ward (1995) *Apmis*. 103:769-96.
10. Moulder (1991) *Microbiol Rev* 55(1):143-190.
11. Comanducci *et al.* (1994) *Infect Immun* 62(12):5491-5497.
12. EP-A-0499681
13. WO95/28487
14. Murdin *et al.* (1993) *Infect Immun* 61:4406-4414
15. Cerrone *et al.* (1991) *Infect Immun* 59(1):79-90.
16. Raulston *et al.* (1993) *J. Biol. Chem.* 268:23139-23147.
17. WO03/049762.
18. Gennaro (2000) *Remington: The Science and Practice of Pharmacy*. 20th ed., ISBN: 0683306472.
19. WO99/24578.
20. WO99/36544.
21. WO99/57280.
22. WO02/079243.
- {23} Costantino *et al.* (1992) *Vaccine* 10:691-698.
- {24} Costantino *et al.* (1999) *Vaccine* 17:1251-1263.
- {25} WO03/007985.
- {26} Covacci & Rappuoli (2000) *J. Exp. Med.* 19:587-592.
- {27} WO93/18150.
- {28} Covacci *et al.* (1993) *Proc. Natl. Acad. Sci. USA* 90: 5791-5795.
- {29} Tummuru *et al.* (1994) *Infect. Immun.* 61:1799-1809.
- {30} Marchetti *et al.* (1998) *Vaccine* 16:33-37.
- {31} Telford *et al.* (1994) *J. Exp. Med.* 179:1653-1658.
- {32} Evans *et al.* (1995) *Gene* 153:123-127.
- {33} WO96/01272 & WO96/01273, especially SEQ ID NO:6.
- {34} WO97/25429.
- {35} WO98/04702.
- {36} Watson (2000) *Pediatr Infect Dis J* 19:331-332.
- {37} Rubin (2000) *Pediatr Clin North Am* 47:269-285, v.
- {38} Jedrzejewski (2001) *Microbiol Mol Biol Rev* 65:187-207.
- {39} WO02/077021.
- {40} Bell (2000) *Pediatr Infect Dis J* 19:1187-1188.
- {41} Iwarson (1995) *APMIS* 103:321-326.
- {42} Gerlich *et al.* (1990) *Vaccine* 8 Suppl:S63-68 & 79-80.
- {43} Hsu *et al.* (1999) *Clin Liver Dis* 3:901-915.
- {44} *Vaccines* (1988) eds. Plotkin & Mortimer. ISBN 0-7216-1946-0.
- {45} Del Giudice *et al.* (1998) *Molecular Aspects of Medicine* 19:1-70.
- {46} Gustafsson *et al.* (1996) *N. Engl. J. Med.* 334:349-355.

-
- {47} Rappuoli *et al.* (1991) *TIBTECH* 9:232-238.
 - {48} Sutter *et al.* (2000) *Pediatr Clin North Am* 47:287-308.
 - {49} Zimmerman & Spann (1999) *Am Fam Physician* 59:113-118, 125-126.
 - {50} WO99/24578.
 - {51} WO99/36544.
 - {52} WO99/57280.
 - {53} WO02/079243.
 - {54} WO99/24578.
 - {55} WO99/36544.
 - {56} WO99/57280.
 - {57} WO00/22430.
 - {58} WO00/66791.
 - {59} WO03/020756.
 - {60} WO01/64920.
 - {61} WO01/64922.
 - {62} Tettelin *et al.* (2000) *Science* 287:1809-1815.
 - {63} Pizza *et al.* (2000) *Science* 287:1816-1820.
 - {64} UK patent application 0227346.4.
 - {65} UK patent applications 0223741.0, 0305831.0 & 0309115.4.
 - {66} Bjune *et al.* (1991) *Lancet* 338(8775):1093-96
 - {67} WO01/52885.
 - {68} Fukasawa *et al.* (1999) *Vaccine* 17:2951-2958.
 - {69} Rosenqvist *et al.* (1998) *Dev. Biol. Stand.* 92:323-333.
 - {70} WO02/02606.
 - {71} Kalman *et al.* (1999) *Nature Genetics* 21:385-389.
 - {72} Read *et al.* (2000) *Nucleic Acids Res* 28:1397-406.
 - {73} Shirai *et al.* (2000) *J. Infect. Dis.* 181(Suppl 3):S524-S527.
 - {74} WO99/27105.
 - {75} WO00/27994.
 - {76} WO00/37494.
 - {77} Ross *et al.* (2001) *Vaccine* 19:4135-4142.
 - {78} Dreesen (1997) *Vaccine* 15 Suppl:S2-6.
 - {79} *MMWR Morb Mortal Wkly Rep* 1998 Jan 16;47(1):12, 19.
 - {80} Anderson (2000) *Vaccine* 19 Suppl 1:S59-65.
 - {81} Kahn (2000) *Curr Opin Pediatr* 12:257-262.
 - {82} Crowe (1995) *Vaccine* 13:415-421.
 - {83} McMichael (2000) *Vaccine* 19 Suppl 1:S101-107.
 - {84} WO02/34771.
 - {85} Dale (1999) *Infect Dis Clin North Am* 13:227-43, viii.
 - {86} Ferretti *et al.* (2001) *PNAS USA* 98: 4658-4663.
 - {87} WO02/34771.
 - {88} Kuroda *et al.* (2001) *Lancet* 357(9264):1225-1240; see also pages 1218-1219.
 - {89} *J Toxicol Clin Toxicol* (2001) 39:85-100.
 - {90} Demicheli *et al.* (1998) *Vaccine* 16:880-884.
 - {91} Stepanov *et al.* (1996) *J Biotechnol* 44:155-160.
 - {92} Rosenberg (2001) *Nature* 411:380-384.
 - {93} Moingeon (2001) *Vaccine* 19:1305-1326.
 - 94. WO00/15255.
 - 95. Ramsay *et al.* (2001) *Lancet* 357(9251):195-196.

-
96. Lindberg (1999) *Vaccine* 17 Suppl 2:S28-36.
 97. Buttery & Moxon (2000) *J R Coll Physicians Lond* 34:163-168.
 98. Ahmad & Chapnick (1999) *Infect Dis Clin North Am* 13:113-133, vii.
 99. Goldblatt (1998) *J. Med. Microbiol.* 47:563-567.
 100. European patent 0 477 508.
 101. US Patent No. 5,306,492.
 102. International patent application WO98/42721.
 103. *Conjugate Vaccines* (eds. Cruse *et al.*) ISBN 3805549326, particularly vol. 10:48-114.
 104. Hermanson (1996) *Bioconjugate Techniques* ISBN: 0123423368 or 012342335X.
 105. *Research Disclosure*, 453077 (Jan 2002)
 106. EP-A-0372501
 107. EP-A-0378881
 108. EP-A-0427347
 109. WO93/17712
 110. WO94/03208
 111. WO98/58668
 112. EP-A-0471177
 113. WO00/56360
 114. WO91/01146
 115. WO00/61761
 116. WO01/72337
 117. Robinson & Torres (1997) *Seminars in Immunology* 9:271-283.
 118. Donnelly *et al.* (1997) *Annu Rev Immunol* 15:617-648.
 119. Scott-Taylor & Dalgleish (2000) *Expert Opin Investig Drugs* 9:471-480.
 120. Apostolopoulos & Plebanski (2000) *Curr Opin Mol Ther* 2:441-447.
 121. Ilan (1999) *Curr Opin Mol Ther* 1:116-120.
 122. Dubensky *et al.* (2000) *Mol Med* 6:723-732.
 123. Robinson & Pertmer (2000) *Adv Virus Res* 55:1-74.
 124. Donnelly *et al.* (2000) *Am J Respir Crit Care Med* 162(4 Pt 2):S190-193.
 125. Davis (1999) *Mt. Sinai J. Med.* 66:84-90.

[126] Cotter *et al.* (1997) *Infect. Immun.* 65:2145-2152.

[127] Perry *et al.* (1997) *J. Immunol.* 158(7):3344-3352.

What is claimed is:

1. A protein consisting of an amino acid sequence of SEQ ID NO: 46, except that the amino acid sequence contains one or more mutations, wherein the one or more mutation(s) involves an amino acid residue(s) selected from the group consisting of 64, 126, 157, 162, 179, 207, 217, 220, 275 and 420.
2. The protein according to claim 1 wherein the mutation is independently a substitution, an insertion or a deletion, preferably comprising one or more of the mutations listed in Table 7.
3. The protein of claim 1 or claim 2 wherein the one or more mutation(s) alter the immunogenicity of the protein.
4. The protein of any one of claims 1 to 3 wherein the protein comprises one or more mutated sequences selected from the group of sequences consisting of SEQ ID Nos 1, 4, 6, 8, 11, 12, 13, 16, 18, 19, 20, 21, 23 and/or 27.
5. The protein of claim 4 comprising SEQ ID No 11, 4 or 6.
6. The protein of claim 4 comprising SEQ ID No 13 or 8.
7. The protein of claim 4 comprising SEQ ID No 12 or 1.
8. The protein of claim 2 comprising a mutation at amino acid residue 64 and/or 162.
9. The protein of claim 4 comprising SEQ ID No 16, 18, 19, 20, 21, 22, 23 or 27.
10. A protein comprising the amino acid sequence of a protein according to any one of the preceding claims or one or more fragment(s) of at least 7 consecutive amino acids of a protein according to any one of the preceding claims.

11. The protein of claim 10 wherein the one or more fragment(s) comprises one or more mutations involving an amino acid residue(s) selected from the group consisting of 64, 126, 157, 162, 179, 207, 217, 220, 275 and/or 420.
12. An antibody which binds to a protein of any one of claims 1-11.
13. A nucleic acid encoding the protein of any one of claims 1-11.
14. A vector comprising a nucleic acid according to claim 13.
15. A host cell transformed with a vector according to claim 14.
16. The protein of any one of claims 1-11, an antibody according to claim 12 or a nucleic acid according to claim 13 for use as a medicament.
17. The protein or nucleic acid of claim 16 for use as an immunogen.
18. The protein of any one of claims 1-11, an antibody according to claim 12 or a nucleic acid according to claim 13 for use as a diagnostic reagent.
19. The use of the protein as defined in any one of claims 1-11, the antibody according to claim 12 or the nucleic acid according to claim 13 in the manufacture of a medicament for preventing or treating a *Chlamydia trachomatis* infection.
20. The use of the protein as defined in any one of claims 1-11, the antibody according to claim 12 or the nucleic acid according to claim 13 in the manufacture of a diagnostic reagent for detecting the presence of *Chlamydia trachomatis* or of antibodies raised against *Chlamydia trachomatis*.
21. The use of the protein as defined in any one of claims 1-11, the antibody according to claim 12 or the nucleic acid according to claim 13 in the manufacture of a reagent which can raise antibodies against *Chlamydia trachomatis*.

22. A method of treating a subject comprising administering to the subject a therapeutically effective amount of a protein according to any one of claims 1-11, an antibody according to claim 12 or a nucleic acid according to claim 13.
23. A process for producing a protein according to any one of claims 1-11, the antibody according to claim 12 or the nucleic acid according to claim 13 comprising the step of culturing a host cell according to claim 15 under conditions which induce protein expression.
24. A process for producing a protein according to any one of claims 1-11, the antibody according to claim 12 or the nucleic acid according to claim 13 wherein the protein or nucleic acid is synthesised in part or in whole using chemical means.
25. A process for detecting a nucleic acid according to claim 13 comprising the steps of (a) contacting a nucleic acid probe with a biological sample under hybridising conditions to form duplexes and (b) detecting said duplexes.
26. A process for detecting a protein according to any one of claims 1-11 comprising the steps of (a) contacting an antibody according to claim 12 with a biological sample under conditions suitable for the formation of antibody-antigen complexes and (b) detecting said complexes.
27. A process for detecting an antibody according to claim 12 comprising the steps of: contacting a protein according to any one of claims 1-11 with a biological sample under conditions suitable for the formation of an antibody-antigen complexes and (b) detecting said complexes.
28. A kit comprising reagents suitable for use in a process according to any one of claims 25-28.
29. An immunogenic composition comprising the protein of any one of claims 1-11, the antibody of example 12 or the nucleic acid of example 13 and an immunologically acceptable excipient.

30. The composition of claim 29 further comprising one or more antigen(s).
31. The composition of claim 29 or 30 further comprising one or more adjuvant(s).
32. The composition of any one of claims 29-31 for use as a medicament.
33. Use of a composition of any one of claims 29-31 in the manufacture of a medicament for preventing or treating or diagnosing a bacterial infection.
34. The use according to claim 33 wherein the bacterial infection is a *Chlamydia trachomatis* infection.
35. An immunogenic composition comprising at least two proteins selected from the group of sequences consisting of SEQ ID Nos 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, 40, 41, 42, 43, 44, and 45, 49-98, 99-180, 181, 182, 183 and/or 184.
36. The composition according to claim 35 wherein the composition comprises SEQ ID No 1 and SEQ ID No 12.
37. The composition according to claim 36 wherein the composition comprises SEQ ID No 13 and SEQ ID No 46.
38. The composition according to any one of claims 35-37 comprising (a) one or more further antigen(s) and/or (d) one or more further adjuvant(s).
39. The composition of any one of claims 35-38 for use as a medicament.
40. Use of a composition of any one of claims 35-38 in the manufacture of a medicament for preventing or treating or diagnosing a bacterial infection.
41. The use according to example 40 wherein the bacterial infection is a *Chlamydia trachomatis* infection.

42. A method of eliciting an immune response in a subject wherein the method comprises administering to a subject a composition according to any one of claims 29-31 or 35-38.
43. A polypeptide comprising one or more fragment(s) of at least 7 consecutive amino acids, preferably at least 9 consecutive amino acids, selected from the group consisting of SEQ 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44 and 45, 47-98, 99-180, 55, 66, 109, 110, 111, 181, 182, 183 and/or 184.
44. The composition according to claim 35 having proteins comprising SEQ ID NOS: 1, 12, 13, 45, and 7.
46. An immunogenic composition comprising one or more peptides selected from the group consisting of SEQ ID Nos 54, 66, 109, 110, 111, 181, 182, 183 and 184.
47. An immunogenic composition comprising one or more peptides selected from the group consisting of SEQ ID Nos 181, 182, 183 and/or 184.
48. The polypeptide according to claim 43 or the composition according to claims 46 or 47 for use as an immunogen.
49. The polypeptide according to claim 48 wherein the use is as an immunogen for raising a humoral and/or a cytotoxic T cell lymphocyte response which is sufficient to protect or treat a disease and/or infection caused by *Chlamydia*.
50. A method of raising an immune response in a mammal comprising the step of administering to the mammal a polypeptide according to claim 43 or an immunogenic composition according to claim 46 or 47.
51. The method of claim 50 wherein the immune response protects or treats a disease and/or an infection caused by *Chlamydia*.
52. The polypeptide according to claim 43 or the composition according to claims 46 or 47 for use as a diagnostic.

53. A method of diagnosing a *Chlamydia* infection in a patient comprising incubating T cell from the patient with a polypeptide as defined in claim 43 or 46 or 47 and detecting the subsequent presence or absence of T-cell proliferation.

54. Use of a polypeptide according to claim 43 or the composition according to claims 46 or 47 in the preparation of a medicament for use in the prevention or treatment of a bacterial infection, preferably a *Chlamydia* infection.

55. An protein or an immunogenic composition comprising SEQ ID Nos 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26 and 27.

56. A protein or an immunogenic composition comprising SEQ ID No 185 wherein amino amino acid residue at position X1 is selected from the group consisting of Glycine (G) or Glutamic acid (E); amino acid at residue X2 is selected from the group consisting of Aspartic acid (D) or Glutamic acid (E) or Asparagine (N); amino acid at residue X3 is selected from the group consisting of Glycine (G) or Arginine (R); amino acid at residue X4 is selected from the group consisting of Threonine (T) or Alanine (A); amino acid at residue X5 is selected from the group consisting of Valine (V) or Isoleucine (I); amino acid at residue X6 is selected from the group consisting of Phenylalanine (F) or Leucine (L); amino acid at residue X7 is selected from the group consisting of Alanine (A) or Aspartic acid (D); amino acid at residue X8 is selected from the group consisting of Histidine (H) or Arginine ®; amino acid at residue X9 is selected from the group consisting of Asparagine (N) or Aspartic acid (D) and amino acid residue at position X10 is selected from the group consisting of Serine (S) or Proline (P) wherein the protein is not SEQ ID No 46.

57. The protein or the immunogenic composition according to claim 56 for use according to any one of claims 16-27.