(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
30 July 2015 (30.07.2015)

(10) International Publication Number
WO 2015/112558 A2

(51) International Patent Classification:
G01N 33/569 (2006.01)

(21) International Application Number:
PCT/US2015/012187

(22) International Filing Date:
21 January 2015 (21.01.2015)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
61/929,655 21 January 2014 (21.01.2014) US
14/511,916 10 October 2014 (10.10.2014) US

(71) Applicant: **ABAXIS, INC.** [US/US]; 3240 Whipple Road, Union City, California 94587 (US).

(72) Inventors: **MEHRA, Rajesh K.**; 25410 Southwick Drive #109, Hayward, California 94544 (US). **ARON, Kenneth P.**; 201 Fair Oaks Street, San Francisco, California 94110 (US). **BLEILE, Dennis M.**; 800 Winterside Circle, San Ramon, California 94583 (US). **ROGERS, Andrew P.**; Union City, California (US). **FORSYTH, Timothy P.**; 1928 Wingate Way, Hayward, California 94541 (US). **WALKER, Jeremy D.**; 22120 Center Street, Castro Valley, California 94546 (US). **CUESICO, Cristina R.**; 4587 Alhambra Drive, Fremont, California 94536 (US).

(74) Agents: **WU, Nan** et al.; Cooley LLP, 1299 Pennsylvania Avenue, NW, Suite 700, Washington, DC 20004-2400 (US).

(81) **Designated States** *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

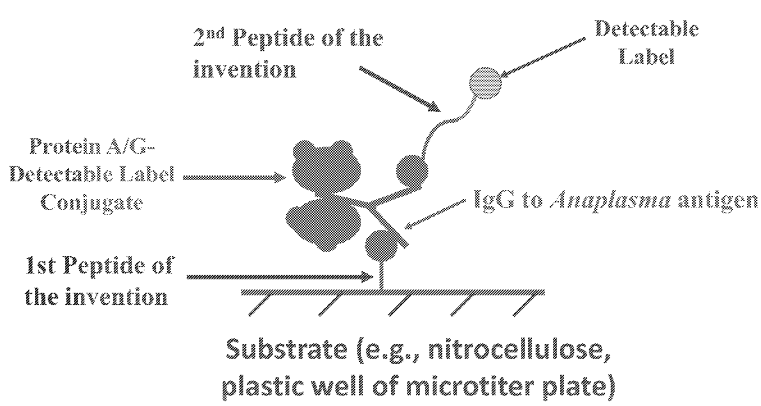
(84) **Designated States** *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:
— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

Published:
— *without international search report and to be republished upon receipt of that report (Rule 48.2(g))*
— *with sequence listing part of description (Rule 5.2(a))*

(54) **Title**: PEPTIDES, DEVICES, AND METHODS FOR THE DETECTION OF ANAPLASMA ANTIBODIES

Fig. 1



(57) **Abstract**: The invention provides populations of isolated peptides useful for the detection of antibodies that bind to *Anaplasma* antigens. The peptide populations comprise peptides derived from immunogenic fragments of the *Anaplasma* Outer Membrane Protein proteins. The invention also provides devices, methods, and kits comprising the populations of isolated peptides useful for the detection of antibodies that bind to *Anaplasma* antigens and the diagnosis of anaplasmosis. Methods of identifying the particular *Anaplasma* species infecting a subject using the peptide populations of the invention are also disclosed.

WO 2015/112558 A2

PEPTIDES, DEVICES, AND METHODS FOR THE DETECTION OF ANAPLASMA ANTIBODIES

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application No. 61/929,655, filed January 21, 2014, and U.S. Application No. 14/511,916, filed October 10, 2014, both of which are hereby incorporated by reference in their entireties.

DESCRIPTION OF THE TEXT FILE SUBMITTED ELECTRONICALLY

[0002] The contents of the text file submitted electronically herewith are incorporated herein by reference in their entirety: A computer readable format copy of the Sequence Listing (filename: ABAX_041_01WO _SeqList_ST25.txt, date recorded January 20, 2015, file size 263 kilobytes).

BACKGROUND OF THE INVENTION

[0003] *Anaplasma* are a genus of gram-negative bacteria that are obligate intracellular pathogens capable of infecting granulocytes, platelets and erythrocytes in vertebrate hosts. *Anaplasma* bacteria are transmitted to hosts through arthropod vectors, particularly various species of ticks. *A. phagocytophilum* infects neutrophils and causes anaplasmosis in mammals, including humans. The incidence of human granulocytotropic (or granulocytic) anaplasmosis (HGA, formerly known as human granulocytotropic ehrlichiosis) has increased steadily, from 1.4 cases per million persons in 2000 to 6.1 cases per million persons in 2010. *A. phagocytophilum* is transmitted primarily by *Ixodes spp.* of ticks. Because these *Ixodes* species ticks also transmit *Borrelia burgdorferi* (the causative agent of Lyme disease), simultaneous infection with *A. phagocytophilum* and *B. burgdorferi* is common.

[0004] *A. platys* causes infectious cyclic thrombocytopenia by infecting platelets and is thought to be transmitted by *Rhipicephalus* and *Dermacentor spp.* ticks. Although dogs are the most common host for *A. platys* infection, infection in other mammals, including cats, impalas, and sheep, have been reported. Co-infection of *A. platys* and *Ehrlichia canis* due to the common vector of transmission has been known to occur.

[0005] Indirect immunofluorescence assays (IFA) and enzyme-linked immunosorbent assays (ELISA) have typically been used to detect *Anaplasma* infection. These assays detect the binding of anti-*Anaplasma* antibodies from a subject's blood, plasma, or serum to infected cells, cell lysates, or partially purified whole *Anaplasma* proteins. However, these assays for detecting anti-*Anaplasma* antibodies are limited in usefulness because of sensitivity and specificity issues directly related to the nature of the *Anaplasma* antigens used in these tests. Although polymerase chain reaction (PCR)-based tests with improved specificity and sensitivity have been developed, there is a continued need in the art for additional sensitive and specific assays for detecting *Anaplasma* antigens and serodiagnosis of anaplasmosis.

SUMMARY OF THE INVENTION

[0006] The present invention is based, in part, on the discovery that certain sequence variants of fragments of the *Anaplasma* outer membrane proteins provide for robust detection of an antibody response against *Anaplasma* species. Accordingly, the invention provides compositions, devices, methods, and kits useful for the detection of antibodies that bind to *Anaplasma* antigens and the diagnosis of anaplasmosis.

[0007] In one embodiment, the present invention provides populations of peptides capable of binding to antibodies that recognize *Anaplasma* antigens. In certain embodiments, the population of isolated peptides comprises three or more different peptides, wherein each peptide in the population comprises a sequence of Abaxis ID 2, E-T-R-V-A-Y-P-Y-X_9-K-D-G-R-T-V-K-X_{17}-D-S-H-X_{21}-F-D-W-Q-T-P-X_{28}-P-K-X_{31}-G-F-K-D-C (SEQ ID NO: 1) or a fragment thereof, wherein X_9 is an amino acid selected from the group consisting of I, P or H, X_{17} is an amino acid selected from the group consisting of I, W, or Y, X_{21} is an amino acid selected from the group consisting of R, D, or N, X_{28} is an amino acid selected from the group consisting of E or N, and X_{31} is an amino acid selected from the group consisting of L or V. In other embodiments, each peptide in the population comprises a sequence of Abaxis ID 3, I-E-X_3-G-Y-E-X_7-F-K-T-X_{11}-G-I-R-X_{15}-S-G-T-K-E-C (SEQ ID NO: 2) or a fragment thereof, wherein X_3 is an amino acid selected from the group consisting of L, V or A, X_7 is an amino acid selected from the group consisting of K, N or Q, X_{11} is an amino acid selected from the group consisting of R, D, or N, and X_{15} is an amino acid selected from the group consisting of E, N or Q.

[0008] In another embodiment of the invention, each peptide in the population comprises a sequence of APL-ID1, E-T-K-V-X_5-Y-X_7-Y-L-K-X_{11}-G-R-T-V-K-L-X_{18}-S-H-X_{21}-F-D-W-X_{25}-T-P-X_{28}-P-K-X_{31}-G-F-K-D-G-G-G-G-G-K-D-G-T-X_{45}-V-E-X_{48}-K-A-X_{51}-K-F-X_{54}-W-N-X_{57}-P-D-X_{60}-R-I-X_{63}-F-K-X_{66}-C (SEQ ID NO: 3) or a fragment thereof, wherein X_5 is an amino acid selected from the group consisting of V or A, X_7 is an amino acid selected from the group consisting of G, I or H, X_{11} is an amino acid selected from the group consisting of E, N, or Q, X_{18} is an amino acid selected from the group consisting of D or N, X_{21} is an amino acid selected from the group consisting of R, D, or N, X_{25} is an amino acid selected from the group consisting of Q, D, or E, X_{28} is an amino acid selected from the group consisting of E or N, X_{31} is an amino acid selected from the group consisting of L or V, X_{45} is an amino acid selected from the group consisting of K or Q, X_{48} is an amino acid selected from the group consisting of F or V, X_{51} is an amino acid selected from the group consisting of D or N, X_{54} is an amino acid selected from the group consisting of E or Q, X_{57} is an amino acid selected from the group consisting of S or Q, X_{60} is an amino acid selected from the group consisting of F or W, X_{63} is an amino acid selected from the group consisting of I or V, and X_{66} is an amino acid selected from the group consisting of Q or D. In yet another embodiment, each peptide in the population comprises a sequence of APL-ID2, C-K-D-G-T-X_6-V-E-X_9-K-A-X_{12}-K-F-X_{15}-W-N-X_{18}-P-D-X_{21}-R-I-X_{24}-F-K-X_{27} (SEQ ID NO: 4) or a fragment thereof, wherein X_6 is an amino acid selected from the group consisting of K or Q, X_9 is an amino acid selected from the group consisting of F or V, X_{12} is an amino acid selected from the group consisting of D or N, X_{15} is an amino acid selected from the group consisting of E or Q, X_{18} is an amino acid selected from the group consisting of S or Q, X_{21} is an amino acid selected from the group consisting of F or W, X_{24} is an amino acid selected from the group consisting of I or V, and X_{27} is an amino acid selected from the group consisting of Q or D. In another embodiment, each peptide in the population comprises a sequence of APL-ID3, C-X_2-G-G-K-S-P-A-R-X_{10}-T-E-E-R-V-A-G-D-L-D-H-K-X_{23}-V-D-S-D-K-K-H-D-A-E-K-T-E-E-K-R-H (SEQ ID NO: 5) or a fragment thereof, wherein X_2 is an amino acid selected from the group consisting of I or V, X_{10} is an amino acid selected from the group consisting of S or Y, and

X_{23} is an amino acid selected from the group consisting of E or N. In certain embodiments, each peptide in the population comprises a sequence of APL-ID5.1, C-G-K-I-L-N-L-V-S-A-V-Q-E-K-K-P-P-E-A-P-A-A-D-E-A-A-G-P-A-T-H (SEQ ID NO: 6) or a fragment thereof.

[0009] In some embodiments of the invention, a population of isolated peptides comprises three or more different peptides, wherein each peptide in the population comprises a sequence of APL-ID6, C-K-D-G-X_5-R-V-E-X_9-K-A-E-X_{13}-F-N-X_{16}-Q-X_{18}-P-N-P-X_{22}-I-K-Y-R-X_{27} (SEQ ID NO: 7) or a fragment thereof, wherein X_5 is an amino acid selected from the group consisting of S or Q, X_9 is an amino acid selected from the group consisting of F or Y, X_{13} is an amino acid selected from the group consisting of R or H, X_{16} is an amino acid selected from the group consisting of W or Y, X_{18} is an amino acid selected from the group consisting of S or Q, X_{22} is an amino acid selected from the group consisting of K or H, and X_{27} is an amino acid selected from the group consisting of N or D. In another embodiment, each peptide in the population comprises a sequence of APL-ID7, C-G-K-I-L-N-L-V-S-X_{10}-X_{11}-N-E-K-K-P-P-E-A-P-A-A-D-E-A-A-G-P-A-T-H (SEQ ID NO: 8) or a fragment thereof, wherein X_{10} is an amino acid selected from the group consisting of V, L or I, and X_{11} is an amino acid selected from the group consisting of A or L. In still another embodiment, each peptide in the population comprises a sequence of APID 2-1, E-T-K-V-X_5-Y-X_7-Y-L-K-X_{11}-G-R-T-V-K-L-D-S-H-X_{21}-F-D-W-X_{25}-T-P-X_{28}-P-K-X_{31}-G-F-K-D-C (SEQ ID NO: 9) or a fragment thereof, wherein X_5 is an amino acid selected from the group consisting of V or A, X_7 is an amino acid selected from the group consisting of G, I or H, X_{11} is an amino acid selected from the group consisting of E, N, or Q, X_{21} is an amino acid selected from the group consisting of R, D, or N, X_{25} is an amino acid selected from the group consisting of Q, D, or E, X_{28} is an amino acid selected from the group consisting of E or N, and X_{31} is an amino acid selected from the group consisting of L or V.

[0010] In certain embodiments, the populations of *Anaplasma* peptides may further comprise one or more antigenic peptides from another microbial species. In one embodiment, the population of *Anaplasma* peptides further comprises one or more antigenic peptides from an *Ehrlichia* species (*e.g.*, *E. canis*, *E. chaffeensis*, *E. ewingii*, and *E. muris*), and/or a *Borrelia* species (*e.g.*, *B. burgdorferi*, *B. afzelli*, or *B. garinii*).

[0011] Peptides of the invention may comprise at least 20, 30, 35, 40, 45, 50, or more amino acids. In some embodiments, peptides of the invention are isolated (*e.g.*, synthetic and/or purified) peptides. In particular embodiments, peptides of the invention are conjugated to a ligand. For example, in certain embodiments, the peptides are biotinylated. In other embodiments, the peptides are conjugated to streptavidin, avidin, or neutravidin. In other embodiments, the peptides are conjugated to a carrier protein (*e.g.*, serum albumin, keyhole limpet hemocyanin (KLH), or an immunoglobulin Fc domain). In still other embodiments, the peptides are conjugated to a dendrimer and/or are part of a multiple antigenic peptides system (MAPS). In certain embodiments, the peptides are conjugated to a detectable entity or label, such as an enzyme, a metallic nanomaterial, or a fluorophore. In certain embodiments, the peptides are conjugated to metallic nanoparticles, nanoshells, nanoplates, nanorings or nanorods.

[0012] In certain embodiments, peptides of the invention are attached to or immobilized on a solid support. In one embodiment, the peptides of the invention are attached to a solid support through a metallic nanolayer. In certain embodiments, the solid support is a bead or plurality of beads (*e.g.*, a colloidal particle, metallic nanomaterial such as nanoparticle, nanoplate, or nanoshell, latex bead, etc.), a flow path in a lateral flow immunoassay device (*e.g.*, a porous membrane), a blot (Western blot, a slot blot, or dot blot), a flow path in an analytical or centrifugal rotor, or a tube or well (*e.g.*, in a plate suitable for an ELISA assay).

[0013] In one aspect, the present invention provides a composition comprising one or more populations of isolated peptides described herein.

[0014] In some embodiments, the composition comprises a population of isolated peptides, said population comprising three or more different peptides, wherein each peptide in the population comprises a sequence, or a fragment thereof, of SEQ ID NO: 1, 2, 3, 4, 5, 6, 7, 8, or 9.

[0015] In certain embodiments, the composition further comprises one or more antigenic peptides from an *Anaplasma* species, an *Ehrlichia* species, and/or a *Borrelia* species.

[0016] In some embodiments, the composition comprises at least two different populations of peptides described herein. In certain embodiments, at least one of the peptide populations is defined by SEQ ID NO: 3. For instance, in one embodiment, at least one of the peptide populations comprises three or more different peptides, wherein each peptide in the population comprises a sequence, or a fragment thereof, of SEQ ID NO: 3.

[0017] In certain embodiments, the composition further comprises a second population of isolated peptides. In some embodiments, the second peptide population is defined by SEQ ID NO: 7. In some other embodiments, each peptide in the second peptide population comprises the sequence, or a fragment thereof, of SEQ ID NO: 6.

[0018] In some embodiments, the composition further comprises a third population of isolated peptides that is different from the first and second peptide populations. In certain embodiments, each peptide in the third peptide population comprises the sequence, or a fragment thereof, of SEQ ID NO: 6.

[0019] In another aspect, the present invention also provides a method for detecting in a sample an antibody to an epitope of an *Anaplasma* antigen. In one embodiment, the method comprises contacting a sample with a peptide or population of peptides of the invention; and detecting formation of an antibody-peptide complex comprising the peptide or one or more peptides in the population, wherein formation of the complex is indicative of an antibody to an epitope of an *Anaplasma* antigen being present in the sample. The methods can be used to detect antibodies to antigens from *A. phagocytophilum*, *A. platys*, or *A. marginale* species.

[0020] In another embodiment, the present invention provides a method for diagnosing anaplasmosis or cyclic thrombocytopenia in a subject. In one embodiment, the method comprises contacting a sample from the subject with a peptide or population of peptides of the invention; and detecting formation of an antibody-peptide complex comprising the peptide or one or more peptides in the population, wherein formation of the complex is indicative of the subject having anaplasmosis or cyclic thrombocytopenia.

[0021] The present invention also includes a method for identifying the species of *Anaplasma* infecting a subject. In one embodiment, the method comprises contacting a sample from the subject with a first peptide or first population of peptides and a second peptide or second population of peptides, wherein the first peptide or first population of peptides specifically binds to antibodies against antigens from multiple *Anaplasma* species, and wherein the second peptide or second population of peptides specifically binds to antibodies against antigens from a single *Anaplasma* species; detecting formation of a first antibody-peptide complex comprising said first peptide or one or more peptides in the first population; and detecting formation of a second antibody-peptide complex comprising said second peptide or one or more peptides in the second population, wherein formation of both the first and second antibody-peptide complexes indicates that the subject is infected with the *Anaplasma* species that is specifically bound by the second population of isolated peptides.

[0022] In certain embodiments of the method, the first peptide or first population of peptides specifically binds to antibodies against antigens from *A. phagocytophilum*, *A. platys, and A. marginale*. In other embodiments, the first peptide or first population of peptides specifically binds to antibodies against antigens from *A. phagocytophilum* and *A. platys*. In some embodiments, the second peptide or second population of peptides specifically binds to antibodies against antigens from *A. platys*. In other embodiments, the second peptide or second population of peptides specifically binds to antibodies against antigens from *A. phagocytophilum*. In one embodiment of the method, the first peptide or first population of peptides is defined by SEQ ID NO: 3 and the second peptide or second population of peptides is defined by SEQ ID NO: 4, and the formation of both the first and second antibody-peptide complexes indicates that the subject is infected with *A. platys*. In another embodiment of the method, the first peptide or first population of peptides is defined by SEQ ID NO: 3 and the second peptide or second population of peptides is defined by SEQ ID NO: 4, and the formation of the first antibody-peptide complex, but not the second antibody-peptide complex indicates that the subject is infected with *A. phagocytophilum*.

[0023] In other embodiments, the method for identifying the species of *Anaplasma* infecting a subject comprises contacting a sample from the subject with a first population of peptides and a cell extract of a single *Anaplasma* species, wherein the first population of isolated peptides specifically binds to antibodies against antigens from multiple *Anaplasma* species; detecting formation of a first antibody-peptide complex comprising one or more peptides in the first population; and detecting formation of an antibody-cell extract complex comprising one or more components in the cell extract, wherein formation of both the first antibody-peptide complex and the antibody-cell extract complex indicates that the subject is infected with the *Anaplasma* species that produced the cell extract.

[0024] In any of the methods described above and herein, the peptide or population of peptides can, in some embodiments, be attached to or immobilized upon a solid support. In one such embodiment, the peptide or population of peptides is attached to the solid support through a metallic (*e.g.*, gold) nanolayer. In certain embodiments, the solid support is a bead or plurality of beads (*e.g.*, a colloidal particle, a metallic nanomaterial such as nanoparticle, nanoplate, nanoshell, nanorod, a latex bead, etc.), a flow path in a lateral flow immunoassay device (*e.g.*, a porous membrane), a flow path in an analytical or centrifugal rotor, a blot (Western blot, a slot blot, or dot blot), or a tube or a well (*e.g.*, in a plate suitable for an ELISA assay). In some embodiments, the solid support comprises metal, glass, a cellulose-based material (*e.g.*, nitrocellulose), or a polymer (*e.g.*, polystyrene, polyethylene, polypropylene, polyester, nylon, polysulfone, etc.). In other embodiments, the peptide or population of different peptides is attached to a dendrimer and/or incorporated into a multiple antigenic peptide system (MAPS) system. In certain other embodiments, the peptide or population of different peptides is attached to BSA, KLH, ovalbumin or a similar carrier.

[0025] In any of the methods described above and herein, the detecting step may comprise performing an ELISA assay. In other embodiments, the detecting step comprises performing a lateral flow immunoassay. In other embodiments, the detecting step comprises performing an agglutination assay. In other embodiments, the detecting step comprises spinning the sample in an analytical or centrifugal rotor. In other embodiments, the detecting step comprises analyzing the sample using a Western blot, a slot blot, or a dot blot. In still other embodiments, the detecting step comprises analyzing the sample with an electrochemical sensor, an optical sensor, or an opto-electronic sensor. In certain embodiments, the detecting step comprises performing a wavelength shift assay. In certain embodiments, the detecting step comprises performing an Indirect Fluorescent Antibody test.

[0026] The sample from the subject used in any of the methods described above and herein, in some embodiments, is a bodily fluid, such as blood, serum, plasma, cerebrospinal fluid, urine, mucus, or saliva. In other embodiments, the sample is a tissue (*e.g.*, a tissue homogenate) or a cell lysate. In certain embodiments, the sample is from a wild animal (*e.g.*, a deer or rodent, such as a mouse, chipmunk, squirrel, etc.). In other embodiments, the sample is from a lab animal (*e.g.*, a mouse, rat, guinea pig, rabbit, monkey, primate, etc.). In other embodiments, the sample is from a domesticated or feral animal (*e.g.*, a dog, a cat, a horse). In still other embodiments, the sample is from a human.

[0027] The present invention also includes kits comprising a peptide or population of peptides of the invention. In one embodiment, the kit comprises at least one population of peptides of the invention and a labeling reagent capable of binding to an antibody that recognizes an epitope of one or more peptides in the population. The labeling reagent may be an anti-human, anti-canine, or anti-feline IgG or IgM antibody conjugated to a detectable label. In other embodiments, the labeling reagent is protein A, protein G, and/or a protein A/G fusion protein conjugated to a detectable label. In related embodiments, the detectable label is an enzyme, a metallic nanomaterial, fluorophore, or colored latex particle. Examples of metallic nanomaterials include, but are not limited to, metallic nanoparticles, nanoshells, nanorings, nanorods, and nanoplates.

[0028] In certain embodiments, the peptides in the kit are attached to or immobilized on a solid support optionally through a metallic nanolayer. In certain embodiments, the solid support is a bead (*e.g.*, a colloidal particle, a metallic nanomaterial such as nanoparticle, nanoplate, or nanoshell, a latex bead, etc.), a flow path in a lateral flow immunoassay device, a flow path in an analytical or centrifugal rotor, or a tube or a well (*e.g.*, in a plate). In some embodiments, the peptide or peptides in the kit are attached to a dendrimer and/or incorporated into a MAPS system. In certain other embodiments, the peptide or mixture of different peptides is attached to BSA.

[0029] In some embodiments, the kits further comprise a population of beads or a plate (*e.g.*, a plate suitable for an ELISA assay). In other embodiments, the kits further comprise a device, such as a lateral flow immunoassay device, an analytical or centrifugal rotor, a Western blot, a dot blot, a slot blot, an electrochemical sensor, an optical sensor, or an opto-electronic sensor. In certain embodiments, the population of beads, the plate, or the device is useful for performing an immunoassay. For example, in certain embodiments, the population of beads, the plate, or the device is useful for detecting formation of an antibody-peptide complex comprising an antibody from a sample and a peptide of the invention. In certain embodiments, a peptide or population of different peptides of the invention is attached to or immobilized on the beads, the plate, or the device.

[0030] The kits of the invention may further comprise a set of instructions indicating, for example, how to use a peptide or population of peptides of the invention to detect an antibody to an *Anaplasma* antigen or to diagnose anaplasmosis or cyclic thrombocytopenia in a subject. In certain embodiments, the kits comprise an instruction indicating how to use a population of beads, a plate, or a device (*e.g.*, comprising a peptide or a population of different peptides of the invention) to detect an antibody to one or more *Anaplasma* antigens or to diagnose anaplasmosis or cyclic thrombocytopenia.

[0031] Additional aspects and embodiments of the invention will be apparent from the detailed description that follows.

BRIEF DESCRIPTION OF THE DRAWINGS

[0032] Figure 1 is a diagram of a double antigen sandwich assay which can be used to detect antibodies to *Anaplasma* antigens. In this embodiment, peptides of the invention are immobilized to a suitable substrate (*e.g.*, nitrocellulose membrane, well of an ELISA plate) at a test site. Antibodies to *Anaplasma* antigens in a test sample are bound by the immobilized peptides of the invention. Test sample antibodies to appropriate *Anaplasma* antigens will then bind to a second set of peptides of the invention that are conjugated to a detectable label (*e.g.*, metallic nanomaterial such as nanoparticle, nanoplate, or nanoshell (*e.g.*, colloidal gold), horse radish peroxidase (HRP), alkaline phosphatase (ALP), β-galactosidase (β-GAL), fluorophore, colored latex particle, quantum dot), which detects the presence of the antibodies bound to the first set of peptides immobilized at the test site. In certain embodiments, to amplify the detection signal, protein A and/or protein G molecules conjugated to a detectable label (*e.g.*, metallic nanomaterial such as nanoparticle, nanoplate, or nanoshell (*e.g.*, colloidal gold), HRP, ALP, β-GAL, fluorophore, colored latex particle, quantum dot) may be applied to the test site where they will bind to the Fc region of any antibodies to *Anaplasma* antigens captured by the immobilized peptides of the invention.

[0033] **Figure 2** is a diagram of one type of indirect sandwich assay which can be used to detect antibodies to *Anaplasma* antigens. In this embodiment, anti-human IgG/IgM, anti-dog IgG/IgM, or anti-cat IgG/IgM antibodies are immobilized to a suitable substrate (*e.g.*, nitrocellulose membrane, well of an ELISA plate) at a test site. Antibodies to *Anaplasma* antigens in a test sample are bound by the immobilized antibodies. Test sample antibodies to appropriate *Anaplasma* antigens will then bind to peptides of the invention that are conjugated to a detectable label (*e.g.*, metallic nanomaterial such as nanoparticle, nanoplate, or nanoshell (*e.g.*, colloidal gold), HRP, ALP, β-GAL, fluorophore, colored latex particle, or quantum dot).

[0034] **Figure 3** is a diagram of another type of indirect sandwich assay which can be used to detect antibodies to *Anaplasma* antigens. In this embodiment, peptides of the invention can be immobilized to a substrate (*e.g.*, nitrocellulose membrane, well of an ELISA plate) to capture anti-*Anaplasma* antibodies in a test sample. Anti-human IgG/IgM, anti-dog IgG/IgM, or anti-cat IgG/IgM antibodies conjugated to a detectable label (*e.g.*, metallic nanomaterial such as nanoparticle, nanoplate, or nanoshell (*e.g.*, colloidal gold), HRP, ALP, β-GAL, fluorophore, colored latex particle, quantum dot) can be used to detect the presence of the antibodies bound to the immobilized peptides at the test site.

[0035] **Figure 4** is a diagram of an immunoassay device which can be used to detect antibodies to *Anaplasma* antigens. In this embodiment of an immunoassay device, peptides of the invention are immobilized to a suitable substrate (*e.g.*, nitrocellulose membrane, well of an ELISA plate) at a test site. Anti-*Anaplasma* antibodies in a test sample are bound by the immobilized peptides of the invention. Protein A, Protein G, or a Protein A/G fusion protein conjugated to a detectable label (*e.g.*, metallic nanomaterial such as nanoparticle, nanoplate, or nanoshell (*e.g.*, colloidal gold), HRP, ALP, β-GAL,fluorophore, colored latex particle, quantum dot) is added to the system and binds to the Fc portion of the captured anti- *Anaplasma* antibody, thereby producing a positive signal. In this embodiment, the device can further comprise a control site at which binding partners that recognize the detectable label-conjugated protein A, detectable label-conjugated protein G, and/or detectable label-conjugated protein A/G fusion are immobilized. Such binding partners may include, but are not limited to, anti-protein A, anti-protein G, mouse IgG, and/or other similar IgG molecules.

[0036] Figure 5 is a line graph of ELISA scores (OD650 nm) with APL-ID1 peptides of plasma samples drawn at various intervals from dogs infected with either *A. phagocytophilum* (dog 3-13) or *A. platys* (dog 15-13).

[0037] Figure 6 is a line graph of ELISA scores (OD650 nm) with APL-ID2 peptides of plasma samples drawn at various intervals from dogs infected with either *A. phagocytophilum* (dog 3-13) or *A. platys* (dog 15-13).

[0038] Figure 7 depicts one example of a lateral flow assay device that can be used to detect antibodies to *Anaplasma* antigens. Peptides of the invention are linked to a carrier protein (*e.g.* bovine serum albumin) and the resulting BSA-peptide conjugates are immobilized on a nitrocellulose (NC) membrane at a test site (T). The same BSA-peptide conjugates are conjugated to a detectable label (*e.g.*, colloidal gold) and deposited in a conjugate pad positioned upstream of the test site. Gold-conjugated protein A and gold-conjugated protein G (*i.e.* amplifier) is added to the conjugate pad to enhance the signal by binding to the Fc portion of the captured anti-*Anaplasma* antibody. The device further comprises a control site (C) at which binding partners that recognize the gold-conjugated protein A and/or gold-conjugated protein G are immobilized.

[0039] Figure 8 illustrates the operation of the lateral flow assay device in Figure 7. A test sample is applied to the sample port of the device and mobilizes the peptide conjugates present on the conjugate pad. Any anti-*Anaplasma* antibodies present in the test sample will specifically bind to the peptide conjugates and the formed complexes will migrate to the nitrocellulose membrane containing the test and control sites. The labeled peptide-antibody complexes are captured by immobilized peptides of the invention at the test site. Gold-conjugated protein A and gold-conjugated protein G also present on the conjugate pad are mobilized by the sample and bind to the Fc regions of IgG and IgM molecules present in the sample. Binding of the gold-conjugated protein A and/or protein G to the captured peptide-antibody complexes amplify the signal at the test site. Gold-conjugated protein A and/or gold-conjugated protein G is captured by a binding partner (*e.g.* anti-Protein A and/or anti-Protein G antibody) immobilized at the control site, thereby producing a signal indicating that the device is operational.

DETAILED DESCRIPTION

[0040] The present invention is based, in part, on the discovery that certain sequence variants of fragments of the *Anaplasma* outer membrane proteins provide for robust detection of an antibody response against *Anaplasma* species. Accordingly, the invention provides compositions, devices, methods, and kits useful for the detection of antibodies that bind to *Anaplasma* antigens and for the diagnosis of anaplasmosis.

[0041] The term "antigen," as used herein, refers to a molecule capable of being recognized by an antibody. An antigen can be, for example, a peptide or a modified form thereof. An antigen can comprise one or more epitopes.

[0042] The term "epitope," as used herein, is a portion of an antigen that is specifically recognized by an antibody. An epitope, for example, can comprise or consist of a portion of a peptide (*e.g.*, a peptide of the invention). An epitope can be a linear epitope, sequential epitope, or a conformational epitope. In certain embodiments, epitopes may comprise non-contiguous regions.

[0043] The terms "nucleic acid," "oligonucleotide" and "polynucleotide" are used interchangeably herein and encompass DNA, RNA, cDNA, whether single stranded or double stranded, as well as chemical modifications thereof.

[0044] Single letter amino acid abbreviations used herein have their standard meaning in the art, and all peptide sequences described herein are written according to convention, with the N-terminal end to the left and the C-terminal end to the right.

Compositions and Devices

[0045] The present invention provides isolated peptides capable of binding to antibodies that recognize *Anaplasma* antigens and devices incorporating such peptides. In one embodiment, the present invention provides a population of isolated peptides comprising three or more different peptides, wherein each peptide in the population comprises a sequence of Abaxis ID 2 (SEQ ID NO: 1), Abaxis ID 3 (SEQ ID NO: 2), APL-ID1 (SEQ ID NO: 3), APL-ID2 (SEQ ID NO: 4), APL-ID3 (SEQ ID NO: 5), APL-ID5.1 (SEQ ID NO: 6), APL-ID6 (SEQ ID NO: 7), APL-ID7 (SEQ ID NO: 8), APID 2-1 (SEQ ID NO: 9), or fragments thereof. For instance, in one embodiment, the population of isolated peptides comprises three or more different peptides, wherein each peptide in the population comprises a sequence of E-T-R-V-A-Y-P-Y-X_9-K-D-G-R-T-V-K-X_{17}-D-S-H-X_{21}-F-D-W-Q-T-P-X_{28}-P-K-X_{31}-G-F-K-D-C (SEQ ID NO: 1), or a fragment thereof, wherein X_9 is an amino acid selected from the group consisting of I, P or H, X_{17} is an amino acid selected from the group consisting of I, W, or Y, X_{21} is an amino acid selected from the group consisting of R, D, or N, X_{28} is an amino acid selected from the group consisting of E or N, and X_{31} is an amino acid selected from the group consisting of L or V.

[0046] In some embodiments, peptides of the invention comprise a sequence of SEQ ID NO: 1, wherein X_{28} is N and/or X_{31} is V. In other embodiments, peptides of the invention comprise a sequence of SEQ ID NO: 1, wherein X_9 is P, X_{17} is I, and/or X_{21} is N. In certain embodiments, the population of isolated peptides comprises three or more peptides comprising or consisting of any one of the sequences in Table 1.

Table 1. Abaxis ID 2 Peptides

Sequence	SEQ ID NO.
E-T-R-V-A-Y-P-Y-I-K-D-G-R-T-V-K-I-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-C	10
E-T-R-V-A-Y-P-Y-P-K-D-G-R-T-V-K-I-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-C	11

Sequence	SEQ ID NO.
E-T-R-V-A-Y-P-Y-H-K-D-G-R-T-V-K-I-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-C	12
E-T-R-V-A-Y-P-Y-I-K-D-G-R-T-V-K-W-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-C	13
E-T-R-V-A-Y-P-Y-I-K-D-G-R-T-V-K-Y-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-C	14
E-T-R-V-A-Y-P-Y-P-K-D-G-R-T-V-K-W-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-C	15
E-T-R-V-A-Y-P-Y-P-K-D-G-R-T-V-K-Y-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-C	16
E-T-R-V-A-Y-P-Y-H-K-D-G-R-T-V-K-W-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-C	17
E-T-R-V-A-Y-P-Y-H-K-D-G-R-T-V-K-Y-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-C	18
E-T-R-V-A-Y-P-Y-I-K-D-G-R-T-V-K-I-D-S-H-D-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-C	19
E-T-R-V-A-Y-P-Y-I-K-D-G-R-T-V-K-W-D-S-H-D-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-C	20
E-T-R-V-A-Y-P-Y-I-K-D-G-R-T-V-K-Y-D-S-H-D-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-C	21
E-T-R-V-A-Y-P-Y-P-K-D-G-R-T-V-K-I-D-S-H-D-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-C	22
E-T-R-V-A-Y-P-Y-P-K-D-G-R-T-V-K-W-D-S-H-D-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-C	23
E-T-R-V-A-Y-P-Y-P-K-D-G-R-T-V-K-Y-D-S-H-D-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-C	24
E-T-R-V-A-Y-P-Y-H-K-D-G-R-T-V-K-I-D-S-H-D-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-C	25
E-T-R-V-A-Y-P-Y-H-K-D-G-R-T-V-K-W-D-S-H-D-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-C	26
E-T-R-V-A-Y-P-Y-H-K-D-G-R-T-V-K-Y-D-S-H-D-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-C	27
E-T-R-V-A-Y-P-Y-I-K-D-G-R-T-V-K-I-D-S-H-N-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-C	28
E-T-R-V-A-Y-P-Y-I-K-D-G-R-T-V-K-W-D-S-H-N-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-C	29
E-T-R-V-A-Y-P-Y-I-K-D-G-R-T-V-K-Y-D-S-H-N-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-C	30
E-T-R-V-A-Y-P-Y-P-K-D-G-R-T-V-K-I-D-S-H-N-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-C	31
E-T-R-V-A-Y-P-Y-P-K-D-G-R-T-V-K-W-D-S-H-N-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-C	32
E-T-R-V-A-Y-P-Y-P-K-D-G-R-T-V-K-Y-D-S-H-N-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-C	33
E-T-R-V-A-Y-P-Y-H-K-D-G-R-T-V-K-I-D-S-H-N-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-C	34

Sequence	SEQ ID NO.
E-T-R-V-A-Y-P-Y-H-K-D-G-R-T-V-K-W-D-S-H-N-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-C	35
E-T-R-V-A-Y-P-Y-H-K-D-G-R-T-V-K-Y-D-S-H-N-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-C	36
E-T-R-V-A-Y-P-Y-I-K-D-G-R-T-V-K-I-D-S-H-R-F-D-W-Q-T-P-N-P-K-L-G-F-K-D-C	37
E-T-R-V-A-Y-P-Y-P-K-D-G-R-T-V-K-I-D-S-H-R-F-D-W-Q-T-P-N-P-K-L-G-F-K-D-C	38
E-T-R-V-A-Y-P-Y-H-K-D-G-R-T-V-K-I-D-S-H-R-F-D-W-Q-T-P-N-P-K-L-G-F-K-D-C	39
E-T-R-V-A-Y-P-Y-I-K-D-G-R-T-V-K-W-D-S-H-R-F-D-W-Q-T-P-N-P-K-L-G-F-K-D-C	40
E-T-R-V-A-Y-P-Y-I-K-D-G-R-T-V-K-Y-D-S-H-R-F-D-W-Q-T-P-N-P-K-L-G-F-K-D-C	41
E-T-R-V-A-Y-P-Y-P-K-D-G-R-T-V-K-W-D-S-H-R-F-D-W-Q-T-P-N-P-K-L-G-F-K-D-C	42
E-T-R-V-A-Y-P-Y-P-K-D-G-R-T-V-K-Y-D-S-H-R-F-D-W-Q-T-P-N-P-K-L-G-F-K-D-C	43
E-T-R-V-A-Y-P-Y-H-K-D-G-R-T-V-K-W-D-S-H-R-F-D-W-Q-T-P-N-P-K-L-G-F-K-D-C	44
E-T-R-V-A-Y-P-Y-H-K-D-G-R-T-V-K-Y-D-S-H-R-F-D-W-Q-T-P-N-P-K-L-G-F-K-D-C	45
E-T-R-V-A-Y-P-Y-I-K-D-G-R-T-V-K-I-D-S-H-D-F-D-W-Q-T-P-N-P-K-L-G-F-K-D-C	46
E-T-R-V-A-Y-P-Y-I-K-D-G-R-T-V-K-W-D-S-H-D-F-D-W-Q-T-P-N-P-K-L-G-F-K-D-C	47
E-T-R-V-A-Y-P-Y-I-K-D-G-R-T-V-K-Y-D-S-H-D-F-D-W-Q-T-P-N-P-K-L-G-F-K-D-C	48
E-T-R-V-A-Y-P-Y-P-K-D-G-R-T-V-K-I-D-S-H-D-F-D-W-Q-T-P-N-P-K-L-G-F-K-D-C	49
E-T-R-V-A-Y-P-Y-P-K-D-G-R-T-V-K-W-D-S-H-D-F-D-W-Q-T-P-N-P-K-L-G-F-K-D-C	50
E-T-R-V-A-Y-P-Y-P-K-D-G-R-T-V-K-Y-D-S-H-D-F-D-W-Q-T-P-N-P-K-L-G-F-K-D-C	51
E-T-R-V-A-Y-P-Y-H-K-D-G-R-T-V-K-I-D-S-H-D-F-D-W-Q-T-P-N-P-K-L-G-F-K-D-C	52
E-T-R-V-A-Y-P-Y-H-K-D-G-R-T-V-K-W-D-S-H-D-F-D-W-Q-T-P-N-P-K-L-G-F-K-D-C	53
E-T-R-V-A-Y-P-Y-H-K-D-G-R-T-V-K-Y-D-S-H-D-F-D-W-Q-T-P-N-P-K-L-G-F-K-D-C	54
E-T-R-V-A-Y-P-Y-I-K-D-G-R-T-V-K-I-D-S-H-N-F-D-W-Q-T-P-N-P-K-L-G-F-K-D-C	55
E-T-R-V-A-Y-P-Y-I-K-D-G-R-T-V-K-W-D-S-H-N-F-D-W-Q-T-P-N-P-K-L-G-F-K-D-C	56
E-T-R-V-A-Y-P-Y-I-K-D-G-R-T-V-K-Y-D-S-H-N-F-D-W-Q-T-P-N-P-K-L-G-F-K-D-C	57

Sequence	SEQ ID NO.
E-T-R-V-A-Y-P-Y-P-K-D-G-R-T-V-K-I-D-S-H-N-F-D-W-Q-T-P-N-P-K-L-G-F-K-D-C	58
E-T-R-V-A-Y-P-Y-P-K-D-G-R-T-V-K-W-D-S-H-N-F-D-W-Q-T-P-N-P-K-L-G-F-K-D-C	59
E-T-R-V-A-Y-P-Y-P-K-D-G-R-T-V-K-Y-D-S-H-N-F-D-W-Q-T-P-N-P-K-L-G-F-K-D-C	60
E-T-R-V-A-Y-P-Y-H-K-D-G-R-T-V-K-I-D-S-H-N-F-D-W-Q-T-P-N-P-K-L-G-F-K-D-C	61
E-T-R-V-A-Y-P-Y-H-K-D-G-R-T-V-K-W-D-S-H-N-F-D-W-Q-T-P-N-P-K-L-G-F-K-D-C	62
E-T-R-V-A-Y-P-Y-H-K-D-G-R-T-V-K-Y-D-S-H-N-F-D-W-Q-T-P-N-P-K-L-G-F-K-D-C	63
E-T-R-V-A-Y-P-Y-I-K-D-G-R-T-V-K-I-D-S-H-R-F-D-W-Q-T-P-E-P-K-V-G-F-K-D-C	64
E-T-R-V-A-Y-P-Y-P-K-D-G-R-T-V-K-I-D-S-H-R-F-D-W-Q-T-P-E-P-K-V-G-F-K-D-C	65
E-T-R-V-A-Y-P-Y-H-K-D-G-R-T-V-K-I-D-S-H-R-F-D-W-Q-T-P-E-P-K-V-G-F-K-D-C	66
E-T-R-V-A-Y-P-Y-I-K-D-G-R-T-V-K-W-D-S-H-R-F-D-W-Q-T-P-E-P-K-V-G-F-K-D-C	67
E-T-R-V-A-Y-P-Y-I-K-D-G-R-T-V-K-Y-D-S-H-R-F-D-W-Q-T-P-E-P-K-V-G-F-K-D-C	68
E-T-R-V-A-Y-P-Y-P-K-D-G-R-T-V-K-W-D-S-H-R-F-D-W-Q-T-P-E-P-K-V-G-F-K-D-C	69
E-T-R-V-A-Y-P-Y-P-K-D-G-R-T-V-K-Y-D-S-H-R-F-D-W-Q-T-P-E-P-K-V-G-F-K-D-C	70
E-T-R-V-A-Y-P-Y-H-K-D-G-R-T-V-K-W-D-S-H-R-F-D-W-Q-T-P-E-P-K-V-G-F-K-D-C	71
E-T-R-V-A-Y-P-Y-H-K-D-G-R-T-V-K-Y-D-S-H-R-F-D-W-Q-T-P-E-P-K-V-G-F-K-D-C	72
E-T-R-V-A-Y-P-Y-I-K-D-G-R-T-V-K-I-D-S-H-D-F-D-W-Q-T-P-E-P-K-V-G-F-K-D-C	73
E-T-R-V-A-Y-P-Y-I-K-D-G-R-T-V-K-W-D-S-H-D-F-D-W-Q-T-P-E-P-K-V-G-F-K-D-C	74
E-T-R-V-A-Y-P-Y-I-K-D-G-R-T-V-K-Y-D-S-H-D-F-D-W-Q-T-P-E-P-K-V-G-F-K-D-C	75
E-T-R-V-A-Y-P-Y-P-K-D-G-R-T-V-K-I-D-S-H-D-F-D-W-Q-T-P-E-P-K-V-G-F-K-D-C	76
E-T-R-V-A-Y-P-Y-P-K-D-G-R-T-V-K-W-D-S-H-D-F-D-W-Q-T-P-E-P-K-V-G-F-K-D-C	77
E-T-R-V-A-Y-P-Y-P-K-D-G-R-T-V-K-Y-D-S-H-D-F-D-W-Q-T-P-E-P-K-V-G-F-K-D-C	78
E-T-R-V-A-Y-P-Y-H-K-D-G-R-T-V-K-I-D-S-H-D-F-D-W-Q-T-P-E-P-K-V-G-F-K-D-C	79
E-T-R-V-A-Y-P-Y-H-K-D-G-R-T-V-K-W-D-S-H-D-F-D-W-Q-T-P-E-P-K-V-G-F-K-D-C	80

Sequence	SEQ ID NO.
E-T-R-V-A-Y-P-Y-H-K-D-G-R-T-V-K-Y-D-S-H-D-F-D-W-Q-T-P-E-P-K-V-G-F-K-D-C	81
E-T-R-V-A-Y-P-Y-I-K-D-G-R-T-V-K-I-D-S-H-N-F-D-W-Q-T-P-E-P-K-V-G-F-K-D-C	82
E-T-R-V-A-Y-P-Y-I-K-D-G-R-T-V-K-W-D-S-H-N-F-D-W-Q-T-P-E-P-K-V-G-F-K-D-C	83
E-T-R-V-A-Y-P-Y-I-K-D-G-R-T-V-K-Y-D-S-H-N-F-D-W-Q-T-P-E-P-K-V-G-F-K-D-C	84
E-T-R-V-A-Y-P-Y-P-K-D-G-R-T-V-K-I-D-S-H-N-F-D-W-Q-T-P-E-P-K-V-G-F-K-D-C	85
E-T-R-V-A-Y-P-Y-P-K-D-G-R-T-V-K-W-D-S-H-N-F-D-W-Q-T-P-E-P-K-V-G-F-K-D-C	86
E-T-R-V-A-Y-P-Y-P-K-D-G-R-T-V-K-Y-D-S-H-N-F-D-W-Q-T-P-E-P-K-V-G-F-K-D-C	87
E-T-R-V-A-Y-P-Y-H-K-D-G-R-T-V-K-I-D-S-H-N-F-D-W-Q-T-P-E-P-K-V-G-F-K-D-C	88
E-T-R-V-A-Y-P-Y-H-K-D-G-R-T-V-K-W-D-S-H-N-F-D-W-Q-T-P-E-P-K-V-G-F-K-D-C	89
E-T-R-V-A-Y-P-Y-H-K-D-G-R-T-V-K-Y-D-S-H-N-F-D-W-Q-T-P-E-P-K-V-G-F-K-D-C	90
E-T-R-V-A-Y-P-Y-I-K-D-G-R-T-V-K-I-D-S-H-R-F-D-W-Q-T-P-N-P-K-L-G-F-K-D-C	91
E-T-R-V-A-Y-P-Y-P-K-D-G-R-T-V-K-I-D-S-H-R-F-D-W-Q-T-P-N-P-K-L-G-F-K-D-C	92
E-T-R-V-A-Y-P-Y-H-K-D-G-R-T-V-K-I-D-S-H-R-F-D-W-Q-T-P-N-P-K-L-G-F-K-D-C	93
E-T-R-V-A-Y-P-Y-I-K-D-G-R-T-V-K-W-D-S-H-R-F-D-W-Q-T-P-N-P-K-L-G-F-K-D-C	94
E-T-R-V-A-Y-P-Y-I-K-D-G-R-T-V-K-Y-D-S-H-R-F-D-W-Q-T-P-N-P-K-L-G-F-K-D-C	95
E-T-R-V-A-Y-P-Y-P-K-D-G-R-T-V-K-W-D-S-H-R-F-D-W-Q-T-P-N-P-K-L-G-F-K-D-C	96
E-T-R-V-A-Y-P-Y-P-K-D-G-R-T-V-K-Y-D-S-H-R-F-D-W-Q-T-P-N-P-K-L-G-F-K-D-C	97
E-T-R-V-A-Y-P-Y-H-K-D-G-R-T-V-K-W-D-S-H-R-F-D-W-Q-T-P-N-P-K-L-G-F-K-D-C	98
E-T-R-V-A-Y-P-Y-H-K-D-G-R-T-V-K-Y-D-S-H-R-F-D-W-Q-T-P-N-P-K-L-G-F-K-D-C	99
E-T-R-V-A-Y-P-Y-I-K-D-G-R-T-V-K-I-D-S-H-D-F-D-W-Q-T-P-N-P-K-L-G-F-K-D-C	100
E-T-R-V-A-Y-P-Y-I-K-D-G-R-T-V-K-W-D-S-H-D-F-D-W-Q-T-P-N-P-K-L-G-F-K-D-C	101
E-T-R-V-A-Y-P-Y-I-K-D-G-R-T-V-K-Y-D-S-H-D-F-D-W-Q-T-P-N-P-K-L-G-F-K-D-C	102
E-T-R-V-A-Y-P-Y-P-K-D-G-R-T-V-K-I-D-S-H-D-F-D-W-Q-T-P-N-P-K-L-G-F-K-D-C	103

Sequence	SEQ ID NO.
E-T-R-V-A-Y-P-Y-P-K-D-G-R-T-V-K-W-D-S-H-D-F-D-W-Q-T-P-N-P-K-L-G-F-K-D-C	104
E-T-R-V-A-Y-P-Y-P-K-D-G-R-T-V-K-Y-D-S-H-D-F-D-W-Q-T-P-N-P-K-L-G-F-K-D-C	105
E-T-R-V-A-Y-P-Y-H-K-D-G-R-T-V-K-I-D-S-H-D-F-D-W-Q-T-P-N-P-K-L-G-F-K-D-C	106
E-T-R-V-A-Y-P-Y-H-K-D-G-R-T-V-K-W-D-S-H-D-F-D-W-Q-T-P-N-P-K-L-G-F-K-D-C	107
E-T-R-V-A-Y-P-Y-H-K-D-G-R-T-V-K-Y-D-S-H-D-F-D-W-Q-T-P-N-P-K-L-G-F-K-D-C	108
E-T-R-V-A-Y-P-Y-I-K-D-G-R-T-V-K-I-D-S-H-N-F-D-W-Q-T-P-N-P-K-L-G-F-K-D-C	109
E-T-R-V-A-Y-P-Y-I-K-D-G-R-T-V-K-W-D-S-H-N-F-D-W-Q-T-P-N-P-K-L-G-F-K-D-C	110
E-T-R-V-A-Y-P-Y-I-K-D-G-R-T-V-K-Y-D-S-H-N-F-D-W-Q-T-P-N-P-K-L-G-F-K-D-C	111
E-T-R-V-A-Y-P-Y-P-K-D-G-R-T-V-K-I-D-S-H-N-F-D-W-Q-T-P-N-P-K-L-G-F-K-D-C	112
E-T-R-V-A-Y-P-Y-P-K-D-G-R-T-V-K-W-D-S-H-N-F-D-W-Q-T-P-N-P-K-L-G-F-K-D-C	113
E-T-R-V-A-Y-P-Y-P-K-D-G-R-T-V-K-Y-D-S-H-N-F-D-W-Q-T-P-N-P-K-L-G-F-K-D-C	114
E-T-R-V-A-Y-P-Y-H-K-D-G-R-T-V-K-I-D-S-H-N-F-D-W-Q-T-P-N-P-K-L-G-F-K-D-C	115
E-T-R-V-A-Y-P-Y-H-K-D-G-R-T-V-K-W-D-S-H-N-F-D-W-Q-T-P-N-P-K-L-G-F-K-D-C	116
E-T-R-V-A-Y-P-Y-H-K-D-G-R-T-V-K-Y-D-S-H-N-F-D-W-Q-T-P-N-P-K-L-G-F-K-D-C	117

[0047] In another embodiment, the population of isolated peptides comprises three or more different peptides, wherein each peptide in the population comprises a sequence of I-E-X_3-G-Y-E-X_7-F-K-T-X_{11}-G-I-R-X_{15}-S-G-T-K-E-C (SEQ ID NO: 2), or a fragment thereof, wherein X_3 is an amino acid selected from the group consisting of L, V or A, X_7 is an amino acid selected from the group consisting of K, N or Q, X_{11} is an amino acid selected from the group consisting of R, D, or N, and X_{15} is an amino acid selected from the group consisting of E, N or Q. In some embodiments, peptides of the invention comprise a sequence of SEQ ID NO: 2, wherein X_3 is A, and/or X_7 is N. In other embodiments, peptides of the invention comprise a sequence of SEQ ID NO: 2, wherein X_{11} is R, and/or X_{15} is Q. In particular embodiments, the population of isolated peptides comprises three or more peptides comprising or consisting of any one of the sequences in Table 2.

Table 2. Abaxis ID 3 Peptides

Sequence	SEQ ID NO.
I-E-L-G-Y-E-K-F-K-T-R-G-I-R-E-S-G-T-K-E-C	118
I-E-L-G-Y-E-N-F-K-T-R-G-I-R-E-S-G-T-K-E-C	119
I-E-L-G-Y-E-Q-F-K-T-R-G-I-R-E-S-G-T-K-E-C	120
I-E-V-G-Y-E-K-F-K-T-R-G-I-R-E-S-G-T-K-E-C	121
I-E-A-G-Y-E-K-F-K-T-R-G-I-R-E-S-G-T-K-E-C	122
I-E-V-G-Y-E-N-F-K-T-R-G-I-R-E-S-G-T-K-E-C	123
I-E-V-G-Y-E-Q-F-K-T-R-G-I-R-E-S-G-T-K-E-C	124
I-E-A-G-Y-E-N-F-K-T-R-G-I-R-E-S-G-T-K-E-C	125
I-E-A-G-Y-E-Q-F-K-T-R-G-I-R-E-S-G-T-K-E-C	126
I-E-L-G-Y-E-K-F-K-T-D-G-I-R-E-S-G-T-K-E-C	127
I-E-L-G-Y-E-N-F-K-T-D-G-I-R-E-S-G-T-K-E-C	128
I-E-L-G-Y-E-Q-F-K-T-D-G-I-R-E-S-G-T-K-E-C	129
I-E-V-G-Y-E-K-F-K-T-D-G-I-R-E-S-G-T-K-E-C	130
I-E-A-G-Y-E-K-F-K-T-D-G-I-R-E-S-G-T-K-E-C	131
I-E-V-G-Y-E-N-F-K-T-D-G-I-R-E-S-G-T-K-E-C	132
I-E-V-G-Y-E-Q-F-K-T-D-G-I-R-E-S-G-T-K-E-C	133
I-E-A-G-Y-E-N-F-K-T-D-G-I-R-E-S-G-T-K-E-C	134
I-E-A-G-Y-E-Q-F-K-T-D-G-I-R-E-S-G-T-K-E-C	135
I-E-L-G-Y-E-K-F-K-T-N-G-I-R-E-S-G-T-K-E-C	136
I-E-L-G-Y-E-N-F-K-T-N-G-I-R-E-S-G-T-K-E-C	137
I-E-L-G-Y-E-Q-F-K-T-N-G-I-R-E-S-G-T-K-E-C	138
I-E-V-G-Y-E-K-F-K-T-N-G-I-R-E-S-G-T-K-E-C	139
I-E-A-G-Y-E-K-F-K-T-N-G-I-R-E-S-G-T-K-E-C	140
I-E-V-G-Y-E-N-F-K-T-N-G-I-R-E-S-G-T-K-E-C	141
I-E-V-G-Y-E-Q-F-K-T-N-G-I-R-E-S-G-T-K-E-C	142
I-E-A-G-Y-E-N-F-K-T-N-G-I-R-E-S-G-T-K-E-C	143
I-E-A-G-Y-E-Q-F-K-T-N-G-I-R-E-S-G-T-K-E-C	144
I-E-L-G-Y-E-K-F-K-T-R-G-I-R-N-S-G-T-K-E-C	145
I-E-L-G-Y-E-N-F-K-T-R-G-I-R-N-S-G-T-K-E-C	146
I-E-L-G-Y-E-Q-F-K-T-R-G-I-R-N-S-G-T-K-E-C	147
I-E-V-G-Y-E-K-F-K-T-R-G-I-R-N-S-G-T-K-E-C	148
I-E-A-G-Y-E-K-F-K-T-R-G-I-R-N-S-G-T-K-E-C	149
I-E-V-G-Y-E-N-F-K-T-R-G-I-R-N-S-G-T-K-E-C	150
I-E-V-G-Y-E-Q-F-K-T-R-G-I-R-N-S-G-T-K-E-C	151
I-E-A-G-Y-E-N-F-K-T-R-G-I-R-N-S-G-T-K-E-C	152
I-E-A-G-Y-E-Q-F-K-T-R-G-I-R-N-S-G-T-K-E-C	153
I-E-L-G-Y-E-K-F-K-T-D-G-I-R-N-S-G-T-K-E-C	154
I-E-L-G-Y-E-N-F-K-T-D-G-I-R-N-S-G-T-K-E-C	155
I-E-L-G-Y-E-Q-F-K-T-D-G-I-R-N-S-G-T-K-E-C	156
I-E-V-G-Y-E-K-F-K-T-D-G-I-R-N-S-G-T-K-E-C	157
I-E-A-G-Y-E-K-F-K-T-D-G-I-R-N-S-G-T-K-E-C	158

Sequence	SEQ ID NO.
I-E-V-G-Y-E-N-F-K-T-D-G-I-R-N-S-G-T-K-E-C	159
I-E-V-G-Y-E-Q-F-K-T-D-G-I-R-N-S-G-T-K-E-C	160
I-E-A-G-Y-E-N-F-K-T-D-G-I-R-N-S-G-T-K-E-C	161
I-E-A-G-Y-E-Q-F-K-T-D-G-I-R-N-S-G-T-K-E-C	162
I-E-L-G-Y-E-K-F-K-T-N-G-I-R-N-S-G-T-K-E-C	163
I-E-L-G-Y-E-N-F-K-T-N-G-I-R-N-S-G-T-K-E-C	164
I-E-L-G-Y-E-Q-F-K-T-N-G-I-R-N-S-G-T-K-E-C	165
I-E-V-G-Y-E-K-F-K-T-N-G-I-R-N-S-G-T-K-E-C	166
I-E-A-G-Y-E-K-F-K-T-N-G-I-R-N-S-G-T-K-E-C	167
I-E-V-G-Y-E-N-F-K-T-N-G-I-R-N-S-G-T-K-E-C	168
I-E-V-G-Y-E-Q-F-K-T-N-G-I-R-N-S-G-T-K-E-C	169
I-E-A-G-Y-E-N-F-K-T-N-G-I-R-N-S-G-T-K-E-C	170
I-E-A-G-Y-E-Q-F-K-T-N-G-I-R-N-S-G-T-K-E-C	171
I-E-L-G-Y-E-K-F-K-T-R-G-I-R-Q-S-G-T-K-E-C	172
I-E-L-G-Y-E-N-F-K-T-R-G-I-R-Q-S-G-T-K-E-C	173
I-E-L-G-Y-E-Q-F-K-T-R-G-I-R-Q-S-G-T-K-E-C	174
I-E-V-G-Y-E-K-F-K-T-R-G-I-R-Q-S-G-T-K-E-C	175
I-E-A-G-Y-E-K-F-K-T-R-G-I-R-Q-S-G-T-K-E-C	176
I-E-V-G-Y-E-N-F-K-T-R-G-I-R-Q-S-G-T-K-E-C	177
I-E-V-G-Y-E-Q-F-K-T-R-G-I-R-Q-S-G-T-K-E-C	178
I-E-A-G-Y-E-N-F-K-T-R-G-I-R-Q-S-G-T-K-E-C	179
I-E-A-G-Y-E-Q-F-K-T-R-G-I-R-Q-S-G-T-K-E-C	180
I-E-L-G-Y-E-K-F-K-T-D-G-I-R-Q-S-G-T-K-E-C	181
I-E-L-G-Y-E-N-F-K-T-D-G-I-R-Q-S-G-T-K-E-C	182
I-E-L-G-Y-E-Q-F-K-T-D-G-I-R-Q-S-G-T-K-E-C	183
I-E-V-G-Y-E-K-F-K-T-D-G-I-R-Q-S-G-T-K-E-C	184
I-E-A-G-Y-E-K-F-K-T-D-G-I-R-Q-S-G-T-K-E-C	185
I-E-V-G-Y-E-N-F-K-T-D-G-I-R-Q-S-G-T-K-E-C	186
I-E-V-G-Y-E-Q-F-K-T-D-G-I-R-Q-S-G-T-K-E-C	187
I-E-A-G-Y-E-N-F-K-T-D-G-I-R-Q-S-G-T-K-E-C	188
I-E-A-G-Y-E-Q-F-K-T-D-G-I-R-Q-S-G-T-K-E-C	189
I-E-L-G-Y-E-K-F-K-T-N-G-I-R-Q-S-G-T-K-E-C	190
I-E-L-G-Y-E-N-F-K-T-N-G-I-R-Q-S-G-T-K-E-C	191
I-E-L-G-Y-E-Q-F-K-T-N-G-I-R-Q-S-G-T-K-E-C	192
I-E-V-G-Y-E-K-F-K-T-N-G-I-R-Q-S-G-T-K-E-C	193
I-E-A-G-Y-E-K-F-K-T-N-G-I-R-Q-S-G-T-K-E-C	194
I-E-V-G-Y-E-N-F-K-T-N-G-I-R-Q-S-G-T-K-E-C	195
I-E-V-G-Y-E-Q-F-K-T-N-G-I-R-Q-S-G-T-K-E-C	196
I-E-A-G-Y-E-N-F-K-T-N-G-I-R-Q-S-G-T-K-E-C	197
I-E-A-G-Y-E-Q-F-K-T-N-G-I-R-Q-S-G-T-K-E-C	198

[0048] In certain embodiments, the population of isolated peptides comprises three or more different peptides, wherein each peptide in the population comprises a sequence of E-T-K-V-X_5-

Y-X_7-Y-L-K-X_{11}-G-R-T-V-K-L-X_{18}-S-H-X_{21}-F-D-W-X_{25}-T-P-X_{28}-P-K-X_{31}-G-F-K-D-G-G-G-G-G-K-D-G-T-X_{45}-V-E-X_{48}-K-A-X_{51}-K-F-X_{54}-W-N-X_{57}-P-D-X_{60}-R-I-X_{63}-F-K-X_{66}-C (SEQ ID NO: 3), or a fragment thereof, wherein X_5 is an amino acid selected from the group consisting of V or A, X_7 is an amino acid selected from the group consisting of G, I or H, X_{11} is an amino acid selected from the group consisting of E, N, or Q, X_{18} is an amino acid selected from the group consisting of D or N, X_{21} is an amino acid selected from the group consisting of R, D, or N, X_{25} is an amino acid selected from the group consisting of Q, D, or E, X_{28} is an amino acid selected from the group consisting of E or N, X_{31} is an amino acid selected from the group consisting of L or V, X_{45} is an amino acid selected from the group consisting of K or Q, X_{48} is an amino acid selected from the group consisting of F or V, X_{51} is an amino acid selected from the group consisting of D or N, X_{54} is an amino acid selected from the group consisting of E or Q, X_{57} is an amino acid selected from the group consisting of S or Q, X_{60} is an amino acid selected from the group consisting of F or W, X_{63} is an amino acid selected from the group consisting of I or V, and X_{66} is an amino acid selected from the group consisting of Q or D.

[0049] In related embodiments, peptides of the invention comprise a sequence of SEQ ID NO: 3, wherein X_5 is A, X_{18} is D, and/or X_{31} is V. In other embodiments, peptides of the invention comprise a sequence of SEQ ID NO: 3, wherein X_{45} is Q, X_{48} is F, and/or X_{51} is N. In still other embodiments, peptides of the invention comprise a sequence of SEQ ID NO: 3, wherein X_{54} is E, X_{57} is S, and/or X_{60} is W. In some embodiments, peptides of the invention comprise a sequence of SEQ ID NO: 3, wherein X_{63} is I and/or X_{66} is D. In particular embodiments, the population of isolated peptides comprises three or more peptides comprising or consisting of any one of the sequences in Table 3.

Table 3. APL-ID1 Peptides

Sequence	SEQ ID NO.
E-T-K-V-V-Y-G-Y-L-K-E-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	199
E-T-K-V-V-Y-I-Y-L-K-E-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	200

Sequence	SEQ ID NO.
E-T-K-V-V-Y-H-Y-L-K-E-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	201
E-T-K-V-A-Y-G-Y-L-K-E-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	202
E-T-K-V-A-Y-I-Y-L-K-E-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	203
E-T-K-V-A-Y-H-Y-L-K-E-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	204
E-T-K-V-V-Y-G-Y-L-K-N-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	205
E-T-K-V-V-Y-I-Y-L-K-N-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	206
E-T-K-V-V-Y-H-Y-L-K-N-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	207
E-T-K-V-A-Y-G-Y-L-K-N-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	208
E-T-K-V-A-Y-I-Y-L-K-N-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	209
E-T-K-V-A-Y-H-Y-L-K-N-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	210
E-T-K-V-V-Y-G-Y-L-K-Q-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	211
E-T-K-V-V-Y-I-Y-L-K-Q-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	212
E-T-K-V-V-Y-H-Y-L-K-Q-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	213
E-T-K-V-A-Y-G-Y-L-K-Q-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	214
E-T-K-V-A-Y-I-Y-L-K-Q-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	215

Sequence	SEQ ID NO.
E-T-K-V-A-Y-H-Y-L-K-Q-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	216
E-T-K-V-V-Y-G-Y-L-K-E-G-R-T-V-K-L-N-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	217
E-T-K-V-V-Y-I-Y-L-K-E-G-R-T-V-K-L-N-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	218
E-T-K-V-V-Y-H-Y-L-K-E-G-R-T-V-K-L-N-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	219
E-T-K-V-A-Y-G-Y-L-K-E-G-R-T-V-K-L-N-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	220
E-T-K-V-A-Y-I-Y-L-K-E-G-R-T-V-K-L-N-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	221
E-T-K-V-A-Y-H-Y-L-K-E-G-R-T-V-K-L-N-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	222
E-T-K-V-V-Y-G-Y-L-K-N-G-R-T-V-K-L-N-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	223
E-T-K-V-V-Y-I-Y-L-K-N-G-R-T-V-K-L-N-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	224
E-T-K-V-V-Y-H-Y-L-K-N-G-R-T-V-K-L-N-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	225
E-T-K-V-A-Y-G-Y-L-K-N-G-R-T-V-K-L-N-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	226
E-T-K-V-A-Y-I-Y-L-K-N-G-R-T-V-K-L-N-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	227
E-T-K-V-A-Y-H-Y-L-K-N-G-R-T-V-K-L-N-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	228
E-T-K-V-V-Y-G-Y-L-K-Q-G-R-T-V-K-L-N-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	229
E-T-K-V-V-Y-I-Y-L-K-Q-G-R-T-V-K-L-N-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	230

Sequence	SEQ ID NO.
E-T-K-V-V-Y-H-Y-L-K-Q-G-R-T-V-K-L-N-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	231
E-T-K-V-A-Y-G-Y-L-K-Q-G-R-T-V-K-L-N-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	232
E-T-K-V-A-Y-I-Y-L-K-Q-G-R-T-V-K-L-N-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	233
E-T-K-V-A-Y-H-Y-L-K-Q-G-R-T-V-K-L-N-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	234
E-T-K-V-V-Y-G-Y-L-K-E-G-R-T-V-K-L-D-S-H-D-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	235
E-T-K-V-V-Y-I-Y-L-K-E-G-R-T-V-K-L-D-S-H-D-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	236
E-T-K-V-V-Y-H-Y-L-K-E-G-R-T-V-K-L-D-S-H-D-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	237
E-T-K-V-A-Y-G-Y-L-K-E-G-R-T-V-K-L-D-S-H-D-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	238
E-T-K-V-A-Y-I-Y-L-K-E-G-R-T-V-K-L-D-S-H-D-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	239
E-T-K-V-A-Y-H-Y-L-K-E-G-R-T-V-K-L-D-S-H-D-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	240
E-T-K-V-V-Y-G-Y-L-K-N-G-R-T-V-K-L-D-S-H-D-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	241
E-T-K-V-V-Y-I-Y-L-K-N-G-R-T-V-K-L-D-S-H-D-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	242
E-T-K-V-V-Y-H-Y-L-K-N-G-R-T-V-K-L-D-S-H-D-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	243
E-T-K-V-A-Y-G-Y-L-K-N-G-R-T-V-K-L-D-S-H-D-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	244
E-T-K-V-A-Y-I-Y-L-K-N-G-R-T-V-K-L-D-S-H-D-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	245

Sequence	SEQ ID NO.
E-T-K-V-A-Y-H-Y-L-K-N-G-R-T-V-K-L-D-S-H-D-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	246
E-T-K-V-V-Y-G-Y-L-K-Q-G-R-T-V-K-L-D-S-H-D-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	247
E-T-K-V-V-Y-I-Y-L-K-Q-G-R-T-V-K-L-D-S-H-D-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	248
E-T-K-V-V-Y-H-Y-L-K-Q-G-R-T-V-K-L-D-S-H-D-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	249
E-T-K-V-A-Y-G-Y-L-K-Q-G-R-T-V-K-L-D-S-H-D-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	250
E-T-K-V-A-Y-I-Y-L-K-Q-G-R-T-V-K-L-D-S-H-D-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	251
E-T-K-V-A-Y-H-Y-L-K-Q-G-R-T-V-K-L-D-S-H-D-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	252
E-T-K-V-V-Y-G-Y-L-K-E-G-R-T-V-K-L-N-S-H-D-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	253
E-T-K-V-V-Y-I-Y-L-K-E-G-R-T-V-K-L-N-S-H-D-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	254
E-T-K-V-V-Y-H-Y-L-K-E-G-R-T-V-K-L-N-S-H-D-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	255
E-T-K-V-A-Y-G-Y-L-K-E-G-R-T-V-K-L-N-S-H-D-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	256
E-T-K-V-A-Y-I-Y-L-K-E-G-R-T-V-K-L-N-S-H-D-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	257
E-T-K-V-A-Y-H-Y-L-K-E-G-R-T-V-K-L-N-S-H-D-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	258
E-T-K-V-V-Y-G-Y-L-K-N-G-R-T-V-K-L-N-S-H-D-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	259
E-T-K-V-V-Y-I-Y-L-K-N-G-R-T-V-K-L-N-S-H-D-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	260

Sequence	SEQ ID NO.
E-T-K-V-V-Y-H-Y-L-K-N-G-R-T-V-K-L-N-S-H-D-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	261
E-T-K-V-A-Y-G-Y-L-K-N-G-R-T-V-K-L-N-S-H-D-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	262
E-T-K-V-A-Y-I-Y-L-K-N-G-R-T-V-K-L-N-S-H-D-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	263
E-T-K-V-A-Y-H-Y-L-K-N-G-R-T-V-K-L-N-S-H-D-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	264
E-T-K-V-V-Y-G-Y-L-K-Q-G-R-T-V-K-L-N-S-H-D-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	265
E-T-K-V-V-Y-I-Y-L-K-Q-G-R-T-V-K-L-N-S-H-D-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	266
E-T-K-V-V-Y-H-Y-L-K-Q-G-R-T-V-K-L-N-S-H-D-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	267
E-T-K-V-A-Y-G-Y-L-K-Q-G-R-T-V-K-L-N-S-H-D-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	268
E-T-K-V-A-Y-I-Y-L-K-Q-G-R-T-V-K-L-N-S-H-D-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	269
E-T-K-V-A-Y-H-Y-L-K-Q-G-R-T-V-K-L-N-S-H-D-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	270
E-T-K-V-V-Y-G-Y-L-K-E-G-R-T-V-K-L-D-S-H-N-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	271
E-T-K-V-V-Y-I-Y-L-K-E-G-R-T-V-K-L-D-S-H-N-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	272
E-T-K-V-V-Y-H-Y-L-K-E-G-R-T-V-K-L-D-S-H-N-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	273
E-T-K-V-A-Y-G-Y-L-K-E-G-R-T-V-K-L-D-S-H-N-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	274
E-T-K-V-A-Y-I-Y-L-K-E-G-R-T-V-K-L-D-S-H-N-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	275

Sequence	SEQ ID NO.
E-T-K-V-A-Y-H-Y-L-K-E-G-R-T-V-K-L-D-S-H-N-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	276
E-T-K-V-V-Y-G-Y-L-K-N-G-R-T-V-K-L-D-S-H-N-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	277
E-T-K-V-V-Y-I-Y-L-K-N-G-R-T-V-K-L-D-S-H-N-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	278
E-T-K-V-V-Y-H-Y-L-K-N-G-R-T-V-K-L-D-S-H-N-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	279
E-T-K-V-A-Y-G-Y-L-K-N-G-R-T-V-K-L-D-S-H-N-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	280
E-T-K-V-A-Y-I-Y-L-K-N-G-R-T-V-K-L-D-S-H-N-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	281
E-T-K-V-A-Y-H-Y-L-K-N-G-R-T-V-K-L-D-S-H-N-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	282
E-T-K-V-V-Y-G-Y-L-K-Q-G-R-T-V-K-L-D-S-H-N-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	283
E-T-K-V-V-Y-I-Y-L-K-Q-G-R-T-V-K-L-D-S-H-N-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	284
E-T-K-V-V-Y-H-Y-L-K-Q-G-R-T-V-K-L-D-S-H-N-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	285
E-T-K-V-A-Y-G-Y-L-K-Q-G-R-T-V-K-L-D-S-H-N-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	286
E-T-K-V-A-Y-I-Y-L-K-Q-G-R-T-V-K-L-D-S-H-N-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	287
E-T-K-V-A-Y-H-Y-L-K-Q-G-R-T-V-K-L-D-S-H-N-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	288
E-T-K-V-V-Y-G-Y-L-K-E-G-R-T-V-K-L-N-S-H-N-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	289
E-T-K-V-V-Y-I-Y-L-K-E-G-R-T-V-K-L-N-S-H-N-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	290

Sequence	SEQ ID NO.
E-T-K-V-V-Y-H-Y-L-K-E-G-R-T-V-K-L-N-S-H-N-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	291
E-T-K-V-A-Y-G-Y-L-K-E-G-R-T-V-K-L-N-S-H-N-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	292
E-T-K-V-A-Y-I-Y-L-K-E-G-R-T-V-K-L-N-S-H-N-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	293
E-T-K-V-A-Y-H-Y-L-K-E-G-R-T-V-K-L-N-S-H-N-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	294
E-T-K-V-V-Y-G-Y-L-K-N-G-R-T-V-K-L-N-S-H-N-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	295
E-T-K-V-V-Y-I-Y-L-K-N-G-R-T-V-K-L-N-S-H-N-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	296
E-T-K-V-V-Y-H-Y-L-K-N-G-R-T-V-K-L-N-S-H-N-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	297
E-T-K-V-A-Y-G-Y-L-K-N-G-R-T-V-K-L-N-S-H-N-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	298
E-T-K-V-A-Y-I-Y-L-K-N-G-R-T-V-K-L-N-S-H-N-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	299
E-T-K-V-A-Y-H-Y-L-K-N-G-R-T-V-K-L-N-S-H-N-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	300
E-T-K-V-V-Y-G-Y-L-K-Q-G-R-T-V-K-L-N-S-H-N-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	301
E-T-K-V-V-Y-I-Y-L-K-Q-G-R-T-V-K-L-N-S-H-N-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	302
E-T-K-V-V-Y-H-Y-L-K-Q-G-R-T-V-K-L-N-S-H-N-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	303
E-T-K-V-A-Y-G-Y-L-K-Q-G-R-T-V-K-L-N-S-H-N-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	304
E-T-K-V-A-Y-I-Y-L-K-Q-G-R-T-V-K-L-N-S-H-N-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	305

Sequence	SEQ ID NO.
E-T-K-V-A-Y-H-Y-L-K-Q-G-R-T-V-K-L-N-S-H-N-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q-C	306
E-T-K-V-V-Y-G-Y-L-K-E-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-D-C	307
E-T-K-V-V-Y-I-Y-L-K-E-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-D-C	308
E-T-K-V-V-Y-H-Y-L-K-E-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-D-C	309
E-T-K-V-A-Y-G-Y-L-K-E-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-D-C	310
E-T-K-V-A-Y-I-Y-L-K-E-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-D-C	311
E-T-K-V-A-Y-H-Y-L-K-E-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-D-C	312
E-T-K-V-V-Y-G-Y-L-K-N-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-D-C	313
E-T-K-V-V-Y-I-Y-L-K-N-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-D-C	314
E-T-K-V-V-Y-H-Y-L-K-N-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-D-C	315
E-T-K-V-A-Y-G-Y-L-K-N-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-D-C	316
E-T-K-V-V-Y-G-Y-L-K-E-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-V-F-K-D-C	317
E-T-K-V-V-Y-I-Y-L-K-E-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-V-F-K-D-C	318
E-T-K-V-V-Y-H-Y-L-K-E-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-V-F-K-D-C	319
E-T-K-V-A-Y-G-Y-L-K-E-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-V-F-K-D-C	320

Sequence	SEQ ID NO.
E-T-K-V-A-Y-I-Y-L-K-E-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-V-F-K-D-C	321
E-T-K-V-A-Y-H-Y-L-K-E-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-V-F-K-D-C	322
E-T-K-V-V-Y-G-Y-L-K-N-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-V-F-K-D-C	323
E-T-K-V-V-Y-I-Y-L-K-N-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-V-F-K-D-C	324
E-T-K-V-V-Y-H-Y-L-K-N-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-V-F-K-D-C	325
E-T-K-V-A-Y-G-Y-L-K-N-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-V-F-K-D-C	326
E-T-K-V-V-Y-G-Y-L-K-E-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-W-R-I-V-F-K-D-C	327
E-T-K-V-V-Y-I-Y-L-K-E-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-W-R-I-V-F-K-D-C	328
E-T-K-V-V-Y-H-Y-L-K-E-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-W-R-I-V-F-K-D-C	329
E-T-K-V-A-Y-G-Y-L-K-E-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-W-R-I-V-F-K-D-C	330
E-T-K-V-A-Y-I-Y-L-K-E-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-W-R-I-V-F-K-D-C	331
E-T-K-V-A-Y-H-Y-L-K-E-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-W-R-I-V-F-K-D-C	332
E-T-K-V-V-Y-G-Y-L-K-N-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-W-R-I-V-F-K-D-C	333
E-T-K-V-V-Y-I-Y-L-K-N-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-W-R-I-V-F-K-D-C	334
E-T-K-V-V-Y-H-Y-L-K-N-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-W-R-I-V-F-K-D-C	335

Sequence	SEQ ID NO.
E-T-K-V-A-Y-G-Y-L-K-N-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-W-R-I-V-F-K-D-C	336
E-T-K-V-V-Y-G-Y-L-K-E-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-Q-P-D-W-R-I-V-F-K-D-C	337
E-T-K-V-V-Y-I-Y-L-K-E-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-Q-P-D-W-R-I-V-F-K-D-C	338
E-T-K-V-V-Y-H-Y-L-K-E-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-Q-P-D-W-R-I-V-F-K-D-C	339
E-T-K-V-A-Y-G-Y-L-K-E-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-Q-P-D-W-R-I-V-F-K-D-C	340
E-T-K-V-A-Y-I-Y-L-K-E-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-Q-P-D-W-R-I-V-F-K-D-C	341
E-T-K-V-A-Y-H-Y-L-K-E-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-Q-P-D-W-R-I-V-F-K-D-C	342
E-T-K-V-V-Y-G-Y-L-K-N-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-Q-P-D-W-R-I-V-F-K-D-C	343
E-T-K-V-V-Y-I-Y-L-K-N-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-Q-P-D-W-R-I-V-F-K-D-C	344
E-T-K-V-V-Y-H-Y-L-K-N-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-Q-P-D-W-R-I-V-F-K-D-C	345
E-T-K-V-A-Y-G-Y-L-K-N-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-Q-P-D-W-R-I-V-F-K-D-C	346
E-T-K-V-V-Y-G-Y-L-K-E-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-Q-W-N-Q-P-D-W-R-I-V-F-K-D-C	347
E-T-K-V-V-Y-I-Y-L-K-E-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-D-K-F-Q-W-N-Q-P-D-W-R-I-V-F-K-D-C	348
E-T-K-V-V-Y-G-Y-L-K-E-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-N-K-F-Q-W-N-Q-P-D-W-R-I-V-F-K-D-C	349
E-T-K-V-V-Y-I-Y-L-K-E-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-G-G-G-G-G-K-D-G-T-K-V-E-F-K-A-N-K-F-Q-W-N-Q-P-D-W-R-I-V-F-K-D-C	350

[0050] In some embodiments, the population of isolated peptides comprises three or more different peptides, wherein each peptide in the population comprises a sequence of C-K-D-G-T-X_6-V-E-X_9-K-A-X_{12}-K-F-X_{15}-W-N-X_{18}-P-D-X_{21}-R-I-X_{24}-F-K-X_{27} (SEQ ID NO: 4), or a fragment thereof, wherein X_6 is an amino acid selected from the group consisting of K or Q, X_9 is an amino acid selected from the group consisting of F or V, X_{12} is an amino acid selected from the group consisting of D or N, X_{15} is an amino acid selected from the group consisting of E or Q, X_{18} is an amino acid selected from the group consisting of S or Q, X_{21} is an amino acid selected from the group consisting of F or W, X_{24} is an amino acid selected from the group consisting of I or V, and X_{27} is an amino acid selected from the group consisting of Q or D. In related embodiments, peptides of the invention comprise a sequence of SEQ ID NO: 4, wherein X_6 is Q, X_9 is F, and/or X_{12} is N. In other embodiments, peptides of the invention comprise a sequence of SEQ ID NO: 4, wherein X_{15} is E, X_{18} is S, and/or X_{21} is W. In still other embodiments, peptides of the invention comprise a sequence of SEQ ID NO: 4, wherein X_{24} is I and/or X_{27} is D. In particular embodiments, the population of isolated peptides comprises three or more peptides comprising or consisting of any one of the sequences in Table 4.

Table 4. APL-ID2 Peptides

Sequence	SEQ ID NO.
C-K-D-G-T-K-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q	351
C-K-D-G-T-K-V-E-V-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q	352
C-K-D-G-T-Q-V-E-F-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q	353
C-K-D-G-T-Q-V-E-V-K-A-D-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q	354
C-K-D-G-T-K-V-E-F-K-A-N-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q	355
C-K-D-G-T-K-V-E-V-K-A-N-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q	356
C-K-D-G-T-Q-V-E-F-K-A-N-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q	357
C-K-D-G-T-Q-V-E-V-K-A-N-K-F-E-W-N-S-P-D-F-R-I-I-F-K-Q	358
C-K-D-G-T-K-V-E-F-K-A-D-K-F-Q-W-N-S-P-D-F-R-I-I-F-K-Q	359
C-K-D-G-T-K-V-E-V-K-A-D-K-F-Q-W-N-S-P-D-F-R-I-I-F-K-Q	360
C-K-D-G-T-Q-V-E-F-K-A-D-K-F-Q-W-N-S-P-D-F-R-I-I-F-K-Q	361
C-K-D-G-T-Q-V-E-V-K-A-D-K-F-Q-W-N-S-P-D-F-R-I-I-F-K-Q	362
C-K-D-G-T-K-V-E-F-K-A-N-K-F-Q-W-N-S-P-D-F-R-I-I-F-K-Q	363
C-K-D-G-T-K-V-E-V-K-A-N-K-F-Q-W-N-S-P-D-F-R-I-I-F-K-Q	364
C-K-D-G-T-Q-V-E-F-K-A-N-K-F-Q-W-N-S-P-D-F-R-I-I-F-K-Q	365
C-K-D-G-T-Q-V-E-V-K-A-N-K-F-Q-W-N-S-P-D-F-R-I-I-F-K-Q	366
C-K-D-G-T-K-V-E-F-K-A-D-K-F-Q-W-N-Q-P-D-F-R-I-I-F-K-Q	367
C-K-D-G-T-K-V-E-V-K-A-D-K-F-Q-W-N-Q-P-D-F-R-I-I-F-K-Q	368
C-K-D-G-T-Q-V-E-F-K-A-D-K-F-Q-W-N-Q-P-D-F-R-I-I-F-K-Q	369
C-K-D-G-T-Q-V-E-V-K-A-D-K-F-Q-W-N-Q-P-D-F-R-I-I-F-K-Q	370

Sequence	SEQ ID NO.
C-K-D-G-T-K-V-E-F-K-A-N-K-F-Q-W-N-Q-P-D-F-R-I-I-F-K-Q	371
C-K-D-G-T-K-V-E-V-K-A-N-K-F-Q-W-N-Q-P-D-F-R-I-I-F-K-Q	372
C-K-D-G-T-Q-V-E-F-K-A-N-K-F-Q-W-N-Q-P-D-F-R-I-I-F-K-Q	373
C-K-D-G-T-Q-V-E-V-K-A-N-K-F-Q-W-N-Q-P-D-F-R-I-I-F-K-Q	374
C-K-D-G-T-K-V-E-F-K-A-D-K-F-Q-W-N-Q-P-D-W-R-I-I-F-K-Q	375
C-K-D-G-T-K-V-E-V-K-A-D-K-F-Q-W-N-Q-P-D-W-R-I-I-F-K-Q	376
C-K-D-G-T-Q-V-E-F-K-A-D-K-F-Q-W-N-Q-P-D-W-R-I-I-F-K-Q	377
C-K-D-G-T-Q-V-E-V-K-A-D-K-F-Q-W-N-Q-P-D-W-R-I-I-F-K-Q	378
C-K-D-G-T-K-V-E-F-K-A-N-K-F-Q-W-N-Q-P-D-W-R-I-I-F-K-Q	379
C-K-D-G-T-K-V-E-V-K-A-N-K-F-Q-W-N-Q-P-D-W-R-I-I-F-K-Q	380
C-K-D-G-T-Q-V-E-F-K-A-N-K-F-Q-W-N-Q-P-D-W-R-I-I-F-K-Q	381
C-K-D-G-T-Q-V-E-V-K-A-N-K-F-Q-W-N-Q-P-D-W-R-I-I-F-K-Q	382
C-K-D-G-T-K-V-E-F-K-A-D-K-F-Q-W-N-Q-P-D-W-R-I-V-F-K-Q	383
C-K-D-G-T-K-V-E-V-K-A-D-K-F-Q-W-N-Q-P-D-W-R-I-V-F-K-Q	384
C-K-D-G-T-Q-V-E-F-K-A-D-K-F-Q-W-N-Q-P-D-W-R-I-V-F-K-Q	385
C-K-D-G-T-Q-V-E-V-K-A-D-K-F-Q-W-N-Q-P-D-W-R-I-V-F-K-Q	386
C-K-D-G-T-K-V-E-F-K-A-N-K-F-Q-W-N-Q-P-D-W-R-I-V-F-K-Q	387
C-K-D-G-T-K-V-E-V-K-A-N-K-F-Q-W-N-Q-P-D-W-R-I-V-F-K-Q	388
C-K-D-G-T-Q-V-E-F-K-A-N-K-F-Q-W-N-Q-P-D-W-R-I-V-F-K-Q	389
C-K-D-G-T-Q-V-E-V-K-A-N-K-F-Q-W-N-Q-P-D-W-R-I-V-F-K-Q	390
C-K-D-G-T-K-V-E-F-K-A-D-K-F-Q-W-N-Q-P-D-W-R-I-V-F-K-D	391
C-K-D-G-T-K-V-E-V-K-A-D-K-F-Q-W-N-Q-P-D-W-R-I-V-F-K-D	392
C-K-D-G-T-Q-V-E-F-K-A-D-K-F-Q-W-N-Q-P-D-W-R-I-V-F-K-D	393
C-K-D-G-T-Q-V-E-V-K-A-D-K-F-Q-W-N-Q-P-D-W-R-I-V-F-K-D	394
C-K-D-G-T-K-V-E-F-K-A-N-K-F-Q-W-N-Q-P-D-W-R-I-V-F-K-D	395
C-K-D-G-T-K-V-E-V-K-A-N-K-F-Q-W-N-Q-P-D-W-R-I-V-F-K-D	396
C-K-D-G-T-Q-V-E-F-K-A-N-K-F-Q-W-N-Q-P-D-W-R-I-V-F-K-D	397
C-K-D-G-T-Q-V-E-V-K-A-N-K-F-Q-W-N-Q-P-D-W-R-I-V-F-K-D	398

[0051] In another embodiment of the invention, the population of isolated peptides comprises three or more different peptides, wherein each peptide in the population comprises a sequence of C-X_2-G-G-K-S-P-A-R-X_{10}-T-E-E-R-V-A-G-D-L-D-H-K-X_{23}-V-D-S-D-K-K-H-D-A-E-K-T-E-E-K-R-H (SEQ ID NO: 5), or a fragment thereof, wherein X_2 is an amino acid selected from the group consisting of I or V, X_{10} is an amino acid selected from the group consisting of S or Y, and X_{23} is an amino acid selected from the group consisting of E or N. In related embodiments, peptides of the invention comprise a sequence of SEQ ID NO: 5, wherein X_2 is V. In other embodiments, peptides of the invention comprise a sequence of SEQ ID NO: 5, wherein X_{10} is Y. In still other embodiments, peptides of the invention comprise a sequence of SEQ ID NO: 5, wherein X_{23} is E. In some embodiments, the population of isolated peptides comprises three or more peptides comprising or consisting of any one of the sequences in Table 5.

Table 5. APL-ID3 Peptides

Sequence	SEQ ID NO.
C-I-G-G-K-S-P-A-R-S-T-E-E-R-V-A-G-D-L-D-H-K-E-V-D-S-D-K-K-H-D-A-E-K-T-E-E-K-R-H	399
C-I-G-G-K-S-P-A-R-Y-T-E-E-R-V-A-G-D-L-D-H-K-E-V-D-S-D-K-K-H-D-A-E-K-T-E-E-K-R-H	400
C-V-G-G-K-S-P-A-R-S-T-E-E-R-V-A-G-D-L-D-H-K-E-V-D-S-D-K-K-H-D-A-E-K-T-E-E-K-R-H	401
C-V-G-G-K-S-P-A-R-Y-T-E-E-R-V-A-G-D-L-D-H-K-E-V-D-S-D-K-K-H-D-A-E-K-T-E-E-K-R-H	402
C-I-G-G-K-S-P-A-R-S-T-E-E-R-V-A-G-D-L-D-H-K-N-V-D-S-D-K-K-H-D-A-E-K-T-E-E-K-R-H	403
C-I-G-G-K-S-P-A-R-Y-T-E-E-R-V-A-G-D-L-D-H-K-N-V-D-S-D-K-K-H-D-A-E-K-T-E-E-K-R-H	404
C-V-G-G-K-S-P-A-R-S-T-E-E-R-V-A-G-D-L-D-H-K-N-V-D-S-D-K-K-H-D-A-E-K-T-E-E-K-R-H	405
C-V-G-G-K-S-P-A-R-Y-T-E-E-R-V-A-G-D-L-D-H-K-N-V-D-S-D-K-K-H-D-A-E-K-T-E-E-K-R-H	406

[0052] In one embodiment, the peptides of the invention comprise a sequence of C-G-K-I-L-N-L-V-S-A-V-Q-E-K-K-P-P-E-A-P-A-A-D-E-A-A-G-P-A-T-H (SEQ ID NO: 6), or a fragment thereof. The population of isolated peptides may comprise three or more peptides, each peptide comprising a sequence of SEQ ID NO: 6 or fragments of this sequence. In some embodiments, peptides comprising the sequence of SEQ ID NO: 6 may be included in other peptide populations of the invention described herein.

[0053] In another embodiment of the invention, the population of isolated peptides comprises three or more different peptides, wherein each peptide in the population comprises a sequence of C-K-D-G-X_5-R-V-E-X_9-K-A-E-X_{13}-F-N-X_{16}-Q-X_{18}-P-N-P-X_{22}-I-K-Y-R-X_{27} (SEQ ID NO: 7), or a fragment thereof, wherein X_5 is an amino acid selected from the group consisting of S or Q, X_9 is an amino acid selected from the group consisting of F or Y, X_{13} is an amino acid selected from the group consisting of R or H, X_{16} is an amino acid selected from the group consisting of W or Y, X_{18} is an amino acid selected from the group consisting of S or Q, X_{22} is an amino acid selected from the group consisting of K or H, and X_{27} is an amino acid selected from the group consisting of N or D.

[0054] In related embodiments, peptides of the invention comprise a sequence of SEQ ID NO: 7, wherein X_5 is Q, X_9 is Y, and/or X_{13} is H. In other embodiments, peptides of the invention comprise a sequence of SEQ ID NO: 7, wherein X_{16} is W and/or X_{22} is K. In still other embodiments, peptides of the invention comprise a sequence of SEQ ID NO: 7, wherein X_{18} is S and/or X_{27} is D. In some embodiments, the population of isolated peptides comprises three or more peptides comprising or consisting of any one of the sequences in Table 6.

Table 6. APL-ID6 Peptides

Sequence	SEQ ID NO.
C-K-D-G-S-R-V-E-F-K-A-E-R-F-N-W-Q-S-P-N-P-K-I-K-Y-R-N	407
C-K-D-G-S-R-V-E-Y-K-A-E-R-F-N-W-Q-S-P-N-P-K-I-K-Y-R-N	408
C-K-D-G-Q-R-V-E-F-K-A-E-R-F-N-W-Q-S-P-N-P-K-I-K-Y-R-N	409
C-K-D-G-Q-R-V-E-Y-K-A-E-R-F-N-W-Q-S-P-N-P-K-I-K-Y-R-N	410
C-K-D-G-S-R-V-E-F-K-A-E-H-F-N-W-Q-S-P-N-P-K-I-K-Y-R-N	411
C-K-D-G-S-R-V-E-Y-K-A-E-H-F-N-W-Q-S-P-N-P-K-I-K-Y-R-N	412
C-K-D-G-Q-R-V-E-F-K-A-E-H-F-N-W-Q-S-P-N-P-K-I-K-Y-R-N	413
C-K-D-G-Q-R-V-E-Y-K-A-E-H-F-N-W-Q-S-P-N-P-K-I-K-Y-R-N	414
C-K-D-G-S-R-V-E-F-K-A-E-R-F-N-Y-Q-S-P-N-P-K-I-K-Y-R-N	415
C-K-D-G-S-R-V-E-Y-K-A-E-R-F-N-Y-Q-S-P-N-P-K-I-K-Y-R-N	416
C-K-D-G-Q-R-V-E-F-K-A-E-R-F-N-Y-Q-S-P-N-P-K-I-K-Y-R-N	417
C-K-D-G-Q-R-V-E-Y-K-A-E-R-F-N-Y-Q-S-P-N-P-K-I-K-Y-R-N	418
C-K-D-G-S-R-V-E-F-K-A-E-H-F-N-Y-Q-S-P-N-P-K-I-K-Y-R-N	419
C-K-D-G-S-R-V-E-Y-K-A-E-H-F-N-Y-Q-S-P-N-P-K-I-K-Y-R-N	420
C-K-D-G-Q-R-V-E-F-K-A-E-H-F-N-Y-Q-S-P-N-P-K-I-K-Y-R-N	421
C-K-D-G-Q-R-V-E-Y-K-A-E-H-F-N-Y-Q-S-P-N-P-K-I-K-Y-R-N	422
C-K-D-G-S-R-V-E-F-K-A-E-R-F-N-W-Q-Q-P-N-P-K-I-K-Y-R-N	423
C-K-D-G-S-R-V-E-Y-K-A-E-R-F-N-W-Q-Q-P-N-P-K-I-K-Y-R-N	424
C-K-D-G-Q-R-V-E-F-K-A-E-R-F-N-W-Q-Q-P-N-P-K-I-K-Y-R-N	425
C-K-D-G-Q-R-V-E-Y-K-A-E-R-F-N-W-Q-Q-P-N-P-K-I-K-Y-R-N	426
C-K-D-G-S-R-V-E-F-K-A-E-H-F-N-W-Q-Q-P-N-P-K-I-K-Y-R-N	427
C-K-D-G-S-R-V-E-Y-K-A-E-H-F-N-W-Q-Q-P-N-P-K-I-K-Y-R-N	428
C-K-D-G-Q-R-V-E-F-K-A-E-H-F-N-W-Q-Q-P-N-P-K-I-K-Y-R-N	429
C-K-D-G-Q-R-V-E-Y-K-A-E-H-F-N-W-Q-Q-P-N-P-K-I-K-Y-R-N	430
C-K-D-G-S-R-V-E-F-K-A-E-R-F-N-Y-Q-Q-P-N-P-K-I-K-Y-R-N	431
C-K-D-G-S-R-V-E-Y-K-A-E-R-F-N-Y-Q-Q-P-N-P-K-I-K-Y-R-N	432
C-K-D-G-Q-R-V-E-F-K-A-E-R-F-N-Y-Q-Q-P-N-P-K-I-K-Y-R-N	433
C-K-D-G-Q-R-V-E-Y-K-A-E-R-F-N-Y-Q-Q-P-N-P-K-I-K-Y-R-N	434

Sequence	SEQ ID NO.
C-K-D-G-S-R-V-E-F-K-A-E-H-F-N-Y-Q-Q-P-N-P-K-I-K-Y-R-N	435
C-K-D-G-S-R-V-E-Y-K-A-E-H-F-N-Y-Q-Q-P-N-P-K-I-K-Y-R-N	436
C-K-D-G-Q-R-V-E-F-K-A-E-H-F-N-Y-Q-Q-P-N-P-K-I-K-Y-R-N	437
C-K-D-G-Q-R-V-E-Y-K-A-E-H-F-N-Y-Q-Q-P-N-P-K-I-K-Y-R-N	438
C-K-D-G-Q-R-V-E-F-K-A-E-H-F-N-W-Q-Q-P-N-P-H-I-K-Y-R-N	439
C-K-D-G-Q-R-V-E-Y-K-A-E-H-F-N-W-Q-Q-P-N-P-H-I-K-Y-R-N	440
C-K-D-G-S-R-V-E-F-K-A-E-R-F-N-Y-Q-Q-P-N-P-H-I-K-Y-R-N	441
C-K-D-G-S-R-V-E-Y-K-A-E-R-F-N-Y-Q-Q-P-N-P-H-I-K-Y-R-N	442
C-K-D-G-Q-R-V-E-F-K-A-E-R-F-N-Y-Q-Q-P-N-P-H-I-K-Y-R-N	443
C-K-D-G-Q-R-V-E-Y-K-A-E-R-F-N-Y-Q-Q-P-N-P-H-I-K-Y-R-N	444
C-K-D-G-S-R-V-E-F-K-A-E-H-F-N-Y-Q-Q-P-N-P-H-I-K-Y-R-N	445
C-K-D-G-S-R-V-E-Y-K-A-E-H-F-N-Y-Q-Q-P-N-P-H-I-K-Y-R-N	446
C-K-D-G-Q-R-V-E-F-K-A-E-H-F-N-Y-Q-Q-P-N-P-H-I-K-Y-R-N	447
C-K-D-G-Q-R-V-E-Y-K-A-E-H-F-N-Y-Q-Q-P-N-P-H-I-K-Y-R-N	448
C-K-D-G-Q-R-V-E-F-K-A-E-H-F-N-W-Q-Q-P-N-P-H-I-K-Y-R-D	449
C-K-D-G-Q-R-V-E-Y-K-A-E-H-F-N-W-Q-Q-P-N-P-H-I-K-Y-R-D	450
C-K-D-G-S-R-V-E-F-K-A-E-R-F-N-Y-Q-Q-P-N-P-H-I-K-Y-R-D	451
C-K-D-G-S-R-V-E-Y-K-A-E-R-F-N-Y-Q-Q-P-N-P-H-I-K-Y-R-D	452
C-K-D-G-Q-R-V-E-F-K-A-E-R-F-N-Y-Q-Q-P-N-P-H-I-K-Y-R-D	453
C-K-D-G-Q-R-V-E-Y-K-A-E-R-F-N-Y-Q-Q-P-N-P-H-I-K-Y-R-D	454
C-K-D-G-S-R-V-E-F-K-A-E-H-F-N-Y-Q-Q-P-N-P-H-I-K-Y-R-D	455
C-K-D-G-S-R-V-E-Y-K-A-E-H-F-N-Y-Q-Q-P-N-P-H-I-K-Y-R-D	456
C-K-D-G-Q-R-V-E-F-K-A-E-H-F-N-Y-Q-Q-P-N-P-H-I-K-Y-R-D	457
C-K-D-G-Q-R-V-E-Y-K-A-E-H-F-N-Y-Q-Q-P-N-P-H-I-K-Y-R-D	458

[0055] In some embodiments of the invention, the population of isolated peptides comprises three or more different peptides, wherein each peptide in the population comprises a sequence of C-G-K-I-L-N-L-V-S-X_{10}-X_{11}-N-E-K-K-P-P-E-A-P-A-A-D-E-A-A-G-P-A-T-H (SEQ ID NO: 8), or a fragment thereof, wherein X_{10} is an amino acid selected from the group consisting of V, L or I, and X_{11} is an amino acid selected from the group consisting of A or L. In such embodiments, peptides of the invention comprise a sequence of SEQ ID NO: 8, wherein X_{11} is A. In other embodiments, peptides of the invention comprise a sequence of SEQ ID NO: 8, wherein X_{10} is I. In still other embodiments, the population of isolated peptides comprises three or more peptides comprising or consisting of any one of the sequences in Table 7.

Table 7. APL-ID7 Peptides

Sequence	SEQ ID NO.
C-G-K-I-L-N-L-V-S-V-A-N-E-K-K-P-P-E-A-P-A-A-D-E-A-A-G-P-A-T-H	459
C-G-K-I-L-N-L-V-S-V-L-N-E-K-K-P-P-E-A-P-A-A-D-E-A-A-G-P-A-T-H	460
C-G-K-I-L-N-L-V-S-L-A-N-E-K-K-P-P-E-A-P-A-A-D-E-A-A-G-P-A-T-H	461
C-G-K-I-L-N-L-V-S-L-L-N-E-K-K-P-P-E-A-P-A-A-D-E-A-A-G-P-A-T-H	462
C-G-K-I-L-N-L-V-S-I-A-N-E-K-K-P-P-E-A-P-A-A-D-E-A-A-G-P-A-T-H	463
C-G-K-I-L-N-L-V-S-I-L-N-E-K-K-P-P-E-A-P-A-A-D-E-A-A-G-P-A-T-H	464

[0056] In other embodiments of the invention, the population of isolated peptides comprises three or more different peptides, wherein each peptide in the population comprises a sequence of E-T-K-V-X_5-Y-X_7-Y-L-K-X_{11}-G-R-T-V-K-L-D-S-H-X_{21}-F-D-W-X_{25}-T-P-X_{28}-P-K-X_{31}-G-F-K-D-C (SEQ ID NO: 9), or a fragment thereof, wherein X_5 is an amino acid selected from the group consisting of V or A, X_7 is an amino acid selected from the group consisting of G, I or H, X_{11} is an amino acid selected from the group consisting of E, N, or Q, X_{21} is an amino acid selected from the group consisting of R, D, or N, X_{25} is an amino acid selected from the group consisting of Q, D, or E, X_{28} is an amino acid selected from the group consisting of E or N, and X_{31} is an amino acid selected from the group consisting of L or V.

[0057] In related embodiments, peptides of the invention comprise a sequence of SEQ ID NO: 9, wherein X_5 is V, X_7 is G, and/or X_{11} is N. In other embodiments, peptides of the invention comprise a sequence of SEQ ID NO: 9, wherein X_{21} is R and/or X_{25} is E. In still other embodiments, peptides of the invention comprise a sequence of SEQ ID NO: 9, wherein X_{28} is N and/or X_{31} is L. In some embodiments, the population of isolated peptides comprises three or more peptides comprising or consisting of any one of the sequences in Table 8.

Table 8. APID 2-1 Peptides

Sequence	SEQ ID NO.
E-T-K-V-V-Y-G-Y-L-K-E-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-C	465
E-T-K-V-V-Y-I-Y-L-K-E-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-C	466
E-T-K-V-V-Y-H-Y-L-K-E-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-C	467
E-T-K-V-A-Y-G-Y-L-K-E-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-C	468
E-T-K-V-A-Y-I-Y-L-K-E-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-C	469
E-T-K-V-A-Y-H-Y-L-K-E-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-C	470
E-T-K-V-V-Y-G-Y-L-K-N-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-C	471
E-T-K-V-V-Y-I-Y-L-K-N-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-C	472
E-T-K-V-V-Y-H-Y-L-K-N-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-C	473
E-T-K-V-A-Y-G-Y-L-K-N-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-C	474
E-T-K-V-A-Y-I-Y-L-K-N-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-C	475
E-T-K-V-A-Y-H-Y-L-K-N-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-C	476
E-T-K-V-V-Y-G-Y-L-K-Q-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-C	477
E-T-K-V-V-Y-I-Y-L-K-Q-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-C	478
E-T-K-V-V-Y-H-Y-L-K-Q-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-C	479
E-T-K-V-A-Y-G-Y-L-K-Q-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-C	480
E-T-K-V-A-Y-I-Y-L-K-Q-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-C	481
E-T-K-V-A-Y-H-Y-L-K-Q-G-R-T-V-K-L-D-S-H-R-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-C	482
E-T-K-V-V-Y-G-Y-L-K-Q-G-R-T-V-K-L-D-S-H-D-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-C	483
E-T-K-V-V-Y-I-Y-L-K-Q-G-R-T-V-K-L-D-S-H-D-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-C	484
E-T-K-V-V-Y-H-Y-L-K-Q-G-R-T-V-K-L-D-S-H-D-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-C	485
E-T-K-V-A-Y-G-Y-L-K-Q-G-R-T-V-K-L-D-S-H-D-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-C	486

Sequence	SEQ ID NO.
E-T-K-V-A-Y-I-Y-L-K-Q-G-R-T-V-K-L-D-S-H-D-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-C	487
E-T-K-V-A-Y-H-Y-L-K-Q-G-R-T-V-K-L-D-S-H-D-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-C	488
E-T-K-V-V-Y-G-Y-L-K-Q-G-R-T-V-K-L-D-S-H-N-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-C	489
E-T-K-V-V-Y-I-Y-L-K-Q-G-R-T-V-K-L-D-S-H-N-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-C	490
E-T-K-V-V-Y-H-Y-L-K-Q-G-R-T-V-K-L-D-S-H-N-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-C	491
E-T-K-V-A-Y-G-Y-L-K-Q-G-R-T-V-K-L-D-S-H-N-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-C	492
E-T-K-V-A-Y-I-Y-L-K-Q-G-R-T-V-K-L-D-S-H-N-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-C	493
E-T-K-V-A-Y-H-Y-L-K-Q-G-R-T-V-K-L-D-S-H-N-F-D-W-Q-T-P-E-P-K-L-G-F-K-D-C	494
E-T-K-V-V-Y-G-Y-L-K-Q-G-R-T-V-K-L-D-S-H-D-F-D-W-D-T-P-E-P-K-L-G-F-K-D-C	495
E-T-K-V-V-Y-I-Y-L-K-Q-G-R-T-V-K-L-D-S-H-D-F-D-W-D-T-P-E-P-K-L-G-F-K-D-C	496
E-T-K-V-V-Y-H-Y-L-K-Q-G-R-T-V-K-L-D-S-H-D-F-D-W-D-T-P-E-P-K-L-G-F-K-D-C	497
E-T-K-V-A-Y-G-Y-L-K-Q-G-R-T-V-K-L-D-S-H-D-F-D-W-D-T-P-E-P-K-L-G-F-K-D-C	498
E-T-K-V-A-Y-I-Y-L-K-Q-G-R-T-V-K-L-D-S-H-D-F-D-W-D-T-P-E-P-K-L-G-F-K-D-C	499
E-T-K-V-A-Y-H-Y-L-K-Q-G-R-T-V-K-L-D-S-H-D-F-D-W-D-T-P-E-P-K-L-G-F-K-D-C	500
E-T-K-V-V-Y-G-Y-L-K-Q-G-R-T-V-K-L-D-S-H-N-F-D-W-D-T-P-E-P-K-L-G-F-K-D-C	501
E-T-K-V-V-Y-I-Y-L-K-Q-G-R-T-V-K-L-D-S-H-N-F-D-W-D-T-P-E-P-K-L-G-F-K-D-C	502
E-T-K-V-V-Y-H-Y-L-K-Q-G-R-T-V-K-L-D-S-H-N-F-D-W-D-T-P-E-P-K-L-G-F-K-D-C	503
E-T-K-V-A-Y-G-Y-L-K-Q-G-R-T-V-K-L-D-S-H-N-F-D-W-D-T-P-E-P-K-L-G-F-K-D-C	504
E-T-K-V-A-Y-I-Y-L-K-Q-G-R-T-V-K-L-D-S-H-N-F-D-W-D-T-P-E-P-K-L-G-F-K-D-C	505
E-T-K-V-A-Y-H-Y-L-K-Q-G-R-T-V-K-L-D-S-H-N-F-D-W-D-T-P-E-P-K-L-G-F-K-D-C	506
E-T-K-V-V-Y-G-Y-L-K-Q-G-R-T-V-K-L-D-S-H-D-F-D-W-E-T-P-E-P-K-L-G-F-K-D-C	507
E-T-K-V-V-Y-I-Y-L-K-Q-G-R-T-V-K-L-D-S-H-D-F-D-W-E-T-P-E-P-K-L-G-F-K-D-C	508
E-T-K-V-V-Y-H-Y-L-K-Q-G-R-T-V-K-L-D-S-H-D-F-D-W-E-T-P-E-P-K-L-G-F-K-D-C	509

Sequence	SEQ ID NO.
E-T-K-V-A-Y-G-Y-L-K-Q-G-R-T-V-K-L-D-S-H-D-F-D-W-E-T-P-E-P-K-L-G-F-K-D-C	510
E-T-K-V-A-Y-I-Y-L-K-Q-G-R-T-V-K-L-D-S-H-D-F-D-W-E-T-P-E-P-K-L-G-F-K-D-C	511
E-T-K-V-A-Y-H-Y-L-K-Q-G-R-T-V-K-L-D-S-H-D-F-D-W-E-T-P-E-P-K-L-G-F-K-D-C	512
E-T-K-V-V-Y-G-Y-L-K-Q-G-R-T-V-K-L-D-S-H-N-F-D-W-E-T-P-E-P-K-L-G-F-K-D-C	513
E-T-K-V-V-Y-I-Y-L-K-Q-G-R-T-V-K-L-D-S-H-N-F-D-W-E-T-P-E-P-K-L-G-F-K-D-C	514
E-T-K-V-V-Y-H-Y-L-K-Q-G-R-T-V-K-L-D-S-H-N-F-D-W-E-T-P-E-P-K-L-G-F-K-D-C	515
E-T-K-V-A-Y-G-Y-L-K-Q-G-R-T-V-K-L-D-S-H-N-F-D-W-E-T-P-E-P-K-L-G-F-K-D-C	516
E-T-K-V-A-Y-I-Y-L-K-Q-G-R-T-V-K-L-D-S-H-N-F-D-W-E-T-P-E-P-K-L-G-F-K-D-C	517
E-T-K-V-A-Y-H-Y-L-K-Q-G-R-T-V-K-L-D-S-H-N-F-D-W-E-T-P-E-P-K-L-G-F-K-D-C	518
E-T-K-V-V-Y-G-Y-L-K-Q-G-R-T-V-K-L-D-S-H-D-F-D-W-E-T-P-N-P-K-L-G-F-K-D-C	519
E-T-K-V-V-Y-I-Y-L-K-Q-G-R-T-V-K-L-D-S-H-D-F-D-W-E-T-P-N-P-K-L-G-F-K-D-C	520
E-T-K-V-V-Y-H-Y-L-K-Q-G-R-T-V-K-L-D-S-H-D-F-D-W-E-T-P-N-P-K-L-G-F-K-D-C	521
E-T-K-V-A-Y-G-Y-L-K-Q-G-R-T-V-K-L-D-S-H-D-F-D-W-E-T-P-N-P-K-L-G-F-K-D-C	522
E-T-K-V-A-Y-I-Y-L-K-Q-G-R-T-V-K-L-D-S-H-D-F-D-W-E-T-P-N-P-K-L-G-F-K-D-C	523
E-T-K-V-A-Y-H-Y-L-K-Q-G-R-T-V-K-L-D-S-H-D-F-D-W-E-T-P-N-P-K-L-G-F-K-D-C	524
E-T-K-V-V-Y-G-Y-L-K-Q-G-R-T-V-K-L-D-S-H-N-F-D-W-E-T-P-N-P-K-L-G-F-K-D-C	525
E-T-K-V-V-Y-I-Y-L-K-Q-G-R-T-V-K-L-D-S-H-N-F-D-W-E-T-P-N-P-K-L-G-F-K-D-C	526
E-T-K-V-V-Y-H-Y-L-K-Q-G-R-T-V-K-L-D-S-H-N-F-D-W-E-T-P-N-P-K-L-G-F-K-D-C	527
E-T-K-V-A-Y-G-Y-L-K-Q-G-R-T-V-K-L-D-S-H-N-F-D-W-E-T-P-N-P-K-L-G-F-K-D-C	528
E-T-K-V-A-Y-I-Y-L-K-Q-G-R-T-V-K-L-D-S-H-N-F-D-W-E-T-P-N-P-K-L-G-F-K-D-C	529
E-T-K-V-A-Y-H-Y-L-K-Q-G-R-T-V-K-L-D-S-H-N-F-D-W-E-T-P-N-P-K-L-G-F-K-D-C	530
E-T-K-V-V-Y-G-Y-L-K-Q-G-R-T-V-K-L-D-S-H-D-F-D-W-E-T-P-N-P-K-V-G-F-K-D-C	531
E-T-K-V-V-Y-I-Y-L-K-Q-G-R-T-V-K-L-D-S-H-D-F-D-W-E-T-P-N-P-K-V-G-F-K-D-C	532

Sequence	SEQ ID NO.
E-T-K-V-V-Y-H-Y-L-K-Q-G-R-T-V-K-L-D-S-H-D-F-D-W-E-T-P-N-P-K-V-G-F-K-D-C	533
E-T-K-V-A-Y-G-Y-L-K-Q-G-R-T-V-K-L-D-S-H-D-F-D-W-E-T-P-N-P-K-V-G-F-K-D-C	534
E-T-K-V-A-Y-I-Y-L-K-Q-G-R-T-V-K-L-D-S-H-D-F-D-W-E-T-P-N-P-K-V-G-F-K-D-C	535
E-T-K-V-A-Y-H-Y-L-K-Q-G-R-T-V-K-L-D-S-H-D-F-D-W-E-T-P-N-P-K-V-G-F-K-D-C	536
E-T-K-V-V-Y-G-Y-L-K-Q-G-R-T-V-K-L-D-S-H-N-F-D-W-E-T-P-N-P-K-V-G-F-K-D-C	537
E-T-K-V-V-Y-I-Y-L-K-Q-G-R-T-V-K-L-D-S-H-N-F-D-W-E-T-P-N-P-K-V-G-F-K-D-C	538
E-T-K-V-V-Y-H-Y-L-K-Q-G-R-T-V-K-L-D-S-H-N-F-D-W-E-T-P-N-P-K-V-G-F-K-D-C	539
E-T-K-V-A-Y-G-Y-L-K-Q-G-R-T-V-K-L-D-S-H-N-F-D-W-E-T-P-N-P-K-V-G-F-K-D-C	540
E-T-K-V-A-Y-I-Y-L-K-Q-G-R-T-V-K-L-D-S-H-N-F-D-W-E-T-P-N-P-K-V-G-F-K-D-C	541
E-T-K-V-A-Y-H-Y-L-K-Q-G-R-T-V-K-L-D-S-H-N-F-D-W-E-T-P-N-P-K-V-G-F-K-D-C	542

[0058] In certain embodiments, peptides of the invention comprise a sequence of SEQ ID NO: 1, SEQ ID NO: 2, SEQ ID NO: 3, SEQ ID NO: 4, SEQ ID NO: 5, SEQ ID NO: 6, SEQ ID NO: 7, SEQ ID NO: 8, or SEQ ID NO: 9 and an additional N-terminal peptide sequence (*e.g.*, an N-terminal extension). The additional N-terminal peptide sequence can comprise 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 20, 25, or more amino acids. In certain embodiments, the N-terminal peptide sequence has a length of about 5 to about 10, about 10 to about 15, about 15 to about 20, about 20 to about 25, about 25 to about 30, about 30 to about 40, or about 40 to about 50 amino acids. In one embodiment, the N-terminal peptide sequence can be one or more linking residues (*e.g.* one or more glycine, cysteine, or serine residues). For instance, in certain embodiments, the carboxyl-terminal cysteine residue in any of the sequences described herein can be located at the amino terminus instead. In a similar manner, the amino-terminal cysteine residue in any of the sequences described herein can be located at the carboxyl terminus instead.

[0059] The additional N-terminal peptide sequence can be a native sequence. As used herein, a "native" sequence is a peptide sequence from a naturally-occurring *Anaplasma* major surface protein 2 (MSP2)/p44 or OMP/p44 sequence, or a variant thereof. In certain embodiments, the peptide sequence is a fragment of a naturally-occurring *Anaplasma* MSP 2/p44 or OMP/p44 sequence. The peptide sequence can be, *e.g.*, from a conserved or non-conserved region of MSP 2/p44 or OMP/p44. The peptide sequence can comprise, *e.g.*, an epitope, such as an immunodominant epitope or any other epitope recognizable by a host (*e.g.*, human, dog, etc.) immune system. *Anaplasma* MSP 2/p44 or OMP/p44 proteins and peptides thereof have been described, *e.g.*, in Genebank Accession Nos. AAO30097.1, ACV85580.1, ACV85559.1, AEH96270.1, ADU56850.1, AEH96270.1, and AAQ91849.1 as well as in U.S. Patent Nos. 7,507,789, 8,303,959, 8,158,370, and U.S. Patent Publication No. 2013/0064842, the contents of each of which are incorporated herein by reference in their entireties.

[0060] Variant polypeptides are at least about 80, 85, 90, 95, 98, or 99% identical to a peptide shown in SEQ ID NOs: 1-543 and are also polypeptides of the invention. Percent sequence identity has an art recognized meaning and there are a number of methods to measure identity between two polypeptide or polynucleotide sequences. *See, e.g.*, Lesk, Ed., Computational Molecular Biology, Oxford University Press, New York, (1988); Smith, Ed., Biocomputing: Informatics And Genome Projects, Academic Press, New York, (1993); Griffin & Griffin, Eds., Computer Analysis Of Sequence Data, Part I, Humana Press, New Jersey, (1994); von Heinje, Sequence Analysis In Molecular Biology, Academic Press, (1987); and Gribskov & Devereux, Eds., Sequence Analysis Primer, M Stockton Press, New York, (1991). Methods for aligning polynucleotides or polypeptides are codified in computer programs, including the GCG program package (Devereux *et al.*, Nuc. Acids Res. 12:387 (1984)), BLASTP, BLASTN, FASTA (Atschul *et al.*, J Molec. Biol. 215:403 (1990)), and Bestfit program (Wisconsin Sequence Analysis Package, Version 8 for Unix, Genetics Computer Group, University Research Park, 575 Science Drive, Madison, Wis. 53711) which uses the local homology algorithm of Smith and Waterman (Adv. App. Math., 2:482-489 (1981)). For example, the computer program ALIGN which employs the FASTA algorithm can be used, with an affine gap search with a gap open penalty of −12 and a gap extension penalty of −2.

[0061] When using any of the sequence alignment programs to determine whether a particular sequence is, for instance, about 95% identical to a reference sequence, the parameters are set such that the percentage of identity is calculated over the full length of the reference polynucleotide and that gaps in identity of up to 5% of the total number of nucleotides in the reference polynucleotide are allowed.

[0062] Variants of the peptide sequences can be readily selected by one of skill in the art, based in part on known properties of the sequence. For example, a variant peptide can include amino acid substitutions (*e.g.*, conservative amino acid substitutions) and/or deletions (*e.g.*, small, single amino acid deletions, or deletions encompassing 2, 3, 4, 5, 10, 15, 20, or more contiguous amino acids). Thus, in certain embodiments, a variant of a native peptide sequence is one that differs from a naturally-occurring sequence by (i) one or more (*e.g.*, 2, 3, 4, 5, 6, or more) conservative amino acid substitutions, (ii) deletion of 1 or more (*e.g.*, 2, 3, 4, 5, 6, or more) amino acids, or (iii) a combination thereof. Deleted amino acids can be contiguous or non-contiguous. Conservative amino acid substitutions are those that take place within a family of amino acids that are related in their side chains and chemical properties. These include, *e.g.*, (1) acidic amino acids: aspartate, glutamate; (2) basic amino acids: lysine, arginine, histidine; (3) nonpolar amino acids: alanine, valine, leucine, isoleucine, proline, phenylalanine, methionine, tryptophan; (4) uncharged polar amino acids: glycine, asparagine, glutamine, cysteine, serine, threonine, tyrosine; (5) aliphatic amino acids: glycine, alanine, valine, leucine, isoleucine, serine, threonine, with serine and threonine optionally grouped separately as aliphatic-hydroxyl; (6) aromatic amino acids: phenylalanine, tyrosine, tryptophan; (7) amide amino acids: asparagine, glutamine; and (9) sulfur-containing amino acids: cysteine and methionine. *See, e.g.*, Biochemistry, 2nd ed., Ed. by L. Stryer, W H Freeman and Co.: 1981. Methods for confirming that variant peptides are suitable are conventional and routine.

[0063] Variants of the peptide sequences encompass variations on previously defined peptide sequences. For example, a previously described peptide sequence comprising a known epitope may be lengthened or shortened, at one or both ends (*e.g.*, by about 1-3 amino acids), and/or one, two, three, four or more amino acids may be substituted by conservative amino acids, etc. Furthermore, if a region of a protein has been identified as containing an epitope of interest, an investigator can "shift" the region of interest (*e.g.*, by about 5 amino acids in either direction) from the endpoints of the original rough region to optimize the activity.

[0064] In certain embodiments, the additional N-terminal peptide sequence can comprise or consist of another peptide having a sequence of SEQ ID NO: 1, SEQ ID NO: 2, SEQ ID NO: 3, SEQ ID NO: 4, SEQ ID NO: 5, SEQ ID NO: 6, SEQ ID NO: 7, SEQ ID NO: 8, or SEQ ID NO: 9. Thus, in some embodiments, a peptide of the invention can be a multimer of sequences having a sequence of SEQ ID NO: 1, SEQ ID NO: 2, SEQ ID NO: 3, SEQ ID NO: 4, SEQ ID NO: 5, SEQ ID NO: 6, SEQ ID NO: 7, SEQ ID NO: 8, or SEQ ID NO: 9. In other embodiments, the N-terminal peptide sequence is a native MSP 2/p44 or OMP/p44 peptide sequence that is naturally adjacent to the N-terminal end of a sequence of any one of SEQ ID NOs: 1 to 9. In other embodiments, the peptide can comprise a fusion of sequences of any one of SEQ ID NOs: 1 to 9 optionally through one or more linking amino acids. For example, in one embodiment, the peptide can comprise a sequence of SEQ ID NO: 1 or SEQ ID NO: 2 linked to SEQ ID NO: 4 optionally through one or more linking amino acids (*e.g.* glycine, serine, or cysteine residues). In another embodiment, the peptide can comprise a sequence of SEQ ID NO: 5 linked to SEQ ID NO: 4 or SEQ ID NO: 6 optionally through one or more linking amino acids (*e.g.* glycine, serine, or cysteine residues). In another embodiment, the peptide can comprise a sequence of SEQ ID NO: 9 linked to SEQ ID NO: 4, SEQ ID NO: 7, or SEQ ID NO: 8 optionally through one or more linking amino acids (*e.g.* glycine, serine, or cysteine residues).

[0065] In certain embodiments, the additional N-terminal peptide sequence is a non-native sequence. As used herein, a "non-native" sequence is any protein sequence, whether from an *Anaplasma* protein or otherwise, other than a native MSP 2/p44 or OMP/p44 peptide sequence. In certain embodiments, the additional N-terminal peptide sequence comprises an epitope of an *Anaplasma* surface antigen. Other *Anaplasma* antigens include, but are not limited to MSP5, HSP60, Asp14 (Kahlon *et al.*, Infect Immun., Vol. 81(1): 65–79, 2013), and the antigens described in Zhi *et al.*, J. Clin. Microbiol., Vol. 35(10): 2606-2611, 1997. Polypeptides or peptides derived from other microorganisms can also be used, including *Ehrlichia* antigens and *Borrelia* antigens. Protein and peptide sequences corresponding to *Ehrlichia* antigens have been described. *See, e.g.*, U.S. Application No. 14/052,296, U.S. Patent Nos. 6,306,402, 6,355,777, 7,204,992, 7,407,770, 8,828,675, and WO2006/138509, the contents of each of which are incorporated herein by reference in their entireties. Protein and peptide sequences corresponding to *Borrelia* antigens have been described. *See, e.g.*, U.S. Patent Nos. 6,716,574, 5,618,533, 5,643,733, 5,643,751, 5,932,220, 6,617,441, 7,887,815, 8,568,989, and 8,758,772, the contents of each of which are incorporated herein by reference in their entireties.

[0066] In certain embodiments, the additional N-terminal peptide sequence is a combination of sequences. For example, the additional N-terminal peptide sequence can comprise a native sequence, a non-native sequence, or any combination of such sequences (*e.g.*, two or more native sequences, two or more non-native sequences, or one or more native sequences in combination with one or more non-native sequences).

[0067] In certain embodiments, peptides of the invention comprise a sequence of SEQ ID NO: 1, SEQ ID NO: 2, SEQ ID NO: 3, SEQ ID NO: 4, SEQ ID NO: 5, SEQ ID NO: 6, SEQ ID NO: 7, SEQ ID NO: 8, or SEQ ID NO: 9 and an additional C-terminal sequence (*e.g.*, a C-terminal extension). The additional C-terminal peptide sequence can comprise 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 20, 25, or more amino acids. In certain embodiments, the additional C-terminal sequence has a length of about 5 to about 10, about 10 to about 15, about 15 to about 20, about 20 to about 25, about 25 to about 30, about 30 to about 40, or about 40 to about 50 amino acids. The additional C-terminal peptide sequence can be a native MSP 2/p44 or OMP/p44 sequence. In certain embodiments, the C-terminal peptide sequence is a fragment of a naturally-occurring *Anaplasma* MSP 2/p44 or OMP/p44 sequence. The peptide sequence can be, *e.g.*, from a conserved or non-conserved region of MSP 2/p44 or OMP/p44. The peptide sequence can comprise, *e.g.*, an epitope, such as an immunodominant epitope or any other epitope recognizable by a host (e.g., human, dog, etc.) immune system.

[0068] In certain embodiments, the additional C-terminal peptide sequence can comprise or consist of another peptide having a sequence of SEQ ID NO: 1, SEQ ID NO: 2, SEQ ID NO: 3, SEQ ID NO: 4, SEQ ID NO: 5, SEQ ID NO: 6, SEQ ID NO: 7, SEQ ID NO: 8, or SEQ ID NO: 9. For example, in certain embodiments, a peptide of the invention can be a multimer of sequences each having a sequence of SEQ ID NO: 1, SEQ ID NO: 2, SEQ ID NO: 3, SEQ ID NO: 4, SEQ ID NO: 5, SEQ ID NO: 6, SEQ ID NO: 7, SEQ ID NO: 8, or SEQ ID NO: 9. In other embodiments, the native sequence is a sequence (*e.g.*, a MSP 2/p44 or OMP/p44 sequence) that is naturally adjacent to the C-terminal end of a sequence of SEQ ID NO: 1, SEQ ID NO: 2,

SEQ ID NO: 3, SEQ ID NO: 4, SEQ ID NO: 5, SEQ ID NO: 6, SEQ ID NO: 7, SEQ ID NO: 8, or SEQ ID NO: 9.

[0069] In certain embodiments, the additional C-terminal peptide sequence is a non-native sequence. In some embodiments, the additional C-terminal peptide sequence comprises an epitope of an *Anaplasma* surface antigen other than MSP 2/p44 or OMP/p44. Polypeptides or peptides derived from other microorganisms can also be used. For instance, in some embodiments, the *Anaplasma* peptide sequence can further comprise an epitope from an *Ehrlichia* or *Borrelia* antigen.

[0070] In certain embodiments, the additional C-terminal peptide sequence is a combination of sequences. For example, the additional C-terminal peptide sequence can comprise a native, a non-native sequence, or any combination of such sequences (*e.g.*, two or more native sequences, two or more non-native sequences, or one or more native sequences in combination with one or more non-native sequences).

[0071] In certain embodiments, peptides of the invention comprise a sequence defined by SEQ ID NO: 1, SEQ ID NO: 2, SEQ ID NO: 3, SEQ ID NO: 4, SEQ ID NO: 5, SEQ ID NO: 6, SEQ ID NO: 7, SEQ ID NO: 8, or SEQ ID NO: 9 and further comprise an additional N-terminal peptide sequence and an additional C-terminal peptide sequence. The additional N-terminal and C-terminal peptide sequences can be as described above. Peptides of the invention generally do not consist of a full-length MSP 2/p44 or OMP/p44 protein. However, in certain embodiments, peptides of the invention can comprise a full-length MSP 2/p44 or OMP/p44 protein. In other embodiments, peptides of the invention do not comprise a full-length MSP 2/p44 or OMP/p44 protein.

[0072] A peptide of the invention comprising an additional N-terminal and/or C-terminal peptide sequence can be designed for diagnosing *Anaplasma* infections (*e.g.* anaplasmosis) early after infection (*e.g.*, within one to two weeks after the onset of infection). For example, in certain embodiments, the additional N-terminal and/or C-terminal peptide sequence comprises an antigen or epitope associated with early stages of *Anaplasma* infection.

[0073] In addition to the sequences described above, the additional N-terminal and C-terminal sequences can comprise or consist of a flexible sequence, designed to better present the peptides of the invention for detection in an immunoassay (*e.g.*, ELISA assay, lateral flow immunoassay, agglutination assay, etc.). Such flexible sequences can be readily identified by persons skilled in the art.

[0074] In certain embodiments, peptides of the invention comprise or consist of 20 or more (*e.g.*, 21, 22, 23, 24, 25, 26, 27, 28, 29, or more) amino acid residues. In certain embodiments, peptides of the invention comprise or consist of 30 or more (*e.g.*, 31, 32, 33, 34, or more) amino acid residues. In certain embodiments, peptides of the invention comprise or consist of 35 or more (*e.g.*, 36, 37, 38, 39, or more) amino acid residues. In certain embodiments, peptides of the invention comprise or consist of 40 or more (*e.g.*, 41, 42, 43, 44, or more) amino acid residues. In certain embodiments, peptides of the invention comprise or consist of 45 or more (*e.g.*, 46, 47, 48, 49, or more) amino acid residues. In certain embodiments, peptides of the invention comprise or consist of 50 or more (*e.g.*, 51, 52, 53, 54, or more) amino acid residues. In certain embodiments, peptides of the invention comprise or consist of 55, 60, 65, 70, 75, 80, 85, 90, 95, 100, or more amino acid residues. In some embodiments, peptides of the invention comprise or consist of about 20 to about 75 amino acids, about 25 to about 65 amino acids, or about 30 to about 55 amino acids.

[0075] In certain embodiments, peptides of the invention comprise an epitope of a peptide sequence described herein. For example, in certain embodiments, peptides of the invention comprise an epitope of a sequence selected from the group consisting of SEQ ID NOs: 1-543.

[0076] In some embodiments, peptides of the invention comprise a fragment of a peptide sequence described herein. For example, in certain embodiments, peptides of the invention comprise a fragment of a sequence selected from the group consisting of SEQ ID NOs: 1-543. The fragment can be, *e.g.*, at least 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, or 44 amino acids in length. The fragment can also be at least 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, or 66 amino acids long. In some embodiments, the fragment is no longer than 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, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, or 66 amino acids long. The fragment can be contiguous or can include one or more deletions (*e.g.*, a deletion of 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, or more amino acid residues). For instance, in one embodiment, peptides of the invention comprise a fragment of SEQ ID NO: 3. Such fragments may comprise at least 10, 15, 20, 25, 30, or 35 contiguous amino acids from SEQ ID NO: 3. In some embodiments, the fragments comprise amino acids 1 to 35 of SEQ ID NO: 3. Thus, in one embodiment, a peptide of the invention comprises or consists of a sequence of E-T-K-V-X_5-Y-X_7-Y-L-K-X_{11}-G-R-T-V-K-L-X_{18}-S-H-X_{21}-F-D-W-X_{25}-T-P-X_{28}-P-K-X_{31}-G-F-K-D (SEQ ID NO: 543), wherein X_5 is an amino acid selected from the group consisting of V or A, X_7 is an amino acid selected from the group consisting of G, I or H, X_{11} is an amino acid selected from the group consisting of E, N, or Q, X_{18} is an amino acid selected from the group consisting of D or N, X_{21} is an amino acid selected from the group consisting of R, D, or N, X_{25} is an amino acid selected from the group consisting of Q, D, or E, X_{28} is an amino acid selected from the group consisting of E or N, and X_{31} is an amino acid selected from the group consisting of L or V.

[0077] Peptides of the invention that comprise a fragment of a peptide sequence described herein can further comprise an additional N-terminal peptide sequence, an additional C-terminal peptide sequence, or a combination thereof. The additional N-terminal and C-terminal peptide sequences can be as described above.

[0078] Peptides of the invention comprising an additional N-terminal or C-terminal peptide sequence can further comprise a linker connecting the peptide (*e.g.*, a peptide of SEQ ID NO: 1, SEQ ID NO: 2, SEQ ID NO: 3, SEQ ID NO: 4, SEQ ID NO: 5, SEQ ID NO: 6, SEQ ID NO: 7, SEQ ID NO: 8, or SEQ ID NO: 9, or a fragment thereof) with the additional N-terminal or C-terminal peptide sequence. The linker can be, *e.g.*, a peptide spacer. Such spacer can consist of, for example, between about one and five (*e.g.*, about three) amino acid residues, preferably uncharged amino acids, *e.g.*, aliphatic residues such as glycine or alanine. In one embodiment, the spacer is a triplet glycine spacer. In another embodiment, the spacer is a triplet alanine spacer. In another embodiment, the spacer consists of five glycine amino acids. In yet another embodiment, the spacer comprises both glycine and alanine residues. Alternatively, the linker can be a chemical (*i.e.*, non-peptide) linker.

[0079] In certain embodiments, peptides of the invention are produced by synthetic chemistry (*i.e.*, a "synthetic peptide"). In other embodiments, peptides of the invention are produced biologically (*i.e.*, by cellular machinery, such as a ribosome, in cell expression systems or *in vitro* translation systems). In certain embodiments, peptides of the invention are isolated. As used herein, an "isolated" peptide is a peptide that has been produced either synthetically or biologically and then purified, at least partially, from the chemicals and/or cellular machinery used to produce the peptide. In certain embodiments, an isolated peptide of the invention is substantially purified. The term "substantially purified," as used herein, refers to a molecule, such as a peptide, that is substantially free of cellular material (proteins, lipids, carbohydrates, nucleic acids, etc.), culture medium, chemical precursors, chemicals used in synthesis of the peptide, or combinations thereof. A peptide that is substantially purified has less than about 40%, 30%, 25%, 20%, 15%, 10%, 5%, 2%, 1% or less of the cellular material, culture medium, other polypeptides, chemical precursors, and/or chemicals used in synthesis of the peptide. Accordingly, a substantially pure molecule, such as a peptide, can be at least about 60%, 70%, 75%, 80%, 85%, 90%, 95%, 98%, or 99%, by dry weight, the molecule of interest. An isolated peptide of the invention can be in water, a buffer, or in a dry form awaiting reconstitution, *e.g.*, as part of a kit. An isolated peptide of the present invention can be in the form of a pharmaceutically acceptable salt. Suitable acids and bases that are capable of forming salts with the peptides of the present invention are well known to those of skill in the art, and include inorganic and organic acids and bases.

[0080] In certain embodiments, peptides of the invention are affinity purified. For example, in certain embodiments, the peptides of the invention are purified by means of their ability to bind to anti-*Anaplasma* antibodies (*e.g.*, antibodies to MSP 2/p44 or OMP/p44 proteins and, optionally, other *Anaplasma* antigens) by contacting such antibodies with the peptides of the invention such that peptide-antibody complexes are able to form, washing the peptide-antibody complexes to remove impurities, and then eluting the peptides from the antibodies. The antibodies can be, *e.g.*, attached to a solid support. Methods of affinity purification are well-known and routine to those skilled in the art.

[0081] In certain embodiments, peptides of the invention are modified. The peptides of the invention may be modified by a variety of techniques, such as by denaturation with heat and/or a detergent (*e.g.*, SDS). Alternatively, peptides of the invention may be modified by association with one or more further moieties. The association can be covalent or non-covalent, and can be, for example, via a terminal amino acid linker, such as lysine or cysteine, a chemical coupling agent, or a peptide bond. The additional moiety can be, for example, a ligand, a ligand receptor, a fusion partner, a detectable label, an enzyme, or a substrate that immobilizes the peptide.

[0082] Peptides of the invention can be conjugated to a ligand, such as biotin (*e.g.*, via a cysteine or lysine residue), a lipid molecule (*e.g.*, via a cysteine residue), or a carrier protein (*e.g.*, serum albumin, immunoglobulin Fc domain, keyhole limpet hemocyanin (KLH) via *e.g.*, a cysteine or lysine residue). Attachment to ligands, such as biotin, can be useful for associating the peptide with ligand receptors, such as avidin, streptavidin, polymeric streptavidin (*see, e.g.*, US 2010/0081125 and US 2010/0267166, both of which are herein incorporated by reference), or neutravidin. Avidin, streptavidin, polymeric streptavidin, or neutravidin, in turn, can be linked to a signaling moiety (*e.g.*, an enzyme, such as horse radish peroxidase (HRP) or alkaline phosphatase (ALP) or β-galactosidase (β-GAL) or other moiety that can be visualized, such as a metallic nanomaterial such as nanoparticle, nanoplate, or nanoshell (*e.g.*, colloidal gold), a fluorescent moiety, or a quantum dot) or a solid substrate (*e.g.*, an Immobilon™ or nitrocellulose membrane or Porex® membrane). Alternatively, the peptides of the invention can be fused or linked to a ligand receptor, such as avidin, streptavidin, polymeric streptavidin, or neutravidin, thereby facilitating the association of the peptides with the corresponding ligand, such as biotin and any moiety (*e.g.*, signaling moiety) or solid substrate attached thereto. Examples of other ligand-receptor pairs are well-known in the art and can similarly be used.

[0083] Peptides of the invention can be fused to a fusion partner (*e.g.*, a peptide or other moiety) that can be used to improve purification, to enhance expression of the peptide in a host cell, to aid in detection, to stabilize the peptide, etc. Examples of suitable compounds for fusion partners include carrier proteins (*e.g.*, serum albumin, immunoglobulin Fc domain, KLH), enzymes (*e.g.*, horse radish peroxidase (HRP), beta-galactosidase, glutathione-S-transferase, alkaline phosphatase), maltose-binding protein (MBP) or a histidine tag, etc. The fusion can be achieved by means of, *e.g.*, a peptide bond. For example, peptides of the invention and fusion partners can be fusion proteins and can be directly fused in-frame or can comprise a peptide linker, as discussed above in the context of additional N-terminal and C-terminal peptide sequences. In certain embodiments, a population of peptides of the invention can be linked by a dendrimer, e.g., as in a MAPS structure.

[0084] In addition, peptides of the invention may be modified to include any of a variety of known chemical groups or molecules. Such modifications include, but are not limited to, glycosylation, acetylation, acylation, ADP-ribosylation, amidation, covalent attachment to polyethylene glycol (*e.g.*, PEGylation), covalent attachment of flavin, covalent attachment of a heme moiety, covalent attachment of a nucleotide or nucleotide derivative, covalent attachment of a lipid or lipid derivative, covalent attachment of phosphatidylinositol, cross-linking, cyclization, disulfide bond formation, demethylation, formation of covalent cross-links, formation of cystine, formation of pyroglutamate, formylation, gamma carboxylation, glycosylation, GPI anchor formation, hydroxylation, iodination, methylation, myristoylation, oxidation, proteolytic processing, phosphorylation, prenylation, racemization, selenoylation, sulfation, ubiquitination, modifications with fatty acids, transfer-RNA mediated addition of amino acids to proteins such as arginylation, etc. Analogues of an amino acid (including unnatural amino acids) and peptides with substituted linkages are also included. Peptides of the invention that consist of any of the sequences discussed herein may be modified by any of the discussed modifications. Such peptides still "consist of" the amino acids.

[0085] Modifications as set forth above are well-known to those of skill in the art and have been described in great detail in the scientific literature. Several particularly common modifications, glycosylation, lipid attachment, sulfation, gamma-carboxylation of glutamic acid residues, hydroxylation and ADP-ribosylation, for instance, are described in many basic texts, such as Proteins-Structure and Molecular Properties, 2nd ed., T. E. Creighton, W.H. Freeman and Company, New York (1993). Many detailed reviews are available on this subject, such as by

Wold, F., Posttranslational Covalent Modification of Proteins, B. C. Johnson, Ed., Academic Press, New York 1-12 (1983); Seifter *et al.* (1990) Meth. Enzymol. 182:626-646 and Rattan *et al.* (1992) Ann. N.Y. Acad. Sci. 663:48-62.

[0086] In certain embodiments, peptides of the invention are attached to or immobilized on a substrate, such as a solid or semi-solid support. The attachment can be covalent or non-covalent, and can be facilitated by a moiety associated with the peptide that enables covalent or non-covalent binding, such as a moiety that has a high affinity to a component attached to the carrier, support or surface. For example, the peptide can be associated with a ligand, such as biotin, and the component associated with the surface can be a corresponding ligand receptor, such as avidin. In some embodiments, the peptide can be associated with a fusion partner, *e.g.*, bovine serum albumin (BSA), which facilitates the attachment of the peptide to a substrate. In other embodiments, the peptides of the invention are attached to or immobilized on a substrate via a metallic nanolayer. In one embodiment, the metallic nanolayer is comprised of cadmium, zinc, mercury, or a noble metal, such as gold, silver, copper, and platinum. The peptide or population of peptides can be attached to or immobilized on the substrate either prior to or after the addition of a sample containing antibody during an immunoassay.

[0087] In certain embodiments, the substrate is a bead or plurality of beads, such as a colloidal particle (*e.g.*, a colloidal nanoparticle made from gold, silver, platinum, copper, cadmium, metal composites, other soft metals, core-shell structure particles, or hollow gold nanospheres) or other type of particle (*e.g.*, a magnetic bead or a particle or nanoparticle comprising silica, latex, polystyrene, polycarbonate, polyacrylate, PVDF, or PMMA). Such particles can comprise a label (*e.g.*, a colorimetric, chemiluminescent, quantum dot or fluorescent label) and can be useful for visualizing the location of the peptides during immunoassays. In certain embodiments, a terminal cysteine of a peptide of the invention is used to bind the peptide directly to a metallic nanomaterial or nanostructure.

[0088] The metallic nanomaterials or nanostructures used in some embodiments of the invention can be made from gold, silver, platinum, palladium, copper, cadmium, metal composites, or other soft metals. In some embodiments, the metallic nanomaterials or nanostructures, including the composite nanostructures, have a geometry selected from spherical nanoparticles, pyramidal nanoparticles, hexagonal nanoparticles, nanoshells, nanoplates, nanotubes, nanowires, and combinations thereof. Examples of metallic nanoshells include gold hollow spheres, gold-coated silica nanoshells, and silica-coated gold shells. Nanoplates have lateral dimensions (e.g. edge lengths) that are greater than their thickness. Nanoplates include nanodisks, nanopolygons, nanohexagons, nanocubes, nanorings, nanostars, and nanoprisms. In some embodiments, the metallic nanostructures have other shapes or irregular shapes. In certain embodiments, the size and shape of the metallic nanostructures are not uniform – i.e. the metallic nanostructures are a heterogeneous mixture of different shapes and sizes of nanostructures.

[0089] For spherical nanoparticles, suitable diameter ranges include from about 5 nm to about 200 nm, from about 10 nm to about 100 nm, and from about 20 nm to about 60 nm. For nanoplates, edge lengths may be from about 10 nm to about 800 nm, from about 20 nm to about 500 nm, from about to 50 nm to about 200 nm, from about 30 nm to about 100 nm, or from about 10 nm to about 300 nm. The thickness of the nanoplates can range from about 1 to about 100 nm, from about 5 nm to about 80 nm, from about 10 nm to about 50 nm, or from about 5 nm to about 20 nm.

[0090] In some embodiments, the nanoplates have an aspect ratio greater than 2. The aspect ratio is the ratio of the edge length to the thickness. Preferably, the nanoplates have an aspect ratio from about 2 to about 25, from about 3 to about 20, from about 5 to about 10, from about 2 to about 15, or from about 10 to about 30.

[0091] In certain embodiments, the substrate is a dot blot or a flow path in a lateral flow immunoassay device. For example, the peptides can be attached or immobilized on a porous membrane, such as a PVDF membrane (*e.g.*, an Immobilon™ membrane), a nitrocellulose membrane, polyethylene membrane, nylon membrane, or a similar type of membrane.

[0092] In certain embodiments, the substrate is a flow path in an analytical or centrifugal rotor. In other embodiments, the substrate is a tube or a well, such as a well in a plate (*e.g.*, a microtiter plate) suitable for use in an ELISA assay. Such substrates can comprise glass, cellulose-based materials, thermoplastic polymers, such as polyethylene, polypropylene, or polyester, sintered structures composed of particulate materials (*e.g.*, glass or various thermoplastic polymers), or cast membrane film composed of nitrocellulose, nylon, polysulfone, or the like. A substrate can be sintered, fine particles of polyethylene, commonly known as porous polyethylene, for example, 0.2-15 micron porous polyethylene from Chromex Corporation (Albuquerque, NM). All of these substrate materials can be used in suitable shapes, such as films, sheets, or plates, or they may be coated onto or bonded or laminated to appropriate inert carriers, such as paper, glass, plastic films, or fabrics. Suitable methods for immobilizing peptides on solid phases include ionic, hydrophobic, covalent interactions and the like.

[0093] Accordingly, in another aspect, the invention provides devices. In certain embodiments, the devices are useful for performing an immunoassay. For example, in certain embodiments, the device is a lateral flow immunoassay device. An exemplary lateral flow immunoassay device comprising peptides of the invention is described in Example 2. In certain embodiments, the lateral flow immunoassay device comprises a population of peptides, wherein each peptide in the population comprises a sequence of SEQ ID NO: 3, SEQ ID NO: 4, SEQ ID NO: 6, SEQ ID NO: 7, or SEQ ID NO: 9. In some embodiments, the device is a slide comprised of a plurality of beads to which a peptide or population of peptides is attached. An example of such a device comprising peptides of the invention suitable for use, for example, in an indirect fluorescent antibody assay is described in Example 3. In other embodiments, the device is an analytical or centrifugal rotor. In other embodiments, the device is a dot blot, slot blot, or Western blot. In other embodiments, the device is a tube or a well, *e.g.*, in a plate suitable for an ELISA assay. An exemplary device comprising peptides of the invention for use in an ELISA assay is described in Example 1. In still other embodiments, the device is an electrochemical sensor, an optical sensor, or an opto-electronic sensor.

[0094] In certain embodiments, the device comprises a peptide or population of peptides of the invention. In other embodiments, the device comprises a mixture of different peptides of the invention. For example, in certain embodiments, the device comprises two, three, four, or more different peptides of the invention. In certain embodiments, the peptide or each peptide in the population comprises a sequence of SEQ ID NO: 1, SEQ ID NO: 2, SEQ ID NO: 3, SEQ ID NO: 4, SEQ ID NO: 5, SEQ ID NO: 6, SEQ ID NO: 7, SEQ ID NO: 8, or SEQ ID NO: 9 or a fragment thereof. In other embodiments, the peptide or each peptide in the population comprises a sequence of SEQ ID NO: 3, SEQ ID NO: 4, or a fragment thereof. In certain embodiments, the population of peptides are attached to or immobilized upon the device optionally through a metallic nanolayer. The devices may be used to detect the presence of antibodies to *Anaplasma* antigens from multiple species (*e.g.*, *A. phagocytophilum*, *A. platys,* and *A. marginale*) in a sample simultaneously. In one embodiment, the device comprises a population of isolated peptides comprising three or more different peptides, wherein each peptide in the population comprises a sequence of SEQ ID NO: 3. In another embodiment, the device comprises a population of isolated peptides comprising three or more different peptides, wherein each peptide in the population comprises a sequence of SEQ ID NO: 4. In another embodiment, the device comprises a population of isolated peptides comprising three or more different peptides, wherein each peptide in the population comprises a sequence of SEQ ID NO: 1. In still another embodiment, the device comprises a population of isolated peptides comprising three or more different peptides, wherein each peptide in the population comprises a sequence of SEQ ID NO: 8. In other embodiments, the device comprises a population of isolated peptides comprising three or more different peptides, wherein each peptide in the population comprises a sequence of SEQ ID NO: 2, SEQ ID NO: 5, SEQ ID NO: 6, SEQ ID NO: 7, or SEQ ID NO: 9.

[0095] In another aspect, the invention provides compositions comprising one or more peptides of the invention. For example, in certain embodiments, the invention provides a composition comprising a peptide comprising a sequence of SEQ ID NO: 3, or populations thereof. In certain embodiments, the composition comprises a population of 2, 3, 4, 5, 6, 7, 8, 9, 10, 15, 20, 25, 30, 40, 50, 60, 70, 80, 90, 100, 150, 200, 250, 300, 400, 500, or more peptides (*e.g.*, all possible peptides defined by SEQ ID NO: 3). Thus, the present invention provides a population of isolated peptides comprising three or more different peptides, wherein each peptide in the population comprises a sequence of SEQ ID NO: 3. In certain embodiments, the peptides in the population or mixture comprise an N-terminal and/or C-terminal addition, and/or are modified (*e.g.*, by association with one or more further moieties), as described herein. In certain embodiments, the peptides comprise the same N-terminal and/or C-terminal additions. In other embodiments, the peptides comprise different N-terminal and/or C-terminal additions.

[0096] In some embodiments, the invention provides a composition comprising a peptide comprising a sequence of SEQ ID NO: 4, or populations thereof. In certain embodiments, the composition comprises a population of 2, 3, 4, 5, 6, 7, 8, 9, 10, 15, 20, 25, 30, 40, 50, 60, 70, 80, 90, 100, 150, 200, 250, 300, 400, 500, or more peptides (*e.g.*, all possible peptides defined by SEQ ID NO: 4). Thus, the present invention provides a population of isolated peptides comprising three or more different peptides, wherein each peptide in the population comprises a sequence of SEQ ID NO: 4. In certain embodiments, the peptides in the population or mixture comprise an N-terminal and/or C-terminal addition, and/or are modified (*e.g.*, by association with one or more further moieties), as described herein. In certain embodiments, the peptides comprise the same N-terminal and/or C-terminal additions. In other embodiments, the peptides comprise different N-terminal and/or C-terminal additions.

[0097] In still other embodiments, the invention provides a composition comprising a peptide comprising a sequence of SEQ ID NO: 1, SEQ ID NO: 2, SEQ ID NO: 5, SEQ ID NO: 6, SEQ ID NO: 7, SEQ ID NO: 8, SEQ ID NO: 9, SEQ ID NO: 543, or populations thereof. In certain embodiments, the composition comprises a population of 2, 3, 4, 5, 6, 7, 8, 9, 10, 15, 20, 25, 30, 40, 50, 60, 70, 80, 90, 100, 150, 200, 250, 300, 400, 500, or more peptides (*e.g.*, all possible peptides defined by SEQ ID NO: 1, SEQ ID NO: 2, SEQ ID NO: 5, SEQ ID NO: 7, SEQ ID NO: 8, SEQ ID NO: 9, SEQ ID NO: 543). Thus, the invention provides a population of isolated peptides comprising three or more different peptides, wherein each peptide in the population comprises a sequence of SEQ ID NO: 1. In another embodiment, the invention provides a population of isolated peptides comprising three or more different peptides, wherein each peptide in the population comprises a sequence of SEQ ID NO: 2. In other embodiments, the invention provides a population of isolated peptides comprising three or more different peptides, wherein each peptide in the population comprises a sequence of SEQ ID NO: 5, SEQ ID NO: 7, SEQ ID NO: 8, SEQ ID NO: 9, or SEQ ID NO: 543. The peptides in the population or mixture may comprise an N-terminal and/or C-terminal addition, and/or be modified (*e.g.*, by association with one or more further moieties), as described herein.

[0098] In some embodiments, the composition comprises a population of isolated peptides, said population comprising three or more different peptides, wherein each peptide in the population comprises a sequence, or a fragment thereof, of SEQ ID NO: 1, 2, 3, 4, 5, 6, 7, 8, or 9.

[0099] In some embodiments, the composition comprises at least two different populations of peptides described herein. In certain embodiments, at least one of the peptide populations is defined by SEQ ID NO: 3 (i.e., comprising three or more different peptides, wherein each peptide in the population comprises a sequence, or a fragment thereof, of SEQ ID NO: 3).

[00100] In certain embodiments, the composition further comprises a second population of isolated peptides. In some embodiments, the second peptide population is defined by SEQ ID NO: 7. In some other embodiments, each peptide in the second peptide population comprises the sequence, or a fragment thereof, of SEQ ID NO: 6.

[00101] In some embodiments, the composition further comprises a third population of isolated peptides that is different from the first and second peptide populations. In certain embodiments, each peptide in the third peptide population comprises the sequence, or a fragment thereof, of SEQ ID NO: 6.

[00102] In a particular embodiment, the composition comprises three different populations of peptides, a first peptide populations which is defined by SEQ ID NO: 3, a second peptide population which is defined by SEQ ID NO: 7, and a third peptide population in which each peptide comprises the sequence, or a fragment thereof, of SEQ ID NO: 6.

[00103] In certain embodiments, the compositions comprise one or more peptides (or one or more populations of peptides) of the invention and one or more additional peptides, such as an *Anaplasma* peptide or antigen, a peptide or antigen from one or more *Ehrlichia* species, and/or a peptide or antigen from one or more *Borrelia* species. The *Anaplasma* peptide or antigen can be any *Anaplasma* surface peptide or antigen, or any peptide or antigen described herein. For instance, in certain embodiments, the compositions comprise a mixture of peptides, wherein each peptide has a sequence of SEQ ID NO: 3, SEQ ID NO: 6, or SEQ ID NO: 7. In other embodiments, the compositions comprise a mixture of peptides, wherein each peptide has a sequence of SEQ ID NO: 3, SEQ ID NO: 4, or SEQ ID NO: 6.

[00104] Suitable *Ehrlichia* peptides that can be mixed with the *Anaplasma* peptides of the invention include any *Ehrlichia* surface peptide or antigen including, but not limited to, OMP-1, p38, p43, p120, p140, p153, p156, p200, gp19, gp36, gp47, gp200, or HGE-3 protein, or any fragment or epitope thereof. Other suitable *Ehrlichia* peptides include peptides described in U.S. Application No. 14/052,296 and U.S. Patent No. 8,828,675, the contents of each of which are hereby incorporated by reference in their entireties. Suitable *Borrelia* peptides that can be mixed with the *Anaplasma* peptides of the invention include any *Borrelia* surface peptide or antigen including, but not limited to, OspA, OspB, DbpA, flagella-associated proteins FlaA (p37) and FlaB (p41), OspC (25 kd), BBK32, BmpA (p39), p21, p39, p66 or p83 protein, or any fragment or epitope thereof. Other suitable *Borrelia* peptides include peptides described in U.S. Patent Nos. 8,568,989 and 8,758,772, the contents of each of which are hereby incorporated by reference in their entireties. The combination may comprise a cocktail (a simple mixture) of individual peptides or polypeptides, it may be in the form of a fusion peptide or polypeptide (*e.g.*, a multimeric peptide), or the peptides may be linked by a dendrimer (*e.g.*, as in a MAPS structure) optionally through a linking residue (*e.g.* lysine or cysteine residue). For instance, in certain embodiments, a composition comprises one or more peptides of the invention (*e.g.*, a peptide having a sequence of SEQ ID NO: 1, SEQ ID NO: 2, SEQ ID NO: 3, SEQ ID NO: 4, SEQ ID NO: 5, SEQ ID NO: 6, SEQ ID NO: 7, SEQ ID NO: 8, SEQ ID NO: 9 or SEQ ID NO: 543) and one or more antigenic *Ehrlichia* peptides and/or one or more antigenic *Borrelia* peptides.

[00105] When a composition comprises multiple peptides or peptide populations, the ratio among the various peptides or peptide populations can be varied in order to tailor the composition's performance, e.g., in terms of sensitivity and selectivity. For example, in a composition comprising two peptide populations, the molar ratio of the two peptide populations can vary anywhere between 20:1 to 1:20, e.g., 20:1, 10:1, 5:1, 3:1, 2:1, 1:1, 1:2, 1:3, 1:5, 1:10, or 1:20. Or, the percentage of weight ratio can vary between 95:5 to 5:95, e.g., 95:5, 90:10, 80:20, 70:30, 60:40, 50:50, 40:60, 30:70, 20:80, 10:90, or 5:95. In a composition comprising three or more peptide populations, the percentage of moles or weight of each peptide population can vary from 1% to 98% of the total moles or weight of all three peptide populations, e.g., 1%, 2%, 5%, 10%, 15%, 20%, 25%, 30%, 33%, 40%, 50%, 60%, 70%, 80%, 90%, 95%, 98%, etc. In a certain embodiment, the composition comprises three peptide populations, APL-ID1 (defined by SEQ ID NO: 3), APL-ID5.1 (each peptide comprising SEQ ID NO: 6), and APL-ID6 (defined by SEQ ID NO: 7) in a weight ratio of 50:25:25. In another embodiment, the composition comprises three peptide populations, APL-ID1 (defined by SEQ ID NO: 3), APL-ID5.1 (each peptide comprising SEQ ID NO: 6), and APL-ID6 (defined by SEQ ID NO: 7), wherein each peptide population constitutes a third of the composition by weight.

[00106] A peptide of the invention may be fused at its N-terminus or C-terminus to another suitable peptide. Two or more copies of a peptide of the invention may be joined to one another, alone or in combination with one or more additional peptides. Combinations of fused and unfused peptides or polypeptides can be used. In one embodiment, the additional peptide(s) contain B-cell and/or T-cell epitopes from an *Anaplasma* peptide or antigen, a peptide or antigen from an infectious *Anaplasma* species, or a peptide or antigen from a causative agent of anaplasmosis.

[00107] In another aspect, the invention provides nucleic acids comprising a sequence encoding a peptide of the invention. Nucleic acids of the invention contain less than an entire microbial genome and can be single- or double-stranded. A nucleic acid can be RNA, DNA, cDNA, genomic DNA, chemically synthesized RNA or DNA or combinations thereof. The nucleic acids can be purified free of other components, such as proteins, lipids and other polynucleotides. For example, the nucleic acids can be 50%, 75%, 90%, 95%, 96%, 97%, 98%, 99%, or 100% purified. The nucleic acids of the invention encode the peptides described herein. In certain embodiments, the nucleic acids encode a peptide having the sequence of SEQ ID NOs: 1-543, or combinations thereof. Nucleic acids of the invention can comprise other nucleotide sequences, such as sequences coding for linkers, signal sequences, TMR stop transfer sequences, transmembrane domains, or ligands useful in protein purification such as glutathione-S-transferase, histidine tag, MBP tag and staphylococcal protein A.

[00108] Nucleic acids of the invention can be isolated. An "isolated" nucleic acid is one that is not immediately contiguous with one or both of the 5′ and 3′ flanking genomic sequences with which it is naturally associated. An isolated nucleic acid can be, *e.g.*, a recombinant DNA molecule of any length, provided that the nucleic acid sequences naturally found immediately flanking the recombinant DNA molecule in a naturally-occurring genome is removed or absent. Isolated nucleic acids also include non-naturally occurring nucleic acid molecules. Nucleic acids of the invention can also comprise fragments that encode immunogenic peptides. Nucleic acids of the invention can encode full-length polypeptides, peptide fragments, and variant or fusion peptides.

[00109] Nucleic acids of the invention can be isolated, at least in part, from nucleic acid sequences present in, for example, a biological sample, such as blood, serum, saliva, or tissue from an infected individual. Nucleic acids can also be synthesized in the laboratory, for example, using an automatic synthesizer. An amplification method such as PCR can be used to amplify nucleic acids, at least in part, from either genomic DNA or cDNA encoding the polypeptides.

[00110] Nucleic acids of the invention can comprise coding sequences for naturally occurring polypeptides or can encode altered sequences that do not occur in nature. If desired, nucleic acids can be cloned into an expression vector comprising expression control elements, including for example, origins of replication, promoters, enhancers, or other regulatory elements that drive expression of the polynucleotides of the invention in host cells. An expression vector can be, for example, a plasmid, such as pBR322, pUC, or ColE1, or an adenovirus vector, such as an adenovirus Type 2 vector or Type 5 vector. Optionally, other vectors can be used, including but not limited to Sindbis virus, simian virus 40, alphavirus vectors, poxvirus vectors, and cytomegalovirus and retroviral vectors, such as murine sarcoma virus, mouse mammary tumor virus, Moloney murine leukemia virus, and Rous sarcoma virus. Minichromosomes such as MC and MC1, bacteriophages, phagemids, yeast artificial chromosomes, bacterial artificial chromosomes, virus particles, virus-like particles, cosmids (plasmids into which phage lambda cos sites have been inserted) and replicons (genetic elements that are capable of replication under their own control in a cell) can also be used.

[00111] Methods for preparing polynucleotides operably linked to an expression control sequence and expressing them in a host cell are well-known in the art. *See, e.g.*, U.S. Pat. No. 4,366,246. A nucleic acid of the invention is operably linked when it is positioned adjacent to or close to one or more expression control elements, which direct transcription and/or translation of the polynucleotide.

[00112] Thus, for example, a peptide of the invention can be produced recombinantly following conventional genetic engineering techniques. To produce a recombinant peptide of the invention, a nucleic acid encoding the peptide is inserted into a suitable expression system. Generally, a recombinant molecule or vector is constructed in which the polynucleotide sequence encoding the selected peptide is operably linked to an expression control sequence permitting expression of the peptide. Numerous types of appropriate expression vectors are known in the art, including, e.g., vectors containing bacterial, viral, yeast, fungal, insect or mammalian expression systems. Methods for obtaining and using such expression vectors are well-known. For guidance in this and other molecular biology techniques used for compositions or methods of the invention, *see, e.g.*, Sambrook *et al.*, Molecular Cloning, A Laboratory Manual, current edition, Cold Spring Harbor Laboratory, New York; Miller *et al.*, Genetic Engineering, 8:277-298 (Plenum Press, current edition), Wu *et al.*, Methods in Gene Biotechnology (CRC Press, New York, N.Y., current edition), Recombinant Gene Expression Protocols, in Methods in Molecular Biology, Vol. 62, (Tuan, ed., Humana Press, Totowa, N.J., current edition), and Current Protocols in Molecular Biology, (Ausubel *et al.*, Eds.,) John Wiley & Sons, NY (current edition), and references cited therein.

[00113] Accordingly, the invention also provides vectors comprising nucleic acids of the invention, and host cells comprising such vectors. In certain embodiments, the vector is a shuttle vector. In other embodiments, the vector is an expression vector (*e.g.*, a bacterial or eukaryotic expression vector). In certain embodiments, the host cell is a bacterial cell. In other embodiments, the host cell is a eukaryotic cell.

[00114] Suitable host cells or cell lines for expression of the recombinant nucleic acids or vectors of the invention include bacterial cells. For example, various strains of *E. coli* (*e.g.*, HB101, MC1061) are well-known as host cells in the field of biotechnology. Various strains of *B. subtilis*, *Pseudomonas*, *Streptomyces*, and other bacilli and the like can also be employed to express the nucleic acids or vectors of the invention. Alternatively, a peptide of the invention can be expressed in yeast, insect, mammalian, or other cell types, using conventional procedures. Cell-free *in vitro* synthesis and/or enzyme-mediated synthetic machineries may also be used.

[00115] The present invention also provides a method for producing a recombinant peptide or polypeptide, which involves transfecting or transforming, *e.g.*, by conventional means such as electroporation, a host cell with at least one expression vector containing a polynucleotide of the invention under the control of an expression control sequence (*e.g.*, a transcriptional regulatory sequence). The transfected or transformed host cell is then cultured under conditions that allow expression of the peptide or polypeptide. The expressed peptide or polypeptide is recovered, isolated, and optionally purified from the cell (or from the culture medium, if expressed extracellularly) by appropriate means known to one of skill in the art, including liquid chromatography such as normal or reversed phase, using HPLC, FPLC and the like, affinity chromatography, such as with inorganic ligands or monoclonal antibodies, size exclusion chromatography, immobilized metal chelate chromatography, gel electrophoresis, and the like. One of skill in the art may select the most appropriate isolation and purification techniques without departing from the scope of this invention. One skilled in the art can determine the purity of the peptide or polypeptide by using standard methods including, *e.g.*, polyacrylamide gel electrophoresis (*e.g.*, SDS-PAGE), capillary electrophoresis, column chromatography (*e.g.*, high performance liquid chromatography (HPLC)), amino-terminal amino acid analysis, and quantitative amino acid analysis.

Methods

[00116] In another aspect, the invention provides methods of detecting in a sample an antibody to an epitope of an *Anaplasma* antigen. In one embodiment, the method comprises contacting a sample with a peptide of the invention, and detecting formation of an antibody-peptide complex comprising said peptide, wherein formation of said complex is indicative of the presence of an antibody to an epitope of an *Anaplasma* antigen in said sample. In some embodiments, the *Anaplasma* antigen is from an infectious *Anaplasma* species, such as *Anaplasma phagocytophilum*, *Anaplasma platys*, or *Anaplasma marginale*. Other species of *Anaplasma* which have been implicated in anaplasmosis can also be detected using the methods of the invention, provided they induce antibodies which can react specifically with a peptide of the invention. Thus, it is to be understood that the term "pathogenic *Anaplasma*," as used herein, refers to any such *Anaplasma* species that causes anaplasmosis in a human or an animal. In particular embodiments, the methods provide detection of antibodies to *Anaplasma* antigens from multiple species in a sample simultaneously.

[00117] In certain embodiments, the method of detecting in a sample an antibody to an epitope of an *Anaplasma* antigen comprises contacting the sample with a population of two, three, four, or more (*e.g.*, 5, 6, 7, 8, 9, 10, 15, 20, 25, 30, 40, 50, 60, 70, 80, 90, 100, 150, 200, 250, 300, 400, 500, or more) different peptides of the invention, and detecting formation of an antibody-peptide complex comprising said one or more peptides in the population, wherein formation of said complex is indicative of an antibody to an epitope of an *Anaplasma* antigen being present in said sample. For instance, in one particular embodiment, the method comprises contacting the sample with a population of two or more different isolated peptides, wherein each isolated peptide comprises a sequence of SEQ ID NO: 3. In another particular embodiment, the method comprises contacting the sample with a population of two or more different isolated peptides, wherein each isolated peptide comprises a sequence of SEQ ID NO: 4. In still another embodiment, the method comprises contacting the sample with a population of two or more different isolated peptides, wherein each isolated peptide comprises a sequence of SEQ ID NO: 1. In some embodiments, the method comprises contacting the sample with a population of two or more different isolated peptides, wherein each isolated peptide comprises a sequence of SEQ ID NO: 2, SEQ ID NO: 5, SEQ ID NO: 6, SEQ ID NO: 7, SEQ ID NO: 8, SEQ ID NO: 9, or SEQ ID NO: 543. In certain embodiments, the method comprises contacting the sample with a mixture of one or more peptides of the invention and one or more other peptides (*e.g.*, an *Ehrlichia* peptide, or antigenic fragment or epitope thereof and/or a *Borrelia* peptide or antigenic fragment or epitope thereof).

[00118] In certain embodiments, the peptide or each peptide in the population is an isolated (*e.g.*, synthetic and/or purified) peptide. In some embodiments, the peptide or population of peptides is attached to or immobilized upon a solid support. In such embodiments, the solid support is a bead or plurality of beads (*e.g.*, a metallic nanomaterial such as nanoparticle, nanoplate, or nanoshell, a nanoparticle, a latex bead, etc.), a flow path in a lateral flow immunoassay device (*e.g.*, a porous membrane), a flow path in an analytical or centrifugal rotor, a blot (Western blot, dot blot, or slot blot), a tube or a well (*e.g.*, in a plate suitable for an ELISA assay), or a sensor (*e.g.*, an electrochemical, optical, or opto-electronic sensor). In some embodiments, the peptide or population of peptides is attached to or immobilized upon a solid support through a metallic nanolayer that, in some embodiments, may be comprised of cadmium, zinc, mercury, or a noble metal (*e.g.*, gold, silver, copper, and platinum). In some embodiments, the peptides or populations of peptides of the invention are immobilized on a composite nanolayer (for example comprising silver and gold) or gold-coated silver nanolayers.

[00119] There are a number of different conventional assays for detecting formation of an antibody-peptide complex comprising a peptide of the invention. For example, in some embodiments, the detecting step comprises performing an ELISA or immunofluorescence assay. In other embodiments, the detecting step comprises performing a lateral flow immunoassay. In other embodiments, the detecting step comprises performing an agglutination assay (*e.g.*, a hemagglutination or particle/bead agglutination assay). In still other embodiments, the detecting step comprises spinning the sample in an analytical or centrifugal rotor. In some embodiments, the detecting step comprises performing a Western blot, slot blot, or dot blot. In certain embodiments, the detecting step comprises performing a wavelength shift assay. Such wavelength shift assays may entail measuring or determining a change in the surface plasmon resonance or localized surface plasmon resonance wavelength resulting from binding of antibodies to peptides attached to metallic nanolayers or metallic nanoparticles/nanoshells/nanoplates. In other embodiments, the detecting step comprises performing an Indirect Fluorescent Antibody test. In some embodiments, the Indirect Fluorescent Antibody test comprises reacting samples suspected of containing antibodies against *Anaplasma* antigens with beads (e.g. latex beads) coated with the peptides of the invention, which are further immobilized on a glass slide, and subsequently reacting the slide with fluorescently labeled anti-dog IgG or IgM antibodies to detect bound anti-*Anaplasma* antibodies. An example of an Indirect Fluorescent Antibody test is described in Example 3. In still other embodiments, the detecting step comprises analyzing the sample with an electrochemical, optical, or opto-electronic sensor. These different assays are described herein and/or are well-known to those skilled in the art.

[00120] In one embodiment, the method involves detecting the presence of naturally occurring antibodies against one or more *Anaplasma* antigens (*e.g.*, the antigen of a pathogenic *Anaplasma*, such as *A. phagocytophilum*, *A. platys*, or *A. marginale*) which are produced by the infected subject's immune system in its biological fluids or tissues, and which are capable of binding specifically to a peptide of the invention or combinations of a peptide of the invention and, optionally, one or more suitable additional antigenic polypeptides or peptides.

[00121] Suitable immunoassay methods typically include: receiving or obtaining (*e.g.*, from a patient) a sample of body fluid or tissue likely to contain antibodies; contacting (*e.g.*, incubating or reacting) a sample to be assayed with a peptide or population of peptides of the invention, under conditions effective for the formation of a specific peptide-antibody complex (*e.g.*, for specific binding of the peptide to the antibody); and assaying the contacted (reacted) sample for the presence of an antibody-peptide reaction (*e.g.*, determining the amount of an antibody-peptide complex). The presence of an elevated amount of the antibody-peptide complex indicates that the subject was exposed to and infected with an infectious *Anaplasma* species. A peptide, including a modified form thereof, which "binds specifically" to (*e.g.*, "is specific for" or binds "preferentially" to) an antibody against an *Anaplasma* antigen interacts with the antibody, or forms or undergoes a physical association with it, in an amount and for a sufficient time to allow detection of the antibody. By "specifically" or "preferentially," it is meant that the peptide has a higher affinity (*e.g.*, a higher degree of selectivity) for such an antibody than for other antibodies in a sample. For example, the peptide can have an affinity for the antibody of at least about 1.5-fold, 2-fold, 2.5-fold, 3-fold, or higher than for other antibodies in the sample. Such affinity or degree of specificity can be determined by a variety of routine procedures, including, *e.g.*, competitive binding studies. In an ELISA assay, a positive response is defined as a value 2 or 3 standard deviations greater than the mean value of a group of healthy controls. In some embodiments, a second tier assay is required to provide an unequivocal serodiagnosis of anaplasmosis.

[00122] Phrases such as "sample containing an antibody" or "detecting an antibody in a sample" are not meant to exclude samples or determinations (*e.g.*, detection attempts) where no antibody is contained or detected. In a general sense, this invention involves assays to determine whether an antibody produced in response to infection with an infectious *Anaplasma* species is present in a sample, irrespective of whether or not it is detected.

[00123] Conditions for reacting peptides and antibodies so that they react specifically are well-known to those of skill in the art. *See, e.g.*, Current Protocols in Immunology (Coligan *et al.*, editors, John Wiley & Sons, Inc).

[00124] The methods of the invention comprise receiving or obtaining a sample of body fluid or tissue likely to contain antibodies from a subject. The antibodies can be, *e.g.*, of IgG, IgE, IgD, IgM, or IgA type. Generally, IgM and/or IgA antibodies are detected, *e.g.*, for detection at early stages of infection. IgG antibodies can be detected when some of the additional peptides discussed above are used in the method (*e.g.*, peptides for the detection of flagellum proteins). The sample is preferably easy to obtain and may be whole blood, plasma, or serum derived from a venous blood sample or even from a finger prick. Tissue from other body parts or other bodily fluids, such as cerebro-spinal fluid (CSF), saliva, gastric secretions, mucus, urine, etc., are known to contain antibodies and may be used as a source of the sample. The sample may also be a tissue extract or a cell lysate.

[00125] Once the peptide or population of peptides of the invention and sample antibody are permitted to react in a suitable medium, an assay is performed to determine the presence or absence of an antibody-peptide reaction. Among the many types of suitable assays, which will be evident to a skilled worker, are immunoprecipitation and agglutination assays.

[00126] In certain embodiments of the invention, the assay comprises: immobilizing the antibody(s) in the sample; adding a peptide or population of peptides of the invention; and detecting the degree of antibody bound to the peptide or peptides, *e.g.*, by the peptide being labeled or by adding a labeled substance, such as a labeled binding partner (*e.g.*, streptavidin-HRP or streptavidin-colloidal gold complex) or a labeled antibody which specifically recognizes the peptide or peptides. *See, e.g.*, Figure 2. In other embodiments, the assay comprises: immobilizing a peptide or population of peptides of the invention; adding the sample containing antibodies; and detecting the amount of antibody bound to the peptide or peptides, *e.g.*, by adding another peptide or population of peptides of the invention conjugated, directly or indirectly, to a label (*e.g.*, metallic nanomaterial such as nanoparticle, nanoplate, or nanoshell, fluorescent label, enzyme (*e.g.*, horseradish peroxidase or alkaline phosphatase)) or by adding a labeled substance, such as a binding partner or a labeled antibody which specifically recognizes the sample antibodies (*e.g.*, anti-human IgG antibodies, anti-human IgM antibodies, anti-dog IgG antibodies, anti-dog IgM antibodies, anti-cat IgG antibodies, anti-cat IgM antibodies, protein A, protein G, protein A/G fusion proteins, protein L, or combinations thereof, etc.). *See, e.g.*, Figures 1, 3, and 4.

[00127] In other embodiments, the assay comprises: immobilizing a peptide or population of peptides of the invention; adding the sample containing antibodies; and detecting the amount of antibody bound to the peptide or peptides, *e.g.*, by adding a first binding partner which specifically recognizes the sample antibodies (*e.g.*, anti-human IgG antibodies, anti-human IgM antibodies, anti-dog IgG antibodies, anti-dog IgM antibodies, anti-cat IgG antibodies, anti-cat IgM antibodies, protein A, protein G, protein A/G fusion proteins, protein L, etc.), and further adding a second binding partner (*e.g.*, protein A, protein G, protein A/G fusion proteins, protein L, etc.), wherein the second binding partner is labeled and recognizes said first binding partner. In still other embodiments, the assay comprises: reacting the peptide or population of peptides and the sample containing antibodies without any of the reactants being immobilized, and then detecting the amount of complexes of antibody and peptide or peptides, *e.g.*, by the peptide being labeled or by adding a labeled substance, such as a labeled binding partner (*e.g.*, streptavidin-HRP or streptavidin-colloidal gold complex) or a labeled antibody which specifically recognizes the peptide.

[00128] Immobilization of a peptide or population of peptides of the invention can be either covalent or non-covalent, and the non-covalent immobilization can be non-specific (*e.g.*, non-specific binding to a polystyrene surface in, *e.g.*, a microtiter well). Specific or semi-specific binding to a solid or semi-solid carrier, support or surface, can be achieved by the peptide having, associated with it, a moiety which enables its covalent or non-covalent binding to the solid or semi-solid carrier, support or surface. For example, the moiety can have affinity to a component attached to the carrier, support or surface. In this case, the moiety may be, *e.g.*, a biotin or biotinyl group or an analogue thereof bound to an amino acid group of the peptide, such as 6-aminohexanoic acid, and the component is then avidin, streptavidin, neutravidin, or an analogue thereof. An alternative is a situation in which the moiety is a histidine tag (*e.g.* six consecutive histidine amino acids) and the carrier comprises a Nitrilotriacetic Acid (NTA) derivative charged with Ni++ or Co++ ions. In certain embodiments, the moiety is a fusion partner, *e.g.*, BSA. In exemplary embodiments, peptides of the invention may be conjugated to BSA via N-terminal and/or C-terminal residues of the peptides. In one embodiment, one, two, three, four, five, 10, 15, 20, 25, 30 or more peptides of the invention may be substituted into, *e.g.*, conjugated with BSA. As would be understood by one skilled in the art, substitution levels may impact the sensitivity of the assay. Lower concentrations of highly substituted BSA are needed to achieve sensitivity offered by high concentrations of BSA-peptide containing fewer molecules of peptide. In certain other embodiments, the fusion partner may be MAPS. In certain exemplary embodiments, MAPS may consist of 4, 8, or more asymmetric branches.

[00129] Suitable carriers, supports, and surfaces include, but are not limited to, metallic nanolayers, beads (*e.g.*, magnetic beads, colloidal particles or metallic nanomaterials, such as metallic nanoparticles, nanoplates, or nanoshells, such as colloidal gold, or particles or nanoparticles comprising silica, latex, polystyrene, polycarbonate, or PDVF), latex or co-polymers such as styrene-divinyl benzene, hydroxylated styrene-divinyl benzene, polystyrene, carboxylated polystyrene, beads of carbon black, non-activated or polystyrene or polyvinyl chloride activated glass, epoxy-activated porous magnetic glass, gelatin or polysaccharide particles or other protein particles, red blood cells, mono- or polyclonal antibodies or Fab fragments of such antibodies.

[00130] The protocols for immunoassays using antigens for detection of specific antibodies are well known in art. For example, a conventional sandwich assay can be used, or a conventional competitive assay format can be used. For a discussion of some suitable types of assays, see Current Protocols in Immunology (*supra*). In certain embodiments, a peptide or population of peptides of the invention is immobilized on a solid or semi-solid surface or carrier by means of covalent or non-covalent binding, either prior to or after the addition of the sample containing antibody.

[00131] Devices for performing specific binding assays, especially immunoassays, are known and can be readily adapted for use in the present methods. Solid phase assays, in general, are easier to perform than heterogeneous assay methods which require a separation step, such as precipitation, centrifugation, filtration, chromatography, or magnetism, because separation of reagents is faster and simpler. Solid-phase assay devices include microtiter plates, flow-through assay devices (*e.g.*, lateral flow immunoassay devices), dipsticks, and immunocapillary or immunochromatographic immunoassay devices.

[00132] In embodiments of the invention, the solid or semi-solid surface or carrier is the floor or wall in a microtiter well, a filter surface or membrane (*e.g.*, a nitrocellulose membrane or a PVDF (polyvinylidene fluoride) membrane, such as an Immobilon™ membrane), polyethylene membrane such as Porex® membrane, a hollow fiber, a beaded chromatographic medium (*e.g.*, an agarose or polyacrylamide gel), a magnetic bead, a fibrous cellulose matrix, an HPLC matrix, an FPLC matrix, a substance having molecules of such a size that the molecules with the peptide bound thereto, when dissolved or dispersed in a liquid phase, can be retained by means of a filter, a substance capable of forming micelles or participating in the formation of micelles allowing a liquid phase to be changed or exchanged without entraining the micelles, a water-soluble polymer, or any other suitable carrier, support or surface.

[00133] In some embodiments of the invention, the peptide is provided with (*e.g.* conjugated to) a suitable label which enables detection. Conventional labels may be used which are capable, alone or in concert with other compositions or compounds, of providing a detectable signal. Suitable labels include, but are not limited to, enzymes (*e.g.*, HRP, beta-galactosidase, alkaline phosphatase, etc.), fluorescent labels, quantum dots, radioactive labels, colored latex particles, and metal-conjugated labels (*e.g.*, metallic nanolayers, metallic nanomaterial-conjugated labels). Suitable metallic nanomaterials include, but are not limited to, metallic nanoparticles, metallic nanoplates, and metallic nanoshells. Suitable metallic nanomaterial labels include, but are not limited to, gold particles or nanoplates, silver particles or nanoplates, copper particles or nanoplates, platinum particles or nanoplates, palladium particles or nanoplates, cadmium particles or nanoplates, composite particles or nanoplates, gold hollow spheres, gold-coated silica nanoshells, and silica-coated gold shells. Metallic nanolayers suitable for detectable layers include nanolayers comprised of cadmium, zinc, mercury, and noble metals, such as gold, silver, copper, and platinum. In some embodiments, the metallic nanolayers comprise composite gold-silver or silver nanolayers coated with gold.

[00134] Suitable detection methods include, *e.g.*, detection of an agent which is tagged, directly or indirectly, with a colorimetric assay (*e.g.*, for detection of HRP or beta-galactosidase activity), visual inspection using light microscopy, immunofluorescence microscopy, including confocal microscopy, or by flow cytometry (FACS), autoradiography (*e.g.*, for detection of a radioactively labeled agent), electron microscopy, immunostaining, subcellular fractionation, or the like. In one embodiment, a radioactive element (*e.g.*, a radioactive amino acid) is incorporated directly into a peptide chain; in another embodiment, a fluorescent label is associated with a peptide via biotin/avidin interaction, association with a fluorescein conjugated antibody, or the like. In one embodiment, a detectable specific binding partner for the antibody is added to the mixture. For example, the binding partner can be a detectable secondary antibody or other binding agent (*e.g.*, protein A, protein G, protein L or combinations thereof) which binds to the first antibody. This secondary antibody or other binding agent can be labeled, *e.g.*, with a radioactive, enzymatic, fluorescent, quantum dot, luminescent, metallic nanomaterial such as metallic nanoparticle, metallic nanoplate, or metallic nanoshell (*e.g.* colloidal gold), or other detectable label, such as an avidin/biotin system. In another embodiment, the binding partner is a peptide or population of peptides of the invention, which can be conjugated directly or indirectly (*e.g.* via biotin/avidin interaction) to an enzyme, such as horseradish peroxidase or alkaline phosphatase or other signaling moiety. In such embodiments, the detectable signal is produced by adding a substrate of the enzyme that produces a detectable signal, such as a chromogenic, fluorogenic, or chemiluminescent substrate.

[00135] A "detection system" for detecting bound peptide, as used herein, may comprise a detectable binding partner, such as an antibody specific for the peptide. In one embodiment, the binding partner is labeled directly. In another embodiment, the binding partner is attached to a signal generating reagent, such as an enzyme that, in the presence of a suitable substrate, can produce a detectable signal. A surface for immobilizing the peptide may optionally accompany the detection system.

[00136] In some embodiments of the invention, the detection procedure comprises visibly inspecting the antibody-peptide complex for a color change, or inspecting the antibody-peptide complex for a physical-chemical change. Physical-chemical changes may occur with oxidation reactions or other chemical reactions. They may be detected by eye, using a spectrophotometer, or the like.

[00137] A particularly useful assay format is a lateral flow immunoassay format. Antibodies to human or animal (*e.g.*, dog, mouse, deer, etc.) immunoglobulins, or staph A, G, or L proteins, can be labeled with a signal generator or reporter (*e.g.*, colloidal gold) that is dried and placed on a glass fiber pad (sample application pad or conjugate pad). The diagnostic peptide or population of peptides of the invention is immobilized on membrane, such as nitrocellulose or a PVDF (polyvinylidene fluoride) membrane (*e.g.*, an Immobilon™ membrane). When a solution of sample (blood, serum, etc.) is applied to the sample application pad (or flows through the conjugate pad), it dissolves the labeled reporter, which then binds to all antibodies in the sample. The resulting complexes are then transported into the next membrane (PVDF or nitrocellulose containing the diagnostic peptide) by capillary action. If antibodies against the diagnostic peptide or population of peptides are present in the sample, they bind to the diagnostic peptide or population of peptides striped on the membrane, thereby generating a signal (*e.g.*, a band that can be seen or visualized). An additional antibody specific to the labeled antibody or a second labeled antibody can be used to produce a control signal.

[00138] An alternative format for the lateral flow immunoassay comprises the peptides or compositions of the invention being conjugated to a ligand (*e.g.*, biotin) and complexed with labeled ligand receptor (*e.g.*, streptavidin-colloidal gold). The labeled peptide complexes can be placed on the sample application pad or conjugate pad. Anti-human IgG/IgM or anti-animal (e.g., dog, mouse, deer) IgG/IgM antibodies or other peptides of the invention are immobilized on a membrane, such as nitrocellulose or PVDF, or Porex® membrane at a test site (*e.g.*, a test line). When sample is added to the sample application pad, antibodies in the sample react with the labeled peptide complexes such that antibodies that bind to peptides of the invention become indirectly labeled. The antibodies in the sample are then transported into the next membrane (PVDF, Porex® membrane, or nitrocellulose containing the diagnostic peptide) by capillary action and bind to the immobilized anti-human IgG/IgM or anti-animal IgG/IgM antibodies (or protein A, protein G, protein A/G fusion proteins, protein L, or combinations thereof) or immobilized peptides of the invention. If any of the sample antibodies are bound to the labeled peptides of the invention, the label associated with the peptides can be seen or visualized at the test site. Another embodiment of this type of lateral flow device in which the peptides of the invention are used both as the immobilized capture agent at a test site and as a soluble labeled complex to react with antibodies in a sample is shown in Figure 1. In such embodiments, to amplify the detection signal, protein A, protein G, and/or protein A/G fusion proteins conjugated to a detectable label (*e.g.*, metallic nanomaterial such as nanoparticle, nanoplate, or nanoshell, HRP, β-GAL, ALP, fluorophore, colored latex particle or quantum dots) may be applied to the test site where they will bind to the Fc region of any antibodies to *Anaplasma* antigens captured by the immobilized peptides of the invention. Suitable controls for this assay can include, *e.g.*, a chicken IgY-colloidal gold conjugate located at the sample application pad or conjugate pad, and an anti-chicken IgY antibody immobilized at a control site located proximal to the test site. Chicken anti-Protein A may also be used as the procedural control line.

[00139] Another assay for the screening of blood products or other physiological or biological fluids is an enzyme linked immunosorbent assay, *i.e.*, an ELISA. Typically in an ELISA, isolated peptides or mixtures or populations of peptides of the invention are adsorbed to the surface of a microtiter well directly or through a capture matrix (*e.g.*, an antibody). Residual, non-specific protein-binding sites on the surface are then blocked with an appropriate agent, such as bovine serum albumin (BSA), heat-inactivated normal goat serum (NGS), or BLOTTO blocking buffer (a buffered solution of nonfat dry milk which also contains a preservative, salts, and an antifoaming agent, available from Thermo Scientific as Blocker™ BLOTTO). The well is then incubated with a biological sample suspected of containing specific anti-*Anaplasma* (*e.g.*, anti-*A. phagocytophilum* or anti-*A. platys*) antibody. The sample can be applied neat, or more often it can be diluted, usually in a buffered solution which contains a small amount (0.1-5.0% by weight) of protein, such as BSA, NGS, or BLOTTO. After incubating for a sufficient length of time to allow specific binding to occur, the well is washed to remove unbound protein and then incubated with an optimal concentration of an appropriate anti-immunoglobulin antibody (*e.g.*, for human subjects, an anti-human immunoglobulin (αHuIg) from another animal, such as dog, mouse, cow, etc.) or another peptide or population of peptides of the invention that is conjugated to an enzyme or other label by standard procedures and is dissolved in blocking buffer. The label can be chosen from a variety of enzymes, including horseradish peroxidase (HRP), beta-galactosidase, alkaline phosphatase (ALP), glucose oxidase, β-GAL, etc. Sufficient time is allowed for specific binding to occur again, then the well is washed again to remove unbound conjugate, and a suitable substrate for the enzyme is added. Color is allowed to develop and the optical density of the contents of the well is determined visually or instrumentally (measured at an appropriate wave length). The cutoff OD value may be defined as the mean OD+3 standard deviations (SDs) of at least 50 serum samples collected from individuals from an area where anaplasmosis is not endemic, or by other such conventional definitions. In the case of a very specific assay, OD+2 SD can be used as a cutoff value.

[00140] In one embodiment of an ELISA, a peptide or population of peptides of the invention is immobilized on a surface, such as a ninety-six-well ELISA plate or equivalent solid phase that is coated with streptavidin or an equivalent biotin-binding compound, such as avidin or neutravidin, at an optimal concentration in an alkaline coating buffer and incubated at 4° C overnight. After a suitable number of washes with standard washing buffers, an optimal concentration of a biotinylated form of a peptide or composition of the invention, dissolved in a conventional blocking buffer, is applied to each well. A sample is then added, and the assay proceeds as above. Conditions for performing ELISA assays are well-known in the art.

[00141] In another embodiment of an ELISA, a peptide or population of peptides of the invention is immobilized on a surface, such as a ninety-six-well ELISA plate or equivalent solid phase via a fusion partner, *e.g.*, BSA or MAPS. A sample is then added and the assay proceeds as above.

[00142] An alternative format for the ELISA assay features the peptide(s) of the invention being attached (*e.g.*, fused) to an appropriate enzyme, such as HRP. Steps for carrying out such an ELISA include: coating the wells of a plate with anti-dog, anti-cat, or anti-human IgG/IgM; incubating samples suspected of containing antibodies to the peptides of the invention with the immobilized anti-species IgG/IgM; removing unreacted sample and washing the wells with a suitable wash buffer; applying enzyme-coupled (*e.g.*, HRP-coupled) peptide or population of peptides of the invention and allowing it to react with any captured anti-*Anaplasma* antibodies; and visualizing the enzyme-coupled peptide by applying an appropriate enzyme substrate (*e.g.*, TMB).

[00143] In another embodiment, the methods comprise an agglutination assay. For example, in certain embodiments, metallic nanoparticles, metallic nanoplates, or metallic nanoshells (*e.g.*, colloidal gold, etc.) or latex beads are conjugated to peptides or compositions of the invention. Subsequently, the biological fluid is incubated with the bead/peptide conjugate, thereby forming a reaction mixture. The reaction mixture is then analyzed to determine the presence of the antibodies. In certain embodiments, the agglutination assays comprise the use of a second population of particles, such as metallic nanoparticles, metallic nanoplates, or metallic nanoshells (*e.g.*, colloidal gold, etc.) or latex beads, conjugated to (1) antibodies specific to the peptides or compositions of the invention, in the case of a competition assay, or (2) antibodies capable of detecting sample antibodies (*e.g.*, anti-human IgG or IgM antibodies, anti-dog IgG or IgM antibodies, anti-cat IgG or IgM antibodies, etc.), in the case of a sandwich assay. Suitable agglutination methods can comprise centrifugation as a means of assessing the extent of agglutination.

[00144] In still other embodiments, peptide or compositions of the invention are electro- or dot-blotted onto nitrocellulose paper. Subsequently, a sample, such as a biological fluid (*e.g.*, serum or plasma) is incubated with the blotted antigen, and antibody in the biological fluid is allowed to bind to the antigen(s). The bound antibody can then be detected, *e.g.*, by standard immunoenzymatic methods or by visualization using metallic nanomaterial such as nanoparticles, nanoplates, or nanoshells coupled to secondary antibodies or other antibody binding agents, such as protein A, protein G, protein A/G fusion proteins, protein L, or combinations thereof.

[00145] It should be understood by one of skill in the art that any number of conventional protein assay formats, particularly immunoassay formats, may be designed to utilize the isolated peptides or populations of peptides of this invention for the detection of *Anaplasma* antibodies and infection by pathogenic *Anaplasma* (*e.g.*, *A. phagocytophilum*, *A. platys*, or *A. marginale*) in a subject. This invention is thus not limited by the selection of the particular assay format, and is believed to encompass assay formats that are known to those of skill in the art.

[00146] In certain embodiments, the sample used in the methods is a bodily fluid, such as blood, plasma, serum, cerebrospinal fluid, urine, or saliva. In other embodiments, the sample is a tissue (*e.g.*, a tissue homogenate) or a cell lysate. In certain embodiments, the sample is from a wild animal (*e.g.*, a deer or rodent, such as a mouse, chipmunk, squirrel, etc.). In other embodiments, the sample is from a lab animal (*e.g.*, a mouse, rat, guinea pig, rabbit, monkey, primate, etc.). In other embodiments, the sample is from a domesticated or feral animal (*e.g.*, a dog, a cat, a horse). In still other embodiments, the sample is from a human.

[00147] Much of the preceding discussion is directed to the detection of antibodies against pathogenic *Anaplasma*. However, it is to be understood that the discussion also applies to the detection of primed T-cells, either *in vitro* or *in vivo*.

[00148] It is expected that a cell-mediated immune response (*e.g.*, a T-helper response) is generated, since IgG is produced. It is therefore expected that it will be possible to determine the immunological reactivity between primed T-cells and a peptide of the invention. *In vitro* this can be done by incubating T-cells isolated from the subject with a peptide or population of peptides of the invention and measuring the immunoreactivity, *e.g.*, by measuring subsequent T-cell proliferation or by measuring release of cytokines from the T-cells, such as IFN-γ. These methods are well-known in the art.

[00149] When a method of the invention is carried out *in vivo*, any of a variety of conventional assays can be used. For example, one can perform an assay in the form of a skin test, *e.g.*, by intradermally injecting, in the subject, a peptide or population of peptides of the invention. A positive skin reaction at the location of injection indicates that the subject has been exposed to and infected with a pathogenic *Anaplasma* species capable of causing anaplasmosis, and a negative skin response at the location of injection indicates that the subject has not been so exposed/infected. This or other *in vivo* tests rely on the detection of a T-cell response in the subject.

[00150] The present invention also provides a method for diagnosing anaplasmosis in a subject. Anaplasmosis in humans was previously known as human granulocytic ehrlichiosis and has more recently been termed human granulocytic anaplasmosis. Some strains of *Anaplamsa* (*e.g.*, *A. platys*) cause cyclic thrombocytopenia in animals (*e.g.* in dogs, the disease is termed Infectious Canine Cyclic Thrombocytopenia (ICCT)). Thus, the present invention also provides a method for diagnosing cyclic thrombocytopenia or ICCT in a subject. The subject can be a subject suspected of having antibody against a causative agent of anaplasmosis or cyclic thrombocytopenia. The diagnostic method is useful for diagnosing subjects exhibiting the clinical symptoms of anaplasmosis or cyclic thrombocytopenia. Clinical symptoms of human anaplasmosis (*i.e.*, human granulocytic anaplasmosis) include, but are not limited to, fever, headache, malaise, chills, myalgia, abdominal pain, cough, confusion, thrombocytopenia, leukopenia, and elevated serum transaminase levels. Clinical symptoms of anaplasmosis or cyclic thrombocytopenia in animals (*e.g.* canines) include, but are not limited to, profound anemia, tachycardia, dyspnea, diarrhea, anorexia, weight loss, ataxia, leukopenia, lethargy, lymphadenomegaly, pale mucous membranes, fever, mucopurulent nasal discharge, inappetance, weak or painful limbs, and lameness.

[00151] In some embodiments, the methods comprise contacting a sample from the subject with a peptide of the invention, and detecting formation of an antibody-peptide complex comprising said peptide, wherein formation of said complex is indicative of the subject having anaplasmosis or cyclic thrombocytopenia. In certain embodiments, the methods comprise contacting the sample with a population of two, three, four, or more (*e.g.*, 5, 6, 7, 8, 9, 10, 15, 20, 25, 30, 40, 50, 60, 70, 80, 90, 100, 150, 200, 250, 300, 400, 500, or more) different peptides of the invention and detecting formation of an antibody-peptide complex comprising said one or more peptides in the population, wherein formation of the complex is indicative of the subject having anaplasmosis or cyclic thrombocytopenia. For instance, in one particular embodiment, the methods comprise contacting the sample with a population of two or more different isolated peptides, wherein each isolated peptide comprises a sequence of SEQ ID NO: 1. In another particular embodiment, the methods comprise contacting the sample with a population of two or more different isolated peptides, wherein each isolated peptide comprises a sequence of SEQ ID NO: 3. In still another embodiment, the methods comprise contacting the sample with a population of two or more different isolated peptides, wherein each isolated peptide comprises a sequence of SEQ ID NO: 4. In some embodiments, the methods comprise contacting the sample with a population of two or more different isolated peptides, wherein each isolated peptide comprises a sequence of SEQ ID NO: 2, SEQ ID NO: 5, SEQ ID NO: 6, SEQ ID NO: 7, SEQ ID NO: 8, SEQ ID NO: 9, or SEQ ID NO: 543.

[00152] In certain embodiments, the methods comprise contacting the sample with a mixture of one or more peptides of the invention and one or more other peptides (*e.g.*, an *Ehrlichia* peptide, or antigenic fragment or epitope thereof, or a *Borrelia* peptide, or antigenic fragment or epitope thereof.) Co-infections with *Anaplasma* and *Ehrlichia* or *Borrelia* species are common. Thus, diagnostic methods of the invention that employ populations of peptides comprising the *Anaplasma* peptides described herein and one or more peptides from an *Ehrlichia* or *Borrelia* species are useful for detecting such co-infections. Exemplary *Ehrlichia* antigenic peptides that may be used with the *Anaplasma* peptides of the invention are described in U.S. Application No. 14/052,296 and U.S. Patent No. 8,828,675, both of which are incorporated by reference herein in their entireties. Exemplary *Borrelia* antigenic peptides that may be used with the *Anaplasma* peptides of the invention are described in U.S. Patent Nos. 8,568,989 and 8,758,772, both of which are incorporated by reference herein in their entireties. Other *Ehrlichia* and *Borrelia* antigens are known in the art and may be used in combination with the *Anaplasma* peptides of the invention to detect co-infections in a subject.

[00153] In certain embodiments, the peptide or each peptide in the population is an isolated (*e.g.*, synthetic and/or purified) peptide. In some embodiments, the peptide or population of different peptides is attached to or immobilized upon a substrate (*e.g.*, a solid or semi-solid support). For example, in certain embodiments, the substrate is a bead or plurality of beads (*e.g.*, a colloidal or other type of particle or metallic nanomaterial such as nanoparticle, nanoplate, or nanoshell), a flow path in a lateral flow immunoassay device (*e.g.*, a porous membrane), a flow path in an analytical or centrifugal rotor, a blot (*e.g.*, a Western blot, dot blot, or slot blot), a tube or a well (*e.g.*, in a plate suitable for an ELISA assay), or a sensor (*e.g.*, an electrochemical, optical, or opto-electronic sensor). In some embodiments, the peptide or population of peptides is attached to or immobilized upon a solid support through a metallic nanolayer that, in some embodiments, may be comprised of cadmium, zinc, mercury, or a noble metal (*e.g.*, gold, silver, copper, and platinum).

[00154] There are a number of different conventional assays for detecting formation of an antibody-peptide complex comprising a peptide of the invention. For example, the detecting step can comprise performing an ELISA assay, performing a lateral flow immunoassay, performing an agglutination assay, performing a wavelength shift assay, analyzing the sample using a Western blot, a slot blot, or a dot blot, performing an Indirect Fluorescent Antibody test, analyzing the sample in an analytical or centrifugal rotor, or analyzing the sample with an electrochemical, optical, or opto-electronic sensor. These different assays are described above and/or are well-known to those skilled in the art.

[00155] In certain embodiments, the sample used in the diagnostic methods of the invention is a bodily fluid, such as blood, plasma, serum, cerebrospinal fluid, urine, or saliva. In other embodiments, the sample is a tissue (*e.g.*, a tissue homogenate) or a cell lysate. In certain embodiments, the subject is a wild animal (*e.g.*, a deer or rodent, such as a mouse, chipmunk, squirrel, etc.). In other embodiments, the subject is a lab animal (*e.g.*, a mouse, rat, guinea pig, rabbit, monkey, primate, etc.). In other embodiments, the subject is a domesticated or feral animal (*e.g.*, a dog, a cat, a horse). In still other embodiments, the subject is a human.

[00156] The present invention also includes a method for identifying the species of *Anaplasma* infecting a subject. Such methods aid in the treatment of the infection in the subject because treatment regimens may differ depending on the particular *Anaplasma* species causing the infection. The species identification methods are also useful in the epidemiology of *Anaplasma* infections and anaplasmosis. In certain embodiments, the method distinguishes between infections caused by *A. phagocytophilum* and infections caused by *A. platys*. In one embodiment, the method comprises contacting a sample from the subject with a first peptide or population of isolated peptides and a second peptide or population of isolated peptides, wherein the first peptide or population of isolated peptides specifically binds to antibodies against antigens from multiple *Anaplasma* species, and wherein the second peptide or population of isolated peptides specifically binds to antibodies against antigens from a single *Anaplasma* species. Formation of a first antibody-peptide complex comprising said first peptide or one or more peptides in the first population and formation of a second antibody-peptide complex comprising said second peptide or one or more peptides in the second population are detected, wherein formation of both the first and second antibody-peptide complexes indicates that the subject is infected with the *Anaplasma* species that is specifically bound by the second peptide or population of isolated peptides.

[00157] In some embodiments, the first peptide or first population of peptides specifically binds to antibodies against antigens from *A. phagocytophilum*, *A. platys*, and *A. marginale*. In certain embodiments, the first peptide or first population of peptides specifically binds to antibodies against antigens from both *A. phagocytophilum* and *A. platys*. For example, in one embodiment, the first peptide comprises a sequence of SEQ ID NO: 3. In another embodiment, the first population of peptides comprises three or more different peptides, wherein each peptide in the population comprises a sequence of SEQ ID NO: 3 or a fragment thereof. In such embodiments, the first population of peptides may comprise three or more peptides listed in Table 3 (*i.e.*, three or more peptides comprising or consisting of sequences of SEQ ID NOs: 199-350).

[00158] In certain embodiments, the second peptide or second population of peptides specifically binds to antibodies against antigens from *A. platys*. For instance, in one embodiment, the second peptide comprises a sequence of SEQ ID NO: 4. In another embodiment, the second population of peptides comprises three or more different peptides, wherein each peptide in the population comprises a sequence of SEQ ID NO: 4 or a fragment thereof. In such embodiments, the first population of peptides may comprise three or more peptides listed in Table 4 (*i.e.*, three or more peptides comprising or consisting of sequences of SEQ ID NOs: 351-398). In other embodiments, the second peptide or second population of peptides may comprise a sequence of SEQ ID NOs. 6-8. In related embodiments, the second population of peptides comprises three or more different peptides listed in Tables 6 or 7 (*i.e.*, three or more peptides comprising or consisting of sequences of SEQ ID NOs: 407-464).

[00159] In such embodiments in which the second peptide or second population of peptides specifically binds to antibodies against antigens from *A. platys*, formation of both the first and second antibody-peptide complexes indicates that the subject is infected with *A. platys*. In related embodiments, formation of the first antibody-peptide complex, but not the second antibody-peptide complex indicates that the subject is infected with *A. phagocytophilum*. For instance, in certain embodiments, the first population of isolated peptides is defined by SEQ ID NO: 3 and the second population of isolated peptides is defined by SEQ ID NO: 4, and formation of both the first and second antibody-peptide complexes is detected indicating that the subject is infected with *A. platys*. In other embodiments, the first population of isolated peptides is defined by SEQ ID NO: 3 and the second population of isolated peptides is defined by any one of SEQ ID NOs: 6 to 8, and formation of both the first and second antibody-peptide complexes is detected indicating that the subject is infected with *A. platys*. In some embodiments, the first population of isolated peptides is defined by SEQ ID NO: 3 and the second population of isolated peptides is defined by SEQ ID NO: 4, and formation of the first antibody-peptide complex, but not the second antibody-peptide complex is detected indicating that the subject is infected with *A. phagocytophilum*. In other embodiments, the first population of isolated peptides is defined by SEQ ID NO: 3 and the second population of isolated peptides is defined by any one of SEQ ID NOs: 6 to 8, and formation of the first antibody-peptide complex, but not the second antibody-peptide complex is detected indicating that the subject is infected with *A. phagocytophilum*.

[00160] In alternative embodiments, the second peptide or second population of peptides specifically binds to antibodies against antigens from *A. phagocytophilum*. For instance, in one embodiment, the second peptide comprises a sequence of SEQ ID NO: 1. In another embodiment, the second population of peptides comprises three or more different peptides, wherein each peptide in the population comprises a sequence of SEQ ID NO: 1 or a fragment thereof. In such embodiments, the first population of peptides may comprise three or more peptides listed in Table 1 (*i.e.*, three or more peptides comprising or consisting of sequences of SEQ ID NOs: 10-117). In other embodiments, the second peptide or second population of peptides may comprise a sequence of SEQ ID NOs. 2, 5, or 9. In related embodiments, the second population of peptides comprises three or more different peptides listed in Tables 2, 5, or 8 (*i.e.*, three or more peptides comprising or consisting of sequences of SEQ ID NOs: 118-198, 399-406, or 465-542).

[00161] In such embodiments in which the second peptide or second population of peptides specifically binds to antibodies against antigens from *A. phagocytophilum*, formation of both the first and second antibody-peptide complexes indicates that the subject is infected with *A. phagocytophilum*. In related embodiments, formation of the first antibody-peptide complex, but not the second antibody-peptide complex indicates that the subject is infected with *A. platys*. For instance, in certain embodiments, the first population of isolated peptides is defined by SEQ ID NO: 3 and the second population of isolated peptides is defined by SEQ ID NO: 1, and formation of both the first and second antibody-peptide complexes is detected indicating that the subject is infected with *A. phagocytophilum*. In other embodiments, the first population of isolated peptides is defined by SEQ ID NO: 3 and the second population of isolated peptides is defined by any one of SEQ ID NOs: 2, 5, or 9, and formation of both the first and second antibody-peptide complexes is detected indicating that the subject is infected with *A. phagocytophilum*. In some embodiments, the first population of isolated peptides is defined by SEQ ID NO: 3 and the second population of isolated peptides is defined by SEQ ID NO: 1, and formation of the first antibody-peptide complex, but not the second antibody-peptide complex is detected indicating that the subject is infected with *A. platys*. In other embodiments, the first population of isolated peptides is defined by SEQ ID NO: 3 and the second population of isolated peptides is defined by any one of SEQ ID NOs: 2, 5, or 9, and formation of the first antibody-peptide complex, but not the second antibody-peptide complex is detected indicating that the subject is infected with *A. platys*.

[00162] The first and second antibody-peptide complexes can be detected using various methods including, but not limited to, performing an ELISA assay, running a lateral flow assay, performing an agglutination assay, performing a Western blot, a slot blot, or dot blot, performing a wavelength shift assay, performing an Indirect Fluorescent Antibody test, or running the sample through an analytical or centrifugal rotor. Such methods and devices for use in the methods are described in detail above.

[00163] In other embodiments, the method for identifying the species of *Anaplasma* infecting a subject comprises contacting a sample from the subject with a first population of peptides and a cell extract of a single *Anaplasma* species, wherein the first population of isolated peptides specifically binds to antibodies against antigens from multiple *Anaplasma* species; detecting formation of a first antibody-peptide complex comprising one or more peptides in the first population; and detecting formation of an antibody-cell extract complex comprising one or more components in the cell extract, wherein formation of both the first antibody-peptide complex and the antibody-cell extract complex indicates that the subject is infected with the *Anaplasma* species that produced the cell extract. In some embodiments, the cell extract is from *A. phagocytophilum*.

[00164] A cell extract comprises components of cells. It can be generated by lysing cells (e.g., with detergents) and removing unwanted components (e.g., using centrifugation to remove insoluble matter such as membrane fragments, vesicles, and nuclei). A cell extract can be a whole-cell lysate or partial-cell lysate. Cell extracts usually consist mostly of cytosol. Various methods of making cell extracts are well known to those of skill in the art. Commercial kits are available for generating cell extracts.

Kits

[00165] In yet another aspect, the invention provides kits for use in the detection and diagnostic assays described herein. In some embodiments, the kits comprise one or more peptides of the invention. In certain embodiments, the kits comprise a population of peptides of the invention. The peptides can comprise a sequence of SEQ ID NO: 1, SEQ ID NO: 2, SEQ ID NO: 3, SEQ ID NO: 4, SEQ ID NO: 5, SEQ ID NO: 6, SEQ ID NO: 7, SEQ ID NO: 8, SEQ ID NO: 9, SEQ ID NO: 543, or fragments thereof. In one embodiment, the kits comprise two or more populations of peptides of the invention. For example, in one embodiment, the kits comprise a first population of peptides defined by SEQ ID NO: 3 and a second population of peptides defined by SEQ ID NO: 4. In particular embodiments, the peptides are attached to or immobilized on a solid support. In some embodiments, the peptides are attached to or immobilized on a solid support through a metallic nanolayer (*e.g.*, cadmium, zinc, mercury, gold, silver, copper, or platinum nanolayer). In certain embodiments, the solid support is a bead or plurality of beads (*e.g.*, a colloidal particle or a metallic nanomaterial such as nanoparticles, nanoplates, or nanoshells), a flow path in a lateral flow immunoassay device, a flow path in an analytical or centrifugal rotor, a tube or a well (*e.g.*, in a plate), or a sensor (*e.g.*, an electrochemical, optical, or opto-electronic sensor).

[00166] Reagents for particular types of assays can also be provided in kits of the invention. Thus, the kits can include a population of beads (*e.g.*, suitable for an agglutination assay or a lateral flow assay), or a plate (*e.g.*, a plate suitable for an ELISA assay). In other embodiments, the kits comprise a device, such as a lateral flow immunoassay device, an analytical or centrifugal rotor, a Western blot, a dot blot, a slot blot, or an electrochemical, optical, or opto-electronic sensor. The population of beads, the plate, and the devices are useful for performing an immunoassay. For example, they can be useful for detecting formation of an antibody-peptide complex comprising an antibody from a sample and a peptide of the invention. In certain embodiments, a peptide, a population of different peptides of the invention, or a peptide composition of the invention is attached to or immobilized on the beads, the plate, or the device.

[00167] In addition, the kits can include various diluents and buffers, labeled conjugates or other agents for the detection of specifically bound antigens or antibodies (e.g. labeling reagents), and other signal-generating reagents, such as enzyme substrates, cofactors and chromogens. In one embodiment, the kits comprise a labeling reagent capable of binding to an antibody that recognizes an epitope of one or more peptides of the invention. For instance, in some embodiments, the kit comprises an anti-human, anti-canine, or anti-feline IgG or IgM antibody conjugated to a detectable label (*e.g.*, a metallic nanomaterial such as a nanoparticle, a nanoplate, or a metallic nanoshell, a metallic nanolayer, a fluorophore, a quantum dot, a colored latex particle, or an enzyme) as a labeling reagent. In other embodiments, the kit comprises protein A, protein G, protein A/G fusion proteins, protein L, or combinations thereof conjugated to a detectable label (*e.g.*, a metallic nanomaterial such as a metallic nanoparticle, a metallic nanoplate, a metallic nanoshell, a metallic nanolayer, a fluorophore, a quantum dot, a colored latex particle, or an enzyme) as a labeling reagent. An exemplary protein A/G fusion protein combines four Fc-binding domains from protein A with two from protein G. *See, e.g.*, Sikkema, J.W.D., Amer. Biotech. Lab, 7:42, 1989 and Eliasson *et al.*, J. Biol. Chem. 263, 4323-4327, 1988, both which are hereby incorporated by reference in their entireties. In still other embodiments, the labeling reagents of the kit are a second population of peptides of the invention conjugated to a detectable label (*e.g.*, a metallic nanomaterial such as a metallic nanoparticle, a metallic nanoplate, a metallic nanoshell, a metallic nanolayer, a fluorophore, a colored latex particle, or an enzyme). The second population of peptides can be the same as or different than the first population of peptides, which may optionally be attached to or immobilized upon a solid support.

[00168] Other components of a kit can easily be determined by one of skill in the art. Such components may include coating reagents, polyclonal or monoclonal capture antibodies specific for a peptide of the invention, or a cocktail of two or more of the antibodies, purified or semi-purified extracts of these antigens as standards, monoclonal antibody detector antibodies, an anti-mouse, anti-dog, anti-cat, anti-chicken, or anti-human antibody conjugated to a detectable label, indicator charts for colorimetric comparisons, disposable gloves, decontamination instructions, applicator sticks or containers, a sample preparatory cup, etc. In one embodiment, a kit comprises buffers or other reagents appropriate for constituting a reaction medium allowing the formation of a peptide-antibody complex.

[00169] Such kits provide a convenient, efficient way for a clinical laboratory to diagnose infection by a pathogenic *Anaplasma* species, such as *A. phagocytophilum*, *A. platys*, or *A. marginale*. Thus, in certain embodiments, the kits further comprise an instruction. For example, in certain embodiments, the kits comprise an instruction indicating how to use a peptide or population of peptides of the invention to detect an antibody to one or more *Anaplasma* antigens or to diagnose anaplasmosis or cyclic thrombocytopenia. In certain embodiments, the kits comprise an instruction indicating how to use a population of beads, a plate, or a device (*e.g.*, comprising a peptide or a population of different peptides of the invention) to detect an antibody to one or more *Anaplasma* antigens or to diagnose anaplasmosis or cyclic thrombocytopenia.

[00170] The peptides, compositions and devices comprising the peptides, kits and methods of the invention offer a number of advantages. For example, they allow for simple, inexpensive, rapid, sensitive and accurate detection of anaplasmosis or cyclic thrombocytopenia, and avoid serologic cross-reactivity with other conditions with similar symptoms. This allows for an accurate diagnosis. Furthermore, a diagnostic test of the invention (*e.g.*, an ELISA assay, lateral flow immunoassay, or agglutination assay) is useful in serum samples that contain anti- MSP 2/p44 or anti-OMP/p44 antibodies or other antibodies produced in response to a vaccine based on the outer surface proteins of *Anaplasma*.

[00171] The following examples illustrate various aspects of the invention. The examples should, of course, be understood to be merely illustrative of only certain embodiments of the invention and not to constitute limitations upon the scope of the invention.

EXAMPLES

<u>Example 1. ELISA Assay</u>

[00172] Two different populations of peptides were synthesized using standard synthesis procedures. Each peptide in the first population of peptides (APL-ID1) contained a sequence of SEQ ID NO: 3. The first population of peptides specifically binds to antibodies elicited by both *A. phagocytophilum* and *A. platys*. Each peptide in the second population of peptides (APL-ID2) contained a sequence of SEQ ID NO: 4. The second population of peptides specifically binds to antibodies elicited primarily by *A. platys*.

[00173] Each peptide in the two populations was linked separately to the carrier protein bovine serum albumin (BSA) using thio-ether chemistry. The resulting BSA-peptide conjugates were used as capture entities in 96-well ELISA plates to create two separate ELISA assays (one population of peptides per plate). The plates were blocked with 5% non-fat milk powder dissolved in 25 mM borate buffer (pH9.5) to prevent undesirable non-specific binding.

[00174] Dogs were inoculated with *A. phagocytophilum*-infected tick cell cultures to initiate exposure of the dogs to *A. phagocytophilum*. Stabilized blood obtained from animals known to harbor *A. platys* infection as determined by PCR and microscopic examination was inoculated into a separate group of dogs for initiating infection with *A. platys*. Blood samples from each group of inoculated dogs were collected at various days following inoculation.

[00175] Plasma prepared from the blood samples was tested for reactivity with the APL-ID1 and APL-ID2 peptides using the ELISA plates described above. The plasma samples were diluted 1:250 to 1:1000 in blocking solution and added to blocked wells in each of the two ELISA plates. After a one-hour incubation period, the unreacted materials were removed by washing the micro wells. The specifically captured anti-peptide dog IgG or IgM were detected by reaction with HRP-labeled Protein A. HRP was assayed using a commercial TMB substrate. The optical density of each well was read at 650 nm with a plate reader.

[00176] Reactivity of plasma samples obtained from an *A. platys*-infected dog (15-13) dog and an *A. phagocytophilum*-infected dog (3-13) with APL-ID1 peptides and APL-ID2 peptides are shown in Figures 5 and 6, respectively. The samples from the *A. phagocytophilum*-infected dog (dog 3-13) showed significant reactivity with APL-ID1 peptides, whereas the reactivity of such samples with APL-ID2 peptides was much lower. In contrast, samples from the *A. platys*-infected dog (dog 15-13) showed similar reactivity towards both populations of peptides. These experimental results show that populations of peptides defined by SEQ ID NO: 3 (APL-ID1) and SEQ ID NO: 4 (APL-ID2) have a high degree of sensitivity in detecting the presence of antibodies to *Anaplasma* antigens. In addition, the results show that these two populations of peptides can be used to identify the infecting species of *Anaplasma*. A sample that tests positive for reactivity with APL-ID1 peptides, but not APL-ID2 peptides is positive for *A.*

phagocytophilum, whereas a sample that tests positive for reactivity for both peptides is positive for *A. platys*.

Example 2. Lateral Flow Assay

[00177] A lateral flow immunoassay in a double antigen sandwich format was constructed to detect the presence of antibodies specific for *Anaplasma* antigens. A population of peptides comprising peptides with a sequence of SEQ ID NO: 3 (APL-ID1), SEQ ID NO: 6 (APL-ID5.1), or SEQ ID NO: 7 (APL-ID6) was linked to BSA and the resulting complexes were used both as test conjugate (peptides labeled with gold nanoparticles) and as capture (immobilized at the test line of the device). The signal produced at the test line was enhanced by Protein A and Protein G-gold conjugates (amplifier) added to the labeled peptide conjugate. The device is depicted in Figure 7.

[00178] The operation of the device is illustrated in Figure 8. To conduct the assay, one drop of anti-coagulated whole blood, serum, or plasma is applied to the sample port of the device. The blood separation pad filters blood cells from whole blood. Plasma (or serum) mobilizes and binds specifically to the test conjugate present on the conjugate pad and any formed antibody-peptide complexes migrate to the nitrocellulose membrane containing the test and the control regions. The application of a chase buffer after sample application moves the free and the bound test conjugates through the nitrocellulose membrane towards the upper absorbent pad. The labeled peptide-antibody complexes move to the test line where immobilized peptides capture labeled peptide-antibody complexes via the second binding sites on the antibodies. Protein A-gold and Protein G-gold conjugates in the conjugate mixture bind to captured antibodies amplifying the detection signal. The appearance of one red line at the test site and a second red line at the control site indicates the presence of antibodies to *Anaplasma* spp. (*e.g.*, *phagocytophilum* or *platys*) in the sample. The appearance of a red line at only the control site indicates the absence of antibodies to all of the *Anaplasma* spp. in the sample. The test is considered invalid if (i) a signal at the test line appears but no signal at the control line is present or (ii) no signal is observed at either the control or test lines.

[00179] Ninety-five dog plasma samples positive for *Anaplasma* spp. as determined by indirect immunofluorescence assay, IDEXX SNAP 4DX Plus™, and ELISA using the same peptide mixture, were tested in the lateral flow device. In addition, fifty-one dog plasma samples that were determined to be negative for *Anaplasma* spp. by the same methods were also evaluated. Each sample was tested twice in the device. Each test was performed by a different operator. At the end of the test period, each test was marked by the operator as either positive or negative. Additionally, scanned images of each test were obtained and analyzed by the ImageJ method. A test where both operators agreed on the designation was recorded as the same designation (pos/neg). Where operators disagreed, a third test was run by a third operator and taken as the final result (pos/neg) for that sample. The results are summarized in Table 9 below. The lateral flow assay had a sensitivity of 97.9% and a specificity of 90.2%. This example demonstrates that a population of peptides comprising peptides having a sequence of SEQ ID NO: 3, SEQ ID NO: 6, or SEQ ID NO: 7 can effectively detect antibodies against *Anaplasma* antigens when employed in a lateral flow assay format.

Table 9. Lateral Flow Assay Results of Known Anaplasma-Positive and Negative Samples

	Negative by Lateral Flow	Positive by Lateral Flow
No. of known negative samples	46	5
No. of known positive samples	2	93

Example 3. Indirect Fluorescent Antibody Assay

[00180] An indirect fluorescent antibody test is constructed using latex beads coated with one or more peptides of the invention. In certain embodiments, the peptides defined by SEQ ID NO: 3 (APL-ID1), SEQ ID NO: 4 (APL-ID2), and/or SEQ ID NO: 6 (APL-ID5.1) are used. The peptides of the invention are coated onto maleimide-derivatized latex beads using thio-ether chemistry. Alternatively, the peptides of the invention may be conjugated to BSA via thio-ether or similar chemistries and are passively absorbed on to latex beads. A population of such beads is then immobilized on a glass slide using known techniques.

[00181] To conduct the assay, one drop of serum or plasma (diluted appropriately with a suitable buffer) from dogs suspected of having anti-*Anaplasma* antibodies, is applied to the glass slide coated with latex beads. Following a suitable incubation time, the unreacted materials are washed away and a drop of fluorescently labeled anti-dog IgG (or IgM) is applied and the slides are incubated for an additional time period. The final preparation is viewed under a fluorescent microscope to determine fluorescently tagged latex beads. The classification of the test serum/plasma as positive or negative is based on comparison with appropriate controls. An enzyme label may be used in place of the fluorescent label in which case the visualization step employs an enzyme substrate. For example, anti-dog IgG/IgM labeled with alkaline phosphatase can be visualized by exposing the slide to a BCIP-nitro BT substrate. Labeled Protein A, Protein G, or Protein A/G fusion can be used in place of labeled anti-dog IgG and anti-dog IgM to detect antibodies bound to the peptide-coated beads.

<u>Example 4. Identification of the Species of *Anaplasma* Infecting Dogs in Unknown Samples</u>

[00182] This example demonstrates successful identification of the species of *Anaplasma* infecting dogs using the peptide populations of the invention and *Anaplasma* cell extracts.

[00183] Forty one dog plasma samples, which were all tested and classified by visual inspection as positive for *Anaplasma* infection using the IDEXX SNAP 4DX Plus™ assay, were tested in an ELISA assay similar to that described in Example 1. Three 96-well ELISA plates were coated with various peptides or cell extract (prepared using a commercial kit from Sigma-Aldrich) at room temperature for 1 hour. Plate 1 was coated with 100 µL/well of a mixture of three peptide populations: APL-ID1 (SEQ ID NO: 3, final concentration 7µg/mL), APL-ID5.1 (SEQ ID NO: 6, final concentration 7µg/mL), and APL-ID6 (SEQ ID NO: 7, final concentration 7µg/mL). Plate 2 was coated with 100 µL/well of a mixture of two peptide populations: APL-ID5.1 (SEQ ID NO: 6, final concentration 7µg/mL), and APL-ID6 (SEQ ID NO: 7, final concentration 7µg/mL). Plate 3 was coated with 100 µL/well of an *A. phagocytophilum* whole-cell lysate (final concentration 5µg/mL). The peptide mixture on plate 1 specifically binds to antibodies elicited by both *A. phagocytophilum* and *A. platys*. The peptide mixture on plate 2 specifically binds to antibodies elicited primarily by *A. platys*. The whole-cell lysate on plate 3 specifically binds to antibodies elicited primarily by *A. phagocytophilum*. The plates were then washed.

[00184] The plates were then blocked with 300 µL/well of 7% non-fat milk in 250 mM borate buffer (pH9.5) at room temperature for 1 hour to prevent undesirable non-specific binding. The plates were washed again.

[00185] Plasma samples from dogs with or without *Anaplasma* infection (the "unknown samples") were diluted 1/100 in 7% milk, and 100 µL/well of each sample were added to the ELISA plates and incubated at room temperature for 1 hour. The plates were washed again.

[00186] The plates were then incubated with 100 µL/well of Protein A-HRP conjugate (diluted 1:1000) at room temperature for 1 hour. The plates were washed again, and 100 µL/well of substrate (TMB) was added and incubated at room temperature for 10 minutes. OD readings of all the samples were obtained and compared to standard curves. For plate 1 and plate 2 (the two "peptide" plates), serial dilutions of pooled positive samples were used to create standard curves. For plate 3 (the lysate plate), a two point curve was made using a negative sample and a canine sample from a dog which was experimentally infected with *A. phagocytophilum* ("3-13").

[00187] Species identification results of these samples using the peptide-cell extract ELISA, along with the results of the SNAP test and an indirect immunofluorescence assay (IFA), are shown in Table 10. Both the SNAP and the IFA tests only detected *Anaplasma* at the genus level and could not be used to determine the species of *Anaplasma*.

Table 10. Identification of *Anaplasma* Species in Unknown Samples

Sample ID	Combo Score[a]	platys Score[b]	phago WCL score[c]	Anaplasma species determined with peptides and cell extract[d]	SNAP 4DX Plus™ (Anaplasma) result[e]	IFA titer[f]
1	214	986	315	platys	31.6%	25600
2	9	1	97	NEG	40.1%	25600
3	37	19	107	phago	14.7%	12800
4	17	5	151	phago	30.1%	25600
5	68	24	38	phago	18.3%	6400
6	37	27	47	phago	23.8%	6400

Sample ID	Combo Score[a]	platys Score[b]	phago WCL score[c]	Anaplasma species determined with peptides and cell extract[d]	SNAP 4DX Plus™ (Anaplasma) result[e]	IFA titer[f]
7	21	6	30	phago	7.0%	3200
8	10	2	39	phago	18.7%	6400
9	29	2	172	phago	32.0%	25600
10	12	1	86	phago	14.5%	12800
11	6	-1	89	NEG	12.4%	3200
12	165	0	110	phago	39.0%	25600
13	52	2	362	phago	37.3%	25600
14	18	-1	69	phago	40.0%	25600
15	49	3	206	phago	39.3%	25600
16	26	10	79	phago	22.2%	3200
17	34	4	30	phago	25.3%	6400
18	40	2	82	phago	34.3%	25600
19	6	2	51	NEG	11.4%	3200
20	22	0	141	phago	26.8%	1600
21	302	245	8	platys	25.9%	12800
22	91	33	10	platys	17.5%	1600
23	12	7	24	phago	46.3%	51200
24	483	714	6	platys	11.7%	6400
25	61	53	18	platys	19.7%	6400
26	117	122	49	platys	7.3%	51200
27	244	140	16	platys	27.7%	12800
28	25	37	15	platys	28.2%	12800
29	56	72	21	platys	17.9%	12800
30	156	250	2	platys	9.2%	1600
31	517	880	17	platys	39.3%	12800
32	23	25	30	phago	8.3%	3200
33	6	4	24	NEG	20.9%	25600
34	18	23	5	platys	13.8%	1600
35	82	79	33	platys	45.0%	6400
36	35	27	18	platys	17.1%	3200
37	354	256	26	platys	49.0%	6400
38	6	19	36	NEG	43.9%	25600
39	20	45	20	platys	19.7%	12800
40	60	186	8	platys	1.3%	1600
41	2	1	46	NEG	4.9%	< 1:50 (NEG)

[a] Combo Score was calculated by comparing OD readings of unknown samples from Plate 1 to a standard curve generated with OD readings of a serially diluted calibrator made of known positive samples analyzed under the same conditions (with peptide populations APL-ID1, APL-ID5.1, and APL-ID6).

[b] platys Score was calculated by comparing OD readings of unknown samples from Plate 2 to a standard curve generated with OD readings of a serially diluted calibrator made of known positive samples analyzed under the same conditions (with peptide populations APL-ID5.1, and APL-ID6).

[c] phago WCL Score was calculated by comparing OD readings of unknown samples from Plate 3 to a two point standard curve comprised of result from a healthy dog's plasma sample (negative control) and result from a plasma sample from 3-13, a dog experimentally infected with *A. phagocytophilum*, analyzed under the same conditions (with *A. phagocytophilum* whole-cell lysate).

[d] Identification of the *Anaplasma* species infecting dogs in unknown samples using the Combo Score, platys Score, and phago WCL Score. Samples with Combo Scores of 9 or lower are classified as negative for *Anaplasma* infection ("NEG"). Samples with Combo Scores higher than 9 are classified as positive for *Anaplasma* infection and the infecting *Anaplasma* species are assigned by comparing the platys Score with the phago WCL Score--samples with higher platys Scores than phago WCL Scores are classified as positive for *A. platys* infection ("platys"), and samples with lower platys Scores than phago WCL Scores are classified as positive for *A. phagocytophilum* infection ("phago"). If a sample's platys Score is identical to its phago WCL Score, and its combo score is greater than 9, the sample is classified as positive for *Anaplasma* infection with species indeterminate.

[e] IDEXX SNAP 4DX Plus™ assay was performed according to manufacturer's instruction. Percentages were calculated through densitometry analysis of images of the SNAP cassettes. They represent "(density of test sample)/(density of test sample + density of positive control)".

[f] The IFA assay was performed with a commercial kit which used *A. phagocytophilum* cells to detect antibodies against *Anaplasma*. IFA titers were determined by serially diluting plasma samples and testing each dilution with immobilized *A. phagocytophilum* cells.

[00188] The result in this Example demonstrates that the species of *Anaplasma* infecting a subject can be successfully identified using the peptide populations and cell extract. In addition, a positive control sample from an *A. phagocytophilum*-infected dog, 3-13, was correctly identified in this Example (data not shown).

[00189] To the extent that any definitions in documents incorporated by reference are inconsistent with the definitions provided herein, the definitions provided herein are controlling. Although the invention has been described with reference to the presently preferred embodiments, it should be understood that various changes and modifications, as would be obvious to one skilled in the art, can be made without departing from the spirit of the invention. Accordingly, the invention is limited only by the following claims.

[00190] The disclosures, including the claims, figures and/or drawings, of each and every patent, patent application, and publication cited herein are hereby incorporated herein by reference in their entireties.

CLAIMS:

1. A composition comprising a population of isolated peptides, said population comprising three or more different peptides, wherein each peptide in the population comprises a sequence of:

(i) Abaxis ID 2 (SEQ ID NO: 1) or a fragment thereof, wherein X_9 is an amino acid selected from the group consisting of I, P or H, X_{17} is an amino acid selected from the group consisting of I, W, or Y, X_{21} is an amino acid selected from the group consisting of R, D, or N, X_{28} is an amino acid selected from the group consisting of E or N, and X_{31} is an amino acid selected from the group consisting of L or V;

(ii) Abaxis ID 3 (SEQ ID NO: 2) or a fragment thereof, wherein X_3 is an amino acid selected from the group consisting of L, V or A, X_7 is an amino acid selected from the group consisting of K, N or Q, X_{11} is an amino acid selected from the group consisting of R, D, or N, and X_{15} is an amino acid selected from the group consisting of E, N or Q;

(iii) APL-ID1 (SEQ ID NO: 3) or a fragment thereof, wherein X_5 is an amino acid selected from the group consisting of V or A, X_7 is an amino acid selected from the group consisting of G, I or H, X_{11} is an amino acid selected from the group consisting of E, N, or Q, X_{18} is an amino acid selected from the group consisting of D or N, X_{21} is an amino acid selected from the group consisting of R, D, or N, X_{25} is an amino acid selected from the group consisting of Q, D, or E, X_{28} is an amino acid selected from the group consisting of E or N, X_{31} is an amino acid selected from the group consisting of L or V, X_{45} is an amino acid selected from the group consisting of K or Q, X_{48} is an amino acid selected from the group consisting of F or V, X_{51} is an amino acid selected from the group consisting of D or N, X_{54} is an amino acid selected from the group consisting of E or Q, X_{57} is an amino acid selected from the group consisting of S or Q, X_{60} is an amino acid selected from the group consisting of F or W, X_{63} is an amino acid selected from the group consisting of I or V, and X_{66} is an amino acid selected from the group consisting of Q or D;

(iv) APL-ID2 (SEQ ID NO: 4) or a fragment thereof, wherein X_6 is an amino acid selected from the group consisting of K or Q, X_9 is an amino acid selected from the group consisting of F or V, X_{12} is an amino acid selected from the group consisting of D or N, X_{15} is an amino acid selected from the group consisting of E or Q, X_{18} is an amino acid selected from the group consisting of S or Q, X_{21} is an amino acid selected from the group consisting of F or W,

X_{24} is an amino acid selected from the group consisting of I or V, and X_{27} is an amino acid selected from the group consisting of Q or D;

(v) APL-ID3 (SEQ ID NO: 5) or a fragment thereof, wherein X_2 is an amino acid selected from the group consisting of I or V, X_{10} is an amino acid selected from the group consisting of S or Y, and X_{23} is an amino acid selected from the group consisting of E or N;

(vi) APL-ID5.1 (SEQ ID NO: 6) or a fragment thereof;

(vii) APL-ID6 (SEQ ID NO: 7) or a fragment thereof, wherein X_5 is an amino acid selected from the group consisting of S or Q, X_9 is an amino acid selected from the group consisting of F or Y, X_{13} is an amino acid selected from the group consisting of R or H, X_{16} is an amino acid selected from the group consisting of W or Y, X_{18} is an amino acid selected from the group consisting of S or Q, X_{22} is an amino acid selected from the group consisting of K or H, and X_{27} is an amino acid selected from the group consisting of N or D;

(viii) APL-ID7 (SEQ ID NO: 8) or a fragment thereof, wherein X_{10} is an amino acid selected from the group consisting of V, L or I, and X_{11} is an amino acid selected from the group consisting of A or L; or

(ix) APID 2-1 (SEQ ID NO: 9) or a fragment thereof, wherein X_5 is an amino acid selected from the group consisting of V or A, X_7 is an amino acid selected from the group consisting of G, I or H, X_{11} is an amino acid selected from the group consisting of E, N, or Q, X_{21} is an amino acid selected from the group consisting of R, D, or N, X_{25} is an amino acid selected from the group consisting of Q, D, or E, X_{28} is an amino acid selected from the group consisting of E or N, and X_{31} is an amino acid selected from the group consisting of L or V.

2. The composition of claim 1, wherein one or more of the peptides is conjugated to a ligand.

3. The composition of any one of the proceeding claims, wherein one or more of the peptides is conjugated to biotin, avidin, streptavidin, neutravidin, serum albumin, keyhole limpet hemocyanin (KLH), an enzyme, or a metallic nanomaterial.

4. The composition of any one of the proceeding claims, wherein the population of peptides is immobilized to a solid support optionally through a metallic nanolayer.

5. The composition of claim 4, wherein the solid support is a plurality of beads, a flow path in a lateral flow immunoassay device, a well in a microtiter plate, or a flow path in a rotor.

6. The composition of any one of the proceeding claims, wherein the fragment is at least 15, 20, 25, 30, 35, 40, 45, 50, 55, or 60 amino acids long.

7. The composition of any one of the proceeding claims, wherein the composition further comprises one or more antigenic peptides from an *Anaplasma* species, an *Ehrlichia* species, and/or a *Borrelia* species.

8. The composition of any one of the proceeding claims, wherein the composition comprises at least two different populations of peptides recited in claim 1.

9. The composition of claim 8, wherein at least one of the populations of peptides is defined by SEQ ID NO: 3.

10. The composition of claim 9, wherein the composition further comprises a second population of isolated peptides defined by SEQ ID NO: 7.

11. The composition of claim 10, wherein the composition further comprises a third population of isolated peptides, wherein each peptide comprises the sequence of SEQ ID NO: 6.

12. The composition of claim 9, wherein the composition further comprises a second population of isolated peptides, wherein each peptide comprises the sequence of SEQ ID NO: 6.

13. A method for detecting in a sample an antibody to an epitope of an *Anaplasma* antigen, the method comprising:

contacting a sample with the composition of any one of claims 1-12; and

detecting formation of an antibody-peptide complex comprising one or more peptides in the composition, wherein formation of said complex is indicative of an antibody to an epitope of an *Anaplasma* antigen being present in said sample.

14. The method of claim 13, wherein said *Anaplasma* antigen is from *Anaplasma phagocytophilum*, *Anaplasma platys*, or *Anaplasma marginale*.

15. The method of any one of claims 13-14, wherein the composition of isolated peptides is immobilized to a solid support optionally through a metallic nanolayer.

16. The method of claim 15, wherein said solid support is a plurality of beads, a flow path in a lateral flow assay device, a well in a microtiter plate, or a flow path in a rotor.

17. The method of any one of claims 13-16, wherein said detecting step comprises (i) performing an ELISA assay, (ii) running a lateral flow assay, (iii) performing an agglutination assay, (iv) performing a Western blot, a slot blot, or dot blot, (v) performing a wavelength shift assay, (vi) performing an Indirect Fluorescent Antibody test, or (vii) running the sample through an analytical or centrifugal rotor.

18. The method of any one of claims 13-17, wherein said sample is from a human, canine, or feline subject.

19. The method of any one of claims 13-18, wherein said sample is a blood, serum, plasma, cerebrospinal fluid, tissue extract, urine, or saliva sample.

20. A method for diagnosing anaplasmosis in a subject, the method comprising:

contacting a sample from the subject with the composition of any one of claims 1-12; and

detecting formation of an antibody-peptide complex comprising one or more peptides in the composition,

wherein formation of the complex is indicative of the subject having anaplasmosis.

21. The method of claim 20, wherein said subject is a human, canine, or feline.

22. A kit comprising the composition of any one of claims 1-12 and a labeling reagent capable of binding to an antibody that recognizes an epitope of one or more peptides in the composition.

23. The kit of claim 22, wherein the peptides in the composition are attached to or immobilized on a solid support optionally through a metallic nanolayer.

24. The kit of claim 22, wherein the labeling reagent is an anti-human, anti-canine, or anti-feline IgG or IgM antibody conjugated to a detectable label.

25. The kit of claim 24, wherein the detectable label is an enzyme, a metallic nanoparticle, metallic nanoshell, metallic nanolayer, fluorophore, or colored latex particle.

26. The kit of claim 22, wherein the labeling reagent is protein A, protein G, and/or a protein A/G fusion protein conjugated to a detectable label.

27. The kit of claim 26, wherein the detectable label is an enzyme, a metallic nanoparticle, metallic nanoshell, metallic nanolayer, fluorophore, or colored latex particle.

28. A method for identifying the species of *Anaplasma* infecting a subject, the method comprising:

(a) contacting a sample from the subject with a first population of isolated peptides and a second population of isolated peptides, wherein the first population of isolated peptides specifically binds to antibodies against antigens from multiple *Anaplasma* species, wherein the second population of isolated peptides specifically binds to antibodies against antigens from a single *Anaplasma* species;

(b) detecting formation of a first antibody-peptide complex comprising one or more peptides in the first population; and

(c) detecting formation of a second antibody-peptide complex comprising one or more peptides in the second population, wherein formation of both the first and second antibody-peptide complexes indicates that the subject is infected with the *Anaplasma* species that is specifically bound by the second population of isolated peptides.

29. The method of claim 28, wherein the first population of isolated peptides specifically binds to antibodies against antigens from *A. phagocytophilum* and *A. platys*.

30. The method of claim 29, wherein the first population of isolated peptides is defined by SEQ ID NO: 3.

31. The method of claim 28, wherein the second population of isolated peptides specifically binds to antibodies against antigens from *A. platys*.

32. The method of claim 31, wherein the second population of isolated peptides is defined by SEQ ID NO: 4.

33. The method of any one of claims 28-32, wherein the first population of isolated peptides is defined by SEQ ID NO: 3 and the second population of isolated peptides is defined by SEQ ID NO: 4, and wherein formation of both the first and second antibody-peptide complexes indicates that the subject is infected with *A. platys*.

34. The method of any one of claims 28-32, wherein the first population of isolated peptides is defined by SEQ ID NO: 3 and the second population of isolated peptides is defined by SEQ ID NO: 4, and wherein formation of the first antibody-peptide complex, but not the second antibody-peptide complex indicates that the subject is infected with *A. phagocytophilum*.

35. A method for identifying the species of *Anaplasma* infecting a subject, the method comprising:

(a) contacting a sample from the subject with a first population of isolated peptides and a cell extract of a single *Anaplasma* species, wherein the first population of isolated peptides specifically binds to antibodies against antigens from multiple *Anaplasma* species;

(b) detecting formation of a first antibody-peptide complex comprising one or more peptides in the first population; and

(c) detecting formation of an antibody-cell extract complex comprising one or more components in the cell extract, wherein formation of both the first antibody-peptide complex and the antibody-cell extract complex indicates that the subject is infected with the *Anaplasma* species that produced the cell extract.

36. The method of claim 35, wherein the first population of isolated peptides specifically binds to antibodies against antigens from *A. phagocytophilum* and *A. platys*.

37. The method of claim 36, wherein the first population of isolated peptides is defined by SEQ ID NO: 3.

38. The method of any one of claims 35-37, wherein the cell extract is from *A. phagocytophilum*.

Fig. 1

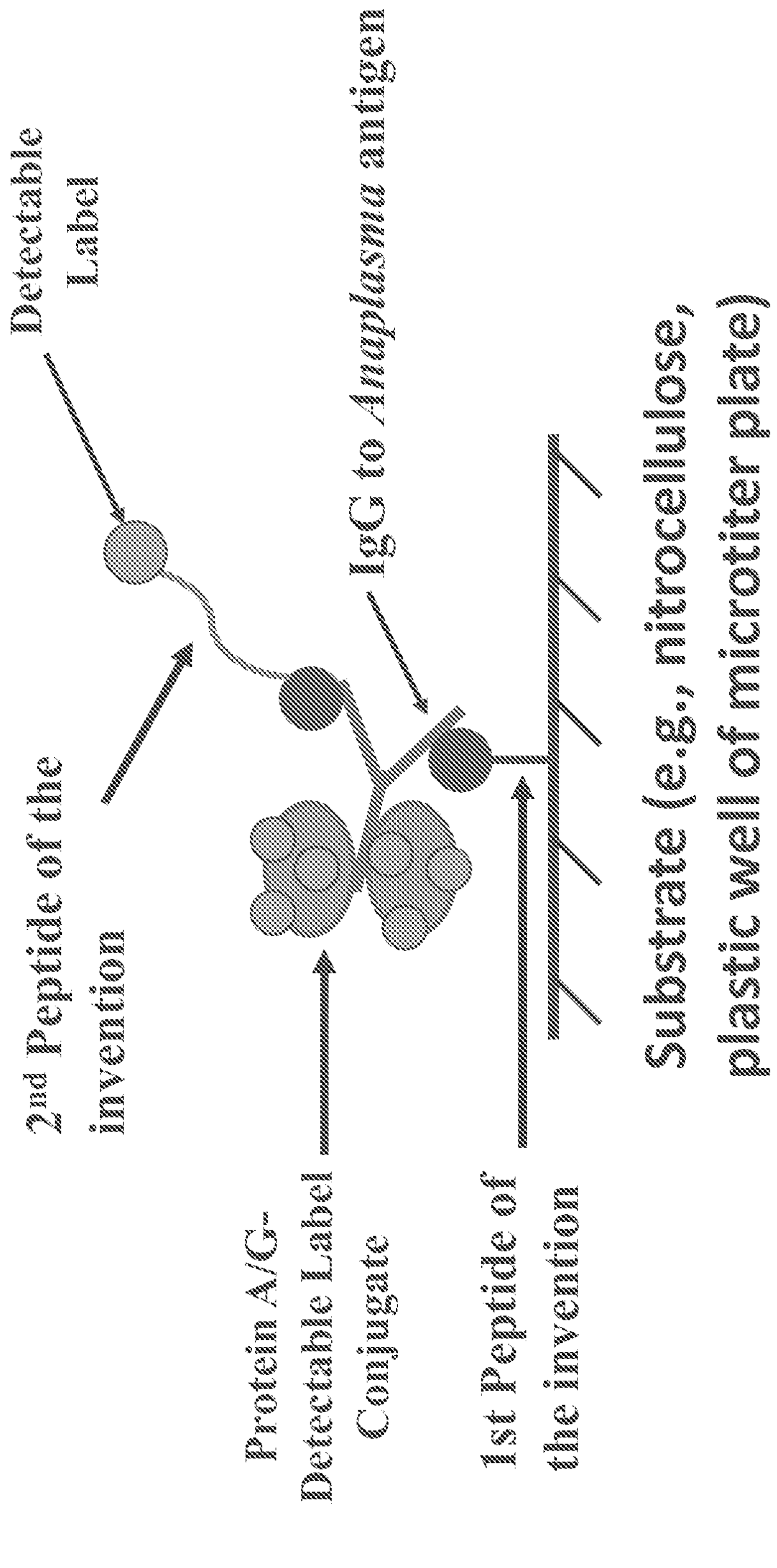

Detectable Label
IgG to *Anaplasma* antigen
2nd Peptide of the invention
Protein A/G-Detectable Label Conjugate
1st Peptide of the invention
Substrate (e.g., nitrocellulose, plastic well of microtiter plate)

Fig. 2

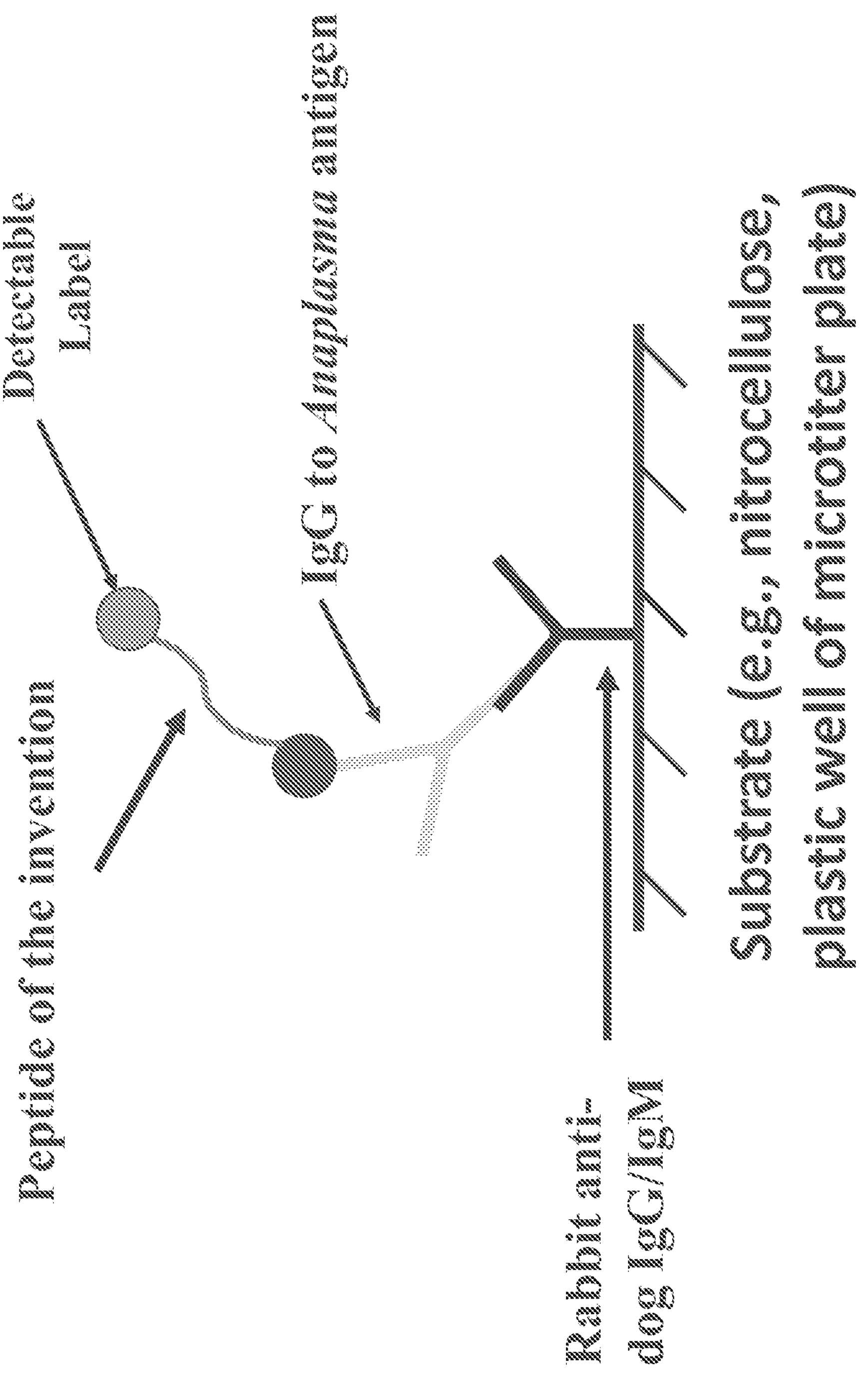

Peptide of the invention
Detectable Label
IgG to *Anaplasma* antigen
Rabbit anti-dog IgG/IgM
Substrate (e.g., nitrocellulose, plastic well of microtiter plate)

Fig. 3

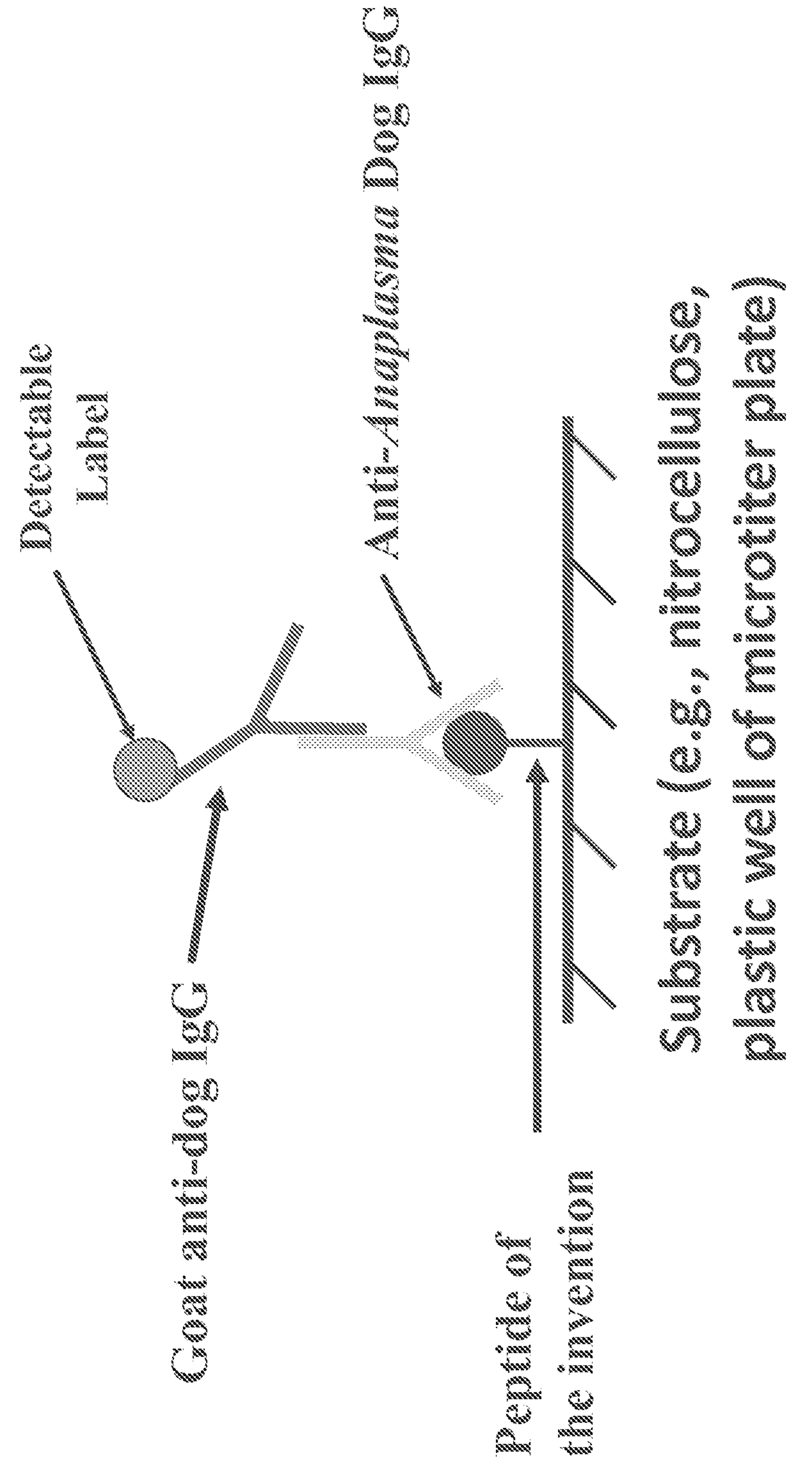

Detectable Label
Anti-*Anaplasma* Dog IgG
Goat anti-dog IgG
Peptide of the invention
Substrate (e.g., nitrocellulose, plastic well of microtiter plate)

Fig. 4

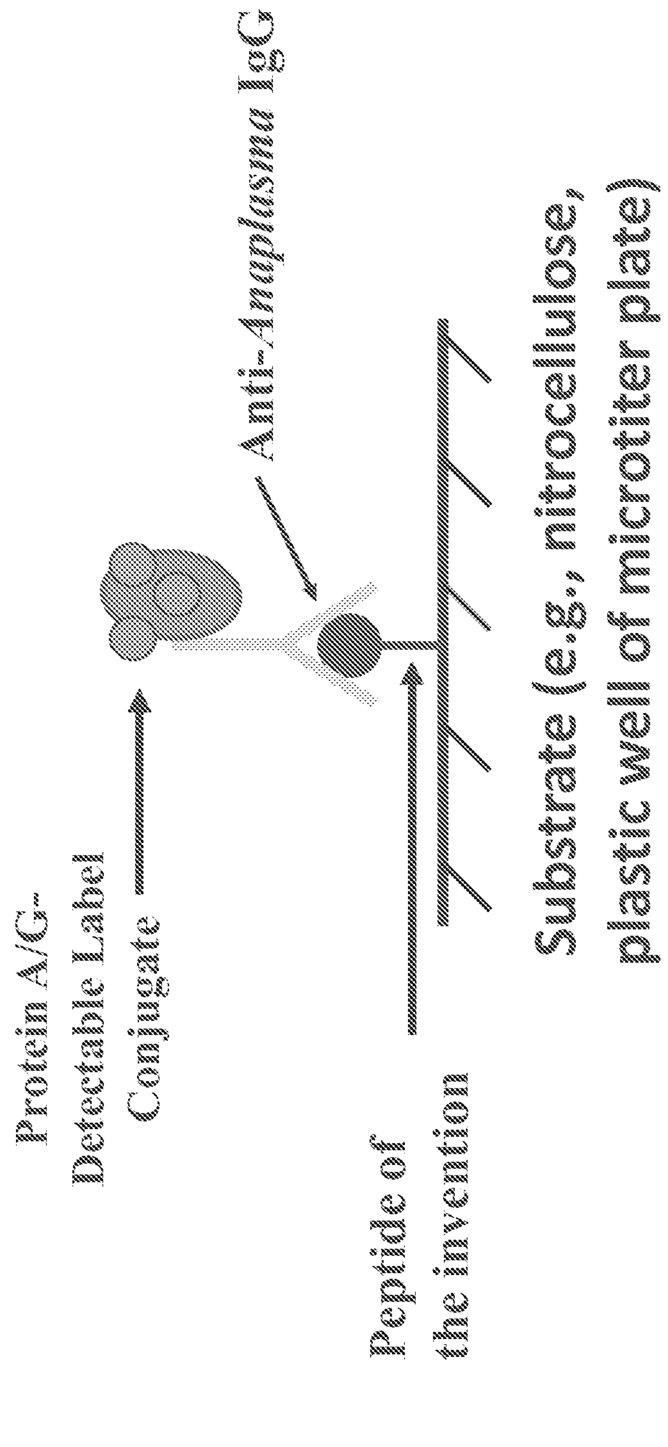

Protein A/G–
Detectable Label
Conjugate
Anti-*Anaplasma* IgG
Peptide of
the invention
Substrate (e.g., nitrocellulose,
plastic well of microtiter plate)

Fig. 5

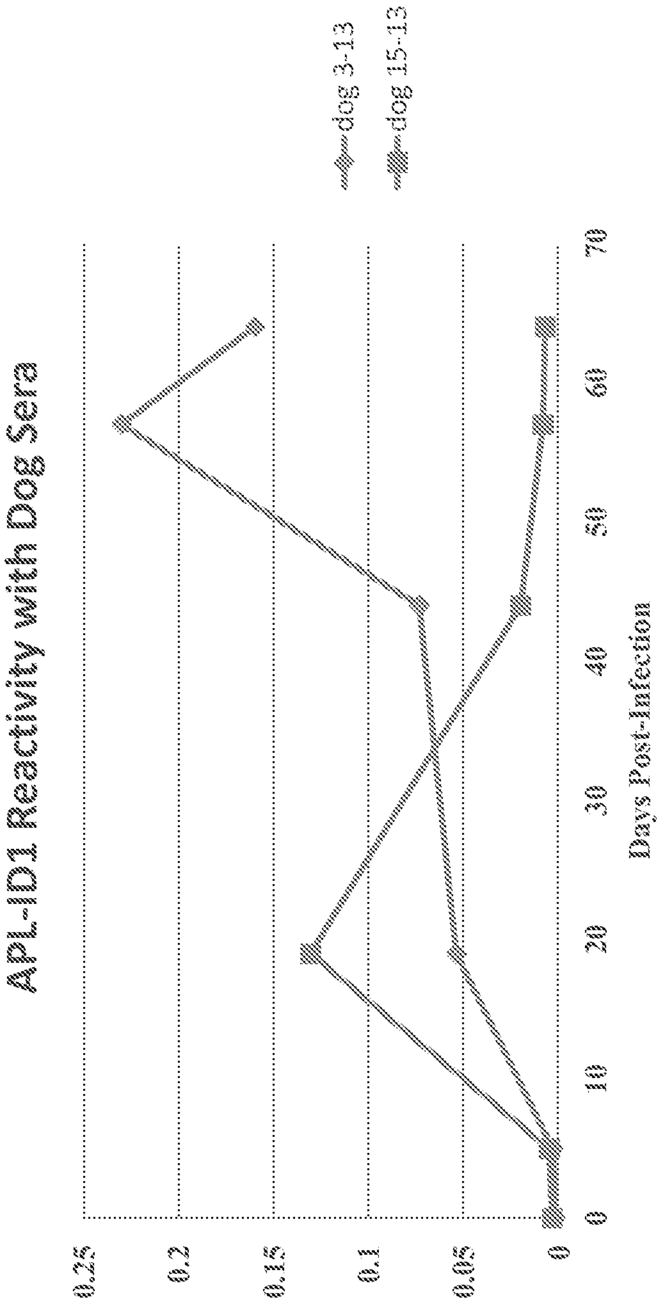
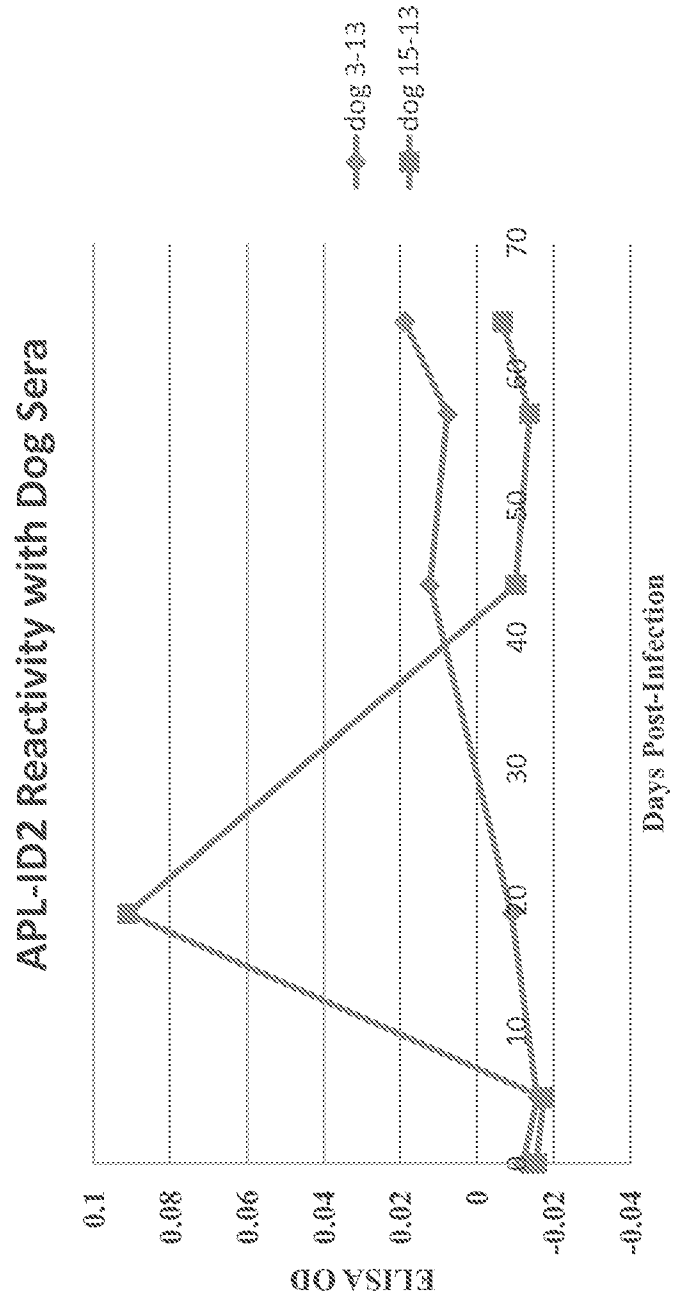

APL-ID1 Reactivity with Dog Sera
ELISA OD
0.25
0.2
0.15
0.1
0.05
0
0
10
20
30
40
50
60
70
Days Post-Infection
dog 3-13
dog 15-13

Fig. 6


APL-ID2 Reactivity with Dog Sera
ELISA OD
0.1
0.08
0.06
0.04
0.02
0
-0.02
-0.04
10
20
30
40
50
60
70
Days Post-Infection
dog 3-13
dog 15-13

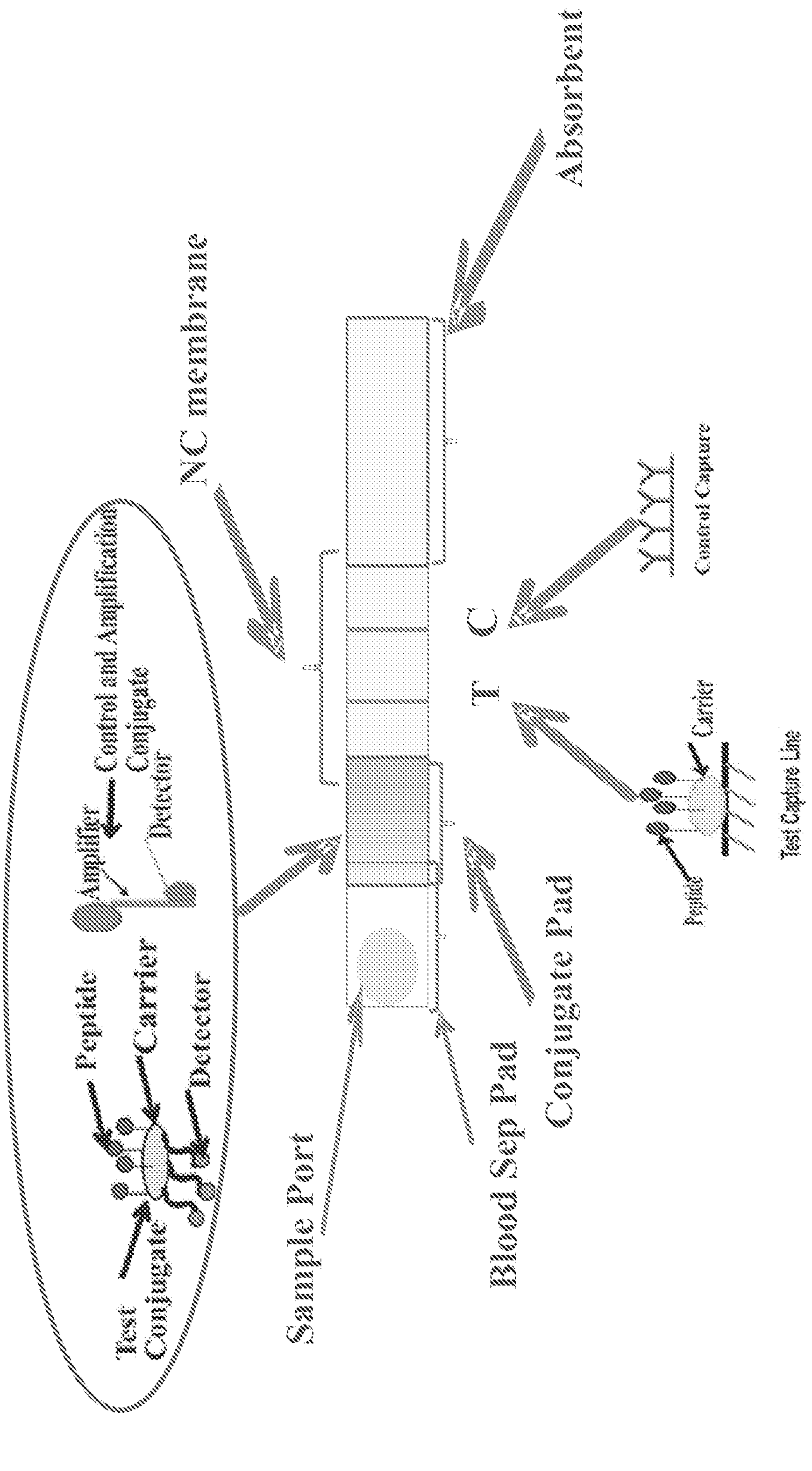
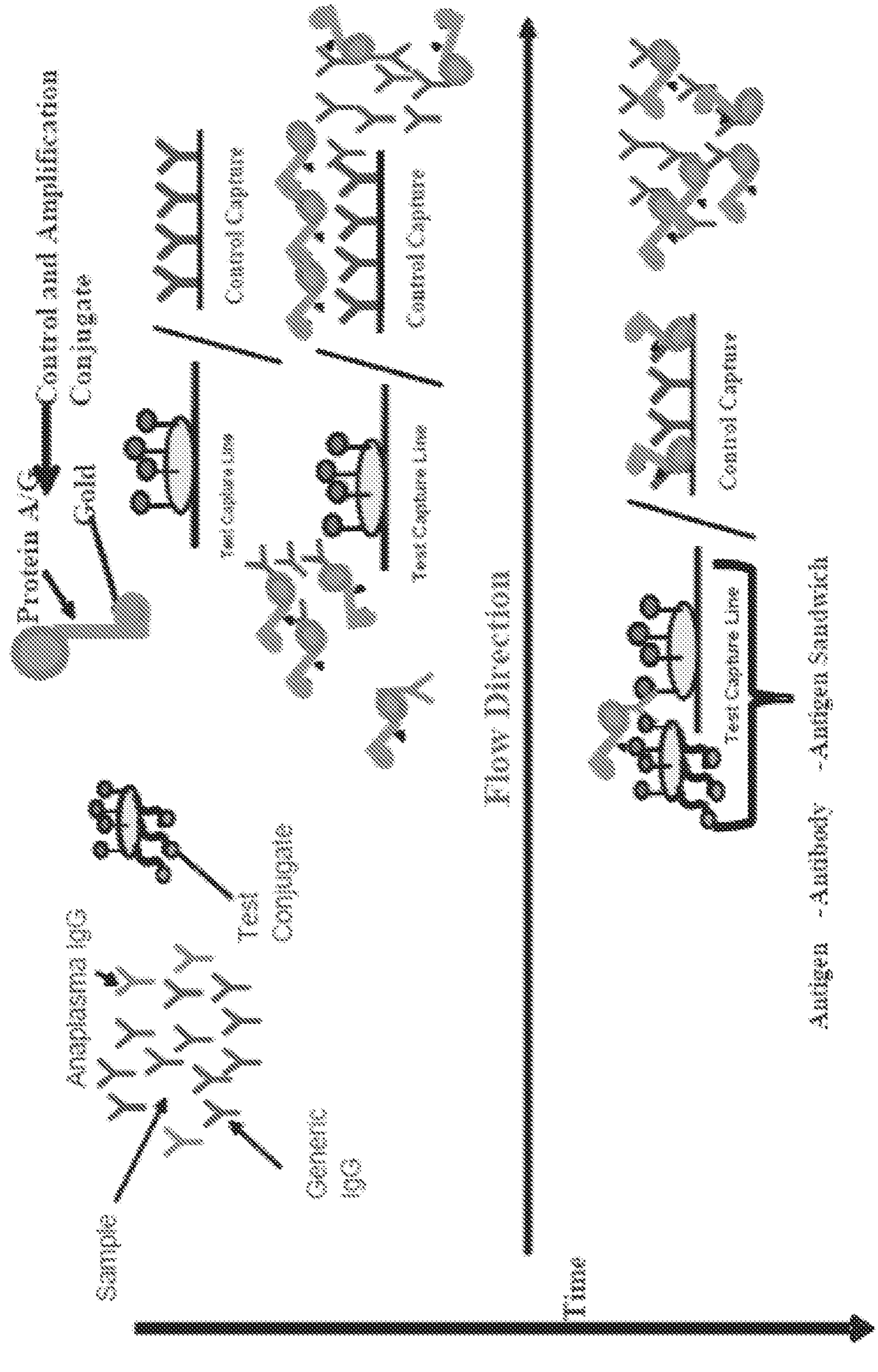

Absorbent
NC membrane
Control and Amplification
Conjugate
Detector
Amplifier
Peptide
Carrier
Detector
Test
Conjugate
Sample Port
Blood Sep Pad
Conjugate Pad
T
C
Control Capture
Carrier
Peptide
Test Capture Line

Fig. 7

Fig. 8


Sample
Anaplasma IgG
Generic IgG
Test Conjugate
Protein A/G
Gold
Control and Amplification Conjugate
Test Capture Line
Control Capture
Test Capture Line
Control Capture
Flow Direction
Time
Test Capture Line
Control Capture
Antigen -Antibody -Antigen Sandwich