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(54) Title: ANAPLASMA PHAGOCYTOPHILUM (APH) ANTIGENS AND ANTIBODIES SPECIFIC FOR ANAPLASMA

(57) Abstract: The invention provides methods and compositions for the detection and treatment of *Anaplasma phagocytophilum* and *Anaplasma platys* infection.



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**TITLE: *Anaplasma phagocytophilum* (Aph) Antigens and Antibodies Specific for *Anaplasma***

**PRIORITY**

5 This application claims priority to U.S. Ser. No. 60/990,420, filed November 27, 2007, which is incorporated herein by reference in its entirety.

**BACKGROUND OF THE INVENTION**

10 Anaplasmosis occurs in numerous mammal species such as humans, horses, dogs, cats, deer, and ruminants and is caused by infection of granulocytic cells with the tick-borne agent *Anaplasma phagocytophilum* ("Aph") (formerly known as *Ehrlichia equi*). Frequently reported clinical signs in granulocytic ehrlichiosis in humans are leukopenia and thrombocytopenia. Common clinical signs in dogs are fever, thrombocytopenia, swelling of the lymph nodes, and anorexia.

15 *Anaplasma platys* ("Apl") (formerly known as *Ehrlichia platys*) is another agent that is likely transmitted through ticks such as *Rhipicephalus sanguineus* or other arthropod. *A. platys* may be co-transmitted by a tick with *Ehrlichia canis*. *A. platys* can cause infectious canine cyclic thrombocytopenia (ICCT), but infected dogs are usually asymptomatic. *A. platys* infection is difficult to detect *in vivo* because the numbers of the bacteria in the blood are usually low. Serologic tests for *Apl* can be inaccurate because of cross-reactivity with other *Anaplasma* sp.

20 Tickborne infectious disease caused by *A. phagocytophilum* in human and dogs is a serious problem, whereas *A. platys* infection is presently considered to be of minor importance. Current serodiagnostic tools for *A. phagocytophilum* can not differentiate the two infections. Methods of detecting *Aph* and *Apl* and methods of differentiating between the two infections are needed in the art.

25 The onset of clinical symptoms occurs during the acute phase of anaplasmosis - typically within 7 to 14 days post infection - and can precede the advent of measurable levels of antibodies against some *Aph* antigens. Thus, there is a need for a rapid, sensitive and reliable immunological test for *Aph* infection in mammals exhibiting clinical symptoms of acute anaplasmosis.

30 **SUMMARY OF THE INVENTION**

One embodiment of the invention provides a purified polypeptide that is at least 95% identical to SEQ ID NO:1, 2, 6, 8, 9, 10, 11, or 12, wherein the purified polypeptide consists of less than about 300, 150, 100, or 50 contiguous naturally occurring *Anaplasma phagocytophilum*

amino acids. The polypeptide can specifically binds an antibody specific for *Anaplasma phagocytophilum*. The purified polypeptide can be linked to an indicator reagent, an amino acid spacer, an amino acid linker, a signal sequence, a stop transfer sequence, a transmembrane domain, a protein purification ligand, a heterologous polypeptide, one or more additional polypeptides comprising SEQ ID NO:1, 2, 6, 8, 9, 10, 11, 12 or a combination thereof. The invention provides isolated polynucleotides that encode the purified polypeptides of the invention.

Another embodiment of the invention provides a method of detecting antibodies that specifically bind an *Anaplasma phagocytophilum* polypeptide in a test sample. The method comprises contacting one or more purified polypeptides at least 95% identical to SEQ ID NO:1, 9 or 11, with the test sample, under conditions that allow polypeptide/antibody complexes to form. The purified polypeptides can consist of less than about 150 contiguous naturally occurring *Anaplasma phagocytophilum* amino acids. The polypeptide/antibody complexes are detected. The detection of the polypeptide/antibody complexes is an indication that antibodies specific for *Anaplasma phagocytophilum* are present in the test sample, and the lack of detection of the polypeptide/antibody complexes is an indication that antibodies specific for *Anaplasma phagocytophilum* are not present in the test sample. The complexes can be contacted with an indicator reagent prior to the detection step. The amount of antibodies in the test sample can be determined. The one or more purified polypeptides can be attached to a substrate. The one or more purified polypeptides can be linked to an indicator reagent, an amino acid spacer, an amino acid linker, a signal sequence, a stop transfer sequence, a transmembrane domain, a protein purification ligand, a heterologous protein, one or more additional polypeptides comprising SEQ ID NO:1, 9, or 11, or a combination thereof.

Even another embodiment of the invention provides a method of detecting an *Anaplasma phagocytophilum* infection in a subject. The method comprises obtaining a biological sample from the subject; contacting one or more purified polypeptides that are at least 95% identical to SEQ ID NO:1, 9 or 11, wherein the purified polypeptides consist of less than about 150 contiguous naturally occurring *Anaplasma phagocytophilum* amino acids, with the biological sample under conditions that allow polypeptide/antibody complexes to form; and detecting the polypeptide/antibody complexes. The detection of the polypeptide/antibody complexes is an indication that the subject has an *Anaplasma phagocytophilum* infection and the lack of detection

of the polypeptide/antibody complexes is an indication that the subject does not have an *Anaplasma phagocytophilum* infection.

Still another embodiment of the invention provides an antibody that specifically binds to a polypeptide consisting of SEQ ID NO:1, 2, 6, 8, 9, 10, 11, or 12. The antibody can be a  
5 monoclonal antibody, polyclonal antibody, a Fab fragment, a Fab' fragment, Fab'-SH fragment, F(ab')<sub>2</sub> fragment, Fv fragment, or a single chain antibody.

Yet another embodiment of the invention provides a method of detecting an *Anaplasma phagocytophilum* polypeptide in a sample. The method comprises contacting one or more antibodies that specifically bind to a polypeptide consisting of SEQ ID NO:1, 9, or 11 with the  
10 sample under conditions that allow polypeptide/antibody complexes to form, and detecting the polypeptide/antibody complexes. The detection of the polypeptide/antibody complexes is an indication that an *Anaplasma phagocytophilum* polypeptide is present in the sample and the lack of detection of the polypeptide/antibody complexes is an indication that an *Anaplasma phagocytophilum* polypeptide is not present in the sample. The one or more antibodies can be  
15 monoclonal antibodies, polyclonal antibodies, Fab fragments, Fab' fragments, Fab'-SH fragments, F(ab')<sub>2</sub> fragments, Fv fragments, or single chain antibodies.

Even another embodiment of the invention provides a method of detecting antibodies that specifically bind an *Anaplasma platys* polypeptide, an *Anaplasma phagocytophilum* polypeptide or both an *Anaplasma platys* polypeptide and an *Anaplasma phagocytophilum* polypeptide. The  
20 method comprises contacting one or more purified polypeptides that are at least 95% identical to SEQ ID NO:2, 6, 8, 10, or 12 with a test sample, under conditions that allow polypeptide/antibody complexes to form, and detecting the polypeptide/antibody complexes. The detection of the polypeptide/antibody complexes is an indication that antibodies specific for *Anaplasma platys* and/or *Anaplasma phagocytophilum* are present in the test sample, and the  
25 lack of detection of the polypeptide/antibody complexes is an indication that antibodies specific for *Anaplasma platys* and/or *Anaplasma phagocytophilum* are not present in the test sample. The amount of antibodies in the test sample can be determined. The one or more purified polypeptides can be attached to a substrate. The one or more purified polypeptides can be linked to an indicator reagent, an amino acid spacer, an amino acid linker, a signal sequence, a stop  
30 transfer sequence, a transmembrane domain, a protein purification ligand, a heterologous protein,

one or more additional polypeptides comprising SEQ ID NO:1, 2, 6, 8, 9, 10, 11, 12 or a combination thereof.

Another embodiment of the invention provides a method of detecting an *Anaplasma phagocytophilum* and/or *Anaplasma platys* infection in a subject. The method comprises  
5 obtaining a biological sample from the subject; contacting one or more purified polypeptides comprising SEQ ID NO:2, 6, 8, 10, or 12 with the biological sample under conditions that allow polypeptide/antibody complexes to form; and detecting the polypeptide/antibody complexes. The detection of the polypeptide/antibody complexes is an indication that the subject has an *Anaplasma phagocytophilum* and/or *Anaplasma platys* infection and the lack of detection of  
10 polypeptide/antibody complexes is an indication that the subject does not have an *Anaplasma phagocytophilum* and/or *Anaplasma platys* infection.

Even another embodiment of the invention provides a method of detecting an *Anaplasma phagocytophilum* polypeptide, an *Anaplasma platys* polypeptide, or an *Anaplasma phagocytophilum* polypeptide and an *Anaplasma platys* polypeptide, in a sample. The method  
15 comprises contacting one or more antibodies that specifically bind to a polypeptide consisting of SEQ ID NO:2, 6, 8, 10, or 12 with the sample under conditions that allow polypeptide/antibody complexes to form, and detecting the polypeptide/antibody complexes. The detection of the polypeptide/antibody complexes is an indication that an *Anaplasma phagocytophilum* polypeptide, an *Anaplasma platys* polypeptide, or an *Anaplasma phagocytophilum* polypeptide  
20 and an *Anaplasma platys* polypeptide is present in the sample and the lack of detection of the polypeptide/antibody complexes is an indication that an *Anaplasma phagocytophilum* and an *Anaplasma platys* polypeptide is not present in the sample.

Still another embodiment of the invention provides a method of detecting *Anaplasma platys* polypeptides and *Anaplasma phagocytophilum* polypeptides in a sample. The method  
25 comprises:

- (a) contacting one or more antibodies that specifically bind to a polypeptide consisting of SEQ ID NO:2, 6, 8, 10, or 12 with the sample under conditions that allow polypeptide/antibody complexes to form and detecting the polypeptide/antibody complexes; and

(b) contacting one or more antibodies that specifically bind to a polypeptide consisting of SEQ ID NO:1, 9, or 11 with the sample under conditions that allow polypeptide/antibody complexes to form and detecting the polypeptide/antibody complexes;

(c) wherein if the polypeptide/antibody complexes are detected in step (a) and in step (b) then the sample contains *Anaplasma phagocytophilum* polypeptides and may also contain *Anaplasma platys* polypeptides; wherein if the polypeptide/antibody complexes are detected in step (a) and are not detected in step (b) then the sample contains *Anaplasma platys* polypeptides and does not contain *Anaplasma phagocytophilum* polypeptides; wherein if the polypeptide complexes are not detected in step (a) and are not detected in step (b) then the sample does not contain *Anaplasma platys* polypeptides and does not contain *Anaplasma phagocytophilum* polypeptides.

Another embodiment of the invention provides a method of detecting antibodies that specifically bind an *Anaplasma platys* polypeptide, an *Anaplasma phagocytophilum* polypeptide, or both an *Anaplasma platys* polypeptide and an *Anaplasma phagocytophilum* polypeptide. The method comprises:

(a) contacting one or more purified polypeptides that are at least 95% identical to SEQ ID NO:2, 6, 8, 10, or 12 with a test sample, under conditions that allow polypeptide/antibody complexes to form and detecting the polypeptide/antibody complexes;

(b) contacting one or more purified polypeptides that are at least 95% identical to SEQ ID NO:1, 9, or 11, wherein the purified polypeptide consists of less than about 150 contiguous naturally occurring *Anaplasma phagocytophilum* amino acids, with a test sample, under conditions that allow polypeptide/antibody complexes to form and detecting the polypeptide/antibody complexes. If the polypeptide/antibody complexes are detected in step (a) and in step (b) then the sample contains antibodies that specifically bind *Anaplasma phagocytophilum* polypeptides and *Anaplasma platys* polypeptides and antibodies that specifically bind only *Anaplasma platys* polypeptides; wherein if the polypeptide/antibody complexes are detected in step (a) and are not detected in step (b) then the sample contains antibodies that specifically bind *Anaplasma platys* polypeptides and *Anaplasma phagocytophilum* polypeptides and does not contain antibodies that specifically bind only *Anaplasma phagocytophilum* polypeptides; wherein if the polypeptide complexes are not detected in step (a) and are not detected in step (b) then the sample does not contain antibodies

specific for *Anaplasma platys* polypeptides and does not contain antibodies specific for *Anaplasma phagocytophilum* polypeptides.

Even another embodiment of the invention provides a composition comprising a purified polypeptide of the invention and a pharmaceutically-acceptable or veterinarily acceptable carrier.

5 The composition can further comprise an adjuvant.

Still another embodiment of the invention provides an immunogen comprising a polypeptide having at least 95% identity to SEQ ID NO:1, 2, 6, 8, 9, 10, 11, or 12, and one or more additional regions or moieties covalently joined to the polypeptide at the carboxyl terminus or amino terminus, wherein each region or moiety has at least one of the following properties:  
10 enhances the immune response, facilitates purification, or facilitates polypeptide stability.

Yet another embodiment of the invention provides a method of treating or ameliorating *Anaplasma platys* infection, *Anaplasma phagocytophilum* infection, or both in a mammalian subject. The method comprises administering to the mammalian subject a therapeutically effective amount of a composition comprising a purified polypeptide of the invention and a  
15 pharmaceutically-acceptable or veterinarily acceptable carrier. The composition can further comprise an adjuvant.

Another embodiment of the invention provides a method of inducing an immune response in a mammal comprising administering to the mammal an immunologically effective amount of a composition comprising a purified polypeptide of the invention and a  
20 pharmaceutically-acceptable or veterinarily acceptable carrier. The composition can further comprise an adjuvant.

Still another embodiment of the invention provides a first purified polypeptide that specifically binds an antibody, wherein the antibody specifically binds a second purified polypeptide, wherein the second purified polypeptide consists of SEQ ID NO:1, 2, 6, 8, 9, 10, 11, or 12. The first purified polypeptide can consist of at least 10, but less than 300 contiguous amino acids of SEQ ID NO: 1, 2, 6, 8, 9, 10, 11 or 12. The first purified polypeptide can be at  
25 least 95% identical to SEQ ID NO: 1, 2, 6, 8, 9, 10, 11 or 12. The first purified polypeptide can be linked to an indicator reagent, an amino acid spacer, an amino acid linker, a signal sequence, a stop transfer sequence, a transmembrane domain, a protein purification ligand, a heterologous  
30 polypeptide, one or more additional polypeptides comprising SEQ ID NO:1, 2, 6, 8, 9, 10, 11, 12, or a combination thereof.

The invention therefore provides methods and compositions for the detection and treatment of *Apl* and/or *Aph* infection.

## DETAILED DESCRIPTION OF THE INVENTION

### 5 *Anaplasma phagocytophilum* Polypeptides

The singular forms "a," "an", and "the" used herein include plural referents unless the context clearly dictates otherwise.

A polypeptide is a polymer of two or more amino acids covalently linked by amide bonds. A polypeptide can be post-translationally modified. A purified polypeptide is a  
10 polypeptide preparation that is substantially free of cellular material, other types of polypeptides, chemical precursors, chemicals used in synthesis of the polypeptide, etc, or combinations thereof. A polypeptide preparation that is substantially free of cellular material, culture medium, chemical precursors, chemicals used in synthesis of the polypeptide, etc. has less than about 30%, 20%, 10%, 5%, 1% or more of other polypeptides, culture medium, chemical precursors,  
15 and/or other chemicals used in synthesis. Therefore, a purified polypeptide is about 70%, 80%, 90%, 95%, 99% or more pure. A purified polypeptide does not include unpurified or semi-purified cell extracts or mixtures of polypeptides that are less than 70% pure.

The term "polypeptides" can refer to one or more of one type of polypeptide (a set of polypeptides). "Polypeptides" can also refer to mixtures of two or more different types of  
20 polypeptides (a mixture of polypeptides). The terms "polypeptides" or "polypeptide" can each also mean "one or more polypeptides."

One embodiment of the invention provides an *Aph* polypeptide as shown in SEQ ID NO: 1, SEQ ID NO:2, SEQ ID NO:8, SEQ ID NO:9, SEQ ID NO:10 or SEQ ID NO:11.

25  
SEQ ID NO:1 (clone14)  
LCATVHHIYQ GNYEDRNNDK GSSRGGGTTY YPMTMSASAS EESLSSIISE  
GXLSKTS LPS YSAATATGTG NXTGEVXSHS HSSGKSSSKP ESRPESNLQN  
VVAETMSQQQ RSVS

30 Wherein the X at position 52 is D or G; the X at position 72 is E or A; and the X at position 77 is absent or is F.

35  
SEQ ID NO:2 (clone13)  
HKGVDSDRKH DAEKTEEEKKH GLGSLCKSLA INLVSLMGTA LVXTPIILLA  
VLLLVLPVY LLCATVHHIY QGNYEDRNND KGSSRGGGTT YYPMTMSASA



SEESLSSIIIS EGXLSKTSLP SYSAATATGT GNXTGEVXSH SHSSGKSSSK  
PESRPESNLQ NVVAETMSQQ QRSVS

Wherein the X at position 43 is A or T; wherein the X at position 113 is D or G; wherein the X at  
5 position 133 is A or E; and wherein the X at position 138 is F or absent.

SEQ ID NO:8 (clone13ext)

10 CLGGKSPART TEERVAGDLD HKGVDSDRKH DAEKTEEKKH GLGSLCKSLA  
INLVSLMGTA LVXTPIILLA VVLLVLVPVY LLCATVHHIY QGNYEDRNND  
KGSSRGGGTT YYPMTMSASA SEESLSSIIIS EGXLSKTSLP SYSAATATGT  
GNXTGEVXSH SHSSGKSSSK PESRPESNLQ NVVAETMSQQ QRSVS

Wherein the X at position 63 is A or T; wherein the X at position 133 is D or G; wherein the X at  
15 position 153 is A or E; and wherein the X at position 158 is F or absent.

SEQ ID NO:9 (p37-1)  
CATVHHIYQG NYEDRNNDKG SSRGGGTTY PMTMSASASE ESL

20 SEQ ID NO:10 (p37-2)  
CLGGKSPART TEERVAGDLD HKGVDSDRKH DAEKTEEKKH G

25 SEQ ID NO:11 (p37-3)  
XXTGEVXSHS HSSGKSSSKP ESRPESNLQN VVAET

Wherein the X at position 1 is C or absent; wherein the X at position 2 is A or E; and wherein the  
X at position 7 is F or absent.

One embodiment of the invention provides a purified polypeptide comprising SEQ ID  
NOs:1, 9 or 11 wherein the polypeptide consists of less than about 150, 140, 130, 120, 110, 90,  
30 80, 70, 60, 50, 40, 35, 30, 25 or 20 (or any range between 150 and 20) contiguous naturally  
occurring *Anaplasma phagocytophilum* amino acids. Another embodiment of the invention  
provides a purified polypeptide comprising SEQ ID NOs:1, 9 or 11 wherein the polypeptide  
consists of more than about 20, 25, 30, 35, 40, 50, 60, 70, 80, 90, 110, 120, 130, 140, or 150 (or  
any range between 20 and 150) contiguous naturally occurring *Anaplasma phagocytophilum*  
35 amino acids. Naturally occurring *Aph* amino acids are any polypeptides naturally produced by  
an *Aph* organism. That is, a purified polypeptide contains a polypeptide shown in SEQ ID NO:1,  
9, or 11, but contains less than about 150, 140, 130, 120, 110, 90, 80, 70, 60, 50, 40, 35, 30, 25 or  
20 contiguous naturally occurring *Anaplasma phagocytophilum* amino acids. That is, the  
purified polypeptide is smaller than the full length polypeptide. The purified polypeptide can

comprise additional heterologous amino acids (that is, amino acids that are not from *Aph*) and even additional *Aph* amino acids as long as they do not naturally occur contiguously with SEQ ID NOs:1, 2, 8, 9, 10, or 11. Another embodiment provides a purified polypeptide comprising SEQ ID NO:2, 6, 8, 10, or 12 wherein the polypeptide consists of less than about 350, 300, 275, 250, 225, 200, 195, 175, 150, 125, 100, 75, 50, 45, 40, 35, 30, or 25 (or any range between 350 and 25) contiguous naturally occurring *Anaplasma phagocytophilum* amino acids. That is, the purified polypeptide is smaller than the full length polypeptide (SEQ ID NO:6). Another embodiment provides a purified polypeptide comprising SEQ ID NO:2, 6, 8, 10, or 12 wherein the polypeptide consists of more than about 25, 30, 35, 40, 45, 50, 75, 100, 125, 150, 175, 195, 200, 225, 250, 275, 300 or 350 (or any range between 25 and 350) contiguous naturally occurring *Anaplasma phagocytophilum* amino acids.

In one embodiment of the invention, a purified polypeptide can comprise SEQ ID NO:9, SEQ ID NO:10 or SEQ ID NO:11, wherein the polypeptide consists of more than about 200, 175, 150, 160, 150, 140, 130, 120, 114, 110, 100, 90, 80, 70, 60, 50, 43, 40, 35, 30, or 25 (or any range between 200 and 25) contiguous naturally occurring *Anaplasma phagocytophilum* amino acids. Another embodiment provides a purified polypeptide comprising SEQ ID NO:9, SEQ ID NO:10 or SEQ ID NO:11, wherein the polypeptide consists of less than about 200, 175, 150, 160, 150, 140, 130, 120, 114, 110, 100, 90, 80, 70, 60, 50, 43, 40, 35, 30, or 25 (or any range between 200 and 25) contiguous naturally occurring *Anaplasma phagocytophilum* amino acids. The fact that these polypeptides are smaller than the full length *Aph* polypeptide APH\_0915 (GenBank Accession Number ABD43857) (SEQ ID NO:6) is important because smaller polypeptides can have greater specificity and/or sensitivity than full length polypeptides in *Apl* and/or *Aph* assays. Additionally, these smaller polypeptides can be less expensive to manufacture, and may be obtained at greater purity, than the full length polypeptide.

SEQ ID NO:6 (APH\_0915 hypothetical protein {*Anaplasma phagocytophilum* HZ})  
 MSFTMSKLSLDPTQGSHTAENIACSIFDMVLGVKSTAKLLAGTWAGTSSTIWKTVTGAAS  
 STKEASSKSYGTLRSSLGSSASRRMLGTCATAALCLTAPLLGAAAAGAAITCALITICMA  
 LLFLVLYTVLHIASQMLRCASLLLSMVCNILHSTFTATKSLGGKSPARTTEERVAGDLD  
 HKGVDSDRKHDAEKTEKKHGLGSLCKSLAINLVSLMGTAIVTTPILLAVVLLVLPVY  
 LLCATVHHIYQGNIEDRNDKGSSRGGGTTYYPMTMSASASEESLSSIISEGGLSKTSLP  
 SYSAATATGTGNATGEVFSHSHSSGKSSSKPESRPESNLQNVVAETMSQQQRSVS

Another embodiment of the invention provides a polypeptide shown in SEQ ID NO:12:

SEQ ID NO:12  
 MSFTMSKLSL DPTQGSHTAE NIACSIFDMV LGVKSTAKLL AGTWAGTSST IWKTVTGAAS 60

STKEASSKSY GTLRSSLGSS ASRRMLGTCA TAALCLTAPL LGAAAAGAAI TCALITICMA 120  
 LLFLVLYTVL HIASQMLRCA SLLLSMVCNI LHSTFTATKS CLGGKSPART TEERVAGDLD 180  
 HKGVDSDRKH DAEKTEEKH GLGSLCKSLA INLVSLMGTA LVXTPILL VVLLVLPVY 240  
 5 LLCATVHHIY QGNYEDRNND KGSSRGGGTT YYPMTMSASA SEESLSSIIS EGXLSKTSLP 300  
 SYSAATATGT GNXTGEVXSH SHSSGKSSSK PESRPESNLQ NVVAETMSQQ QRSVS

wherein the X at position 223 is A or T, the X at position 293 is D or G, the X at position 313 is E or A and the X at position 318 is F or absent.

One embodiment of the invention provides a purified polypeptide that is less than about 10 360, 350, 300, 250, 200, 175, 150, 125, 100, 90, 80, 70, 60, 50, 40, 35, 30, 25, 20, or 10 contiguous naturally *Aph* amino acids and greater than about 10, 20, 25, 30, 35, 40, 50, 60, 70, 80, 90, 100, 125, 150, 175, 200, 250, 300, 350, or 360 contiguous amino acids of SEQ ID NOs:1-2, 6, and 8-10 (or any range between 360 and 10 amino acids).

One embodiment of the invention provides a purified polypeptide comprising at least 15 about 10, 20, 25, 30, 35, 40, 50, 60, 70, 80, 90, 100, 125, 150, 175, 200, 225, 250, 275, 300, 325, 350, 360 or more contiguous amino acids of SEQ ID NOs:1-2, 6, and 8-12. Therefore, a polypeptide of the invention can be, for example, about 19 to about 40; about 19 to about 50; about 19 to about 100; or about 19 to about 150 amino acids in length.

Variant polypeptides are at least about 79 % or 80%, or about 81, 82, 83, 84, 85, 86, 87, 20 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, or 99% identical to the polypeptide sequences shown in SEQ ID NOs:1-2, 6, and 8-12 and are also polypeptides of the invention. For example, a variant polypeptide of SEQ ID NO:11 can be about at least 97% (about 1 amino acid change), 94% (about 2 amino acid changes), 91% (about 3 amino acid changes), 89% (about 4 amino acid changes), 86% (about 5 amino acid changes), identical to SEQ ID NO:11.

25 One embodiment of the invention provides a purified polypeptide that is less than 150 contiguous amino acids and greater than about 10, 20, 30, 35, 40, 50, 60, 70, 80, 90, 100, 110, 120, 130 or 140 contiguous amino acids of SEQ ID NO:6 (or SEQ ID NO:6 having an A at position 223, a D at position 293, an E at position 313, and no amino acid at position 318). For example, a purified polypeptide of the invention is less than about 150 contiguous amino acids of 30 SEQ ID NO:6 (or SEQ ID NO:6 having an A at position 223, a D at position 293, an E at position 313, and no amino acid at position 318) and greater than about 30 contiguous amino acids of SEQ ID NO:6 (or SEQ ID NO:6 having an A at position 223, a D at position 293, an E at position 313, and no amino acid at position 318). Purified polypeptides of the invention can

comprise, e.g., amino acids 150-355, 161-355, 181-355, 242-355 and fragments thereof of about greater than 10, 20, 30, 35, 40, 50, 60, 70, 80, 90, 100, 110, 120, 130 or 140 contiguous amino acids of SEQ ID NO:6 (or SEQ ID NO:6 having an A at position 223, a D at position 293, an E at position 313, and no amino acid at position 318).

5 One embodiment of the invention provides a purified polypeptide comprising at least about 10, 20, 25, 30, 35, 40, 50, 60, 70, 80, 90, 100, 110, 120, 130, 140, 150, 160, 170, 190 or more contiguous amino acids of SEQ ID NOs:1, 2, 6, 8, 9, 10, 11, or 12.

Another embodiment of the invention provides a purified polypeptide comprising SEQ ID NO:1, 9, or 11, wherein the polypeptide consists of less than about 150 contiguous naturally occurring *Anaplasma phagocytophilum* amino acids or a purified polypeptide comprising SEQ ID NO: 2, 6, 8, 10, or 12, wherein the polypeptide consists of less than about 300 contiguous naturally occurring *Anaplasma phagocytophilum* amino acids.

Variant polypeptides at least about 80, or about 90, 91, 92, 93, 94, 95, 96, 98, or 99% identical to the polypeptide sequences shown in SEQ ID NOs:1, 2, 6, 8, 9, 10, 11, or 12 are also polypeptides of the invention. Variant polypeptides have one or more conservative amino acid variations or other minor modifications and retain biological activity, *i.e.*, are biologically functional equivalents. A biologically active equivalent has substantially equivalent function when compared to the corresponding wild-type polypeptide. In one embodiment of the invention a polypeptide has 1, 2, 3, 4, 5, 10, 15, 20, 30, 40 or 50 conservative amino acid substitutions.

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, WI 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.

5 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.

10 Variant polypeptides can generally be identified by modifying one of the polypeptide sequences of the invention, and evaluating the properties of the modified polypeptide to determine if it is a biological equivalent. A variant is a biological equivalent if it reacts substantially the same as a polypeptide of the invention in an assay such as an immunohistochemical assay, an enzyme-linked immunosorbent Assay (ELISA), a  
15 radioimmunoassay (RIA), immunoenzyme assay or a western blot assay, *e.g.* has 90-110% of the activity of the original polypeptide. In one embodiment, the assay is a competition assay wherein the biologically equivalent polypeptide is capable of reducing binding of the polypeptide of the invention to a corresponding reactive antigen or antibody by about 80, 95, 99, or 100%. An antibody that specifically binds a corresponding wild-type polypeptide also specifically binds  
20 the variant polypeptide.

A conservative substitution is one in which an amino acid is substituted for another amino acid that has similar properties, such that one skilled in the art of peptide chemistry would expect the secondary structure and hydropathic nature of the polypeptide to be substantially unchanged. In general, the following groups of amino acids represent conservative changes: (1)  
25 ala, pro, gly, glu, asp, gln, asn, ser, thr; (2) cys, ser, tyr, thr; (3) val, ile, leu, met, ala, phe; (4) lys, arg, his; and (5) phe, tyr, trp, his.

A polypeptide of the invention can further comprise a signal (or leader) sequence that co-translationally or post-translationally directs transfer of the protein. The polypeptide can also comprise a linker or other sequence for ease of synthesis, purification or identification of the  
30 polypeptide (*e.g.*, poly-His), or to enhance binding of the polypeptide to a solid support. For

example, a polypeptide can be conjugated to an immunoglobulin Fc region or bovine serum albumin.

A polypeptide can be covalently or non-covalently linked to an amino acid sequence to which the polypeptide is not normally associated with in nature, *i.e.*, a heterologous amino acid sequence. A heterologous amino acid sequence can be from a non-*Anaplasma phagocytophilum* organism, a synthetic sequence, or an *Anaplasma phagocytophilum* sequence not usually located at the carboxy or amino terminus of a polypeptide of the invention. Additionally, a polypeptide can be covalently or non-covalently linked to compounds or molecules other than amino acids, such as indicator reagents. A polypeptide can be covalently or non-covalently linked to an amino acid spacer, an amino acid linker, a signal sequence, a stop transfer sequence, a transmembrane domain, a protein purification ligand, or a combination thereof. A polypeptide can also be linked to a moiety (*i.e.*, a functional group that can be a polypeptide or other compound) that enhances an immune response (e.g., cytokines such as IL-2), a moiety that facilitates purification (e.g., affinity tags such as a six-histidine tag, trpE, glutathione, maltose binding protein), or a moiety that facilitates polypeptide stability (e.g., polyethylene glycol; amino terminus protecting groups such as acetyl, propyl, succinyl, benzyl, benzyloxycarbonyl or t-butyloxycarbonyl; carboxyl terminus protecting groups such as amide, methylamide, and ethylamide). In one embodiment of the invention a protein purification ligand can be one or more C amino acid residues at, for example, the amino terminus or carboxy terminus or both termini of a polypeptide of the invention. An amino acid spacer is a sequence of amino acids that are not associated with a polypeptide of the invention in nature. An amino acid spacer can comprise about 1, 5, 10, 20, 100, or 1,000 amino acids.

If desired, a polypeptide of the invention can be part of a fusion protein, which can also contain other amino acid sequences, such as amino acid linkers, amino acid spacers, signal sequences, TMR stop transfer sequences, transmembrane domains, as well as ligands useful in protein purification, such as glutathione-S-transferase, histidine tag, and *Staphylococcal* protein A, or combinations thereof. More than one polypeptide of the invention can be present in a fusion protein. A polypeptide of the invention can be operably linked to non-*Anaplasma phagocytophilum* proteins or *Anaplasma phagocytophilum* proteins to form fusion proteins. A fusion protein of the invention can comprise one or more of *Anaplasma phagocytophilum* polypeptides of the invention, fragments thereof, or combinations thereof. A fusion protein does

not occur in nature. The term "operably linked" means that the polypeptide of the invention and the other polypeptides are fused in-frame to each other either to the N-terminus or C-terminus of the polypeptide of the invention.

Polypeptides of the invention can be in a multimeric form. That is, a polypeptide can  
5 comprise one or more copies of an *Anaplasma phagocytophilum* polypeptide of the invention or a combination thereof. A multimeric polypeptide can be a multiple antigen peptide (MAP). See e.g., Tam, J. Immunol. Methods, 196:17-32 (1996).

Polypeptides of the invention can comprise an antigen that is recognized by an antibody specific for *Anaplasma phagocytophilum*. The antigen can comprise one or more epitopes (i.e.,  
10 antigenic determinants). An epitope can be a linear epitope, sequential epitope or a conformational epitope. Epitopes within a polypeptide of the invention can be identified by several methods. See, e.g., U.S. Patent No. 4,554,101; Jameson & Wolf, *CABIOS* 4:181-186 (1988). For example, a polypeptide of the invention can be isolated and screened. A series of short peptides, which together span an entire polypeptide sequence, can be prepared by  
15 proteolytic cleavage. By starting with, for example, 100-mer polypeptide fragments (or smaller fragments), each fragment can be tested for the presence of epitopes recognized in an ELISA. For example, in an ELISA assay an *Anaplasma phagocytophilum* polypeptide, such as a 100-mer polypeptide fragment, is attached to a solid support, such as the wells of a plastic multi-well plate. A population of antibodies are labeled, added to the solid support and allowed to bind to  
20 the unlabeled antigen, under conditions where non-specific absorption is blocked, and any unbound antibody and other proteins are washed away. Antibody binding is detected by, for example, a reaction that converts a colorless substrate into a colored reaction product. Progressively smaller and overlapping fragments can then be tested from an identified 100-mer to map the epitope of interest.

25 A polypeptide of the invention can be produced recombinantly. A polynucleotide encoding a polypeptide of the invention can be introduced into a recombinant expression vector, which can be expressed in a suitable expression host cell system using techniques well known in the art. A variety of bacterial, yeast, plant, mammalian, and insect expression systems are available in the art and any such expression system can be used. Optionally, a polynucleotide  
30 encoding a polypeptide can be translated in a cell-free translation system. A polypeptide can also be chemically synthesized or obtained from *Anaplasma phagocytophilum* cells.

An immunogenic polypeptide of the invention can comprise an amino acid sequence shown in SEQ ID NOs:1, 2, 6, 8, 9, 10, 11, 12 or fragments thereof. An immunogenic polypeptide can elicit antibodies or other immune responses (*e.g.*, T-cell responses of the immune system) that recognize epitopes of a polypeptide having SEQ ID NOs:1, 2, 6, 8, 9, 10, 11, or 12. An immunogenic polypeptide of the invention can also be a fragment of a polypeptide that has an amino acid sequence shown in SEQ ID NOs:1, 2, 6, 8, 9, 10, 11, or 12. An immunogenic polypeptide fragment of the invention can be about 6, 10, 15, 20, 25, 30, 40, 50, 60, 70, 80, 90, 100, 150, 175, 200, 250, 300, 350 or more amino acids in length (or any range between 6 and 350). An immunogenic polypeptide of the invention can be about 350, 300, 250, 200, 175, 150, 125, 100, 90, 80, 70, 60, 50, 40, 30, 25, 20, 15, 10, 6, or less amino acids in length (or any range between 350 and 6).

#### **Anaplasma phagocytophilum Polynucleotides**

Polynucleotides of the invention contain less than an entire microbial genome and can be single- or double-stranded nucleic acids. A polynucleotide can be RNA, DNA, cDNA, genomic DNA, chemically synthesized RNA or DNA or combinations thereof. The polynucleotides can be purified free of other components, such as proteins, lipids and other polynucleotides. For example, the polynucleotide can be 50%, 75%, 90%, 95%, 96%, 97%, 98%, 99%, or 100% purified. A nucleic acid molecule existing among hundreds to millions of other nucleic acid molecules within, for example, cDNA or genomic libraries, or gel slices containing a genomic DNA restriction digest are not to be considered an isolated polynucleotide. The polynucleotides of the invention encode the polypeptides of the invention described above. In one embodiment of the invention the polynucleotides encode a polypeptide shown in SEQ ID NOs:1, 2, 6, 8, 9, 10, 11, 12 or fragments thereof. Examples of polynucleotides of the invention include: SEQ ID NOs 3, 4, 5, and 7.

SEQ ID NO:3 (clone14)  
 TTATGCGCTA CAGTGCACCA CATCTATCAA GGAAATTACG AAGATCGCAA CAACGACAAA GGTAGCTCCC  
 GTGGCGGCGG TACTACATAT TATCCAATGA CAATGTCTGC AAGTGCTTCT GAAGAGTCCC TTAGCAGCAT  
 AATATCTGAA GGAGNTTTGA GTAAGACATC GCTACCAAGT TACTCCGCAG CCACTGCTAC AGGTACTGGA  
 AATGNAACTG GTGAGGTTTN NNCACATTCT CATTTCATCTG GTAAAAGTAG CAGCAAACCA GAATCTCGCC  
 CTGAGAGCAA TCTACAGAAT GTGGTAGCAG AAACCATGTC GCAGCAACAA AGGAGCGTCT CC

Wherein the N at position 155 is A or G; wherein the N at position 215 is A or C; and wherein the three N's at positions 230-232 are all T's or are all absent.

SEQ ID NO:4 (clone 13)



CACAAAGGGG TGGATTCAGA TCGGAAGCAT GATGCAGAGA AAACAGAAGA GAAAAAACAT GGTTTGGGTA  
 GCCTCTGCAA ATCACTCGCG ATAAATCTGG TCTCCTTAAT GGAACAGCG CTAGTTNCCA CACCCATAAT  
 ACTACTTGCA GTAGTTCTAT TAGTGTTGGT GCCAGTATAT CTGTTATGCG CTACAGTGCA CCACATCTAT  
 CAAGGAAATT ACGAAGATCG CAACAACGAC AAAGGTAGCT CCCGTGGCGG CGGTACTACA TATTATCCAA  
 5 TGACAATGTC TGCAAGTGCT TCTGAAGAGT CCCTTAGCAG CATAATATCT GAAGGAGNTT TGAGTAAGAC  
 ATCGCTACCA AGTTACTCCG CAGCCACTGC TACAGGTACT GGAAATGNAA CTGGTGAGGT TTNNNCACAT  
 TCTCATTCAT CTGGTAAAAG TAGCAGCAAA CCAGAATCTC GCCCTGAGAG CAATCTACAG AATGTGGTAG  
 CAGAAACCAT GTCGCAGCAA CAAAGGAGCG TCTCC

- 10 Wherein the N at position 127 is G or A; wherein the N at position 338 is A or G; wherein the N at position 398 is A or C; wherein the three N's at positions 413-415 are all T's or are absent.

SEQ ID NO:5 (APH\_0915 hypothetical gene {*Anaplasma phagocytophilum* HZ})

TTGAGTTTTACAATGTGCAAGTTATCGCTTGACCCTACTCAGGGCTCACATACAGCAGAG  
 15 AATATTGCTTGTTCATCTTTGATATGGTACTTGGTGTAAAGTCCACTGCAAACTGTTA  
 GCAGGTACGTGGGCTGGTACAAGCAGCACTATTTGGAAGACAGTAACAGGAGCAGCTTCC  
 TCAACTAAAGAAGCGTCATCAAAGTCGTATGGAACCCTACGTAGTTTCTTGGGCTCTTCC  
 GCTTCTAGAAGGATGCTAGGAACCTTGCCTACCGCCGCTCTCTGCTTAACTGCACCTTTG  
 CTTGGCGCAGCCGCTGCCGAGCGGCAATAACATGTGCCTTGATAACCATTTGCATGGCT  
 20 TTGCTGTTCTCGTTTTGTACACCGTACTCCACATTGCCTCTCAGATGTTGCGTTGTGCA  
 TCGCTACTGTTGAGCATGGTATGCAATATCCTGCACAGCACATTACCGCAACTAAGTCT  
 TGCCTCGGAGGTAAAGTCACCTGCGCGAACAACCTGAAGAGCGGGTAGCTGGGGATTTAGAT  
 CACAAAGGGGTGGATTTCAGATCGGAAGCATGATGCAGAGAAAACAGAAGAGAAAAACAT  
 GGTTTGGGTAGCCTCTGCAATCACTCGCGATAAATCTGGTCTCCTTAATGGGAACAGCG  
 25 CTAGTTACCACACCCATAATACTACTTGCAGTAGTTCTATTAGTGTTGGTGCCAGTATAT  
 CTGTTATGCGCTACAGTGCAACCATCTATCAAGGAAATTACGAAGATCGCAACAACGAC  
 AAAGGTAGCTCCCGTGGCGGCGGTACTACATATTATCCAATGACAATGTCTGCAAGTGCT  
 TCTGAAGAGTCCCTTAGCAGCATAATATCTGAAGGAGGTTTGAGTAAGACATCGCTACCA  
 AGTTACTCCGCAGCCACTGCTACAGGTACTGGAAATGCAACTGGTGAGGTTTTTTCACAT  
 30 TCTCATTCATCTGGTAAAAGTAGCAGCAAAACCAGAATCTCGCCCTGAGAGCAATCTACAG  
 AATGTGGTAGCAGAAACCATGTGCGCAGCAACAAAGGAGCGTCTCC

SEQ ID NO:7 (clone 13ext)

TGCCTCGGAG GTAAGTCACC TCGCGAACA ACTGAAGAGC GGGTAGCTGG GGATTTAGAT CACAAAGGGG  
 35 TGGATTCAGA TCGGAAGCAT GATGCAGAGA AAACAGAAGA GAAAAAACAT GGTTTGGGTA GCCTCTGCAA  
 ATCACTCGCG ATAAATCTGG TCTCCTTAAT GGAACAGCG CTAGTTNCCA CACCCATAAT ACTACTTGCA  
 GTAGTTCTAT TAGTGTTGGT GCCAGTATAT CTGTTATGCG CTACAGTGCA CCACATCTAT CAAGGAAATT  
 ACGAAGATCG CAACAACGAC AAAGGTAGCT CCCGTGGCGG CGGTACTACA TATTATCCAA TGACAATGTC  
 TGCAAGTGCT TCTGAAGAGT CCCTTAGCAG CATAATATCT GAAGGAGNTT TGAGTAAGAC ATCGCTACCA  
 40 AGTTACTCCG CAGCCACTGC TACAGGTACT GGAAATGNAA CTGGTGAGGT TTNNNCACAT TCTCATTCAT  
 CTGGTAAAAG TAGCAGCAAA CCAGAATCTC GCCCTGAGAG CAATCTACAG AATGTGGTAG CAGAAACCAT  
 GTCGCAGCAA CAAAGGAGCG TCTCC

- 45 Wherein the N at position 187 is G or A; wherein the N at position 398 is A or G; wherein the N at position 458 is A or C; wherein the three N's at positions 473-475 are all T's or are all absent.

Polynucleotides of the invention can consist of less than about 900, 825, 750, 675, 600, 500, 450, 420, 390, 360, 330, 300, 225, 150, 120, or 90 (or any range between 900 and 90) contiguous, naturally occurring *Aph* polynucleotides. Polynucleotides of the invention can

consist of greater than about 90, 120, 150, 225, 300, 330, 360, 390, 420, 450, 500, 600, 675, 750, 825, 900 or more (or any range between 90 and 900) contiguous, naturally occurring *Aph* polynucleotides. The purified polynucleotides can comprise additional heterologous nucleotides (that is, nucleotides that are not from *Aph*) and even additional *Aph* amino acids as long as they do not naturally occur contiguously with SEQ ID NOs:3, 4, 5, or 7. Polynucleotides 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, and *Staphylococcal* protein A. One embodiment of the invention provides a purified polynucleotide comprising at least about 6, 10, 15, 20, 25, 30, 40, 50, 75, 100, 200, 300, 400, 500, 600, 700, 800, 900, 1,000, or more contiguous nucleotides of SEQ ID NOs:3, 4, 5, 7 or other polynucleotides that encode polypeptides shown in SEQ ID NOs:1, 2, 6, 8, 9, 10, 11, 12.

Polynucleotides of the invention can be isolated. An isolated polynucleotide is a naturally-occurring polynucleotide that is not immediately contiguous with one or both of the 5' and 3' flanking genomic sequences that it is naturally associated with. An isolated polynucleotide can be, for example, 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 polynucleotides also include non-naturally occurring nucleic acid molecules. A nucleic acid molecule existing among hundreds to millions of other nucleic acid molecules within, for example, cDNA or genomic libraries, or gel slices containing a genomic DNA restriction digest are not to be considered an isolated polynucleotide.

Polynucleotides of the invention can also comprise fragments that encode immunogenic polypeptides. Polynucleotides of the invention can encode full-length polypeptides, polypeptide fragments, and variant or fusion polypeptides.

Degenerate nucleotide sequences encoding polypeptides of the invention, as well as homologous nucleotide sequences that are at least about 80, or about 90, 96, 98, or 99% identical to the polynucleotide sequences of the invention and the complements thereof are also polynucleotides of the invention. Percent sequence identity can be calculated as described in the "Polypeptides" section. Degenerate nucleotide sequences are polynucleotides that encode a polypeptide of the invention or fragments thereof, but differ in nucleic acid sequence from the

wild-type polynucleotide sequence, due to the degeneracy of the genetic code. Complementary DNA (cDNA) molecules, species homologs, and variants of *Anaplasma phagocytophilum* polynucleotides that encode biologically functional *Anaplasma phagocytophilum* polypeptides also are *Anaplasma phagocytophilum* polynucleotides.

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

10 Polynucleotides of the invention can comprise coding sequences for naturally occurring polypeptides or can encode altered sequences that do not occur in nature. If desired, polynucleotides 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  
15 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  
20 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.

25 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. Patent No. 4,366,246. A polynucleotide 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.

30 Polynucleotides of the invention can be used, for example, as probes or primers, for example, PCR primers, to detect the presence of *Anaplasma phagocytophilum* and/or *Anaplasma platys* polynucleotides in a test sample, such as a biological sample. Probes are molecules

capable of interacting with a target nucleic acid, typically in a sequence specific manner, for example, through hybridization. Primers are a subset of probes that can support an enzymatic manipulation and that can hybridize with a target nucleic acid such that the enzymatic manipulation occurs. A primer can be made from any combination of nucleotides or nucleotide derivatives or analogs available in the art that do not interfere with the enzymatic manipulation.

A probe or primer can be about 6, 10, 15, 20, 25, 30, 40, 50, 75, 100, 200, 300, 400, 500, 600, 700, 800, 900, 1,000, or more contiguous nucleotides of SEQ ID NOs:3, 4, 5, 7 or other polynucleotides that encode polypeptides shown in SEQ ID NOs:1, 2, 6, and 8-12.

The hybridization of nucleic acids is well understood in the art and discussed herein. Typically a probe can be made from any combination of nucleotides or nucleotide derivatives or analogs available in the art. The ability of such probes and primers to specifically hybridize to *Anaplasma phagocytophilum* polynucleotide sequences will enable them to be of use in detecting the presence of complementary sequences in a given test sample. Polynucleotide probes and primers of the invention can hybridize to complementary sequences in a test sample such as a biological sample, including saliva, sputum, blood, plasma, serum, urine, feces, cerebrospinal fluid, amniotic fluid, wound exudate, or tissue. Polynucleotides from the sample can be, for example, subjected to gel electrophoresis or other size separation techniques or can be immobilized without size separation. The polynucleotide probes or primers can be labeled. Suitable labels, and methods for labeling probes and primers, are known in the art, and include, for example, radioactive labels incorporated by nick translation or by kinase, biotin labels, fluorescent labels, chemiluminescent labels, bioluminescent labels, metal chelator labels and enzyme labels. The polynucleotides from the sample are contacted with the probes or primers under hybridization conditions of suitable stringencies.

Depending on the application, varying conditions of hybridization can be used to achieve varying degrees of selectivity of the probe or primer towards the target sequence. For applications requiring high selectivity, relatively stringent conditions can be used, such as low salt and/or high temperature conditions, such as provided by a salt concentration of from about 0.02 M to about 0.15 M salt at temperatures of from about 50°C to about 70°C. For applications requiring less selectivity, less stringent hybridization conditions can be used. For example, salt conditions from about 0.14 M to about 0.9M salt, at temperatures ranging from about 20°C to about 55°C. The presence of a hybridized complex comprising the probe or primer and a

complementary polynucleotide from the test sample indicates the presence of *Apl* and/or an *Apl* polynucleotide sequence in the sample.

### **Antibodies**

Antibodies of the invention are antibody molecules that specifically bind to an *Anaplasma phagocytophilum* polypeptide of the invention, variant polypeptides of the invention, or fragments thereof. An antibody of the invention can be specific for an *Anaplasma phagocytophilum* polypeptide, for example, an antibody specific for one or more of SEQ ID NO: 1, 9 or 11. In another embodiment of the invention an antibody is specific for both an *Anaplasma phagocytophilum* polypeptide and an *Anaplasma platys* polypeptide (e.g., an antibody specific for SEQ ID NO:2, 6, 8, 10 or 12). In another embodiment of the invention an antibody is specific for both an *Anaplasma phagocytophilum* polypeptide and another *Anaplasma* polypeptide. One of skill in the art can easily determine if an antibody is specific for an *Anaplasma phagocytophilum* polypeptide or *Anaplasma platys* polypeptide using assays described herein. An antibody of the invention can be a polyclonal antibody, a monoclonal antibody, a single chain antibody (scFv), or an antigen binding fragment of an antibody. Antigen-binding fragments of antibodies are a portion of an intact antibody comprising the antigen binding site or variable region of an intact antibody, wherein the portion is free of the constant heavy chain domains of the Fc region of the intact antibody. Examples of antigen binding antibody fragments include Fab, Fab', Fab'-SH, F(ab')<sub>2</sub> and F<sub>v</sub> fragments.

An antibody of the invention can be any antibody class, including for example, IgG, IgM, IgA, IgD and IgE. An antibody or fragment thereof binds to an epitope of a polypeptide of the invention. An antibody can be made *in vivo* in suitable laboratory animals or *in vitro* using recombinant DNA techniques. Means for preparing and characterizing antibodies are well known in the art. See, e.g., Dean, *Methods Mol. Biol.* 80:23-37 (1998); Dean, *Methods Mol. Biol.* 32:361-79 (1994); Baileg, *Methods Mol. Biol.* 32:381-88 (1994); Gullick, *Methods Mol. Biol.* 32:389-99 (1994); Drenckhahn *et al. Methods Cell. Biol.* 37:7-56 (1993); Morrison, *Ann. Rev. Immunol.* 10:239-65 (1992); Wright *et al. Crit. Rev. Immunol.* 12:125-68 (1992). For example, polyclonal antibodies can be produced by administering a polypeptide of the invention to an animal, such as a human or other primate, mouse, rat, rabbit, guinea pig, goat, pig, dog, cow, sheep, donkey, or horse. Serum from the immunized animal is collected and the antibodies are purified from the plasma by, for example, precipitation with ammonium sulfate, followed by

chromatography, such as affinity chromatography. Techniques for producing and processing polyclonal antibodies are known in the art.

“Specifically binds,” “specifically bind,” or “specific for” means that a first antigen, *e.g.*, an *Anaplasma phagocytophilum* polypeptide, recognizes and binds to an antibody of the invention with greater affinity than to other, non-specific molecules. “Specifically binds,” “specifically bind,” or “specific for” also means a first antibody, *e.g.*, an antibody raised against SEQ ID NOs:1-2, 6, and 8-12, recognizes and binds to SEQ ID NOs:1-2, 6, and 8-12, with greater affinity than to other non-specific molecules. A non-specific molecule is an antigen that shares no common epitope with the first antigen. In a preferred embodiment of the invention a non-specific molecule is not derived from *Anaplasma sp.* An *Anaplasma sp.* is any species of the genus *Anaplasma*. For example, an antibody raised against a first antigen (*e.g.*, a polypeptide) to which it binds more efficiently than to a non-specific antigen can be described as specifically binding to the first antigen. In one embodiment, an antibody or antigen-binding portion thereof specifically binds to a polypeptide of SEQ ID NOs:1, 2, 6, 8, 9, 10, 11, 12 or fragments thereof when it binds with a binding affinity  $K_a$  of  $10^7$  l/mol or more. Specific binding can be tested using, for example, an enzyme-linked immunosorbant assay (ELISA), a radioimmunoassay (RIA), or a western blot assay using methodology well known in the art.

Antibodies of the invention include antibodies and antigen binding fragments thereof that (a) compete with a reference antibody for binding to SEQ ID NOs:1, 2, 6, 8, 9, 10, 11, 12 or antigen binding fragments thereof; (b) binds to the same epitope of SEQ ID NOs: 1, 2, 6, 8, 9, 10, 11, 12 or antigen binding fragments thereof as a reference antibody; (c) binds to SEQ ID NOs: 1, 2, 6, 8, 9, 10, 11, 12 or antigen binding fragments thereof with substantially the same  $K_d$  as a reference antibody; and/or (d) binds to SEQ ID NOs: 1, 2, 6, 8, 9, 10, 11, 12 or fragments thereof with substantially the same off rate as a reference antibody, wherein the reference antibody is an antibody or antigen-binding fragment thereof that specifically binds to a polypeptide of SEQ ID NOs: 1, 2, 6, 8, 9, 10, 11, 12 or antigen binding fragments thereof with a binding affinity  $K_a$  of  $10^7$  l/mol or more.

One embodiment of the invention provides a first purified polypeptide that specifically binds an antibody, wherein the antibody specifically binds a second purified polypeptide, wherein the second purified polypeptide consists of SEQ ID NO:1, 2, 6, 8, 9, 10, 11, That is, polypeptides of the invention include polypeptides that can specifically bind to antibodies that

are capable of specifically binding to a purified polypeptide that consists of SEQ ID NO:1, 2, 6, 8, 9, 10, 11. The first purified polypeptide can consist of at least 10 but less than 300 contiguous amino acids of SEQ ID NO: 1, 2, 6, 8, 9, 10, 11 or 12. The first purified polypeptide can be at least 95% identical to SEQ ID NO: 1, 2, 6, 8, 9, 10, 11 or 12.

5            Monoclonal antibodies directed against epitopes present on a polypeptide of the invention can also be readily produced. For example, normal B cells from a mammal, such as a mouse, which was immunized with a polypeptide of the invention can be fused with, for example, HAT-sensitive mouse myeloma cells to produce hybridomas. Hybridomas producing *Anaplasma phagocytophilum*-specific antibodies can be identified using RIA or ELISA and isolated by  
10    cloning in semi-solid agar or by limiting dilution. Clones producing *Anaplasma phagocytophilum*-specific antibodies are isolated by another round of screening. Monoclonal antibodies can be screened for specificity using standard techniques, for example, by binding a polypeptide of the invention to a microtiter plate and measuring binding of the monoclonal antibody by an ELISA assay. Techniques for producing and processing monoclonal antibodies  
15    are known in the art. *See e.g.*, Kohler & Milstein, *Nature*, 256:495 (1975). Particular isotypes of a monoclonal antibody can be prepared directly, by selecting from the initial fusion, or prepared secondarily, from a parental hybridoma secreting a monoclonal antibody of a different isotype by using a sib selection technique to isolate class-switch variants. *See* Steplewski *et al.*, *P.N.A.S. U.S.A.* 82:8653 1985; Spria *et al.*, *J. Immunolog. Meth.* 74:307, 1984. Monoclonal antibodies of  
20    the invention can also be recombinant monoclonal antibodies. *See, e.g.*, U.S. Patent No. 4,474,893; U.S. Patent No. 4,816,567. Antibodies of the invention can also be chemically constructed. *See, e.g.*, U.S. Patent No. 4,676,980.

Antibodies of the invention can be chimeric (*see, e.g.*, U.S. Patent No. 5,482,856), humanized (*see, e.g.*, Jones *et al.*, *Nature* 321:522 (1986); Reichmann *et al.*, *Nature* 332:323  
25    (1988); Presta, *Curr. Op. Struct. Biol.* 2:593 (1992)), caninized, canine, or human antibodies. Human antibodies can be made by, for example, direct immortalization, phage display, transgenic mice, or a Trimeria methodology, *see e.g.*, Reisener *et al.*, *Trends Biotechnol.* 16:242-246 (1998).

Antibodies that specifically bind *Anaplasma phagocytophilum* antigens (*e.g.*, *Anaplasma phagocytophilum* polypeptides), are particularly useful for detecting the presence of *Anaplasma phagocytophilum* antigens in a sample, such as a serum, blood, plasma, urine, fecal, tissue, or  
30    saliva sample from an *Anaplasma phagocytophilum*-infected animal. An immunoassay for

*Anaplasma phagocytophilum* antigen can utilize one antibody or several antibodies. An immunoassay for *Anaplasma phagocytophilum* antigen can use, for example, a monoclonal antibody specific for an *Anaplasma phagocytophilum* epitope, a combination of monoclonal antibodies specific for epitopes of one *Anaplasma phagocytophilum* polypeptide, monoclonal antibodies specific for epitopes of different *Anaplasma phagocytophilum* polypeptides, polyclonal antibodies specific for the same *Anaplasma phagocytophilum* antigen, polyclonal antibodies specific for different *Anaplasma phagocytophilum* antigens, or a combination of monoclonal and polyclonal antibodies. Immunoassay protocols can be based upon, for example, competition, direct reaction, or sandwich type assays using, for example, labeled antibody. Antibodies of the invention can be labeled with any type of label known in the art, including, for example, fluorescent, chemiluminescent, radioactive, enzyme, colloidal metal, radioisotope and bioluminescent labels. Other antibodies of the invention can specifically bind *Aph* antigens and *Apl* antigens, or *Aph* antigens and other *Anaplasma sp.* antigens and can be used as described for *Aph* above.

Antibodies of the invention or antigen-binding fragments thereof can be bound to a support and used to detect the presence of *Apl*, *Anaplasma sp.* and/or *Aph* antigens. Supports include, for example, glass, polystyrene, polypropylene, polyethylene, dextran, nylon, amylases, natural and modified celluloses, polyacrylamides, agaroses and magletite.

Antibodies of the invention can further be used to isolate *Anaplasma sp.*, *Apl*, and/or *Aph* organisms or antigens by immunoaffinity columns. The antibodies can be affixed to a solid support by, for example, adsorption or by covalent linkage so that the antibodies retain their immunoselective activity. Optionally, spacer groups can be included so that the antigen binding site of the antibody remains accessible. The immobilized antibodies can then be used to bind *Anaplasma* organisms or *Anaplasma* antigens from a sample, such as a biological sample including saliva, serum, sputum, blood, urine, feces, cerebrospinal fluid, amniotic fluid, wound exudate, or tissue. The bound *Anaplasma* organisms or *Anaplasma* antigens are recovered from the column matrix by, for example, a change in pH.

Antibodies of the invention can also be used in immunolocalization studies to analyze the presence and distribution of a polypeptide of the invention during various cellular events or physiological conditions. Antibodies can also be used to identify molecules involved in passive immunization and to identify molecules involved in the biosynthesis of non-protein antigens.



Identification of such molecules can be useful in vaccine development. Antibodies of the invention, including, for example, monoclonal antibodies and single chain antibodies, can be used to monitor the course of amelioration of a disease caused by *Anaplasma sp.*, *Apl* and/or *Aph*. By measuring the increase or decrease of antibodies specific for *Apl*, *Anaplasma sp.* and/or *Aph* in a test sample from an animal, it can be determined whether a particular therapeutic regiment aimed at ameliorating the disorder is effective. Antibodies can be detected and/or quantified using for example, direct binding assays such as RIA, ELISA, or western blot assays.

#### **Methods of Detection**

The methods of the invention can be used to detect antibodies or antibody fragments specific for *Anaplasma sp.*, *Apl*, or *Aph*; *Anaplasma* antigens, *Apl* antigens, *Aph* antigens; *Anaplasma sp.* polynucleotides, *Apl* polynucleotides, *Aph* polynucleotides; or a combination thereof in a test sample, such as a biological sample, an environmental sample, or a laboratory sample. A test sample can potentially comprise *Anaplasma sp.* polynucleotides, *Apl* polynucleotides, *Aph* polynucleotides, *Anaplasma sp.* polypeptides, *Apl* polypeptides, *Aph* polypeptides, antibodies specific for *Anaplasma sp.*, antibodies specific for *Apl*, and/or antibodies specific for *Aph*, combinations thereof, unrelated antibodies, unrelated polypeptides, unrelated polynucleotides, or none of the above. A biological sample can include, for example, sera, saliva, blood, cells, plasma, urine, feces, or tissue from a mammal such as a horse, cat, dog or human. The test sample can be untreated, precipitated, fractionated, separated, diluted, concentrated, or purified.

In one embodiment methods of the invention comprise contacting one or more polypeptides of the invention with a test sample under conditions that allow polypeptide/antibody complexes, *i.e.*, immunocomplexes, to form. That is, polypeptides of the invention specifically bind to antibodies specific for *Anaplasma sp.*, *Apl* and/or *Aph* antigens located in the sample. In one embodiment of the invention one or more polypeptides of the invention (e.g., SEQ ID NOs:1, 9, 11 or fragments thereof) specifically bind to antibodies that are specific for *Aph* antigens and do not specifically bind to *Apl* antigens. In another embodiment of the invention one or more polypeptides of the invention (e.g., SEQ ID NOs: 2, 6, 8, 10, or 12 or fragments thereof) specifically bind to antibodies that are specific for both *Aph* and *Apl* antigens. One of skill in the art is familiar with assays and conditions that are used to detect antibody/polypeptide complex binding. The formation of a complex between

polypeptides and anti-*Anaplasma sp.*, anti-*Apl* and/or anti-*Aph* antibodies in the sample is detected.

Antibodies of the invention can be used in a method of the diagnosis of *Anaplasma sp.*, *Apl*, and/or *Aph* infection by obtaining a test sample from, *e.g.*, a human or animal suspected of having an *Anaplasma sp.*, *Apl*, and/or *Aph* infection. The test sample is contacted with antibodies of the invention under conditions enabling the formation of antibody-antigen complexes (*i.e.*, immunocomplexes). One of skill in the art is aware of conditions that enable and are appropriate for formation of antigen/antibody complexes. The amount of antibody-antigen complexes can be determined by methodology known in the art. A level that is higher than that formed in a control sample indicates an *Anaplasma sp.*, *Apl*, and/or *Aph* infection. A control sample is a sample that does not comprise any *Aph* and/or *Apl* polypeptides or antibodies specific for *Aph* and/or *Apl*. In one embodiment of the invention the control contains no *Anaplasma sp.* polypeptides or antibodies specific for *Anaplasma sp.* In one embodiment of the invention an antibody is specific for *Aph* antigens only. In another embodiment of the invention an antibody is specific for both *Aph* and *Apl* antigens. Alternatively, a polypeptide of the invention can be contacted with a test sample. Antibodies specific for *Anaplasma sp.*, *Apl*, and/or *Aph* in a positive test sample will form antigen-antibody complexes under suitable conditions. The amount of antibody-antigen complexes can be determined by methods known in the art.

In one embodiment of the invention, *Anaplasma phagocytophilum* and/or *Anaplasma platys* infection can be detected in a subject. A biological sample is obtained from the subject. One or more purified polypeptides comprising SEQ ID NO: 2, 6, 8, 10, or 12, are contacted with the biological sample under conditions that allow polypeptide/antibody complexes to form. The purified polypeptides can consist of less than about 300 contiguous naturally occurring *Anaplasma phagocytophilum* amino acids. The polypeptide/antibody complexes are detected. The detection of the polypeptide/antibody complexes is an indication that the mammal has an *Anaplasma phagocytophilum* and/or *Anaplasma platys* infection. Because SEQ ID NO: 2, 6, 8, 10, or 12, are specific for both anti-*Apl* and anti-*Aph* antibodies, the detected infection can be *Aph* infection, *Apl* infection or both *Apl* and *Aph* infection. The lack of detection of polypeptide/antibody complexes is an indication that the subject does not have an *Anaplasma phagocytophilum* and/or *Anaplasma platys* infection.

Another embodiment of the invention provides a method of detecting an *Anaplasma phagocytophilum* infection in a subject. The method comprises obtaining a biological sample from the subject and contacting one or more purified polypeptides comprising SEQ ID NO:1, 9 or 11, with the biological sample under conditions that allow polypeptide/antibody complexes to form. The purified polypeptides can consist of less than about 150 contiguous naturally occurring *Anaplasma phagocytophilum* amino acids. The polypeptide/antibody complexes are detected. The detection of the polypeptide/antibody complexes is an indication that the subject has an *Anaplasma phagocytophilum* infection and the lack of detection of the polypeptide/antibody complexes is an indication that the subject does not have an *Anaplasma phagocytophilum* infection.

In one embodiment of the invention, *Apl* and/or *Aph* infection can be detected in a subject by about 5 days, 6 days, 7 days, 8 days, 9 days, 10 days, 12 days, 14 days, 15 days, 16 days, 17 days, 18 days, 19 days, 20 days, 21 days or more after the subject acquired the *Apl* and/or *Aph* infection. In one embodiment of the invention, *Apl* and/or *Aph* infection can be detected in a subject by about 21 days, 20 days, 19 days, 18 days, 17 days, 16 days, 15 days, 14 days, 13 days, 12 days, 11 days, 10 days, 9 days, 8 days, 7 days, 6 days, 5 days, or less after the subject acquired the *Aph* and/or *Apl* infection.

In one embodiment of the invention, the polypeptide/antibody complex is detected when an indicator reagent, such as an enzyme conjugate, which is bound to the antibody, catalyzes a detectable reaction. Optionally, an indicator reagent comprising a signal generating compound can be applied to the polypeptide/antibody complex under conditions that allow formation of a polypeptide/antibody/indicator complex. The polypeptide/antibody/indicator complex is detected. Optionally, the polypeptide or antibody can be labeled with an indicator reagent prior to the formation of a polypeptide/antibody complex. The method can optionally comprise a positive or negative control.

In one embodiment of the invention, one or more antibodies of the invention are attached to a solid phase or substrate. A test sample potentially comprising a protein comprising a polypeptide of the invention is added to the substrate. One or more antibodies that specifically bind polypeptides of the invention are added. The antibodies can be the same antibodies used on the solid phase or can be from a different source or species and can be linked to an indicator reagent, such as an enzyme conjugate. Wash steps can be performed prior to each addition. A

chromophore or enzyme substrate is added and color is allowed to develop. The color reaction is stopped and the color can be quantified using, for example, a spectrophotometer.

In another embodiment of the invention, one or more antibodies of the invention are attached to a solid phase or substrate. A test sample potentially comprising a protein comprising  
5 a polypeptide of the invention is added to the substrate. Second anti-species antibodies that specifically bind polypeptides of the invention are added. These second antibodies are from a different species than the solid phase antibodies. Third anti-species antibodies are added that specifically bind the second antibodies and that do not specifically bind the solid phase antibodies are added. The third antibodies can comprise an indicator reagent such as an enzyme  
10 conjugate. Wash steps can be performed prior to each addition. A chromophore or enzyme substrate is added and color is allowed to develop. The color reaction is stopped and the color can be quantified using, for example, a spectrophotometer.

Assays of the invention include, but are not limited to those based on competition, direct reaction or sandwich-type assays, including, but not limited to enzyme linked immunosorbent  
15 assay (ELISA), western blot, IFA, radioimmunoassay (RIA), hemagglutination (HA), fluorescence polarization immunoassay (FPIA), and microtiter plate assays (any assay done in one or more wells of a microtiter plate). One assay of the invention comprises a reversible flow chromatographic binding assay, for example a SNAP® assay. *See* U.S. Pat. No. 5,726,010.

Assays can use solid phases or substrates or can be performed by immunoprecipitation or  
20 any other methods that do not utilize solid phases. Where a solid phase or substrate is used, one or more polypeptides of the invention are directly or indirectly attached to a solid support or a substrate such as a microtiter well, magnetic bead, non-magnetic bead, column, matrix, membrane, fibrous mat composed of synthetic or natural fibers (*e.g.*, glass or cellulose-based materials or thermoplastic polymers, such as, polyethylene, polypropylene, or polyester),  
25 sintered structure composed of particulate materials (*e.g.*, glass or various thermoplastic polymers), or cast membrane film composed of nitrocellulose, nylon, polysulfone or the like (generally synthetic in nature). In one embodiment of the invention a substrate is sintered, fine particles of polyethylene, commonly known as porous polyethylene, for example, 10-15 micron porous polyethylene from Chromex Corporation (Albuquerque, NM). All of these substrate  
30 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.

In one type of assay format, one or more polypeptides can be coated on a solid phase or substrate. A test sample suspected of containing an anti-*Anaplasma sp.*, anti-*Apl*, and/or anti-*Aph* antibody or antigen-binding fragment thereof is incubated with an indicator reagent comprising a signal generating compound conjugated to an antibody or antigen-binding antibody fragment specific for *Anaplasma sp.*, *Apl*, and/or *Aph* for a time and under conditions sufficient to form antigen/antibody complexes of either antibodies of the test sample to the polypeptides of the solid phase or the indicator reagent compound conjugated to an antibody specific for *Anaplasma sp.*, *Apl*, and/or *Aph* to the polypeptides of the solid phase. The reduction in binding of the indicator reagent conjugated to an anti-*Anaplasma sp.*, anti-*Apl*, and/or anti-*Aph* antibody to the solid phase can be quantitatively measured. A measurable reduction in the signal compared to the signal generated from, e.g., a confirmed negative *Anaplasma sp.*, *Apl*, and/or *Aph* test sample indicates the presence of anti-*Anaplasma sp.*, anti-*Apl*, and/or anti-*Aph* antibody in the test sample. This type of assay can quantitate the amount of anti-*Anaplasma sp.*, anti-*Apl*, and/or anti-*Aph* antibodies in a test sample.

In another type of assay format, one or more polypeptides of the invention are coated onto a support or substrate. A polypeptide of the invention is conjugated to an indicator reagent and added to a test sample. This mixture is applied to the support or substrate. If antibodies specific for *Anaplasma sp.*, *Apl*, and/or *Aph* are present in the test sample they will bind the one or more polypeptides conjugated to an indicator reagent and to the one or more polypeptides immobilized on the support. The polypeptide/antibody/indicator complex can then be detected. This type of assay can quantitate the amount of anti-*Anaplasma sp.*, anti-*Apl*, and/or anti-*Aph* antibodies in a test sample.

In another type of assay format, one or more polypeptides of the invention are coated onto a support or substrate. The test sample is applied to the support or substrate and incubated. Unbound components from the sample are washed away by washing the solid support with a wash solution. If *Anaplasma sp.* specific, *Apl* specific, and/or *Aph* specific antibodies are present in the test sample, they will bind to the polypeptide coated on the solid phase. This polypeptide/antibody complex can be detected using a second species-specific antibody that is conjugated to an indicator reagent. The polypeptide/antibody/anti-species antibody indicator

complex can then be detected. This type of assay can quantitate the amount of anti-*Anaplasma sp.*, anti-*Apl*, and/or anti-*Aph* antibodies in a test sample.

The formation of a polypeptide/antibody complex or a polypeptide/antibody/indicator complex can be detected by e.g., radiometric, colorimetric, fluorometric, size-separation, or precipitation methods. Optionally, detection of a polypeptide/antibody complex is by the addition of a secondary antibody that is coupled to an indicator reagent comprising a signal generating compound. Indicator reagents comprising signal generating compounds (labels) associated with a polypeptide/antibody complex can be detected using the methods described above and include chromogenic agents, catalysts such as enzyme conjugates fluorescent compounds such as fluorescein and rhodamine, chemiluminescent compounds such as dioxetanes, acridiniums, phenanthridiniums, ruthenium, and luminol, radioactive elements, direct visual labels, as well as cofactors, inhibitors, magnetic particles, and the like. Examples of enzyme conjugates include alkaline phosphatase, horseradish peroxidase, beta-galactosidase, and the like. The selection of a particular label is not critical, but it will be capable of producing a signal either by itself or in conjunction with one or more additional substances.

Formation of the complex is indicative of the presence of anti-*Anaplasma sp.*, anti-*Apl*, and/or anti-*Aph* antibodies in a test sample. Therefore, the methods of the invention can be used to diagnose *Anaplasma sp.*, *Apl*, and/or *Aph* infection in a patient.

The methods of the invention can also indicate the amount or quantity of anti-*Anaplasma sp.*, anti-*Apl* and/or anti-*Aph* antibodies in a test sample. With many indicator reagents, such as enzyme conjugates, the amount of antibody present is proportional to the signal generated. Depending upon the type of test sample, it can be diluted with a suitable buffer reagent, concentrated, or contacted with a solid phase without any manipulation. For example, it usually is preferred to test serum or plasma samples that previously have been diluted, or concentrated specimens such as urine, in order to determine the presence and/or amount of antibody present.

The invention further comprises assay kits (e.g., articles of manufacture) for detecting anti-*Anaplasma sp.*, anti-*Apl* and/or anti-*Aph* antibodies or antigen-binding antibody fragments, *Anaplasma* polypeptides, *Apl* polypeptides, and/or *Aph* polypeptides in a sample. A kit comprises one or more polypeptides of the invention and means for determining binding of the polypeptide to anti-*Anaplasma sp.* antibodies, anti-*Apl* antibodies, and/or or anti-*Aph* antibodies or antigen-binding antibody fragments in the sample. A kit or article of manufacture can also

comprise one or more antibodies or antigen-binding antibody fragments of the invention and means for determining binding of the antibodies or antigen-binding antibody fragments to *Anaplasma sp.* polypeptides, *Apl* polypeptides, and/or *Aph* polypeptides in the sample. A kit can comprise a device containing one or more polypeptides or antibodies of the invention and  
5 instructions for use of the one or more polypeptides or antibodies for, *e.g.*, the identification of an *Anaplasma sp.*, *Apl*, and/or *Aph* infection in a mammal. The kit can also comprise packaging material comprising a label that indicates that the one or more polypeptides or antibodies of the kit can be used for the identification of *Anaplasma sp.*, *Apl*, and/or *Aph* infection. Other components such as buffers, controls, and the like, known to those of ordinary skill in art, can be  
10 included in such test kits. The polypeptides, antibodies, assays, and kits of the invention are useful, for example, in the diagnosis of individual cases of *Anaplasma sp.*, *Apl*, and/or *Aph* infection in a patient, as well as epidemiological studies of *Anaplasma sp.*, *Apl*, and/or *Aph* outbreaks.

Polypeptides and assays of the invention can be combined with other polypeptides or  
15 assays to detect the presence of *Anaplasma sp.* along with other organisms. For example, polypeptides and assays of the invention can be combined with reagents that detect heartworm and/or *Borrelia burgdorferi* and/or *Ehrlichia canis*.

Polynucleotides of the invention can be used to detect the presence of *Anaplasma sp.*, *Apl* and/or *Aph* polynucleotides in a sample. The polynucleotides can be used to detect *Anaplasma  
20 sp.*, *Apl* and/or *Aph* polynucleotides in a sample by a simple hybridization reaction and can also be used in, *e.g.*, polymerase chain reactions (PCR) such as a real-time PCR reaction. Methods and compositions of the invention can also be used to differentially detect the presence *Aph* from other *Anaplasma sp.*, such as *Apl*.

PCR assays are well described in the art, including, for example, U.S. Pat. Nos.  
25 4,683,195; U.S. Pat. No. 4,683,202; U.S. Pat. No. 4,965,188. Generally, polynucleotide primers are annealed to denatured strands of a target nucleic acid. Primer extension products are formed by polymerization of deoxynucleoside triphosphates by a polymerase. PCR then involves repetitive cycles of template nucleic acid denaturation, primer annealing and extension of the annealed primers by the action of a thermostable polymerase. The process results in exponential  
30 amplification of the target *Anaplasma sp.* nucleic acids in the test sample, which allows for the detection of target polynucleotides existing in very low concentrations in a sample.

Real-time PCR assays are based on the detection of a signal, *e.g.*, a fluorescent reporter signal. This signal increases in direct proportion to the amount of PCR product in a reaction. Real-time PCR is any amplification technique that makes it possible to monitor the evolution of an ongoing amplification reaction. *See*, Quantitation of DNA/RNA Using Real-Time PCR  
5 Detection, Perkin Elmer Applied Biosystems (1999); PCR Protocols (Academic Press New York, 1989). By recording the amount of fluorescence emission at each cycle, it is possible to monitor the PCR reaction during exponential phase where the first significant increase in the amount of PCR product correlates to the initial amount of target template. The higher the starting copy number of the nucleic acid target, the sooner a significant increase in fluorescence is  
10 observed.

One embodiment of the invention provides a method for detecting and/or quantifying *Anaplasma sp.*, *Apl* and/or *Aph* polynucleotides in a test sample. Sense primers and antisense primers can be added to a test sample under conditions suitable for a polymerase chain reaction. The primers hybridize with *Anaplasma sp.*, *Apl* and/or *Aph* polynucleotides such that an  
15 amplification product is formed if *Anaplasma sp.*, *Apl* and/or *Aph* polynucleotides are present in the test sample. Amplification products are detected and the presence and/or quantity of *Anaplasma sp.*, *Apl* and/or *Aph* polynucleotides is determined. Amplification products can be detected with a polynucleotide probe that hybridizes, under conditions suitable for a polymerase chain reaction, with an *Anaplasma sp.*, *Apl* and/or *Aph* polynucleotide sequence. The  
20 amplification product can be quantified by measuring a detection signal from the probe and comparing said detection signal to a second probe detection signal from a quantification standard. The quantification standard can be extracted in parallel with the test sample.

One embodiment of the invention provides a method for differentially detecting *Anaplasma platys* polypeptides and *Anaplasma phagocytophilum* polypeptides in a sample. The method  
25 comprises:

- (a) contacting one or more antibodies that specifically bind to a polypeptide consisting of SEQ ID NO: 2, 6, 8, 10, or 12 with a sample under conditions that allow polypeptide/antibody complexes to form and detecting the polypeptide/antibody complexes; and
- 30 (b) contacting one or more antibodies that specifically bind to a polypeptide consisting of SEQ ID NO:1, 9, or 11 with the sample under conditions that



allow polypeptide/antibody complexes to form and detecting the polypeptide/antibody complexes.

If the polypeptide/antibody complexes are detected in step (a) and in step (b) then the sample contains *Anaplasma phagocytophilum* polypeptides and may also contain *Anaplasma platys* polypeptides. Another test can be run that is specific for *Anaplasma platys*, if desired, in order to determine if *Anaplasma platys* is indeed present. If the polypeptide/antibody complexes are detected in step (a) and are not detected in step (b) then the sample contains *Anaplasma platys* polypeptides and does not contain *Anaplasma phagocytophilum* polypeptides. If the polypeptide complexes are not detected in step (a) and are not detected in step (b) then the sample does not contain *Anaplasma platys* polypeptides and does not contain *Anaplasma phagocytophilum* polypeptides.

Another embodiment of the invention provides a method of detecting antibodies that specifically bind an *Anaplasma platys* polypeptide, an *Anaplasma phagocytophilum* polypeptide, or both an *Anaplasma platys* polypeptide and an *Anaplasma phagocytophilum* polypeptide. The method comprises:

- (a) contacting one or more purified polypeptides comprising SEQ ID NO: 2, 6, 8, 10, or 12, with a test sample, under conditions that allow polypeptide/antibody complexes to form and detecting the polypeptide/antibody complexes; and
- (b) contacting one or more purified polypeptides comprising SEQ ID NO:1, 9, or 11, wherein the purified polypeptide with a test sample, under conditions that allow polypeptide/antibody complexes to form and detecting the polypeptide/antibody complexes.

If the polypeptide/antibody complexes are detected in step (a) and in step (b) then the sample contains antibodies that specifically bind *Anaplasma phagocytophilum* polypeptides and *Anaplasma platys* polypeptides (that is, antibodies that are capable of specifically binding both *Anaplasma platys* and *Anaplasma phagocytophilum* polypeptides) and antibodies that specifically bind only *Anaplasma platys* polypeptides. If the polypeptide/antibody complexes are detected in step (a) and are not detected in step (b) then the sample contains antibodies that specifically bind *Anaplasma platys* polypeptides and *Anaplasma phagocytophilum* polypeptides and does not contain antibodies that specifically bind only *Anaplasma phagocytophilum* polypeptides. If the polypeptide complexes are not detected in step (a) and are not detected in

step (b) then the sample does not contain antibodies specific for *Anaplasma platys* polypeptides and does not contain antibodies specific for *Anaplasma phagocytophilum* polypeptides. In one embodiment, the purified polypeptides comprising SEQ ID NO: 2, 6, 8, 10, or 12, consist of less than about 300 contiguous naturally occurring *Anaplasma phagocytophilum* amino acids and the polypeptides comprising SEQ ID NO:1, 9, or 11, consist of less than about 150 contiguous naturally occurring *Anaplasma phagocytophilum* amino acids.

**Methods of Treatment, Amelioration, or Prevention of a Disease Caused by *Aph* and/or *Apl***

Polypeptides, polynucleotides, and antibodies of the invention can be used to treat, ameliorate, or prevent a disease caused by *Apl* and/or *Aph*. For example, an antibody, such as a monoclonal antibody of the invention or antigen-binding fragments thereof, can be administered to an animal, such as a human or dog. In one embodiment of the invention an antibody or antigen-binding fragment thereof is administered to an animal in a pharmaceutical composition comprising a pharmaceutically acceptable carrier. A pharmaceutical composition comprises a therapeutically effective amount of an antibody or antigen-binding fragments thereof. A therapeutically effective amount is an amount effective in alleviating the symptoms of an *Apl* and/or *Aph* infection or in reducing the amount of *Apl* and/or *Aph* organisms in a subject.

Polypeptides or polynucleotides of the invention can be present in an immunogenic composition and used to elicit an immune response in a host. An immunogenic composition or immunogen is capable of inducing an immune response in an animal. An immunogenic polypeptide or polynucleotide composition of the invention is particularly useful in sensitizing an immune system of an animal such that, as one result, an immune response is produced that ameliorates or prevents the effect of *Apl* and/or *Aph* infection. The elicitation of an immune response in animal model can be useful to determine, for example, optimal doses or administration routes. Elicitation of an immune response can also be used to treat, prevent, or ameliorate a disease or infection caused by *Apl* and/or *Aph*. An immune response includes humoral immune responses or cell mediated immune responses, or a combination thereof. An immune response can also comprise the promotion of a generalized host response, e.g., by promoting the production of defensins.

One embodiment of the invention provides an immunogen that comprises a polypeptide of the invention and one or more additional regions or moieties covalently joined to the polypeptide at the carboxyl terminus or amino terminus. Each region or moiety can, for

example, enhance the immune response, facilitate purification of the immunogen, or facilitate polypeptide stability.

Polypeptide stability can be enhanced by adding, for example, polyethylene glycol to the amino or carboxyl terminus of the polypeptide. Other regions or moieties that can improve polypeptide stability include, for example, amino terminus protecting groups such as acetyl, propyl, succinyl, benzyl, benzyloxycarbonyl or t-butyloxycarbonyl and carboxyl terminus protecting groups such as amide, methylamide, and ethylamide.

Polypeptide purification can be enhanced by adding a region or moiety to the carboxyl or amino terminus to facilitate purification. Examples of groups that can be used to facilitate purification include affinity tags such as six-histidine tag, trpE, glutathione and maltose-binding protein.

The ability of a polypeptide to produce an immune response can be enhanced with certain additional regions or moieties. Examples of groups that can be joined to a polypeptide to enhance an immune response include cytokines such as IL-2. *See, e.g., Buchan et al., 2000. Molecular Immunology 37:545-552.*

The generation of an antibody titer by an animal against *Apl* and/or *Aph* can be important in protection from infection and clearance of infection. Detection and/or quantification of antibody titers after delivery of a polypeptide or polynucleotide can be used to identify epitopes that are particularly effective at eliciting antibody titers. Epitopes responsible for a strong antibody response to *Apl* and/or *Aph* can be identified by eliciting antibodies directed against *Apl* and/or *Aph* polypeptides of different lengths. Antibodies elicited by a particular polypeptide epitope can then be tested using, for example, an ELISA assay to determine which polypeptides contain epitopes that are most effective at generating a strong response. Polypeptides or fusion proteins that contain these epitopes or polynucleotides encoding the epitopes can then be constructed and used to elicit a strong antibody response.

A polypeptide, polynucleotide, or antibody of the invention can be administered to a mammal, such as a mouse, rabbit, guinea pig, macaque, baboon, chimpanzee, human, cow, sheep, pig, horse, dog, cat, or to animals such as chickens or ducks, to elicit antibodies *in vivo*. Injection of a polynucleotide has the practical advantages of simplicity of construction and modification. Further, injection of a polynucleotide results in the synthesis of a polypeptide in the host. Thus, the polypeptide is presented to the host immune system with native post-

translational modifications, structure, and conformation. A polynucleotide can be delivered to a subject as “naked DNA.”

Administration of a polynucleotide, polypeptide, or antibody can be by any means known in the art, including intramuscular, intravenous, intrapulmonary, intramuscular, intradermal, intraperitoneal, or subcutaneous injection, aerosol, intranasal, infusion pump, suppository, mucosal, topical, and oral, including injection using a biological ballistic gun (“gene gun”). A polynucleotide, polypeptide, or antibody can be accompanied by a protein carrier for oral administration. A combination of administration methods can also be used to elicit an immune response. Antibodies can be administered at a daily dose of about 0.5 mg to about 200 mg. In one embodiment of the invention antibodies are administered at a daily dose of about 20 to about 100 mg.

Pharmaceutically acceptable carriers and diluents and veterinarily acceptable carriers and diluents for therapeutic use are well known in the art and are described in, for example, Remington’s Pharmaceutical Sciences, Mack Publishing Co. (A.R. Gennaro ed. (1985)). The carrier should not itself induce the production of antibodies harmful to the host. Such carriers include, but are not limited to, large, slowly metabolized, macromolecules, such as proteins, polysaccharides such as latex functionalized SEPHAROSE®, agarose, cellulose, cellulose beads and the like, polylactic acids, polyglycolic acids, polymeric amino acids such as polyglutamic acid, polylysine, and the like, amino acid copolymers, peptoids, lipitoids, and inactive, avirulent virus particles or bacterial cells. Liposomes, hydrogels, cyclodextrins, biodegradable nanocapsules, and bioadhesives can also be used as a carrier for a composition of the invention.

Pharmaceutically acceptable salts can also be used in compositions of the invention, for example, mineral salts such as hydrochlorides, hydrobromides, phosphates, or sulfates, as well as salts of organic acids such as acetates, propionates, malonates, or benzoates. Especially useful protein substrates are serum albumins, keyhole limpet hemocyanin, immunoglobulin molecules, thyroglobulin, ovalbumin, tetanus toxoid, and other proteins well known to those of skill in the art. Compositions of the invention can also contain liquids or excipients, such as water, saline, phosphate buffered saline, Ringer’s solution, Hank’s solution, glucose, glycerol, dextrose, malodextrin, ethanol, or the like, singly or in combination, as well as substances such as wetting agents, emulsifying agents, tonicity adjusting agents, detergent, or pH buffering agents. Additional active agents, such as bacteriocidal agents can also be used.

If desired, co-stimulatory molecules, which improve immunogen presentation to lymphocytes, such as B7-1 or B7-2, or cytokines such as MIP1 $\alpha$ , GM-CSF, IL-2, and IL-12, can be included in a composition of the invention. Optionally, adjuvants can also be included in a composition. Adjuvants are substances that can be used to nonspecifically augment a specific  
5 immune response. Generally, an adjuvant and a polypeptide of the invention are mixed prior to presentation to the immune system, or presented separately, but are presented into the same site of the animal. Adjuvants can include, for example, oil adjuvants (*e.g.* Freund's complete and incomplete adjuvants) mineral salts (*e.g.* Alk(SO<sub>4</sub>)<sub>2</sub>; AlNa(SO<sub>4</sub>)<sub>2</sub>, AlNH<sub>4</sub>(SO<sub>4</sub>), Silica, Alum, Al(OH)<sub>3</sub>, and Ca<sub>3</sub>(PO<sub>4</sub>)<sub>2</sub>), polynucleotides (*i.e.* Poly IC and Poly AU acids), and certain natural  
10 substances (*e.g.* wax D from *Mycobacterium tuberculosis*, as well as substances found in *Corynebacterium parvum*, *Bordetella pertussis* and members of the genus *Brucella*. Adjuvants which can be used include, but are not limited to MF59-0, aluminum hydroxide, N-acetyl-muramyl-L-threonyl-D-isoglutamine (thr-MDP), N-acetyl-nor-muramyl-L-alanyl-D-isoglutamine (CGP 11637), referred to as nor-MDP), N-acetylmuramyl-L-alanyl-D-  
15 isoglutaminyl-L-alanine-2-(1'-2'-dipalmitoyl-sn-glycero-3-hydroxyphosphoryloxy)-ethylamine (CGP 19835A, referred to as MTP-PE), and RIBI, which contains three components extracted from bacteria, monophosphoryl lipid A, trehalose dimycolate and cell wall skeleton (MPL+TDM+CWS) in a 2% squalene/TWEEN® (polysorbate) 80 emulsion.

The compositions of the invention can be formulated into ingestible tablets, buccal  
20 tablets, troches, capsules, elixirs, suspensions, syrups, wafers, injectable formulations, mouthwashes, dentrifices, and the like. The percentage of one or more polypeptides, polynucleotides, or antibodies of the invention in such compositions and preparations can vary from 0.1% to 60% of the weight of the unit.

Administration of polypeptides, polynucleotides, or antibodies can elicit an immune  
25 response in the animal that lasts for at least 1 week, 1 month, 3 months, 6 months, 1 year, or longer. Optionally, an immune response can be maintained in an animal by providing one or more booster injections of the polypeptide, polynucleotide, or antibodies at 1 month, 3 months, 6 months, 1 year, or more after the primary injection. If desired, co-stimulatory molecules or adjuvants can also be provided before, after, or together with the compositions.

30 A composition of the invention comprising a polypeptide, polynucleotide, antibody, or a combination thereof is administered in a manner compatible with the particular composition used

and in an amount that is effective to elicit an immune response as detected by, for example, an ELISA. A polynucleotide can be injected intramuscularly to a mammal, such as a baboon, chimpanzee, dog, or human, at a dose of 1 ng/kg, 10 ng/kg, 100 ng/kg, 1000 ng/kg, 0.001 mg/kg, 0.1 mg/kg, or 0.5 mg/kg. A polypeptide or antibody can be injected intramuscularly to a mammal at a dose of 0.01, 0.05, 0.5, 0.75, 1.0, 1.5, 2.0, 2.5, 5 or 10 mg/kg.

Polypeptides, polynucleotides, or antibodies, or a combination thereof can be administered either to an animal that is not infected with *Apl* and/or *Aph* or can be administered to an *Apl* and/or *Aph*-infected animal. An immunologically effective amount or therapeutically effective amount means the administration of that amount to an individual, either in a single dose or as part of series, is effective for treatment, amelioration, or prevention of *Apl* and or *Aph* infection. The particular dosages of polynucleotide, polypeptides, or antibodies in a composition will depend on many factors including, but not limited to the species, age, gender, concurrent medication, general condition of the mammal to which the composition is administered, and the mode of administration of the composition. An effective amount of the composition of the invention can be readily determined using only routine experimentation.

All patents, patent applications, and other scientific or technical writings referred to anywhere herein are incorporated by reference in their entirety. The invention illustratively described herein suitably can be practiced in the absence of any element or elements, limitation or limitations that are not specifically disclosed herein. Thus, for example, in each instance herein any of the terms "comprising", "consisting essentially of", and "consisting of" may be replaced with either of the other two terms, while retaining their ordinary meanings. The terms and expressions which have been employed are used as terms of description and not of limitation, and there is no intention that in the use of such terms and expressions of excluding any equivalents of the features shown and described or portions thereof, but it is recognized that various modifications are possible within the scope of the invention claimed. Thus, it should be understood that although the present invention has been specifically disclosed by embodiments, optional features, modification and variation of the concepts herein disclosed may be resorted to by those skilled in the art, and that such modifications and variations are considered to be within the scope of this invention as defined by the description and the appended claims.

In addition, where features or aspects of the invention are described in terms of Markush groups or other grouping of alternatives, those skilled in the art will recognize that the invention

is also thereby described in terms of any individual member or subgroup of members of the Markush group or other group.

## EXAMPLES

### Example 1. Sera from *Aph* or *Apl* infected dogs react specifically with one or more antigens from a hypothetical *Aph* open reading frame

Based on a combination of genomic and protein structural analysis, the hypothetical open reading frame (ORF) Aph\_0915 was selected from the genome of *Aph* (Dunning Hotopp *et al.* PLoS Genet 2(2): e21 (Feb. 2006)). Two polynucleotide regions (SEQ ID NOs: 3 and 4) encoding C-terminal fragments of the APH\_0915 ORF were PCR amplified using genomic *Aph* DNA isolated from a blood sample of a Minnesota dog known to be infected with *Aph*. The PCR products were cloned into an expression vector for protein expression in *E. coli* according to methods well known in the art. Following induction of recombinant protein expression, crude *E. coli* whole cell lysates were analyzed for expression of the recombinant protein, and for reactivity to sera from *Aph* or *Apl* infected dogs, using SDS-PAGE electrophoresis and western blotting according to methods well known in the art. The dog sera were obtained from experimentally infected animals, and were used at 1:300 dilution. Crude lysates from *E. coli* vectors comprising SEQ ID NO:3 or SEQ ID NO:4, expressing polypeptides of SEQ ID NO: 2 (wherein the X at position 43 was A; wherein the X at position 113 was D; wherein the X at position 133 was E; and wherein the X at position 138 was absent) or SEQ ID NO:1 (wherein the X at position 52 was D; the X at position 72 was E; and the X at position 77 was absent), respectively, exhibited specific antigen reactivity (above background levels of *E. coli* cross reactivity) to sera from *Aph* infected dogs. In addition, the crude lysate from clone 13 (expressing polypeptide of SEQ ID NO: 2, wherein the X at position 43 was A; wherein the X at position 113 was D; wherein the X at position 133 was E; and wherein the X at position 138 was absent) exhibited specific antigen reactivity to sera from *Apl* infected dogs. However, crude lysate from clone 14, expressing polypeptide of SEQ ID NO:1 (wherein the X at position 52 was D; the X at position 72 was E; and the X at position 77 was absent) did not exhibit specific antigen reactivity to sera from *Apl* infected dogs.

In addition, the full-length APH\_0915 ORF (SEQ ID NO:5, having a G at position 667, an A at position 878, an A at position 938, and wherein 953, 954, and 955 are absent) encoding

the full-length APH\_0915 protein (SEQ ID NO:6 having an A at position 223, a D at position 293, an E at position 313, and no amino acid at position 318), and a polynucleotide region termed "clone 13ext" (SEQ ID NO:7; wherein the N at position 187 was G; wherein the N at position 398 was A; wherein the N at position 458 was A; and wherein the three N's at positions 473-475 were absent) encoding a C-terminal fragment (SEQ ID NO:8; wherein the X at position 63 was A; wherein the X at position 133 was D; wherein the X at position 153 was E; and wherein the X at position 158 was absent) of APH\_0915 were PCR cloned and expressed in *E. coli* as described above in this Example. The resulting crude whole cell lysates exhibited specific antigen reactivity to dog serum (from a naturally *Aph* infected dog exhibiting clinical symptoms of Anaplasmosis) on western blot. Thus, polypeptides comprising SEQ ID NOs:1, 2, 6 and 8 reacted with antibodies from sera of *Aph* infected dogs. The polypeptide having SEQ ID NO:1 did not react with antibodies from *Apl* infected dogs, and was therefore specific for *Aph* only.

## Example 2

### Nucleotide Sequence and Comparison of Clones 13 and 14

The DNA sequence of clones 13 and 14 were determined. The sequences are aligned with the sequence of APH\_0915 (Genbank Acc. No. ABD43857) below. (SEQ ID NOs 5, 4, and 3).

20	APH_0915	1	TTGAGTTTTACAATGTGCGAAGTTATCGCTTGACCCTACTCAGGGCTCACATACAGCAGAG
		61	AATATTGCTTGTTCTATCTTTGATATGGTACTTGGTGTAAGTCCACTGCAAACTGTTA
		121	GCAGGTACGTGGGCTGGTACAAGCAGCACTATTTGGAAGACAGTAACAGGAGCAGCTTCC
		181	TCAACTAAAGAAGCGTCATCAAAGTCGTATGGAACCTACGTAGTTCCTTGGGCTCTTCC
25		241	GCTTCTAGAAGGATGCTAGGAAGTTGCGCTACCGCCGCTCTCTGCTTAACTGCACCTTTG
		301	CTTGGCGCAGCCGCTGCCGGAGCGGCAATAACATGTGCCTTGATAACCATTTGCATGGCT
		361	TTGCTGTTCTCGTTTTGTACACCGTACTCCACATTGCCTCTCAGATGTTGCGTTGTGCA
		421	TCGCTACTGTTGAGCATGGTATGCAATATCCTGCACAGCACATTCACCGCAACTAAGTCT
		481	TGCCTCGGAGGTAAGTCACCTGCGCGAACAACCTGAAGAGCGGGTAGCTGGGGATTTAGAT
30	APH_0915	541	CACAAAGGGGTGGATTTCAGATCGGAAGCATGATGCAGAGAAAAACAGAAGAGAAAAACAT
	clone13	1	CACAAAGGGGTGGATTTCAGATCGGAAGCATGATGCAGAGAAAAACAGAAGAGAAAAACAT
35	APH_0915	601	GGTTTGGGTAGCCTCTGCAAATCACTCGCGATAAATCTGGTCTCCTTAATGGGAACAGCG
	clone13	61	GGTTTGGGTAGCCTCTGCAAATCACTCGCGATAAATCTGGTCTCCTTAATGGGAACAGCG
40	APH_0915	661	CTAGTTACCACACCCATAATACTACTTGCAGTAGTTCTATTAGTGTTGGTGCCAGTATAT
	clone13	121	CTAGTTGCCACACCCATAATACTACTTGCAGTAGTTCTATTAGTGTTGGTGCCAGTATAT
	APH_0915	721	CTGTTATGCGCTACAGTGCACCACATCTATCAAGGAAATTACGAAGATCGCAACAACGAC
	clone13	181	CTGTTATGCGCTACAGTGCACCACATCTATCAAGGAAATTACGAAGATCGCAACAACGAC
45	clone14	1	---TTATGCGCTACAGTGCACCACATCTATCAAGGAAATTACGAAGATCGCAACAACGAC



5	APH_0915	781	AAAGGTAGCTCCCGTGGCGGCGGTACTACATATTATCCAATGACAATGTCTGCAAGTGCT	
	clone13	241	AAAGGTAGCTCCCGTGGCGGCGGTACTACATATTATCCAATGACAATGTCTGCAAGTGCT	
	clone14	58	AAAGGTAGCTCCCGTGGCGGCGGTACTACATATTATCCAATGACAATGTCTGCAAGTGCT	
10	APH_0915	841	TCTGAAGAGTCCCTTAGCAGCATAATATCTGAAGGAGGTTTGAGTAAGACATCGCTACCA	
	clone13	301	TCTGAAGAGTCCCTTAGCAGCATAATATCTGAAGGAGATTTGAGTAAGACATCGCTACCA	
	clone14	118	TCTGAAGAGTCCCTTAGCAGCATAATATCTGAAGGAGATTTGAGTAAGACATCGCTACCA	
15	APH_0915	901	AGTTACTCCGCAGCCACTGCTACAGGTACTGGAAATGCAACTGGTGAGGTTTTTTCACAT	
	clone13	361	AGTTACTCCGCAGCCACTGCTACAGGTACTGGAAATGAAACTGGTGAGGTTT---CACAT	
	clone14	178	AGTTACTCCGCAGCCACTGCTACAGGTACTGGAAATGAAACTGGTGAGGTTT---CACAT	
20	APH_0915	961	TCTCATTCATCTGGTAAAAGTAGCAGCAAACCAGAATCTCGCCCTGAGAGCAATCTACAG	
	clone13	418	TCTCATTCATCTGGTAAAAGTAGCAGCAAACCAGAATCTCGCCCTGAGAGCAATCTACAG	
	clone14	235	TCTCATTCATCTGGTAAAAGTAGCAGCAAACCAGAATCTCGCCCTGAGAGCAATCTACAG	
25	APH_0915	1021	AATGTGGTAGCAGAAACCATGTGCGCAGCAACAAAGGAGCGTCTCC	(SEQ ID NO:5)
	clone13	478	AATGTGGTAGCAGAAACCATGTGCGCAGCAACAAAGGAGCGTCTCC	(SEQ ID NO:4)
	clone14	295	AATGTGGTAGCAGAAACCATGTGCGCAGCAACAAAGGAGCGTCTCC	(SEQ ID NO:3)

The underlining represents differences between the clone 13/clone 14 sequences and the Aph\_0915 genomic sequence. Furthermore, the DNA sequence of clone 13ext and that of a full-length clone were determined, revealing the same sequence differences (as compared to Genbank Acc. No. ABD43857) identified in clone 13 and clone 14.

### Example 3

#### Clone 13, but not clone 14, detects *Apl* in field samples

An experiment was conducted to determine the reactivity of SEQ ID NO:1 (clone 14) (wherein the X at position 52 was D; the X at position 72 was E; and the X at position 77 was absent) or SEQ ID NO:2 (clone 13) (wherein the X at position 43 was A; wherein the X at position 113 was D; wherein the X at position 133 was E; and wherein the X at position 138 was absent) with sera from *Apl*-infected dogs on western blots (Table 2). Sera from thirteen dogs known to be infected with *Apl* were tested. These sera were derived from dogs living on the Hopi Indian Reservations, Arizona, where only *Apl* (not *Aph*) is prevalent. See, Table 2.

SEQ ID NO:1 (wherein the X at position 52 was D; the X at position 72 was E; and the X at position 77 was absent) was not reactive with any of the 13 *Apl* positive samples. Thus, SEQ ID NO:1 is specific for anti-*Aph* antibodies (see, Example 1) in that it does not react with anti-*Apl* antibodies.

SEQ ID NO:2 (wherein the X at position 43 was A; wherein the X at position 113 was D; wherein the X at position 133 was E; and wherein the X at position 138 was absent) was reactive with all 13 of the *Apl* positive samples. Thus, SEQ ID NO:2 can detect both anti-*Aph* (see, examples 1 and 5) and anti-*Apl* antibodies. See, Table 2.

5

**Table 2.**

<b>Hopi <i>Apl</i> Sample</b>	<b>clone 14 western</b>	<b>clone 13 western</b>
HP 118	-	+
HP 127	-	+
HP 136	-	+
HP 141	-	+
HP 166	-	+
HP 168	-	+
HP 170	-	+
HP 186	-	+
HP 199	-	+
HP 214	-	+
HP 230	-	+
HP 235	-	+
HP 242	-	+

**Example 4**10 **Detection of *Aph* by clone 14 with field samples**

Fifty canine serum samples from an area of Minnesota where only *Aph* (not *Apl*) is prevalent, were tested in this experiment. Of these 50 samples, 47 were known *Aph* positives, and 3 samples were known *Aph* negatives. Sensitivity of SEQ ID NO:1 (clone 14; wherein the X at position 52 was D; the X at position 72 was E; and the X at position 77 was absent), for *Aph* was tested by western blots (as described above). Out of the 47 known positive samples, 39 were positive on the clone 14 western assay. Out of the 3 known negative samples, 2 were negative, and 1 positive, on the clone 14 western assay (Table 3). Thus, the SEQ ID NO:1 assay showed 83% (39/47) sensitivity for *Aph* positive samples (Table 3).

15

**Table 3.**

	<b>Clone 14 western assay</b>	
	<b>Positive</b>	<b>Negative</b>
<b><i>Aph</i> Positive</b>	<b>39</b>	<b>8</b>
<b><i>Aph</i> Negative</b>	<b>1</b>	<b>2</b>

**Example 5****Detection of *Aph* antibody by SEQ ID NO:2 (clone 13)**

5 An experiment was conducted to determine whether a polypeptide comprising SEQ ID NO:2 (clone 13) (wherein the X at position 43 was A; wherein the X at position 113 was D; wherein the X at position 133 was E; and wherein the X at position 138 was absent) can detect *Aph* antibodies in sera from dogs exhibiting clinical symptoms of acute Anaplasmosis.

10 A purified preparation of a recombinant polypeptide comprising SEQ ID NO:2 (wherein the X at position 43 was A; wherein the X at position 113 was D; wherein the X at position 133 was E; and wherein the X at position 138 was absent) was coated on Immulon® 4 wells overnight at 3 ug/mL in carbonate buffer, pH 9.6. The wells were washed 3x with PBST and blocked with 1% BSA in PBS for 1h. Test samples (dog sera) diluted 1:200 in PRRS Sample Diluent, were added to the wells and incubated for 1h. The wells were washed 6x with HW  
15 PetChek® Wash Buffer. Anti-dog (H+L):HRPO 1:4000 in Enzyme Conjugate Diluent was added and incubated for 1h. The wells were washed 6x with HW PetChek® Wash Buffer. 50 µl TMB was added for 10 min and then of 50 µl stop solution was added. The wells were read at A650.

20 This indirect ELISA was performed with sera from *Aph* infected dogs exhibiting clinical symptoms of acute anaplasmosis. Four random samples from normal dogs were tested as negative controls to determine a cut off OD value (cut off = mean + 2xSD). Test samples producing OD values above this cutoff value were deemed “positives” and are represented by “+” in Table 4.

**Table 4**

ID	Clone 13
ME-485	+
ME-487	+
ME-560	+
ME-562	+
ME-568	+
ME-601	+
ME-616	+
ME-631	+
ME-661	+
ME-670	+
ME-699	+

ME-703	+
ME-710	+
ME-716	+
ME-734	+
ME-741	+
ME-748	-
ME-753	+
ME-476	+
ME-534	+
ME-630	+
ME-639	-
ME-653	-
ME-691	-
ME-700	+
ME-746	+

Of the 26 samples tested, 22 samples were positive in the ELISA using SEQ ID NO:2. These results demonstrate that a polypeptide comprising SEQ ID NO:2 can detect *Aph* antibodies in sera from dogs having symptoms of acute anaplasmosis with high sensitivity.

#### 5 **Example 6. Detection of *Aph* antibody with synthetic polypeptides**

Synthetic polypeptides having an amino acid sequence of SEQ ID NO:9, SEQ ID NO:10, or SEQ ID NO:11 were evaluated for their ability to detect *Aph* antibody in an indirect ELISA assay. Each of the three peptides was coated on microtiter plates in serial dilution (0.0 – 0.5  
10 ul/ml) and tested for reactivity to serum obtained from a naturally infected dog (this dog exhibited symptoms of acute anaplasmosis, and was a known seropositive for *Aph* infection). A pooled sample from 10 normal dogs was used as negative control.

Briefly, synthetic polypeptides having amino acid sequences of SEQ ID NO:9 (p37-1), SEQ ID NO:10 (p37-2), or SEQ ID NO:11 (p37-3; wherein the X at position 1 was C; wherein  
15 the X at position 2 was E; and wherein the X at position 7 was absent), were coated onto Immulon® 4 wells overnight in carbonate buffer, pH 9.6. The wells were washed 2x with HW PetChek® Wash Buffer, followed by blocking for 2 hours with 2% TWEEN® (polysorbate) 20, 2.5% Sucrose in 0.1M Tris (pH 7.6), and dried overnight. Dog serum diluted (1:100) in IBR  
20 Conjugate Diluent (IDEXX Laboratories) was added to the wells and incubated for 45 min. The wells were washed 5x with HW PetChek® Wash Buffer. Rabbit anti-dog antibody (H+L) conjugated to HRPO diluted (1:2000) in IBR Conjugate Diluent was added and incubated for 45 min. The wells were washed 6x with HW PetChek® Wash Buffer. 60 µl TMB was added for 10

min and then of 50  $\mu$ l stop solution was added. The optical density (OD) was read at A650 (Table 5).

**Table 5**

peptide	peptide concentration (ug/ml)	<i>Aph</i> dog serum (OD)	normal dog serum (OD)
p37-1	0	0.28	0.15
	0.06	0.56	0.15
	0.125	0.59	0.16
	0.25	0.58	0.18
	0.5	0.72	0.19
p37-2	0	0.30	0.17
	0.06	0.48	0.16
	0.125	1.06	0.16
	0.25	1.93	0.19
	0.5	2.28	0.22
p37-3	0	0.30	0.15
	0.06	0.45	0.15
	0.125	0.56	0.15
	0.25	0.82	0.19
	0.5	1.26	0.37

The results in Table 5 show that all three synthetic polypeptides tested (SEQ ID NO:9 (p37-1), SEQ ID NO:10 (p37-2), SEQ ID NO:11 (p37-3) (wherein the X at position 1 was C; wherein the X at position 2 was E; and wherein the X at position 7 was absent)) were reactive with sera from a symptomatic, *Aph*-infected dog. At polypeptide concentrations ranging from 0.125 to 0.5ug/ml, the strongest signal was obtained with SEQ ID NO:10 (p37-2).

#### **Example 7**

##### **Detection of *Aph* antibody by polypeptide p37-2**

An experiment was conducted to determine whether a synthetic polypeptide comprising SEQ ID NO:10 (p37-2) can detect *Aph* antibodies in sera from dogs exhibiting clinical symptoms of acute Anaplasmosis.

An ELISA was performed as described herein in Example 6, except the synthetic peptide was coated at 0.5 ug/ml. The test samples were sera from *Aph* infected dogs exhibiting clinical symptoms of acute anaplasmosis. Four random samples from normal dogs were tested as negative controls to determine a cut off OD value (cut off = mean + 2xSD). Test samples

producing OD values above this cutoff value were deemed “positives” and are represented by “+” in Table 6.

**Table 6**

ID	P37-2
ME-485	+
ME-487	+
ME-560	+
ME-562	+
ME-568	+
ME-601	+
ME-616	+
ME-631	+
ME-661	+
ME-670	+
ME-699	+
ME-703	+
ME-710	+
ME-716	+
ME-734	+
ME-741	+
ME-748	-
ME-753	+
ME-476	+
ME-534	+
ME-630	+
ME-639	-
ME-653	-
ME-691	-
ME-700	+
ME-746	+

- 5           Of the 26 samples tested, 22 samples were positive in the ELISA using SEQ ID NO:10. These results demonstrate that a polypeptide comprising SEQ ID NO:10 can detect *Aph* antibodies in sera from dogs having symptoms of acute anaplasmosis with high sensitivity.

10   **Example 8 Early detection of *Aph* antibody in sera of experimentally infected dogs by peptide p37-2**

- 15           An indirect ELISA was conducted to determine the time course of seroreactivity to peptide p37-2 (SEQ ID NO:10) following experimental *Aph* infection (Table 7). The assay was performed according to the procedure as described herein in Example 6, except the synthetic peptide was coated at 0.5 ug/ml. Canine sera were obtained from two experimentally infected

dogs. One of these dogs was infected with *Aph* strain Webster (a human isolate), and developed thrombocytopenia which reached its worst levels at day 10. Lymph node swelling was first detected at day 7. The second dog was infected with *Aph* strain MN98E.4 (a canine isolate), and developed thrombocytopenia which reached its worst levels at day 14. Mild lymph node swelling was first detected at day 4, and fever peaked at day 9 in the second dog. Blood samples were taken at various time points post-infection. *Aph* seroreactivity was first detected at day 7 in sera from the dog infected with strain Webster, and at day 14 in sera from the dog infected with strain MN98E.4 (Table 7). Thus, p37-2 can detect of *Aph* infection in dogs at about 7-14 days post-infection. Since the onset of clinical symptoms of acute anaplasmosis typically occurs within 1-2 weeks from the time of infection, p37-2 is useful as a diagnostic tool as early as the time of onset of symptoms.

**Table 7.**

<b><i>Aph</i> strain</b>	<b>days post- infection</b>	<b>p37-2 ELISA cut-off=0.21</b>
Webster	0	-
	2	-
	4	-
	7	+
	10	+
	14	+
	17	+
	21	+
	24	+
MN98E.4	0	-
	2	-
	4	-
	7	-
	10	-
	14	+
	17	+
	21	+
	24	+

## **Example 9**

### **Detection of *Apl* antibody by polypeptide p37-2**

An experiment was conducted to determine whether a synthetic polypeptide comprising SEQ ID NO:10 (p37-2) can detect *Apl* antibodies in sera from two experimentally infected dogs. The assay was performed as described herein in Example 6, except the synthetic peptide was

coated at 0.5 ug/ml. Samples from 10 normal dogs were tested as negative controls to determine a cut off OD value (cut off = mean + 2xSD). Test samples producing OD values above this cutoff value were deemed “positives” and are represented by “+” in Table 7.

**Table 7**

Canine ID	Days Post Infection	p37-2
A5	3	-
	7	-
	10	+
	14	+
	17	+
	21	+
	24	+
	28	+
	35	+
	42	+
	49	+
	56	+
	63	+
	71	+
	79	+
A6	3	-
	7	-
	10	+
	13	+
	17	+
	21	+
	24	+
	28	+
	34	+
	42	+
	49	+
	56	+
	62	+
	70	+
	78	+

5 Sera from both dogs were positive starting at day 10 post-infection in the ELISA using SEQ ID NO:10. These results demonstrate that a polypeptide comprising SEQ ID NO:10 can detect *Apl* antibodies in sera from *Apl* infected dogs, as early as 10 days post-infection.

While the working examples provided herein were performed on sera from dogs, a skilled artisan will appreciate that the compositions and methods disclosed herein are readily applicable  
 10 to the detection of *Aph* and/or *Apl* in other host species of *Aph* and/or *Apl*, such as for example humans, horses, cats, deer and ruminants.



**CLAIMS**

We claim:

- 5 1. A purified polypeptide that is at least 95% identical to SEQ ID NO:1, 2, 6, 8, 9, 10, 11, or 12, wherein the purified polypeptide consists of less than about 300 contiguous naturally occurring *Anaplasma phagocytophilum* amino acids.
2. The purified polypeptide of claim 1, wherein the purified polypeptide consists of less than about 150 contiguous naturally occurring *Anaplasma phagocytophilum* amino acids or  
10 wherein the purified polypeptide consists of less than about 50 contiguous naturally occurring *Anaplasma phagocytophilum* amino acids.
3. An isolated polynucleotide that encodes the purified polypeptide of claim 1.
4. The purified polypeptide of claim 1, wherein the purified polypeptide is linked to an indicator reagent, an amino acid spacer, an amino acid linker, a signal sequence, a stop transfer  
15 sequence, a transmembrane domain, a protein purification ligand, a heterologous polypeptide, one or more additional polypeptides comprising SEQ ID NO:1, 2, 6, 8, 9, 10, 11, 12, or a combination thereof.
5. A method of detecting antibodies that specifically bind an *Anaplasma phagocytophilum* polypeptide in a test sample, comprising:  
20 (a) contacting one or more purified polypeptides at least 95% identical to SEQ ID NO:1, 9 or 11, wherein the purified polypeptides consist of less than about 150 contiguous naturally occurring *Anaplasma phagocytophilum* amino acids, with the test sample, under conditions that allow polypeptide/antibody complexes to form;  
(b) detecting the polypeptide/antibody complexes;  
25 wherein the detection of the polypeptide/antibody complexes is an indication that antibodies specific for *Anaplasma phagocytophilum* are present in the test sample.
6. The method of claim 5, further comprising contacting the complexes of step (a) with an indicator reagent prior to the performance of step (b).
7. The method of claim 5, wherein the amount of antibodies in the test sample is  
30 determined.
8. The method of claim 5, wherein the one or more purified polypeptides are attached to a substrate.

9. The method of claim 5, wherein the one or more purified polypeptides are linked to an indicator reagent, an amino acid spacer, an amino acid linker, a signal sequence, a stop transfer sequence, a transmembrane domain, a protein purification ligand, a heterologous protein, one or more additional polypeptides comprising SEQ ID NO:1, 9, or 11, or a combination thereof.

5 10. A method of detecting an *Anaplasma phagocytophilum* infection in a subject comprising:  
(a) obtaining a biological sample from the subject;  
(b) contacting one or more purified polypeptides that are at least 95% identical to SEQ ID NO:1, 9 or 11, wherein the purified polypeptides consist of less than about 150 contiguous naturally occurring *Anaplasma phagocytophilum* amino acids, with the biological sample under  
10 conditions that allow polypeptide/antibody complexes to form;

(c) detecting the polypeptide/antibody complexes;  
wherein the detection of the polypeptide/antibody complexes is an indication that the subject has an *Anaplasma phagocytophilum* infection.

11. An antibody that specifically binds to a polypeptide consisting of SEQ ID NO:1, 2, 6, 8,  
15 9, 10, 11, or 12.

12. The antibody of claim 11, wherein the antibody is a monoclonal antibody, polyclonal antibody, a Fab fragment, a Fab' fragment, Fab'-SH fragment, F(ab')<sub>2</sub> fragment, Fv fragment, or a single chain antibody.

13. A method of detecting an *Anaplasma phagocytophilum* polypeptide in a sample  
20 comprising:

(a) contacting one or more antibodies that specifically bind to a polypeptide consisting of SEQ ID NO:1, 9, or 11 with the sample under conditions that allow polypeptide/antibody complexes to form;

(b) detecting the polypeptide/antibody complexes;  
25 wherein the detection of the polypeptide/antibody complexes is an indication that an *Anaplasma phagocytophilum* polypeptide is present in the sample.

14. The method of claim 13, wherein the one or more antibodies are monoclonal antibodies, polyclonal antibodies, Fab fragments, Fab' fragments, Fab'-SH fragments, F(ab')<sub>2</sub> fragments, Fv fragments, or single chain antibodies.

15. A method of detecting antibodies that specifically bind an *Anaplasma platys* polypeptide, an *Anaplasma phagocytophilum* polypeptide or both an *Anaplasma platys* polypeptide and an *Anaplasma phagocytophilum* polypeptide, comprising:

(a) contacting one or more purified polypeptides that are at least 95% identical to SEQ ID NO:2, 6, 8, 10, or 12 with a test sample, under conditions that allow polypeptide/antibody complexes to form;

(b) detecting the polypeptide/antibody complexes;  
wherein the detection of the polypeptide/antibody complexes is an indication that antibodies specific for *Anaplasma platys* and/or *Anaplasma phagocytophilum* are present in the test sample.

16. The method of claim 15, further comprising contacting the complexes of step (a) with an indicator reagent prior to the performance of step (b).

17. The method of claim 15, wherein the amount of antibodies in the test sample is determined.

18. The method of claim 15, wherein the one or more purified polypeptides are attached to a substrate.

19. The method of claim 15, wherein the one or more purified polypeptides are linked to an indicator reagent, an amino acid spacer, an amino acid linker, a signal sequence, a stop transfer sequence, a transmembrane domain, a protein purification ligand, a heterologous protein, one or more additional polypeptides comprising SEQ ID NO:1, 2, 6, 8, 9, 10, 11, 12, or a combination thereof.

20. A method of detecting an *Anaplasma phagocytophilum* and/or *Anaplasma platys* infection in a subject comprising:

(a) obtaining a biological sample from the subject;  
(b) contacting one or more purified polypeptides comprising SEQ ID NO:2, 6, 8, 10, 12, with the biological sample under conditions that allow polypeptide/antibody complexes to form;  
(c) detecting the polypeptide/antibody complexes;  
wherein the detection of the polypeptide/antibody complexes is an indication that the subject has an *Anaplasma phagocytophilum* and/or *Anaplasma platys* infection.

21. A method of detecting an *Anaplasma phagocytophilum* polypeptide, an *Anaplasma platys* polypeptide, or an *Anaplasma phagocytophilum* polypeptide and an *Anaplasma platys* polypeptide, in a sample comprising:

(a) contacting one or more antibodies that specifically bind to a polypeptide consisting of SEQ ID NO:2, 6, 8, 10, or 12 with the sample under conditions that allow polypeptide/antibody complexes to form;

(b) detecting the polypeptide/antibody complexes;

5 wherein the detection of the polypeptide/antibody complexes is an indication that an *Anaplasma phagocytophilum* polypeptide, an *Anaplasma platys* polypeptide, or an *Anaplasma phagocytophilum* polypeptide and an *Anaplasma platys* polypeptide is present in the sample.

22. The method of claim 21, wherein the one or more antibodies are monoclonal antibodies, polyclonal antibodies, Fab fragments, Fab' fragments, Fab'-SH fragments, F(ab')<sub>2</sub> fragments, Fv  
10 fragments, or single chain antibodies.

23. A method of detecting *Anaplasma platys* polypeptides and/or *Anaplasma phagocytophilum* polypeptides in a sample comprising:

(a) contacting one or more antibodies that specifically bind to a polypeptide consisting of SEQ ID NO:2, 6, 8, 10, 12 with the sample under conditions that allow  
15 polypeptide/antibody complexes to form and detecting the polypeptide/antibody complexes;

(b) contacting one or more antibodies that specifically bind to a polypeptide consisting of SEQ ID NO:1, 9, or 11 with the sample under conditions that allow polypeptide/antibody complexes to form and detecting the polypeptide/antibody complexes;

20 wherein if the polypeptide/antibody complexes are detected in step (a) and in step (b) then the sample contains *Anaplasma phagocytophilum* polypeptides and may also contain *Anaplasma platys* polypeptides; wherein if the polypeptide/antibody complexes are detected in step (a) and are not detected in step (b) then the sample contains *Anaplasma platys* polypeptides and does not contain *Anaplasma phagocytophilum* polypeptides; wherein if the polypeptide complexes are not  
25 detected in step (a) and are not detected in step (b) then the sample does not contain *Anaplasma platys* polypeptides and does not contain *Anaplasma phagocytophilum* polypeptides.

24. A method of detecting antibodies that specifically bind an *Anaplasma platys* polypeptide, an *Anaplasma phagocytophilum* polypeptide, or both an *Anaplasma platys* polypeptide and an *Anaplasma phagocytophilum* polypeptide, comprising:

(a) contacting one or more purified polypeptides at least 95% identical to SEQ ID NO:2, 6, 8, 10, or 12 with a test sample, under conditions that allow polypeptide/antibody complexes to form and detecting the polypeptide/antibody complexes; and

(b) contacting one or more purified polypeptides at least 95% identical to SEQ ID NO:1, 9, or 11, wherein the purified polypeptide consists of less than about 150 contiguous naturally occurring *Anaplasma phagocytophilum* amino acids, with a test sample, under conditions that allow polypeptide/antibody complexes to form and detecting the polypeptide/antibody complexes;

wherein if the polypeptide/antibody complexes are detected in step (a) and in step (b) then the sample contains antibodies that specifically bind *Anaplasma phagocytophilum* polypeptides and *Anaplasma platys* polypeptides and antibodies that specifically bind only *Anaplasma platys* polypeptides; wherein if the polypeptide/antibody complexes are detected in step (a) and are not detected in step (b) then the sample contains antibodies that specifically bind *Anaplasma platys* polypeptides and *Anaplasma phagocytophilum* polypeptides and does not contain antibodies that specifically bind only *Anaplasma phagocytophilum* polypeptides; wherein if the polypeptide complexes are not detected in step (a) and are not detected in step (b) then the sample does not contain antibodies specific for *Anaplasma platys* polypeptides and does not contain antibodies specific for *Anaplasma phagocytophilum* polypeptides.

25. A composition comprising the purified polypeptide of claim 1 and a pharmaceutically-acceptable or veterinarily acceptable carrier.

26. The composition of claim 25, further comprising an adjuvant.

27. An immunogen comprising a polypeptide having at least 95% identity to SEQ ID NO:1, 2, 6, 8, 9, 10, 11, or 12, and one or more additional regions or moieties covalently joined to the polypeptide at the carboxyl terminus or amino terminus, wherein each region or moiety has at least one of the following properties: enhances the immune response, facilitates purification, or facilitates polypeptide stability.

28. A method of treating or ameliorating *Anaplasma platys* infection, *Anaplasma phagocytophilum* infection, or both in a mammalian subject comprising administering to the mammalian subject a therapeutically effective amount of a composition according to claim 25.

29. A method of inducing an immune response in a mammal comprising administering an immunologically effective amount of the composition of claim 25 to the mammal.

30. A first purified polypeptide that specifically binds an antibody, wherein the antibody specifically binds a second purified polypeptide, wherein the second purified polypeptide consists of SEQ ID NO:1, 2, 6, 8, 9, 10, 11, or 12.

31. The first purified polypeptide of claim 30, wherein the first purified polypeptide consists of at least 10, but less than 300 contiguous amino acids of SEQ ID NO: 1, 2, 6, 8, 9, 10, 11 or 12.

32. The first purified polypeptide of claim 30, wherein the first purified polypeptide is at least 95% identical to SEQ ID NO: 1, 2, 6, 8, 9, 10, 11 or 12.

33. The first purified polypeptide of claim 30, wherein the first purified polypeptide is linked to an indicator reagent, an amino acid spacer, an amino acid linker, a signal sequence, a stop transfer sequence, a transmembrane domain, a protein purification ligand, a heterologous polypeptide, one or more additional polypeptides comprising SEQ ID NO:1, 2, 6, 8, 9, 10, 11, 12, or a combination thereof.