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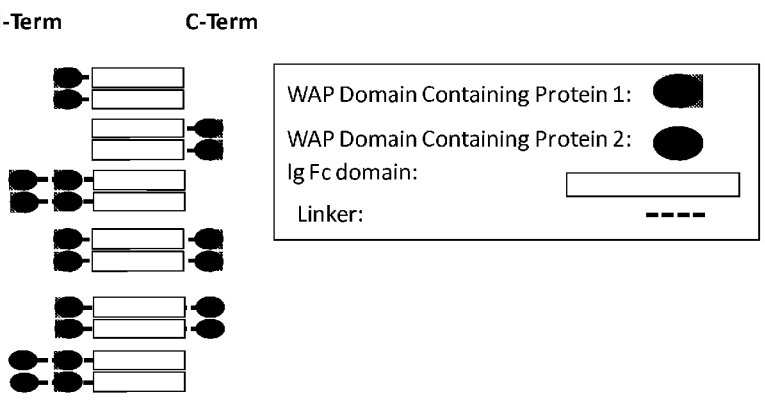
[Continued on next page]

(54) Title: WAP DOMAIN FUSION POLYPEPTIDES AND METHODS OF USE THEREOF

FIGURE 1A



(57) Abstract: This invention relates to fusion proteins that include a whey acidic protein (WAP) domain-containing polypeptide and a second polypeptide. Additionally, the invention relates to fusion proteins that include a WAP domain-containing polypeptide, a second polypeptide, and a third polypeptide. The second and/or third polypeptides of the fusion proteins of the invention are an Fc polypeptide; an albumin polypeptide; a cytokine targeting polypeptide; or a serpin polypeptide. This invention also relates to methods of using such molecules in a variety of therapeutic and diagnostic indications, as well as methods of producing such molecules.

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WAP DOMAIN FUSION POLYPEPTIDES AND METHODS OF USE THEREOF

Related Applications

[0001] This application claims the benefit of U.S. Provisional Application No. 61/502052, filed June 28, 2011; U.S. Provisional Application No. 61/565625, filed December 1, 2011; and U.S. Provisional Application No. 61/638168, filed April 25, 2012; and U.S. Provisional Application No. 61/638516, filed April 26, 2012. The contents of each of these applications are hereby incorporated by reference in their entirety.

Field of the Invention

[0002] This invention relates to molecules, particularly polypeptides, more particularly fusion proteins that include a whey acidic protein (WAP) domain-containing polypeptide or an amino acid sequence that is derived from a WAP domain-containing polypeptide, and second polypeptide. Additionally, the invention relates to fusion proteins that include a WAP domain-containing polypeptide or an amino acid sequence that is derived from a WAP domain-containing polypeptide, a second polypeptide, and a third polypeptide. Specifically, this invention relates to fusion proteins that include WAP domain-containing polypeptides and a second polypeptide or fusion proteins that include WAP domain-containing polypeptides, a second polypeptide, and a third polypeptide, where the second and third polypeptides of the fusion proteins of the invention can be at least one of the following: an Fc polypeptide or an amino acid this derived from an Fc polypeptide; an albumin polypeptide, or an amino acid sequence that is derived from an albumin polypeptide; a cytokine targeting polypeptides or an amino acid sequence that is derived from a cytokine targeting polypeptide; and a serpin polypeptide or an amino acid sequence that is derived from a serpin polypeptide. This invention also relates to methods of using such molecules in a variety of therapeutic and diagnostic indications, as well as methods of producing such molecules.

Background of the Invention

[0003] Aberrant serine protease activity or an imbalance of protease-to-protease inhibitor can lead to protease-mediated tissue destruction and inflammatory responses. Accordingly, there exists a need for therapeutics and therapies that target aberrant serine protease activity and/or imbalance of protease-to-protease inhibitor.

Summary of the Invention

[0004] The fusion proteins described herein include at least a whey acidic protein (WAP) domain-containing polypeptide or an amino acid sequence that is derived from a WAP domain-containing polypeptide (Polypeptide 1), and second polypeptide (Polypeptide 2). Additionally the fusion proteins described herein include a whey acidic protein (WAP) domain-containing polypeptide or an amino acid sequence that is derived from a WAP domain-containing polypeptide (Polypeptide 1), a second polypeptide (Polypeptide 2), and a third polypeptide (Polypeptide 3). Specifically, this invention relates to fusion proteins that include a WAP domain-containing polypeptide and a second polypeptide or a WAP domain-containing polypeptide, a second polypeptide, and a third polypeptide, where the second and third polypeptides can include at least one of the following; an Fc polypeptide or an amino acid this derived from an Fc polypeptide; an albumin polypeptide or an amino acid sequence that is derived from an albumin polypeptide; a cytokine targeting polypeptides or an amino acid sequence that is derived from a cytokine targeting polypeptide; and a serpin polypeptide or an amino acid sequence that is derived from a serpin polypeptide.

[0005] As used interchangeably herein, the terms "fusion protein" and "fusion polypeptide" refer to a WAP domain-containing polypeptide or an amino acid sequence derived from a WAP domain-containing polypeptide operably linked to at least a second polypeptide or an amino acid sequence derived from a second polypeptide. The individualized elements of the fusion protein can be linked in any of a variety of ways, including for example, direct attachment, the use of an intermediate or spacer peptide, the use of a linker region, the use of a hinge region, or the use of both a linker and a hinge region. In some embodiments, the linker region may fall within the sequence of the hinge region, or alternatively, the hinge region may fall within the sequence of the linker region. Preferably, the linker region is a peptide sequence. For example, the linker peptide includes anywhere from zero to 40 amino acids, *e.g.*, from zero to 35 amino acids, from zero to 30 amino acids, from zero to 25 amino acids, or from zero to 20 amino acids. Preferably, the hinge region is a peptide sequence. For example, the hinge peptide includes anywhere from zero to 75 amino acids, *e.g.*, from zero to 70 amino acids, from zero to 65 amino acids or from zero to 62 amino acids. In embodiments where the fusion protein includes both a linker region and hinge region, preferably each of the linker region and the hinge region is a

peptide sequence. In these embodiments, the hinge peptide and the linker peptide together include anywhere from zero to 90 amino acids, *e.g.*, from zero to 85 amino acids or from zero to 82 amino acids.

[0006] In some embodiments, the WAP domain-based portion and the second polypeptide-based portion of the fusion protein can be linked non-covalently through an intermediate binding polypeptide. In some embodiments, the WAP domain-based portion and the second polypeptide-based portion of the fusion protein may be non-covalently linked.

[0007] In some embodiments, fusion proteins according to the invention can have one of the following formulae, in an N-terminus to C-terminus direction or in a C-terminus to N-terminus direction:

Polypeptide $1_{(a)}$ – $hinge_m$ – Polypeptide $2_{(b)}$

Polypeptide $1_{(a)}$ – $linker_n$ – Polypeptide $2_{(b)}$

Polypeptide $1_{(a)}$ – $linker_n$ – $hinge_m$ – Polypeptide $2_{(b)}$

Polypeptide $1_{(a)}$ – $hinge_m$ – $linker_n$ – Polypeptide $2_{(b)}$

Polypeptide $1_{(a)}$ – Polypeptide $2_{(b)}$– Polypeptide $3_{(c)}$

Polypeptide $1_{(a)}$ – $hinge_m$ – Polypeptide $2_{(b)}$– $hinge_m$ – Polypeptide $3_{(c)}$

Polypeptide $1_{(a)}$ – $linker_n$ – Polypeptide $2_{(b)}$– $linker_n$ – Polypeptide $3_{(c)}$

Polypeptide $1_{(a)}$ – $hinge_m$ – $linker_n$ – Polypeptide $2_{(b)}$–$hinge_m$ – $linker_n$ – Polypeptide $3_{(c)}$ Polypeptide $1_{(a)}$ – $linker_n$ – $hinge_m$ – Polypeptide $2_{(b)}$– $linker_n$ – $hinge_m$– Polypeptide $3_{(c)}$

where n is an integer from zero to 20, where m is an integer from 1 to 62 and where a, b, and c are an integer of at least one. These embodiments include the above formulations and any variation or combination thereof. For example, the order of polypeptides in the formulae also includes Polypeptide $3_{(c)}$ – Polypeptide $1_{(a)}$– Polypeptide $2_{(b)}$, Polypeptide $2_{(b)}$ – Polypeptide $3_{(c)}$– Polypeptide $1_{(a)}$, or any variation or combination thereof.

[0008] In some embodiments, the Polypeptide 1 sequence includes a whey acidic protein (WAP) domain-containing polypeptide. The WAP domain is an evolutionarily conserved sequence motif of 50 amino acids containing eight cysteines found in a characteristic 4-disulfide core arrangement (also called a four-disulfide core motif). The WAP domain sequence motif is a functional motif characterized by serine protease

inhibition activity in a number of proteins. WAP domain-containing polypeptides suitable for use in the fusion proteins provided herein include, by way of non-limiting example, secretory leukocyte protease inhibitor (SLPI), Elafin, and Eppin.

[0009] In some embodiments, the Polypeptide 1 sequence includes a secretory leukocyte protease inhibitor (SLPI) polypeptide sequence or an amino acid sequence that is derived from SLPI. In some embodiments, the Polypeptide 1 sequence includes a portion of the SLPI protein, such as for example, the WAP2 domain or a sub-portion thereof. In a preferred embodiment, the SLPI polypeptide sequence or an amino acid sequence that is derived from SLPI that is derived from a human SLPI polypeptide sequence.

[0010] In some embodiments, the fusion protein includes a full-length human SLPI polypeptide sequence having the following amino acid sequence:

```
  1 MKSSGLFPFL VLLALGTLAP WAVEGSGKSF KAGVCPPKKS AQCLRYKKPE CQSDWQCPGK
 61 KRCCPDTCGI KCLDPVDTPN PTRRKPGKCP VTYGQCLMLN PPNFCEMDGQ CKRDLKCCMG
121 MCGKSCVSPV KA (SEQ ID NO: 1)
```

[0011] In some embodiments, the fusion protein includes a human SLPI polypeptide sequence that is at least 50%, 60%, 65%, 70%, 75%, 80%, 85%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98% or 99% identical to the amino acid sequence of SEQ ID NO: 1.

[0012] In some embodiments, the fusion protein includes a portion of the full-length human SLPI polypeptide sequence, where the portion has the following amino acid sequence:

```
  1 SGKSFKAGVC PPKKSAQCLR YKKPECQSDW QCPGKKRCCP DTCGIKCLDP VDTPNPTRRK
 61 PGKCPVTYGQ CLMLNPPNFC EMDGQCKRDL KCCMGMCGKS CVSPVKA (SEQ ID NO: 2)
```

[0013] In some embodiments, the fusion protein includes a human SLPI polypeptide sequence that is at least 50%, 60%, 65%, 70%, 75%, 80%, 85%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98% or 99% identical to the amino acid sequence of SEQ ID NO: 2.

[0014] In some embodiments, the fusion protein includes the WAP2 domain of the full-length human SLPI polypeptide sequence, where the WAP2 domain has the following amino acid sequence:

```
  1 TRRKPGKCPV TYGQCLMLNP PNFCEMDGQC KRDLKCCMGM CGKSCVSPVK A (SEQ ID NO:
3)
```

[0015] In some embodiments, the fusion protein includes a human SLPI polypeptide sequence that is at least 50%, 60%, 65%, 70%, 75%, 80%, 85%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98% or 99% identical to the amino acid sequence of SEQ ID NO: 3.

[0016] In some embodiments, the SLPI polypeptide sequence is or the amino acid sequence derived from an SLPI polypeptide is derived from, one or more of the human SLPI polypeptide sequences shown in GenBank Accession Nos. CAA28187.1, NP_003055.1, EAW75869.1, P03973.2, AAH20708.1, CAB64235.1, CAA28188.1, AAD19661.1, and/or BAG35125.1.

[0017] In some embodiments, the fusion protein includes a full-length human elafin polypeptide sequence having the following amino acid sequence:

```
1  MRASSFLIVV VFLIAGTLVL EAAVTGVPVK GQDTVKGRVP FNGQDPVKGQ VSVKGQDKVK
61 AQEPVKGPVS TKPGSCPIIL IRCAMLNPPN RCLKDTDCPG IKKCCEGSCG MACFVPQ
(SEQ ID NO: 4)
```

[0018] In some embodiments, the fusion protein includes a human elafin polypeptide sequence that is at least 50%, 60%, 65%, 70%, 75%, 80%, 85%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98% or 99% identical to the amino acid sequence of SEQ ID NO: 4.

[0019] In some embodiments, the fusion protein includes a portion of the full-length human elafin polypeptide sequence, where the portion has the following amino acid sequence:

```
 1 AVTGVPVKGQ DTVKGRVPFN GQDPVKGQVS VKGQDKVKAQ EPVKGPVSTK PGSCPIILIR
61 CAMLNPPNRC LKDTDCPGIK KCCEGSCGMA CFVPQ
 (SEQ ID NO: 5)
```

[0020] In some embodiments, the fusion protein includes a human elafin polypeptide sequence that is at least 50%, 60%, 65%, 70%, 75%, 80%, 85%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98% or 99% identical to the amino acid sequence of SEQ ID NO: 5.

[0021] In some embodiments, the fusion protein includes the WAP domain of the full-length human elafin polypeptide sequence, where the WAP domain has the following amino acid sequence:

1 VSTKPGSCPI ILIRCAMLNP PNRCLKDTDC PGIKKCCEGS CGMACFVPQ
(SEQ ID NO: 6)

[0022] In some embodiments, the fusion protein includes a human elafin polypeptide sequence that is at least 50%, 60%, 65%, 70%, 75%, 80%, 85%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98% or 99% identical to the amino acid sequence of SEQ ID NO: 6.

[0023] In some embodiments, the Elafin polypeptide sequence is or the amino acid sequence derived from an Elafin polypeptide is derived from, one or more of the human elafin polypeptide sequences shown in GenBank Accession Nos. P19957.3, NP_002629.1, BAA02441.1, EAW75814.1, EAW75813.1, Q8IUB2.1, and/or NP_542181.1.

[0024] In some embodiments, the Polypeptide 1 sequence includes an Eppin polypeptide sequence or an amino acid sequence that is derived from Eppin. In some embodiments, the Polypeptide 1 sequence includes a portion of the Eppin protein, such as for example, the WAP domain or a sub-portion thereof. In a preferred embodiment, the Eppin polypeptide sequence is or an amino acid sequence that is derived from Eppin is derived from, a human Eppin polypeptide sequence.

[0025] In some embodiments, the Eppin polypeptide sequence is or the amino acid sequence derived from an Eppin polypeptide is derived from one or more of the human Eppin polypeptide sequences shown in GenBank Accession Nos. O95925.1, NP_065131.1, AAH44829.2, AAH53369.1, AAG00548.1, AAG00547.1, and/or AAG00546.1.

[0026] In some embodiments, the fusion proteins contain one or more mutations. For example, the fusion protein contains at least one mutation at a methionine (Met) residue in the non-Fc portion of the fusion protein, for example in the SLPI portion of the fusion protein. In these Met mutations, the Met residue can be substituted with any amino acid. For example, the Met residue can be substituted with an amino acid with a hydrophobic side chain, such as, for example, leucine (Leu, L) or valine (Val, V). Without wishing to be bound by theory, the Met mutation(s) prevent oxidation and subsequent inactivation of the inhibitory activity of the fusion proteins of the invention. In some embodiments, the Met mutation is at position 98 of an SLPI polypeptide, for example, the Met mutation is Met98Leu (M98L) in SEQ ID NO: 8.

[0027] In some embodiments, the fusion proteins are modified to increase or otherwise inhibit proteolytic cleavage, for example, by mutating proteolytic cleavage sites.

In some embodiments, the proteolytic cleavage site mutation occurs at a residue in the SLPI portion of the fusion protein. For example, the proteolytic cleavage site mutation occurs at a residue in the amino acid sequence of SEQ ID NO: 2 selected from Ser15, Ala16, Glu17, and combinations thereof.

[0028] In some embodiments, the second polypeptide (Polypeptide 2) of the WAP domain-containing fusion protein is an Fc polypeptide or derived from an Fc polypeptide. These embodiments are referred to collectively herein as "WAP-Fc fusion proteins." The WAP-Fc fusion proteins described herein include at least a WAP domain-containing polypeptide or an amino acid sequence that is derived from a WAP domain-containing polypeptide and an Fc polypeptide or an amino acid sequence that is derived from an Fc polypeptide.

[0029] In some embodiments, the WAP-Fc fusion protein includes a single WAP domain containing polypeptide. In other embodiments, the WAP-Fc fusion proteins include more than one WAP domain containing polypeptide, collectively referred to herein as "$WAP_{(a')}$-Fc fusion protein," where (a′) is an integer of at least 2. In some embodiments, WAP domain containing polypeptides in a $WAP_{(a')}$-Fc fusion protein can include the same amino acid sequence. For example, the WAP domain-containing polypeptides of the $WAP_{(a')}$-Fc fusion protein can be derived from a SLPI or an Elafin polypeptide, but not both (e.g., Elafin-Fc-Elafin, or SLPI-Fc-SLPI). In other embodiments of WAP domain containing polypeptides in a $WAP_{(a')}$-Fc fusion protein can include distinct amino acid sequences. For example, the fusion protein incorporates amino acid sequences derived from both SLPI and Elafin (e.g., SLPI-Fc-Elafin, or Elafin-Fc-SLPI).

[0030] In some embodiments, the WAP domain-containing polypeptide of the WAP-Fc fusion protein is derived from any one of the amino acid sequences of SEQ ID NOs 1-6. In some embodiments, the WAP domain-containing polypeptide of the WAP-Fc fusion protein has at least 50%, 60%, 65%, 70%, 75%, 80%, 85%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98% or 99% sequence identity to any one of the amino acid sequences having SEQ ID NO. 1, 2, 3, 4, 5 or 6.

[0031] In some embodiments, the WAP domain-containing polypeptide sequence of the WAP-Fc fusion protein is or is derived from sequences shown in GenBank Accession Nos. CAA28187.1, NP_003055.1, EAW75869.1, P03973.2, AAH20708.1, CAB64235.1, CAA28188.1, AAD19661.1, BAG35125.1., P19957.3, NP_002629.1, BAA02441.1,

EAW75814.1, EAW75813.1, Q8IUB2.1, and/or NP_542181.1., O95925.1, NP_065131.1, AAH44829.2, AAH53369.1, AAG00548.1, AAG00547.1, and/or AAG00546.1.

[0032] In some embodiments, the Fc polypeptide of the WAP-Fc fusion protein is a human Fc polypeptide, for example, a human IgG Fc polypeptide sequence or an amino acid sequence that is derived from a human IgG Fc polypeptide sequence. In some embodiments, the Fc polypeptide is a human IgG1 Fc polypeptide or an amino acid sequence that is derived from a human IgG1 Fc polypeptide sequence. In some embodiments, the Fc polypeptide is a human IgG2 Fc polypeptide or an amino acid sequence that is derived from a human IgG2 Fc polypeptide sequence. In some embodiments, the Fc polypeptide is a human IgG3 Fc polypeptide or an amino acid sequence that is derived from a human IgG3 Fc polypeptide sequence. In some embodiments, the Fc polypeptide is a human IgG4 Fc polypeptide or an amino acid sequence that is derived from a human IgG4 Fc polypeptide sequence. In some embodiments, the Fc polypeptide is a human IgM Fc polypeptide or an amino acid sequence that is derived from a human IgM Fc polypeptide sequence.

[0033] In some embodiments where the fusion protein of the invention includes an Fc polypeptide, the Fc polypeptide of the fusion protein includes a human IgG1 Fc polypeptide sequence having the following amino acid sequence:

```
  1 APELLGGPSV FLFPPKPKDT LMISRTPEVT CVVVDVSHED PEVKFNWYVD GVEVHNAKTK
 61 PREEQYNSTY RVVSVLTVLH QDWLNGKEYK CKVSNKALPA PIEKTISKAK GQPREPQVYT
121 LPPSRDELTK NQVSLTCLVK GFYPSDIAVE WESNGQPENN YKTTPPVLDS DGSFFLYSKL
181 TVDKSRWQQG NVFSCSVMHE ALHNHYTQKS LSLSPGK (SEQ ID NO: 7)
```

[0034] In some embodiments, where the fusion protein of the invention includes an Fc polypeptide, the Fc polypeptide of the fusion protein includes a human IgG1 Fc polypeptide sequence that is at least 50%, 60%, 65%, 70%, 75%, 80%, 85%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98% or 99% identical to the amino acid sequence of SEQ ID NO: 7.

[0035] In some embodiments where the fusion protein of the invention includes an Fc polypeptide, the Fc polypeptide of the fusion protein includes a human IgG2 Fc polypeptide sequence having the following amino acid sequence:

```
  1 APPVAGPSVF LFPPKPKDTL MISRTPEVTC VVVDVSHEDP EVQFNWYVDG VEVHNAKTKP
 61 REEQFNSTFR VVSVLTVVHQ DWLNGKEYKC KVSNKGLPAP IEKTISKTKG QPREPQVYTL
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121 PPSREEMTKN QVSLTCLVKG FYPSDIAVEW ESNGQPENNY KTTPPMLDSD GSFFLYSKLT
181 VDKSRWQQGN VFSCSVMHEA LHNHYTQKSL SLSPGK (SEQ ID NO: 8)
```

[0036] In some embodiments where the fusion protein of the invention includes an Fc polypeptide, the Fc polypeptide of the fusion protein includes a human IgG2 Fc polypeptide sequence that is at least 50%, 60%, 65%, 70%, 75%, 80%, 85%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98% or 99% identical to the amino acid sequence of SEQ ID NO: 8.

[0037] In some embodiments where the fusion protein of the invention includes an Fc polypeptide, the Fc polypeptide of fusion protein includes a human IgG3 Fc polypeptide sequence having the following amino acid sequence:

```
  1 APELLGGPSV FLFPPKPKDT LMISRTPEVT CVVVDVSHED PEVQFKWYVD GVEVHNAKTK
 61 PREEQYNSTF RVVSVLTVLH QDWLNGKEYK CKVSNKALPA PIEKTISKTK GQPREPQVYT
121 LPPSREEMTK NQVSLTCLVK GFYPSDIAVE WESSGQPENN YNTTPPMLDS DGSFFLYSKL
181 TVDKSRWQQG NIFSCSVMHE ALHNRFTQKS LSLSPGK (SEQ ID NO: 9)
```

[0038] In some embodiments where the fusion protein of the invention includes an Fc polypeptide, the Fc polypeptide of the fusion protein includes a human IgG3 Fc polypeptide sequence that is at least 50%, 60%, 65%, 70%, 75%, 80%, 85%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98% or 99% identical to the amino acid sequence of SEQ ID NO: 9.

[0039] In some embodiments where the fusion protein of the invention includes an Fc polypeptide, the Fc polypeptide of the fusion protein includes a human IgG4 Fc polypeptide sequence having the following amino acid sequence:

```
  1 APEFLGGPSV FLFPPKPKDT LMISRTPEVT CVVVDVSQED PEVQFNWYVD GVEVHNAKTK
 61 PREEQFNSTY RVVSVLTVLH QDWLNGKEYK CKVSNKGLPS SIEKTISKAK GQPREPQVYT
121 LPPSQEEMTK NQVSLTCLVK GFYPDIAVEW ESNGQPENNY KTTPPVLDSD GSFFLYSRLT
181 VDKSRWQEGN VFSCSVMHEA LHNHYTQKSL SLSLGK (SEQ ID NO: 10)
```

[0040] In some embodiments where the fusion protein of the invention includes an Fc polypeptide, the Fc polypeptide of the fusion protein includes a human IgG4 Fc polypeptide sequence that is at least 50%, 60%, 65%, 70%, 75%, 80%, 85%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98% or 99% identical to the amino acid sequence of SEQ ID NO: 10.

[0041] In some embodiments where the fusion protein of the invention includes an Fc polypeptide, the Fc polypeptide of the fusion protein includes a human IgM Fc polypeptide sequence having the following amino acid sequence:

```
  1 IAELPPKVSV FVPPRDGFFG NPRKSKLICQ ATGFSPRQIQ VSWLREGKQV GSGVTTDQVQ
 61 AEAKESGPTT YKVTSTLTIK ESDWLGQSMF TCRVDHRGLT FQQNASSMCV PDQDTAIRVF
121 AIPPSFASIF LTKSTKLTCL VTDLTTYDSV TISWTRQNGE AVKTHTNISE SHPNATFSAV
181 GEASICEDDW NSGERFTCTV THTDLPSPLK QTISRPKG (SEQ ID NO: 11)
```

[0042] In some embodiments, where the fusion protein of the invention includes an Fc polypeptide, the Fc polypeptide of the fusion protein includes a human IgM Fc polypeptide sequence that is at least 50%, 60%, 65%, 70%, 75%, 80%, 85%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98% or 99% identical to the amino acid sequence of SEQ ID NO: 11.

[0043] In some embodiments of the fusion proteins provided herein, the second polypeptide (Polypeptide 2) of the WAP domain containing fusion protein is a cytokine targeting polypeptide, or derived from a cytokine targeting polypeptide. These embodiments are referred to collectively herein as "WAP-cytokine targeting polypeptide fusion proteins." The WAP-cytokine targeting polypeptide fusion proteins described herein include at least a WAP domain containing polypeptide or an amino acid sequence that is derived from a WAP domain containing polypeptide and a cytokine targeting polypeptide, or derivation thereof. In some embodiments, the WAP-cytokine targeting polypeptide fusion protein includes a single WAP domain containing polypeptide. In other embodiments, the WAP-cytokine targeting polypeptide fusion protein includes more than one WAP domain containing polypeptide, and these embodiments are collectively referred to herein as "$WAP_{(a')}$- cytokine targeting polypeptide fusion proteins," wherein (a′) is an integer of at least 2. In some embodiments, each WAP domain containing polypeptide in a $WAP_{(a')}$-cytokine targeting polypeptide fusion protein can include the same amino acid sequence. In other embodiments, each WAP domain containing polypeptide of a $WAP_{(a')}$- cytokine targeting polypeptide fusion protein can include distinct amino acid sequences.

[0044] In some embodiments, the WAP domain-containing polypeptide of the WAP-cytokine targeting polypeptide fusion protein is derived from any one of the amino acid sequences of SEQ ID NOs 1-6. In some embodiments, the WAP domain-containing polypeptide of the WAP-cytokine targeting polypeptide fusion protein has at least 50%, 60%, 65%, 70%, 75%, 80%, 85%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98% or

99% sequence identity to any one of the amino acid sequences having SEQ ID NO. 1, 2, 3, 4, 5 or 6.

[0045] In some embodiments, the WAP domain-containing polypeptide sequence of the WAP-cytokine targeting polypeptide fusion protein is or is derived from sequences shown in GenBank Accession Nos. CAA28187.1, NP_003055.1, EAW75869.1, P03973.2, AAH20708.1, CAB64235.1, CAA28188.1, AAD19661.1, BAG35125.1., P19957.3, NP_002629.1, BAA02441.1, EAW75814.1, EAW75813.1, Q8IUB2.1, and/or NP_542181.1., O95925.1, NP_065131.1, AAH44829.2, AAH53369.1, AAG00548.1, AAG00547.1, and/or AAG00546.1.

[0046] In some embodiments, the cytokine targeting polypeptide of the WAP-cytokine targeting polypeptide fusion protein is a cytokine receptor or derived from a cytokine receptor. In a preferred embodiment, the cytokine targeting polypeptide is or an amino acid sequence that is derived from the cytokine receptor is derived from a human cytokine receptor sequence. In other embodiments, the cytokine targeting polypeptide is an antibody or antibody fragment, for example an anti-cytokine antibody or anti-cytokine antibody fragment. The term antibody fragment includes single chain, Fab fragment, a $F(ab')_2$ fragment, a scFv, a scAb, a dAb, a single domain heavy chain antibody, and a single domain light chain antibody. In a preferred embodiment, the cytokine targeting polypeptide is or an amino acid sequence that is derived from the antibody or antibody fragment is derived from a chimeric, humanized, or fully human antibody sequence. In other embodiments, the cytokine targeting polypeptide binds a cytokine receptor and prevents binding of a cytokine to the receptor.

[0047] The WAP-cytokine targeting polypeptide fusion protein can incorporate a portion of a WAP-Fc fusion protein. For example, an antibody contains an Fc polypeptide. Therefore, in some embodiments, where the cytokine targeting polypeptide is a cytokine-targeting antibody, the WAP-cytokine targeting polypeptide fusion protein will incorporate a portion of the WAP-Fc fusion protein. Furthermore, most receptor fusion proteins that are of therapeutic utility, are Fc fusion proteins. Thus, in some embodiments, wherein the WAP-cytokine targeting polypeptide fusion protein is a WAP-cytokine receptor fusion protein, the WAP-cytokine targeting polypeptide fusion protein may incorporate an Fc polypeptide in addition to the WAP domain-containing polypeptide portion and the cytokine receptor portion.

[0048] In some embodiments, where the WAP-cytokine targeting polypeptide fusion protein includes an Fc polypeptide sequence, the Fc polypeptide sequence is derived from any one of the amino acid sequences having the SEQ ID NO. 7, 8, 9, 10, or 11. In some embodiments, where the WAP-cytokine targeting fusion protein includes an Fc polypeptide sequence, the Fc polypeptide sequence has at least 50%, 60%, 65%, 70%, 75%, 80%, 85%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98% or 99% sequence identity to the amino acid sequence of any one of the sequences having the SEQ ID NO. 7, 8, 9, 10, or 11.

[0049] In some embodiments, the WAP domain containing polypeptide and the cytokine targeting polypeptide are operably linked via a linker region, for example, a glycine-serine linker or glycine-serine based linker. In some embodiments, the WAP domain containing polypeptide and the cytokine targeting polypeptide are operably linked via a hinge region. In some embodiments, the WAP domain containing polypeptide and the cytokine targeting polypeptide are operably linked via a linker region and a hinge region. In other embodiments, the serpin polypeptide and the cytokine targeting polypeptide are directly attached.

[0050] In some embodiments of the fusion proteins provided herein, the second polypeptide (Polypeptide 2) of the WAP domain containing fusion protein is a serpin polypeptide, or derived from a serpin polypeptide. These embodiments are referred to collectively herein as "WAP-serpin fusion proteins." The WAP-serpin fusion proteins described herein include at least a WAP domain containing polypeptide or an amino acid sequence that is derived from a WAP domain containing polypeptide, and a serpin polypeptide or an amino acid sequence that is derived from a serpin polypeptide.

[0051] In some embodiments, the WAP domain-containing polypeptide of the WAP-serpin fusion protein is derived from any one of the amino acid sequences of SEQ ID NOs 1-6. In some embodiments, the WAP domain-containing polypeptide of the WAP-serpin fusion protein has at least 50%, 60%, 65%, 70%, 75%, 80%, 85%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98% or 99% sequence identity to any one of the amino acid sequences having SEQ ID NO. 1, 2, 3, 4, 5 or 6.

[0052] In some embodiments, the WAP domain-containing polypeptide sequence of the WAP-serpin fusion protein is or is derived from sequences shown in GenBank Accession Nos. CAA28187.1, NP_003055.1, EAW75869.1, P03973.2, AAH20708.1, CAB64235.1, CAA28188.1, AAD19661.1, BAG35125.1., P19957.3, NP_002629.1, BAA02441.1, EAW75814.1, EAW75813.1, Q8IUB2.1, and/or NP_542181.1., O95925.1,

NP_065131.1, AAH44829.2, AAH53369.1, AAG00548.1, AAG00547.1, and/or AAG00546.1.

[0053] The WAP-serpin fusion proteins described herein include a WAP domain-containing polypeptide and a serpin polypeptide or an amino acid sequence that is derived from a serpin polypeptide. Serpins are a group of proteins with similar structures that were first identified as a set of proteins able to inhibit proteases. Serpin proteins suitable for use in the fusion proteins provided herein include, by way of non-limiting example, alpha-1 antitrypsin (AAT), antitrypsin-related protein (SERPINA2), alpha 1-antichymotrypsin (SERPINA3), kallistatin (SERPINA4), monocyte neutrophil elastase inhibitor (SERPINB1), PI-6 (SERPINB6), antithrombin (SERPINC1), plasminogen activator inhibitor 1 (SERPINE1), alpha 2-antiplasmin (SERPINF2), complement 1-inhibitor (SERPING1), and neuroserpin (SERPINI1).

[0054] In some embodiments, the serpin polypeptide sequence comprises an alpha-1 antitrypsin (AAT) polypeptide sequence or an amino acid sequence that is derived from AAT. In some embodiments, the serpin polypeptide sequence comprises a portion of the AAT protein. In some embodiments, the serpin polypeptide sequence comprises at least the reactive site loop portion of the AAT protein. In some embodiments where the fusion protein of the invention includes a serpin polypeptide, the serpin polypeptide of the fusion protein includes the reactive site loop portion of the AAT protein or includes at least the amino acid sequence GTEAAGAMFLEAIPMSIPPEVKFNK (SEQ ID NO: 12). In a preferred embodiment, the AAT polypeptide sequence is or an amino acid sequence that is derived from AAT is derived from a human AAT polypeptide sequence. In some embodiments where the fusion protein of the invention includes a serpin polypeptide, the serpin polypeptide of the fusion protein includes a modified variant of the reactive site loop portion of the AAT protein or includes at least the amino acid sequence GTEAAGA**E**FLEAIP**L**SIPPEVKFNK (SEQ ID NO: 38).

[0055] In some embodiments of the WAP-serpin fusion proteins, the serpin polypeptide includes a full-length human AAT polypeptide sequence having the following amino acid sequence:

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  1 EDPQGDAAQK TDTSHHDQDH PTFNKITPNL AEFAFSLYRQ LAHQSNSTNI FFSPVSIATA
 61 FAMLSLGTKA DTHDEILEGL NFNLTEIPEA QIHEGFQELL RTLNQPDSQL QLTTGNGLFL
121 SEGLKLVDKF LEDVKKLYHS EAFTVNFGDT EEAKKQINDY VEKGTQGKIV DLVKELDRDT
181 VFALVNYIFF KGKWERPFEV KDTEEEDFHV DQVTTVKVPM MKRLGMFNIQ HCKKLSSWVL
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241 LMKYLGNATA IFFLPDEGKL QHLENELTHD IITKFLENED RRSASLHLPK LSITGTYDLK
301 SVLGQLGITK VFSNGADLSG VTEEAPLKLS KAVHKAVLTI DEKGTEAAGA MFLEAIPMSI
361 PPEVKFNKPF VFLMIEQNTK SPLFMGKVVN PTQK (SEQ ID NO: 13)

[0056] In some embodiments of the WAP-serpin fusion proteins, the serpin polypeptide includes a human AAT polypeptide sequence that is at least 50%, 60%, 65%, 70%, 75%, 80%, 85%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98% or 99% identical to the amino acid sequence of SEQ ID NO: 13.

[0057] In some embodiments of the WAP-serpin fusion proteins, the serpin polypeptide includes the AAT polypeptide sequence or the amino acid sequence derived from an AAT polypeptide or is derived from one or more of the human AAT polypeptide sequences shown in GenBank Accession Nos. AAB59495.1, CAJ15161.1, P01009.3, AAB59375.1, AAA51546.1, CAA25838.1, NP_001002235.1, CAA34982.1, NP_001002236.1, NP_000286.3, NP_001121179.1, NP_001121178.1, NP_001121177.1, NP_001121176.16, NP_001121175.1, NP_001121174.1, NP_001121172.

[0058] In some embodiments, the WAP-serpin domain fusion protein can also include an Fc polypeptide or an amino acid sequence that is derived from an Fc polypeptide. These embodiments are referred to collectively herein as "WAP-Fc-serpin fusion proteins." In these embodiments, no particular order is to be construed by this terminology. For example, the order of the fusion protein can be WAP-Fc-serpin, serpin-WAP-Fc, or any variation or combination thereof. The WAP-Fc-serpin fusion proteins described herein include at least a WAP domain-containing polypeptide or an amino acid sequence that is derived from a WAP domain-containing polypeptide, a serpin polypeptide or an amino acid sequence that is derived from a serpin polypeptide, and an Fc polypeptide or an amino acid sequence that is derived from an Fc polypeptide.

[0059] In some embodiments, where the WAP-serpin polypeptide fusion protein includes an Fc polypeptide sequence, the Fc polypeptide sequence is derived from any one of the amino acid sequences having the SEQ ID NO. 7, 8, 9, 10, or 11. In some embodiments, where the WAP-serpin fusion protein includes an Fc polypeptide sequence, the Fc polypeptide sequence has at least 50%, 60%, 65%, 70%, 75%, 80%, 85%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98% or 99% sequence identity to the amino acid sequence of any one of the sequences having the SEQ ID NO. 7, 8, 9, 10, or 11.

[0060] In some embodiments, the WAP-serpin domain fusion protein can also include an albumin polypeptide or an amino acid sequence that is derived from an albumin polypeptide. These embodiments are referred to collectively herein as "WAP-albumin-serpin fusion proteins." In these embodiments, no particular order is to be construed by this terminology. For example, the order of the fusion protein can be WAP-albumin-serpin, serpin-albumin-WAP, or any variation combination thereof. The WAP-albumin-serpin fusion proteins described herein include at least a WAP domain-containing polypeptide or an amino acid sequence that is derived from a WAP domain-containing polypeptide, a serpin polypeptide or an amino acid sequence that is derived from a serpin, and an albumin polypeptide or an amino acid sequence that is derived from an albumin polypeptide.

[0061] In some embodiments, where the WAP-serpin domain fusion protein includes an albumin polypeptide sequence, the albumin polypeptide sequence is derived from any one of the amino acid sequences of SEQ ID NO. 14-15, described herein. In other embodiments, where the serpin-WAP domain fusion protein includes an albumin polypeptide sequence, the albumin polypeptide sequence has at least 50%, 60%, 65%, 70%, 75%, 80%, 85%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98% or 99% sequence identity to any one of the amino acid sequences having SEQ ID NO. 14 or 15.

[0062] In some embodiments of the fusion protein provided herein, the second polypeptide (Polypeptide 2) of the WAP domain containing fusion protein is an albumin polypeptide or is derived from an albumin polypeptide. These embodiments are referred to collectively herein as "WAP-albumin fusion proteins." The WAP-albumin fusion proteins described herein include at least a WAP domain containing polypeptide or an amino acid sequence that is derived from a WAP domain containing polypeptide and an albumin polypeptide or an amino acid sequence that is derived from an albumin polypeptide. In addition this invention relates to WAP domain containing polypeptide albumin binding polypeptide fusion proteins, wherein the albumin is operably linked to the WAP domain containing polypeptide via an intermediate binding molecule. Herein, the WAP domain containing polypeptide is non-covalently or covalently bound to human serum albumin.

[0063] In some embodiments, the WAP domain-containing polypeptide of the WAP-albumin fusion protein is derived from any one of the amino acid sequences of SEQ ID NOs 1-6. In some embodiments, the WAP domain-containing polypeptide of the WAP-albumin fusion protein has at least 50%, 60%, 65%, 70%, 75%, 80%, 85%, 90%, 91%,

92%, 93%, 94%, 95%, 96%, 97%, 98% or 99% sequence identity to any one of the amino acid sequences having SEQ ID NO. 1, 2, 3, 4, 5 or 6.

[0064] In some embodiments, the WAP domain-containing polypeptide sequence of the WAP-albumin fusion protein is or is derived from sequences shown in GenBank Accession Nos. CAA28187.1, NP_003055.1, EAW75869.1, P03973.2, AAH20708.1, CAB64235.1, CAA28188.1, AAD19661.1, BAG35125.1., P19957.3, NP_002629.1, BAA02441.1, EAW75814.1, EAW75813.1, Q8IUB2.1, and/or NP_542181.1., O95925.1, NP_065131.1, AAH44829.2, AAH53369.1, AAG00548.1, AAG00547.1, and/or AAG00546.1.

[0065] In some embodiments where the fusion protein of the invention includes an albumin polypeptide sequence, the albumin polypeptide sequence of the fusion protein is a human serum albumin (HSA) polypeptide or an amino acid sequence derived from HSA. In some embodiments where the fusion protein of the invention includes an albumin polypeptide sequence, the albumin polypeptide sequence of the fusion protein, the fusion protein includes a HSA polypeptide sequence having the following amino acid sequence:

DAHKSEVAHRFKDLGEENFKALVLIAFAQYLQQCPFEDHVKLVNEVTEFAKTCVADESAEN
CDKSLHTLFGDKLCTVATLRETYGEMADCCAKQEPERNECFLQHKDDNPNLPRLVRPEVDV
MCTAFHDNEETFLKKYLYEIARRHPYFYAPELLFFAKRYKAAFTECCQAADKAACLLPKLD
ELRDEGKASSAKQRLKCASLQKFGERAFKAWAVARLSQRFPKAEFAEVSKLVTDLTKVHTE
CCHGDLLECADDRADLAKYICENQDSISSKLKECCEKPLLEKSHCIAEVENDEMPADLPSL
AADFVESKDVCKNYAEAKDVFLGMFLYEYARRHPDYSVVLLLRLAKTYETTLEKCCAAADP
HECYAKVFDEFKPLVEEPQNLIKQNCELFEQLGEYKFQNALLVRYTKKVPQVSTPTLVEVS
RNLGKVGSKCCKHPEAKRMPCAEDYLSVVLNQLCVLHEKTPVSDRVTKCCTESLVNRRPCF
SALEVDETYVPKEFNAETFTFHADICTLSEKERQIKKQTALVELVKHKPKATKEQLKAVMD
DFAAFVEKCCKADDKETCFAEEGKKLVAASQAALGL (SEQ ID NO: 14)

[0066] In some embodiments where the fusion protein of the invention includes an albumin polypeptide sequence, the albumin polypeptide sequence of the fusion protein includes a human serum albumin polypeptide sequence that is at least 50%, 60%, 65%, 70%, 75%, 80%, 85%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98% or 99% identical to the amino acid sequence of SEQ ID NO: 14.

[0067] In some embodiments of the WAP-albumin fusion proteins, the albumin polypeptide sequence includes a domain 3 of human serum albumin polypeptide sequence having the following amino acid sequence:

EEPQNLIKQNCELFEQLGEYKFQNALLVRYTKKVPQVSTPTLVEVSRNLGKVGSKCCK
HPEAKRMPCAEDYLSVVLNQLCVLHEKTPVSDRVTKCCTESLVNRRPCFSALEVDETYVP
KEFNAETFTFHADICTLSEKERQIKKQTALVELVKHKPKATKEQLKAVMDDFAAFVEKCC
KADDKETCFAEEGKKLVA (SEQ ID NO: 15)

[0068] In some embodiments of the WAP-albumin fusion proteins, the albumin polypeptide sequence includes a human serum albumin polypeptide sequence that is at least 50%, 60%, 65%, 70%, 75%, 80%, 85%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98% or 99% identical to the amino acid sequence of SEQ ID NO: 15.

[0069] In some embodiment the WAP domain-containing polypeptide is linked to the human serum albumin via an intermediate albumin binding polypeptide. The albumin binding polypeptide can be an antibody or an antibody fragment or derived from an antibody or antibody fragment. In a preferred embodiment, the albumin binding polypeptide is or an amino acid sequence that is derived from the antibody or antibody fragment is derived from a chimeric, humanized, or fully human antibody sequence. The term antibody fragment includes single chain, Fab fragment, a $F(ab')_2$ fragment, a scFv, a scAb, a dAb, a single domain heavy chain antibody, and a single domain light chain antibody. In addition the albumin binding polypeptide can be an albumin binding peptide. Another embodiment of the this invention is a WAP domain-containing polypeptide-albumin binding polypeptide fusion, wherein the albumin binding polypeptide is the domain 3 of streptococcal protein G or a sequence derived from domain 3 of streptococcal protein G. In other embodiments the WAP domain-containing polypeptide and the human serum albumin is directly attached.

[0070] In some embodiments, the fusion proteins contain one or more mutations. For example, the fusion protein contains at least one mutation at a methionine (Met) residue in the non-Fc portion of the fusion protein, for example in the SLPI portion of the fusion protein. In these Met mutations, the Met residue can be substituted with any amino acid. For example, the Met residue can be substituted with an amino acid with a hydrophobic side chain, such as, for example, leucine (Leu, L) or valine (Val, V). Without wishing to be

bound by theory, the Met mutation(s) prevent oxidation and subsequent inactivation of the inhibitory activity of the fusion proteins of the invention. In some embodiments, the Met mutation is at position 98 of an SLPI polypeptide. For example, a Met mutation that occurs at a residue in the amino acid sequence of SEQ ID NO: 8 is Met98Leu (M98L).

[0071] In some embodiments, the fusion proteins are modified to increase or otherwise inhibit proteolytic cleavage, for example, by mutating proteolytic cleavage sites. In some embodiments, the proteolytic cleavage site mutation occurs at a residue in the SLPI portion of the fusion protein. For example, the proteolytic cleavage site mutation occurs at a residue in the amino acid sequence of SEQ ID NO: 2 selected from Ser15, Ala16, Glu17, and combinations thereof.

[0072] In some embodiments, the fusion proteins are modified to alter or otherwise modulate an Fc effector function of the fusion protein, while simultaneously retaining binding and inhibitory function as compared to an unaltered fusion protein. Fc effector functions include, by way of non-limiting examples, Fc receptor binding, prevention of proinflammatory mediator release upon binding to the Fc receptor, phagocytosis, modified antibody-dependent cell-mediated cytotoxicity (ADCC), modified complement-dependent cytotoxicity (CDC), modified glycosylation at Asn297 residue (EU index of Kabat numbering, *Kabat et al* 1991 *Sequences of Proteins of Immunological Interest*) of the Fc polypeptide. In some embodiments, the fusion proteins are mutated or otherwise modified to influence Fc receptor binding. In some embodiments, the Fc polypeptide is modified to enhance FcRn binding. Examples of Fc polypeptide mutations that enhance binding to FcRn are Met252Tyr, Ser254Thr, Thr256Glu (M252Y, S256T, T256E) (Kabat numbering, Dall'Acqua *et al* 2006, *J. Biol Chem* Vol 281(33) 23514–23524), or Met428Leu and Asn434Ser (M428L, N434S) (Zalevsky *et al* 2010 *Nature Biotech*, Vol 28(2) 157-159). (EU index of *Kabat et al* 1991 *Sequences of Proteins of Immunological Interest*).

[0073] The fusion proteins and variants thereof provided herein exhibit inhibitory activity, for example by inhibiting a serine protease such as human neutrophil elastase (NE), a chemotrypsin-fold serine protease that is secreted by neutrophils during an inflammatory response. The fusion proteins provided herein completely or partially reduce or otherwise modulate serine protease expression or activity upon binding to, or otherwise interacting with, a serine protease, *e.g.*, a human serine protease. The reduction or modulation of a biological function of a serine protease is complete or partial upon interaction between the fusion proteins and the human serine protease protein, polypeptide and/or peptide. The

fusion proteins are considered to completely inhibit serine protease expression or activity when the level of serine protease expression or activity in the presence of the fusion protein is decreased by at least 95%, *e.g.*, by 96%, 97%, 98%, 99% or 100% as compared to the level of serine protease expression or activity in the absence of interaction, e.g., binding, with a fusion protein described herein. The fusion proteins are considered to partially inhibit serine protease expression or activity when the level of serine protease expression or activity in the presence of the fusion protein is decreased by less than 95%, *e.g.*, 10%, 20%, 25%, 30%, 40%, 50%, 60%, 75%, 80%, 85% or 90% as compared to the level of serine protease expression or activity in the absence of interaction, e.g., binding, with a fusion protein described herein.

[0074] The fusion proteins described herein are useful in a variety of therapeutic, diagnostic and prophylactic indications. For example, the fusion proteins are useful in treating a variety of diseases and disorders in a subject. In some embodiments, the fusion proteins described herein, are useful in treating, alleviating a symptom of, ameliorating and/or delaying the progression of a disease or disorder in a subject suffering from or identified as being at risk for a disease or disorder selected from alpha-1-antitrypsin (AAT) deficiency, emphysema, chronic obstructive pulmonary disease (COPD), acute respiratory distress syndrome (ARDS), allergic asthma, cystic fibrosis, cancers of the lung, ischemia-reperfusion injury, including, *e.g.*, ischemia/reperfusion injury following cardiac transplantation, myocardial infarction, arthritis, rheumatoid arthritis, septic arthritis, psoriatic arthritis, ankylosing spondylitis, Crohn's disease, psoriasis, type I and/or type II diabetes, bacterial infections, fungal infections, viral infections, pneumonia, sepsis, graft versus host disease (GVHD), wound healing, Systemic lupus erythematosis, and Multiple sclerosis.

[0075] The fusion proteins and variants thereof provided herein exhibit inhibitory activity, for example by inhibiting a serine protease. The fusion proteins provided herein completely or partially reduce or otherwise modulate serine protease expression or activity upon binding to, or otherwise interacting with, a serine protease, *e.g.*, a human serine protease. The reduction or modulation of a biological function of a serine protease is complete or partial upon interaction between the fusion proteins and the human serine protease protein, polypeptide and/or peptide. The fusion proteins are considered to completely inhibit serine protease expression or activity when the level of serine protease expression or activity in the presence of the fusion protein is decreased by at least 95%, *e.g.*,

by 96%, 97%, 98%, 99% or 100% as compared to the level of serine protease expression or activity in the absence of interaction, e.g., binding, with a fusion protein described herein. The fusion proteins are considered to partially inhibit serine protease expression or activity when the level of serine protease expression or activity in the presence of the fusion protein is decreased by less than 95%, *e.g.*, 10%, 20%, 25%, 30%, 40%, 50%, 60%, 75%, 80%, 85% or 90% as compared to the level of serine protease expression or activity in the absence of interaction, e.g., binding, with a fusion protein described herein.

[0076] Pharmaceutical compositions according to the invention can include a fusion protein of the invention, including modified fusion proteins and other variants, along with a suitable carrier. These pharmaceutical compositions can be included in kits, such as, for example, diagnostic kits.

Brief Description of the Drawings

[0077] Figure 1A is a schematic representation of some embodiments of WAP domain containing polypeptide-Fc fusion proteins according to the invention. The WAP domain containing polypeptide can be located at any position within the fusion protein. Variants of these fusion proteins incorporating more than one WAP domain containing polypeptide are also represented. Figure 1B is a photograph of a SDS-PAGE gel showing Elafin-Fc1 (lane 1, human IgG1 Fc), and SLPI-Fc1 (lane 2, human IgG1 Fc). Figure 1C is a graph showing the inhibition of neutrophil elastase activity by Elafin-Fc and SLPI-Fc fusion proteins. Figure 1D is a photograph of a SDS-PAGE gel showing the fusion protein consisting Elafin-Fc-SLPI. Figure 1E is a graph showing the inhibition of neutrophil elastase activity by Elafin-Fc-SLPI. Serum derived AAT is shown as a control for NE inhibition. Figure 1F is a graph depicting the serum concentrations over time of recombinant SLPI compared to SLPI-Fc in rats (3 per test protein) dosed with 10mg/kg protein. The half life of SLPI-Fc is substantially longer than that of recombinant SLPI.

[0078] Figure 2A is a schematic representation of some embodiments of the WAP domain containing polypeptide-cytokine targeting fusion proteins of the invention. The WAP domain containing polypeptide can be fused to either the heavy chain, the light chain, or both of an antibody. WAP domain containing polypeptide -cytokine receptor fusion proteins are also depicted. Figure 2B is a photograph of a SDS-PAGE gel showing the D2E7 antibody (lane 1), the D2E7 antibody with-SLPI fused to heavy chain (lane 2), and

the D2E7 antibody with SLPI fused to the light chain (lane 3). Figure 2C is a graph showing the inhibition of neutrophil elastase activity by a D2E7 antibody fused to SLPI on either the heavy chain or the light chain. Serum derived AAT is shown and positive control, whereas the D2E7 antibody alone is shown as a negative control for NE inhibition.

[0079] Figure 3A is a schematic representation of some embodiments of the serpin-Fc-WAP fusion proteins. Figure 3B is a photograph of a SDS-PAGE gel showing AAT-Fc-Elafin (lane 1) and AAT-Fc-SLPI (lane 2). Figure 3C is a graph showing the inhibition of neutrophil elastase activity by an AAT-Fc-Elafin fusion protein and an AAT-Fc-SLPI fusion protein. An AAT-Fc fusion protein and serum derived AAT are included for comparison.

[0080] Figure 4 is a schematic representation of some embodiments of the WAP domain containing polypeptide-HSA fusion proteins.

Detailed Description of the Invention

[0081] The whey acidic protein (WAP) domain is motif of approximately 50 amino acids characterized by eight conserved cysteines at defined positions, which form four disulfide bonds (Ranganathan *et al* 1999 *J. Mol. Graphics Modell.* **17**, 134–136). The most well characterized function of the WAP domain is serine protease inhibition. Several WAP domain containing proteins are involved in innate immune protection of multiple epithelia; surfaces (Abe *et al* 1991 J. *Clin. Invest.* 87(6): 2207–15; Maruyama *et al* 1994 *J Clin Invest.* 94(1):368–375; Si-Tahar et al 2000 *Gastroenterology* 118(6): 1061–71; King *et al* 2003 *Reproductive Biology and Endocrinology* 1:116). Some of these proteins have been shown to possess antibacterial activities. Exemplary WAP domain containing proteins are secretory leukocyte protease inhibitor (SLPI), Elafin, and Eppin.

[0082] The SLPI and Elafin genes are members of the trappin gene family. Proteins encoded by members of the trappin genes, are characterized by an N-terminal transglutaminase domain substrate and a C-terminal WAP domain (Schalkwijk *et al* 1999 *Biochem. J.* **340:**569–577). SLPI and Elafin are inhibitors of neutrophil serine proteases, yet have slightly distinct target proteases. While SLPI and Elafin are both potent inhibitors of neutrophil elastase, SLPI has also inhibits Cathepsin G but not Proteinase-3, and Elafin inhibits Proteinase-3, but not Cathepsin G (Eisenberg, *et al.* 1990 *J. Biol. Chem.* **265**, 7976–7981, Rao *et al* 1993 *Am. J. Respir. Cell Mol. Biol.* **8**, 612–616, Ying *et al* 2001 *Am.*

J. Respir. Cell Mol. Biol. **24**, 83–89). In addition, Elafin inhibits endogenous vascular elastase (EVE), a serine protease produced by diseased vascular tissue (Rabinovitch, M. 1999 *Am. J. Physiol. Lung Cell. Mol. Physiol.* 277, L5–L12; Cowan, *et al* 1996 *J. Clin. Invest.* 97,2452–2468).

[0083] During inflammation and injury proteases released from neutrophils generally serve to amplify the inflammatory response, through degradation the ECM, generation of chemotactic peptides, MMP activation, and the induction of proteolytic and pro-inflammatory cytokine signaling cascades. SLPI and Elafin represent endogenous regulators of inflammatory signaling that serve to prevent excess inflammation and protect tissues from proteolytic destruction at sites of local inflammation.

[0084] In numerous *in vitro* and *in vivo* both SLPI and Elafin demonstrated to maintain board anti-inflammatory properties (Doumas *et al*. 2005. *Infect Immun* 73, 1271-1274; Williams *et al* 2006 *Clin Sci* (Lond) 110, 21-35, Scott *et al* 2011 *Biochem. Soc. Trans.* 39(5) 1437–1440; Shaw and Wiedow, 2011 *Biochem. Soc. Trans*. 39, 1450–1454). While many of the anti-inflammatory activities of these proteins are due to protease inhibition, both SLPI and Elafin possess anti-inflammatory capacities that are independent of direct protease inhibition. For instance both bind bacterial LPS and prevent its binding to CD14 and downstream signaling by macrophages (Ding *et al* 1999 *Infect. Immun*. 67 4485-4489, McMichael *et al* 2005 *Am. J. Respir. Cell Mol. Biol*. 32 443-452). Studies using human monocytes exposed to LPS, have shown that SLPI inhibited Toll-like receptor and NF-κB activation and subsequent IL-8 and TNFα production signaling in monocytes exposed to LPS (Lentsch *et al* 1999 *Am. J. Pathol*. **154**, 239–247; Taggart *et al* 2005 *J. Exp. Med*. 202, 1659–1668). SLPI deficient mice are significantly more susceptible to LPS induced endotoxin shock and had higher rates of mortality (Nakamura et al 2003 *J. Exp. Med*. 197, 669–674). Similarly, mice that overexpressed Elafin displayed reduced pro-inflammatory cytokines, including TNFα, MIP-2 and MCP-1, compared to than wild-type mice following LPS challenge (Sallenave *et al* 2003 *Infect. Immun*. 71, 3766–3774).

[0085] In addition to their anti-protease and anti-inflammatory activities, SLPI and Elafin possess anti-infective functionalities against a board class of pathogens, including viruses, bacteria, and fungi. Both SLPI and Elafin have demonstrated antibacterial activity against Gram-positive and Gram-negative species. SLPI has been found to be effective against pathogenic species common in the upper airways such as *Pseudomonas aeruginosa* and

Staphylococcus aureus, in addition to *Staphylococcus epidermidis* and *Escherichia coli.* While Elafin also exhibits bactericidal activity against *Ps. aeruginosa* and *S. aureus* (Hiemstra, *et al* 1996 *Infect. Immun.* 64, 4520–4524; Wiedow *et al* 1998 *Biochem. Biophys. Res. Commun.* 248, 904–909; Simpson *et al* 2001 *Hum. Gene Ther.* 12, 1395–1406; Meyer-Hoffert *et al.* 2003 *Exp. Dermatol.* 12, 418–425; Simpson *et al* 1999 *FEBS Lett.* 452, 309–313). SLPI has been demonstrated to have fungicidal activity against the pathogenic fungi *Aspergillus fumigatus* and *Candida albicans* (Tomee *et al* 1997 *J. Infect. Dis.* **176:**740–747; Chattopadhyay *et al* 2004 *Infect. Immun.* **72:**1956–1963). SLPI also been shown to have anti-HIV activity (McNeely *et al* 1995 *J. Clin. Investig.* 96:456–464; McNeely *et al* 1997*Blood* 90:1141–1149; Hocini *et al* 2002 *Clin. Diagn. Lab. Immunol.* **7:**515–518; Pillay *et al* 2001 *J. Infect. Dis.* 183:653–656).

[0086] Based upon reported studies, it has been suggested that recombinant human SLPI may be useful in the treatment of allergic asthma, emphysema, cystic fibrosis, AAT deficiency, COPD, ARDS, arthritis, bacterial, fungal, and viral infections, spinal cord injuries, wound healing, and ischemia/reperfusion injury following cardiac transplantation (Lucey, E.C., Stone, P.J., Ciccolella, D.E., Breuer, R., Christensen, T.G., Thompson, R.C., and Snider, G.L. (1990). Recombinant human secretory leukocyte-protease inhibitor: in vitro properties, and amelioration of human neutrophil elastase-induced emphysema and secretory cell metaplasia in the hamster. J Lab Clin Med *115*, 224-232; Stolk, J., Rudolphus, A., and Kramps, J.A. (1991). Lipopolysaccharide-induced alveolar wall destruction in the hamster is inhibited by intratracheal treatment with r-secretory leukocyte protease inhibitor. Ann N Y Acad Sci *624*, 350-352; Stromatt, S.C. (1993). Secretory leukocyte protease inhibitor in cystic fibrosis. Agents Actions Suppl *42*, 103-110; Watterberg, K.L., Carmichael, D.F., Gerdes, J.S., Werner, S., Backstrom, C., and Murphy, S. (1994). Secretory leukocyte protease inhibitor and lung inflammation in developing bronchopulmonary dysplasia. J Pediatr *125*, 264-269; McNeely, T.B., Dealy, M., Dripps, D.J., Orenstein, J.M., Eisenberg, S.P., and Wahl, S.M. (1995). Secretory leukocyte protease inhibitor: a human saliva protein exhibiting anti-human immunodeficiency virus 1 activity in vitro. J Clin Invest *96*, 456-464; Fath, M.A., Wu, X., Hileman, R.E., Linhardt, R.J., Kashem, M.A., Nelson, R.M., Wright, C.D., and Abraham, W.M. (1998). Interaction of secretory leukocyte protease inhibitor with heparin inhibits proteases involved in asthma. J Biol Chem *273*, 13563-13569; Jin, F., Nathan, C.F., Radzioch, D., and Ding, A. (1998). Lipopolysaccharide-related stimuli induce expression of the secretory leukocyte protease

inhibitor, a macrophage-derived lipopolysaccharide inhibitor. Infect Immun *66*, 2447-2452; Song, X., Zeng, L., Jin, W., Thompson, J., Mizel, D.E., Lei, K., Billinghurst, R.C., Poole, A.R., and Wahl, S.M. (1999). Secretory leukocyte protease inhibitor suppresses the inflammation and joint damage of bacterial cell wall-induced arthritis. J Exp Med *190*, 535-542; Wright, C.D., Havill, A.M., Middleton, S.C., Kashem, M.A., Lee, P.A., Dripps, D.J., O'Riordan, T.G., Bevilacqua, M.P., and Abraham, W.M. (1999). Secretory leukocyte protease inhibitor prevents allergen-induced pulmonary responses in animal models of asthma. J Pharmacol Exp Ther *289*, 1007-1014; Ashcroft, G.S., Lei, K., Jin, W., Longenecker, G., Kulkarni, A.B., Greenwell-Wild, T., Hale-Donze, H., McGrady, G., Song, X.Y., and Wahl, S.M. (2000). Secretory leukocyte protease inhibitor mediates non-redundant functions necessary for normal wound healing. Nat Med 6, 1147-1153; Mulligan, M.S., Lentsch, A.B., Huber-Lang, M., Guo, R.F., Sarma, V., Wright, C.D., Ulich, T.R., and Ward, P.A. (2000). Anti-inflammatory effects of mutant forms of secretory leukocyte protease inhibitor. Am J Pathol *156*, 1033-1039; Forteza, R.M., Ahmed, A., Lee, T., and Abraham, W.M. (2001). Secretory leukocyte protease inhibitor, but not alpha-1 protease inhibitor, blocks tryptase-induced bronchoconstriction. Pulm Pharmacol Ther 14, 107-110; Pillay, K., Coutsoudis, A., Agadzi-Naqvi, A.K., Kuhn, L., Coovadia, H.M., and Janoff, E.N. (2001). Secretory leukocyte protease inhibitor in vaginal fluids and perinatal human immunodeficiency virus type 1 transmission. J Infect Dis *183*, 653-656; Feuerstein, G. (2006). Inflammation and stroke: therapeutic effects of adenoviral expression of secretory Leukocyte Protease Inhibitor. Front Biosci 11, 1750-1757; Weldon, S., McGarry, N., Taggart, C.C., and McElvaney, N.G. (2007). The role of secretory leucoprotease inhibitor in the resolution of inflammatory responses. Biochem Soc Trans *35*, 273-276; Nishimura, J., Saiga, H., Sato, S., Okuyama, M., Kayama, H., Kuwata, H., Matsumoto, S., Nishida, T., Sawa, Y., Akira, S., Yoshikai, Y., Yamamoto, M., and Takeda, K. (2008). Potent antimycobacterial activity of mouse secretory leukocyte protease inhibitor. J Immunol *180*, 4032-4039; Schneeberger, S., Hautz, T., Wahl, S.M., Brandacher, G., Sucher, R., Steinmassl, O., Steinmassl, P., Wright, C.D., Obrist, P., Werner, E.R., Mark, W., Troppmair, J., Margreiter, R., and Amberger, A. (2008). The effect of secretory leukocyte protease inhibitor (SLPI) on ischemia/reperfusion injury in cardiac transplantation. Am J Transplant *8*, 773-782; Ghasemlou, N., Bouhy, D., Yang, J., Lopez-Vales, R., Haber, M., Thuraisingam, T., He, G., Radzioch, D., Ding, A., and David, S. (2010). Beneficial effects of secretory leukocyte protease inhibitor after spinal cord injury. Brain 133, 126-138;

Marino, R., Thuraisingam, T., Camateros, P., Kanagaratham, C., Xu, Y.Z., Henri, J., Yang, J., He, G., Ding, A., and Radzioch, D. (2011). Secretory leukocyte protease inhibitor plays an important role in the regulation of allergic asthma in mice. J Immunol *186*, 4433-4442).

[0087] Recombinant versions of SLPI and Elafin have be generated the administered to man. In fact recombinant Elafin is currently being evaluated in a human clinical trial to treat the inflammatory component of various types of vascular injuries (ref). The recombinant version of both SLPI and Elafin display very short serum halves (<3hours, Bergenfeldt *et al* 1990 *Scand J Clin Lab Invest*. 50(7):729-37, WO/2011/107505). The short half life represents a major limitation to the therapeutic use of these proteins. Thus effective treatment with these version of the protein would require frequent dosing (multiple doses per day).

[0088] The fusion proteins of the present invention were generated to enhance therapeutic potential of SLPI and Elafin. To extend the half life of recombinant SLPI and Elafin, Fc and albumin fusion proteins were created. While it was known that fusion of Fc domains or albumin to some proteins, protein domains or peptides could extend their half-lives (*see e.g.*, Jazayeri, J.A., and Carroll, G.J. (2008). Fc-based cytokines : prospects for engineering superior therapeutics. BioDrugs *22*, 11-26; Huang, C. (2009). Receptor-Fc fusion therapeutics, traps, and MIMETIBODY technology. Curr Opin Biotechnol *20*, 692-699; Kontermann, R.E. (2009). Strategies to extend plasma half-lives of recombinant antibodies. BioDrugs *23*, 93-109; Schmidt, S.R. (2009). Fusion-proteins as biopharmaceuticals--applications and challenges. Curr Opin Drug Discov Devel *12*, 284-295), it was unknown, prior to the studies described herein, whether a Fc domain or albumin fused to SLPI or Elafin, would disable their capacity to inhibit neutrophil elastase or have the desired effect of increasing serum half life. The studies described herein demonstrate that the fusion proteins of the present invention are capable of potent NE inhibition and display enhanced serum half lives. These fusions proteins of the present invention provide more effective therapeutics over the previous unmodified versions of SLPI or Elafin.

[0089] In some embodiments, the WAP domain fusion proteins include SLPI or Elafin polypeptide sequences fused to a cytokine targeting protein.

[0090] In some embodiments, the fusion proteins described herein include at least a WAP domain containing polypeptide or an amino acid sequence that is derived from a WAP domain containing polypeptide and a cytokine targeting polypeptide or an amino acid sequence that is derived from a cytokine targeting polypeptide. For example, the invention

provides WAP domain containing polypeptide or a sequence derived from a WAP domain containing polypeptide fused to a human cytokine receptor or derivative thereof. Another embodiment of the invention provides WAP domain containing polypeptide or a sequence derived from a WAP domain containing polypeptide fused to a cytokine targeting antibody, *e.g.*, an anti-cytokine antibody, or a sequence derived from of a cytokine targeting antibody, *e.g.*, an anti-cytokine antibody, or sequence derived from a fragment of cytokine targeting antibody, *e.g.*, a fragment of an anti-cytokine antibody. For example, the invention provides a WAP domain containing polypeptide or a sequence derived from a WAP domain containing polypeptide fused to a cytokine targeting polypeptide in which the cytokine targeting polypeptide binds any of the following human cytokines: TNFα, IgE, IL-12, IL-23, IL-6, IL-1α, IL-1β, IL-17, IL-13, the p40 subunit of IL-12 and IL-23, IL-4, IL-10, IL-2, IL-18, IL-27, or IL-32.

[0091] For example, in some embodiments, the cytokine targeting polypeptide targets TNFα and includes any of the following TNFα-targeting polypeptide or sequences derived from the following TNFα-targeting polypeptides: Remicade®, Humira®, Simponi®, Cimiza®, or Enbrel®.

[0092] For example, in some embodiments, the cytokine targeting polypeptide targets IgE and includes any of the following IgE-targeting polypeptide or sequences derived from the following IgE-targeting polypeptides: Xolair® or FcεRI.

[0093] For example, in some embodiments, the cytokine targeting polypeptide targets the shared p40 subunit of IL-12 and IL-23 and includes the Stelara® polypeptide or sequences derived from the Stelara® polypeptide.

[0094] For example, Stelara®, the cytokine targeting polypeptide targets IL-13 and includes the CDP7766 polypeptide or sequences derived from the CDP7766 polypeptide.

[0095] The invention provides a WAP domain containing polypeptide or a sequence derived from a WAP domain containing polypeptide fused to a cytokine targeting polypeptide in which the cytokine targeting polypeptide binds any of the following human cytokine receptors of TNFα, IgE, IL-12, IL-23, IL-6, IL-1α, IL-1β, IL-17, IL-13, the p40 subunit of IL-12 and IL-23, IL-4, IL-10, IL-2, IL-18, IL-27, or IL-32, thereby preventing binding between receptor and cytokine.

[0096] In some embodiments, the fusion proteins described herein include at least a SLPI polypeptide or an amino acid sequence that is derived from SLPI and a cytokine

targeting polypeptide or an amino acid sequence that is derived from a cytokine targeting polypeptide. For example, the invention provides SLPI fused a cytokine targeting polypeptide in which the cytokine targeting polypeptide binds any of the following human cytokines: TNFα, IgE, IL-6, IL-1α, IL-1β, IL-12, IL-17, IL-13, IL-23, the p40 subunit of IL-12 and IL-23, IL-4, IL-10, IL-2, IL-18, IL-27, or IL-32.

[0097] In some embodiments, the fusion proteins described herein include at least an Elafin polypeptide or an amino acid sequence that is derived from Elafin and a cytokine targeting polypeptide or an amino acid sequence that is derived from a cytokine targeting polypeptide. For example, the invention provides Elafin fused a cytokine targeting polypeptide in which the cytokine targeting polypeptide binds any of the following human cytokines: TNFα, IgE, IL-6, IL-1α, IL-1β, IL-12, IL-17, IL-13, IL-23, the p40 subunit of IL-12 and IL-23, IL-4, IL-10, IL-2, IL-18, IL-27, or IL-32.

[0098] In some embodiments the cytokine targeting polypeptide binds a cytokine receptor and prevents binding between receptor and cytokine. For example, the present invention includes a serpin fused to a cytokine receptor targeting antibody. For example, the invention provides SLPI fused a cytokine targeting polypeptide in which the cytokine targeting polypeptide binds the receptor of any of the following human cytokines: TNFα, IgE, IL-6, IL-1α, IL-1β, IL-12, IL-17, IL-13, IL-23, the p40 subunit of IL-12 and IL-23, IL-4, IL-10, IL-2, IL-18, IL-27, or IL-32. For example, the invention provides Elafin fused a cytokine targeting polypeptide in which the cytokine targeting polypeptide binds the receptor of any of the following human cytokines: TNFα, IgE, IL-6, IL-1α, IL-1β, IL-12, IL-17, IL-13, IL-23, the p40 subunit of IL-12 and IL-23, IL-4, IL-10, IL-2, IL-18, IL-27, or IL-32.

[0099] For example, in some embodiments, the cytokine targeting polypeptide targets the IL-6 receptor and includes the Actemra® polypeptide or sequences derived from the Actemra® polypeptide. For example, Actemra® the cytokine targeting polypeptide targets the IL-6 receptor and includes the tocilizumab polypeptide or sequences derived from the tocilizumab polypeptide.

[00100] The targeting of inflammatory cytokines and immune-stimulating agents by protein therapeutics has demonstrated clinical success in numerous inflammatory conditions. The most common proteins used as cytokine targeting agents are the soluble cytokine receptors and monoclonal antibodies and fragments thereof. A significant

drawback with targeting cytokines is the increased risk of infection in these patients, as evidenced by the TNFα targeting biologics, Remicade®, Humira®, Simponi®, Cimiza®, and Enbrel®, and the IL-12/23 p40 targeting antibody, Stelara®. This is likely to be a common problem of targeting inflammatory cytokines leading to immune suppression in patients. As mentioned above, SLPI and Elafin demonstrate both anti-infective and anti-inflammatory activities. Thus, the WAP domain containing polypeptide-cytokine targeting polypeptide fusion proteins of this invention can dampen aberrant cytokine activities while alleviating the risk of infections.

[00101] In some embodiments, the fusion proteins described herein include at least the following components: a WAP domain containing polypeptide or an amino acid sequence that is derived from a WAP domain containing, a serpin polypeptide or an amino acid sequence that is derived from a serpin and an Fc polypeptide or an amino acid sequence that is derived from an Fc polypeptide. For example, the invention provides a WAP domain-containing polypeptide, serpin polypeptide, and human IgG1-Fc, IgG2-Fc, IgG3-Fc, IgG4-Fc or IgM-Fc derivatives operably linked together in any functional combination. In some embodiments, the serpin polypeptide is human AAT or derived from AAT. The WAP-Fc-serpin fusion proteins of the invention are expected to have enhanced anti-protease, anti-infective, and anti-inflammatory properties over fusion proteins composed of only a WAP domain containing polypeptide or a serpin polypeptide.

[00102] In some embodiments the fusion proteins described herein include at least a WAP domain containing polypeptide or an amino acid sequence that is derived from a WAP domain containing and a human serum albumin (HSA) polypeptide or an amino acid sequence that is derived from a HSA polypeptide. Further embodiments of invention include WAP domain containing polypeptide-albumin binding polypeptide fusion proteins, wherein the albumin binding polypeptide is responsible for the association of the WAP domain containing polypeptide and HSA. Thereby the invention includes both covalent and non-covalent linkages of the serpin polypeptide and the HSA polypeptide or sequences derived from the WAP domain containing polypeptide or an HSA polypeptide. For example, the invention provides a WAP domain containing polypeptide fused to human HSA, or HSA derivatives, or HSA binding peptide or polypeptides.

[00103] In some embodiments, the fusion proteins described herein include at least a SLPI polypeptide or an amino acid sequence that is derived from SLPI and a HSA

polypeptide or an amino acid sequence that is derived from a HSA polypeptide. For example, the invention provides SLPI fused to HSA or a fragment derived from HSA, or an albumin binding polypeptide. In some embodiments, the fusion proteins described herein include at least a Elafin polypeptide or an amino acid sequence that is derived from Elafin and a HSA polypeptide or an amino acid sequence that is derived from an HSA polypeptide. For example, the invention provides Elafin fused to HSA or a fragment derived from HSA, or an albumin binding polypeptide.

[00104] The fusion proteins and fusion protein derivatives described herein are expected to be useful in treating a variety of indications, including, by way of non-limiting example, alpha-1-antitrypsin (AAT) deficiency, emphysema, chronic obstructive pulmonary disease (COPD), ischemia-reperfusion injury, including, *e.g.*, ischemia/reperfusion injury following cardiac transplantation, arthritis, allergic asthma, acute respiratory distress syndrome (ARDS), cystic fibrosis, type I and/or type II diabetes, deficiency, bacterial, fungal, and viral infections, spinal cord injury, wound healing, graft rejection, graft versus host disease (GVHD), pulmonary arterial hypertension (PAH), chronic thromboembolic pulmonary hypertension and ischemia/reperfusion injury following cardiac transplantation.

[00105] Unless otherwise defined, scientific and technical terms used in connection with the present invention shall have the meanings that are commonly understood by those of ordinary skill in the art. Further, unless otherwise required by context, singular terms shall include pluralities and plural terms shall include the singular. Generally, nomenclatures utilized in connection with, and techniques of, cell and tissue culture, molecular biology, and protein and oligo- or polynucleotide chemistry and hybridization described herein are those well known and commonly used in the art. Standard techniques are used for recombinant DNA, oligonucleotide synthesis, and tissue culture and transformation (*e.g.,* electroporation, lipofection). Enzymatic reactions and purification techniques are performed according to manufacturer's specifications or as commonly accomplished in the art or as described herein. The foregoing techniques and procedures are generally performed according to conventional methods well known in the art and as described in various general and more specific references that are cited and discussed throughout the present specification. *See e.g.,* Sambrook *et al.* Molecular Cloning: A Laboratory Manual (2d ed., Cold Spring Harbor Laboratory Press, Cold Spring Harbor, N.Y. (1989)). The nomenclatures utilized in connection with, and the laboratory procedures and techniques of, analytical chemistry, synthetic organic chemistry, and medicinal and

pharmaceutical chemistry described herein are those well known and commonly used in the art. Standard techniques are used for chemical syntheses, chemical analyses, pharmaceutical preparation, formulation, and delivery, and treatment of patients. The term patient includes human and veterinary subjects.

[00106] It will be appreciated that administration of therapeutic entities in accordance with the invention will be administered with suitable carriers, buffers, excipients, and other agents that are incorporated into formulations to provide improved transfer, delivery, tolerance, and the like. A multitude of appropriate formulations can be found in the formulary known to all pharmaceutical chemists: Remington's Pharmaceutical Sciences (15th ed, Mack Publishing Company, Easton, PA (1975)), particularly Chapter 87 by Blaug, Seymour, therein. These formulations include, for example, powders, pastes, ointments, jellies, waxes, oils, lipids, lipid (cationic or anionic) containing vesicles (such as Lipofectin™), DNA conjugates, anhydrous absorption pastes, oil-in-water and water-in-oil emulsions, emulsions carbowax (polyethylene glycols of various molecular weights), semi-solid gels, and semi-solid mixtures containing carbowax. Any of the foregoing mixtures may be appropriate in treatments and therapies in accordance with the present invention, provided that the active ingredient in the formulation is not inactivated by the formulation and the formulation is physiologically compatible and tolerable with the route of administration. *See* also Baldrick P. "Pharmaceutical excipient development: the need for preclinical guidance." Regul. Toxicol Pharmacol. 32(2):210-8 (2000), Wang W. "Lyophilization and development of solid protein pharmaceuticals." Int. J. Pharm. 203(1-2):1-60 (2000), Charman WN "Lipids, lipophilic drugs, and oral drug delivery-some emerging concepts." J Pharm Sci. 89(8):967-78 (2000), Powell *et al.* "Compendium of excipients for parenteral formulations" PDA J Pharm Sci Technol. 52:238-311 (1998) and the citations therein for additional information related to formulations, excipients and carriers well known to pharmaceutical chemists.

[00107] Therapeutic formulations of the invention, which include a fusion protein of the invention, are used to treat or alleviate a symptom associated with a disease or disorder associated with aberrant serine protease activity in a subject. The present invention also provides methods of treating or alleviating a symptom associated with a disease or disorder associated with aberrant serine protease activity in a subject. A therapeutic regimen is carried out by identifying a subject, *e.g.*, a human patient suffering from (or at risk of developing) a disease or disorder associated with aberrant serine protease activity, using

standard methods, including any of a variety of clinical and/or laboratory procedures. The term patient includes human and veterinary subjects. The term subject includes humans and other mammals.

[00108] Efficaciousness of treatment is determined in association with any known method for diagnosing or treating the particular disease or disorder associated with aberrant serine protease activity. Alleviation of one or more symptoms of the disease or disorder associated with aberrant serine protease activity indicates that the fusion protein confers a clinical benefit.

[00109] Methods for the screening of fusion proteins that possess the desired specificity include, but are not limited to, enzyme linked immunosorbent assay (ELISA), enzymatic assays, flow cytometry, and other immunologically mediated techniques known within the art.

[00110] The fusion proteins described herein may be used in methods known within the art relating to the localization and/or quantitation of a target such as a serine protease, *e.g.*, for use in measuring levels of these targets within appropriate physiological samples, for use in diagnostic methods, for use in imaging the protein, and the like). The terms "physiological sample" and "biological sample," used interchangeably, herein are intended to include tissues, cells and biological fluids isolated from a subject, as well as tissues, cells and fluids present within a subject. Included within the usage of the terms "physiological sample" and "biological sample", therefore, is blood and a fraction or component of blood including blood serum, blood plasma, or lymph.

[00111] In a given embodiment, fusion proteins specific for a given target, or derivative, fragment, analog or homolog thereof, that contain the target-binding domain, are utilized as pharmacologically active compounds (referred to hereinafter as "Therapeutics").

[00112] A fusion protein of the invention can be used to isolate a particular target using standard techniques, such as immunoaffinity, chromatography or immunoprecipitation. Detection can be facilitated by coupling (*i.e.*, physically linking) the fusion protein to a detectable substance. Examples of detectable substances include various enzymes, prosthetic groups, fluorescent materials, luminescent materials, bioluminescent materials, and radioactive materials. Examples of suitable enzymes include horseradish peroxidase, alkaline phosphatase, β-galactosidase, or acetylcholinesterase; examples of suitable prosthetic group complexes include streptavidin/biotin and avidin/biotin; examples

of suitable fluorescent materials include umbelliferone, fluorescein, fluorescein isothiocyanate, rhodamine, dichlorotriazinylamine fluorescein, dansyl chloride or phycoerythrin; an example of a luminescent material includes luminol; examples of bioluminescent materials include luciferase, luciferin, and aequorin, and examples of suitable radioactive material include ^{125}I, ^{131}I, ^{35}S or ^{3}H.

[00113] A therapeutically effective amount of a fusion protein of the invention relates generally to the amount needed to achieve a therapeutic objective. As noted above, this may be a binding interaction between the fusion protein and its target that, in certain cases, interferes with the functioning of the target. The amount required to be administered will furthermore depend on the binding affinity of the fusion protein for its specific target, and will also depend on the rate at which an administered fusion protein is depleted from the free volume other subject to which it is administered. Common ranges for therapeutically effective dosing of a fusion protein or fragment thereof invention may be, by way of nonlimiting example, from about 0.1 mg/kg body weight to about 250 mg/kg body weight. Common dosing frequencies may range, for example, from twice daily to once a month.

[00114] Where fusion protein fragments are used, the smallest inhibitory fragment that specifically binds to the target is preferred. For example, peptide molecules can be designed that retain the ability to bind the target. Such peptides can be synthesized chemically and/or produced by recombinant DNA technology. (*See*, *e.g.*, Marasco et al., Proc. Natl. Acad. Sci. USA, 90: 7889-7893 (1993)). The formulation can also contain more than one active compound as necessary for the particular indication being treated, preferably those with complementary activities that do not adversely affect each other. Alternatively, or in addition, the composition can comprise an agent that enhances its function, such as, for example, a cytotoxic agent, cytokine, chemotherapeutic agent, growth-inhibitory agent, an anti-inflammatory agent or anti-infective agent. Such molecules are suitably present in combination in amounts that are effective for the purpose intended.

[00115] The active ingredients can also be entrapped in microcapsules prepared, for example, by coacervation techniques or by interfacial polymerization, for example, hydroxymethylcellulose or gelatin-microcapsules and poly-(methylmethacrylate) microcapsules, respectively, in colloidal drug delivery systems (for example, liposomes, albumin microspheres, microemulsions, nano-particles, and nanocapsules) or in macroemulsions.

[00116] The formulations to be used for *in vivo* administration must be sterile. This is readily accomplished by filtration through sterile filtration membranes.

[00117] Sustained-release preparations can be prepared. Suitable examples of sustained-release preparations include semipermeable matrices of solid hydrophobic polymers containing the fusion protein, which matrices are in the form of shaped articles, *e.g.*, films, or microcapsules. Examples of sustained-release matrices include polyesters, hydrogels (for example, poly(2-hydroxyethyl-methacrylate), or poly(vinylalcohol)), polylactides (U.S. Pat. No. 3,773,919), copolymers of L-glutamic acid and γ ethyl-L-glutamate, non-degradable ethylene-vinyl acetate, degradable lactic acid-glycolic acid copolymers such as the LUPRON DEPOT ™ (injectable microspheres composed of lactic acid-glycolic acid copolymer and leuprolide acetate), and poly-D-(-)-3-hydroxybutyric acid. While polymers such as ethylene-vinyl acetate and lactic acid-glycolic acid enable release of molecules for over 100 days, certain hydrogels release proteins for shorter time periods.

Pharmaceutical compositions

[00118] The fusion proteins of the invention (also referred to herein as "active compounds"), and derivatives, fragments, analogs and homologs thereof, can be incorporated into pharmaceutical compositions suitable for administration. Such compositions typically comprise the fusion protein and a pharmaceutically acceptable carrier. As used herein, the term "pharmaceutically acceptable carrier" is intended to include any and all solvents, dispersion media, coatings, antibacterial and antifungal agents, isotonic and absorption delaying agents, and the like, compatible with pharmaceutical administration. Suitable carriers are described in the most recent edition of Remington's Pharmaceutical Sciences, a standard reference text in the field, which is incorporated herein by reference. Preferred examples of such carriers or diluents include, but are not limited to, water, saline, ringer's solutions, dextrose solution, and 5% human serum albumin. Liposomes and non-aqueous vehicles such as fixed oils may also be used. The use of such media and agents for pharmaceutically active substances is well known in the art. Except insofar as any conventional media or agent is incompatible with the active compound, use thereof in the compositions is contemplated. Supplementary active compounds can also be incorporated into the compositions.

[00119] A pharmaceutical composition of the invention is formulated to be compatible with its intended route of administration. Examples of routes of administration

include parenteral, *e.g.*, intravenous, intradermal, subcutaneous, oral (*e.g.*, inhalation), transdermal (*i.e.,* topical), transmucosal, and rectal administration. Solutions or suspensions used for parenteral, intradermal, or subcutaneous application can include the following components: a sterile diluent such as water for injection, saline solution, fixed oils, polyethylene glycols, glycerine, propylene glycol or other synthetic solvents; antibacterial agents such as benzyl alcohol or methyl parabens; antioxidants such as ascorbic acid or sodium bisulfite; chelating agents such as ethylenediaminetetraacetic acid (EDTA); buffers such as acetates, citrates or phosphates, and agents for the adjustment of tonicity such as sodium chloride or dextrose. The pH can be adjusted with acids or bases, such as hydrochloric acid or sodium hydroxide. The parenteral preparation can be enclosed in ampoules, disposable syringes or multiple dose vials made of glass or plastic.

[00120] Pharmaceutical compositions suitable for injectable use include sterile aqueous solutions (where water soluble) or dispersions and sterile powders for the extemporaneous preparation of sterile injectable solutions or dispersion. For intravenous administration, suitable carriers include physiological saline, bacteriostatic water, Cremophor EL™ (BASF, Parsippany, N.J.) or phosphate buffered saline (PBS). In all cases, the composition must be sterile and should be fluid to the extent that easy syringeability exists. It must be stable under the conditions of manufacture and storage and must be preserved against the contaminating action of microorganisms such as bacteria and fungi. The carrier can be a solvent or dispersion medium containing, for example, water, ethanol, polyol (for example, glycerol, propylene glycol, and liquid polyethylene glycol, and the like), and suitable mixtures thereof. The proper fluidity can be maintained, for example, by the use of a coating such as lecithin, by the maintenance of the required particle size in the case of dispersion and by the use of surfactants. Prevention of the action of microorganisms can be achieved by various antibacterial and antifungal agents, for example, parabens, chlorobutanol, phenol, ascorbic acid, thimerosal, and the like. In many cases, it will be preferable to include isotonic agents, for example, sugars, polyalcohols such as manitol, sorbitol, sodium chloride in the composition. Prolonged absorption of the injectable compositions can be brought about by including in the composition an agent which delays absorption, for example, aluminum monostearate and gelatin.

[00121] Sterile injectable solutions can be prepared by incorporating the active compound in the required amount in an appropriate solvent with one or a combination of

ingredients enumerated above, as required, followed by filtered sterilization. Generally, dispersions are prepared by incorporating the active compound into a sterile vehicle that contains a basic dispersion medium and the required other ingredients from those enumerated above. In the case of sterile powders for the preparation of sterile injectable solutions, methods of preparation are vacuum drying and freeze-drying that yields a powder of the active ingredient plus any additional desired ingredient from a previously sterile-filtered solution thereof.

[00122] Oral compositions generally include an inert diluent or an edible carrier. They can be enclosed in gelatin capsules or compressed into tablets. For the purpose of oral therapeutic administration, the active compound can be incorporated with excipients and used in the form of tablets, troches, or capsules. Oral compositions can also be prepared using a fluid carrier for use as a mouthwash, wherein the compound in the fluid carrier is applied orally and swished and expectorated or swallowed. Pharmaceutically compatible binding agents, and/or adjuvant materials can be included as part of the composition. The tablets, pills, capsules, troches and the like can contain any of the following ingredients, or compounds of a similar nature: a binder such as microcrystalline cellulose, gum tragacanth or gelatin; an excipient such as starch or lactose, a disintegrating agent such as alginic acid, Primogel, or corn starch; a lubricant such as magnesium stearate or Sterotes; a glidant such as colloidal silicon dioxide; a sweetening agent such as sucrose or saccharin; or a flavoring agent such as peppermint, methyl salicylate, or orange flavoring.

[00123] For administration by inhalation, the compounds are delivered in the form of an aerosol spray from pressured container or dispenser which contains a suitable propellant, *e.g.*, a gas such as carbon dioxide, or a nebulizer.

[00124] Systemic administration can also be by transmucosal or transdermal means. For transmucosal or transdermal administration, penetrants appropriate to the barrier to be permeated are used in the formulation. Such penetrants are generally known in the art, and include, for example, for transmucosal administration, detergents, bile salts, and fusidic acid derivatives. Transmucosal administration can be accomplished through the use of nasal sprays or suppositories. For transdermal administration, the active compounds are formulated into ointments, salves, gels, or creams as generally known in the art.

[00125] The compounds can also be prepared in the form of suppositories (*e.g.*, with conventional suppository bases such as cocoa butter and other glycerides) or retention enemas for rectal delivery.

[00126] In one embodiment, the active compounds are prepared with carriers that will protect the compound against rapid elimination from the body, such as a controlled release formulation, including implants and microencapsulated delivery systems. Biodegradable, biocompatible polymers can be used, such as ethylene vinyl acetate, polyanhydrides, polyglycolic acid, collagen, polyorthoesters, and polylactic acid. Methods for preparation of such formulations will be apparent to those skilled in the art. The materials can also be obtained commercially from Alza Corporation and Nova Pharmaceuticals, Inc. Liposomal suspensions can also be used as pharmaceutically acceptable carriers. These can be prepared according to methods known to those skilled in the art, for example, as described in U.S. Patent No. 4,522,811.

[00127] It is especially advantageous to formulate oral or parenteral compositions in dosage unit form for ease of administration and uniformity of dosage. Dosage unit form as used herein refers to physically discrete units suited as unitary dosages for the subject to be treated; each unit containing a predetermined quantity of active compound calculated to produce the desired therapeutic effect in association with the required pharmaceutical carrier. The specification for the dosage unit forms of the invention are dictated by and directly dependent on the unique characteristics of the active compound and the particular therapeutic effect to be achieved, and the limitations inherent in the art of compounding such an active compound for the treatment of individuals.

[00128] The pharmaceutical compositions can be included in a container, pack, or dispenser together with instructions for administration.

[00129] The invention will be further described in the following examples, which do not limit the scope of the invention described in the claims.

EXAMPLES

Example 1: SLPI-Fc and Elafin-Fc Fusion Proteins and Variants

[00130] Exemplary, but non-limiting examples of SLPI-Fc and Elafin Fc fusion proteins according to the invention include the following sequences, where the SLPI or Elafin polypeptide portion of the fusion protein is shown in bold, the WAP domain is underlined, the IgG-Fc polypeptide portion of the fusion protein is italicized, the Met98Leu (ML) mutation in SLPI is boxed, the Fc mutations Met252Tyr, Ser254Thr, Thr256Glu

(YTE) or Met428Leu, Asn434Ser (LS) which enhance FcRn binding are boxed, in bold text, and shaded in grey. While these examples include a hinge sequence and/or a linker sequence, fusion proteins of the invention can be made using any hinge sequence and/or a linker sequence suitable in length and/or flexibility. Alternatively fusion proteins can be made without using a hinge and/or a linker sequence. For example, the polypeptide components can be directly attached.

[00131] An exemplary SLPI-Fc fusion protein is the SLPI-hFc. As shown below, the SLPI polypeptide portion of the fusion protein is shown in bold (SEQ ID NO: 2), the WAP domain is underlined, and the IgG-Fc polypeptide portion of the fusion protein is italicized (SEQ ID NO: 7).

SLPI-hFc1 (human IgG1 Fc, long Hinge) (SEQ ID NO:16)

SGKSFKAGVCPPKKSAQCLRYKKPECQSDWQCPGKKRCCPDTCGIKCLDPVDTPNPTRRKP GKCPVTYGQCLMLNPPNFCEMDGQCKRDLKCCMGMCGKSCVSPVKAEPKSCDKTHTCPPCP *APELLGGPSVFLFPPKPKDTLMISRTPEVTCVVVDVSHEDPEVKFNWYVDGVEVHNAKTKP REEQYNSTYRVVSVLTVLHQDWLNGKEYKCKVSNKALPAPIEKTISKAKGQPREPQVYTLP PSRDELTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTTPPVLDSDGSFFLYSKLTVD KSRWQQGNVFSCSVMHEALHNHYTQKSLSLSPGK* **(SEQ ID NO:16)**

[00132] An exemplary SLPI-Fc fusion protein is the SLPI-hFc2 (human IgG2 Fc, long Hinge). As shown below, the SLPI polypeptide portion of the fusion protein is shown in bold (SEQ ID NO: 2), the WAP domain is underlined, and the IgG-Fc polypeptide portion of the fusion protein is italicized (SEQ ID NO: 8).

SLPI-hFc2 (human IgG2 Fc, long Hinge) (SEQ ID NO:17)

SGKSFKAGVCPPKKSAQCLRYKKPECQSDWQCPGKKRCCPDTCGIKCLDPVDTPNPTRRKP GKCPVTYGQCLMLNPPNFCEMDGQCKRDLKCCMGMCGKSCVSPVKAERKCCVECPPCP*APP VAGPSVFLFPPKPKDTLMISRTPEVTCVVVDVSHEDPEVQFNWYVDGVEVHNAKTKPREEQ FNSTFRVVSVLTVVHQDWLNGKEYKCKVSNKGLPAPIEKTISKTKGQPREPQVYTLPPSRE EMTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTTPPMLDSDGSFFLYSKLTVDKSRW QQGNVFSCSVMHEALHNHYTQKSLSLSPGK* (SEQ ID NO:17)

[00133] An exemplary SLPI-Fc fusion protein is the SLPI-ML-hFc1. As shown below, the SLPI polypeptide portion of the fusion protein is shown in bold (SEQ ID NO:

39), the WAP domain is underlined, the IgG-Fc polypeptide portion of the fusion protein is italicized (SEQ ID NO: 7), and Met98Leu (ML) mutation in SLPI is boxed.

SLPI-ML-hFc1 (human IgG1 Fc, Met98Leu) (SEQ ID NO:18)

SGKSFKAGVCPPKKSAQCLRYKKPECQSDWQCPGKKRCCPDTCGIKCLDPVDTPNPTRRKP GKCPVTYGQCLMLNPPNFCEMDGQCKRDLKCCMGLCGKSCVSPVKAEPKSCDKTHTCPPCP *APELLGGPSVFLFPPKPKDTLMISRTPEVTCVVVDVSHEDPEVKFNWYVDGVEVHNAKTKP REEQYNSTYRVVSVLTVLHQDWLNGKEYKCKVSNKALPAPIEKTISKAKGQPREPQVYTLP PSRDELTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTTPPVLDSDGSFFLYSKLTVD KSRWQQGNVFSCSVMHEALHNHYTQKSLSLSPGK* **(SEQ ID NO:18)**

[00134] An exemplary SLPI-Fc fusion protein is the SLPI-hFc1-YTE. As shown below, the SLPI polypeptide portion of the fusion protein is shown in bold (SEQ ID NO: 39), the WAP domain is underlined, the IgG-Fc polypeptide portion of the fusion protein is italicized (SEQ ID NO: 40), and the Fc mutations Met252Tyr, Ser254Thr, Thr256Glu (YTE) are boxed, in bold text, and shaded in grey.

SLPI-hFc1-YTE (human IgG1 Fc, Met252Tyr, Ser254Thr, Thr256Glu) (SEQ ID NO:19)

SGKSFKAGVCPPKKSAQCLRYKKPECQSDWQCPGKKRCCPDTCGIKCLDPVDTPNPTRRKP GKCPVTYGQCLMLNPPNFCEMDGQCKRDLKCCMGLCGKSCVSPVKAEPKSCDKTHTCPPCP *APELLGGPSVFLFPPKPKDTLYITREPEVTCVVVDVSHEDPEVKFNWYVDGVEVHNAKTKP REEQYNSTYRVVSVLTVLHQDWLNGKEYKCKVSNKALPAPIEKTISKAKGQPREPQVYTLP PSRDELTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTTPPVLDSDGSFFLYSKLTVD KSRWQQGNVFSCSVMHEALHNHYTQKSLSLSPGK* **(SEQ ID NO:19)**

[00135] An exemplary SLPI-Fc fusion protein is the SLPI-hFc1-LS. As shown below, the SLPI polypeptide portion of the fusion protein is shown in bold (SEQ ID NO: 39), the WAP domain is underlined, the IgG-Fc polypeptide portion of the fusion protein is italicized (SEQ ID NO: 41), and Met428Leu, Asn434Ser (LS) which enhance FcRn binding are boxed, in bold text, and shaded in grey.

SLPI-hFc1-LS (human IgG1 Fc, Met428Leu, Asn434Ser)

SGKSFKAGVCPPKKSAQCLRYKKPECQSDWQCPGKKRCCPDTCGIKCLDPVDTPNPTRRKP
GKCPVTYGQCLMLNPPNFCEMDGQCKRDLKCCMGLCGKSCVSPVKAEPKSCDKTHTCPPCP
APELLGGPSVFLFPPKPKDTLMISRTPEVTCVVVDVSHEDPEVKFNWYVDGVEVHNAKTKP
REEQYNSTYRVVSVLTVLHQDWLNGKEYKCKVSNKALPAPIEKTISKAKGQPREPQVYTLP
PSRDELTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTTPPVLDSDGSFFLYSKLTVD
KSRWQQGNVFSCSVMHEALHSHYTQKSLSLSPGK **(SEQ ID NO:20)**

[00136] An exemplary Elafin-Fc fusion protein is the Elafin-hFc1. As shown below, the Elafin polypeptide portion of the fusion protein is shown in bold (SEQ ID NO: 5), the WAP domain is underlined, the IgG-Fc polypeptide portion of the fusion protein is italicized (SEQ ID NO: 41), and the Asn434Ser (LS) which enhance FcRn binding are boxed, in bold text, and shaded in grey.

Elafin-hFc1 (human IgG1)
AVTGVPVKGQDTVKGRVPFNGQDPVKGQVSVKGQDKVKAQEPVKGPVSTKPGSCPIILIRC
AMLNPPNRCLKDTDCPGIKKCCEGSCGMACFVPQEPKSCDKTHTCPPC*PAPELLGGPSVFL*
FPPKPKDTLMISRTPEVTCVVVDVSHEDPEVKFNWYVDGVEVHNAKTKPREEQYNSTYRVV
SVLTVLHQDWLNGKEYKCKVSNKALPAPIEKTISKAKGQPREPQVYTLPPSRDELTKNQVS
LTCLVKGFYPSDIAVEWESNGQPENNYKTTPPVLDSDGSFFLYSKLTVDKSRWQQGNVFSC
SVMHEALHSHYTQKSLSLSPGK **(SEQ ID NO:21)**

[00137] An exemplary SPLI-Fc fusion protein is the SLPI-hFc1-SLPI. As shown below, the SLPI polypeptide portion of the fusion protein is shown in bold (SEQ ID NO: 39), the WAP domain is underlined, and the IgG-Fc polypeptide portion of the fusion protein is italicized (SEQ ID NO: 7).

SLPI-hFc1-SLPI (human IgG1)
SGKSFKAGVCPPKKSAQCLRYKKPECQSDWQCPGKKRCCPDTCGIKCLDPVDTPNPTRRKP
GKCPVTYGQCLMLNPPNFCEMDGQCKRDLKCCMGLCGKSCVSPVKAEPKSCDKTHTCPPCP
APELLGGPSVFLFPPKPKDTLMISRTPEVTCVVVDVSHEDPEVKFNWYVDGVEVHNAKTKP
REEQYNSTYRVVSVLTVLHQDWLNGKEYKCKVSNKALPAPIEKTISKAKGQPREPQVYTLP
PSRDELTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTTPPVLDSDGSFFLYSKLTVD
*KSRWQQGNVFSCSVMHEALHNHYTQKSLSLSPGK*ASTGS**SGKSFKAGVCPPKKSAQCLRYK**

KPECQSDWQCPGKKRCCPDTCGIKCLDPVDTPNPTRRKPGKCPVTYGQCLMLNPPNFCEMD GQCKRDLKCCMGLCGKSCVSPVKA (SEQ ID NO:22)

[00138] An exemplary Elafin-Fc fusion protein is the Elafin-hFc1-Elafin. As shown below, the Elafin polypeptide portion of the fusion protein is shown in bold (SEQ ID NO: 5), the WAP domain is underlined, and the IgG-Fc polypeptide portion of the fusion protein is italicized (SEQ ID NO: 7).

Elafin-hFc1-Elafin (human IgG1)

AVTGVPVKGQDTVKGRVPFNGQDPVKGQVSVKGQDKVKAQEPVKGPVSTKPGSCPIILIRC AMLNPPNRCLKDTDCPGIKKCCEGSCGMACFVPQ*EPKSCDKTHTCPPCPAPELLGGPSVFL FPPKPKDTLMISRTPEVTCVVVDVSHEDPEVKFNWYVDGVEVHNAKTKPREEQYNSTYRVV SVLTVLHQDWLNGKEYKCKVSNKALPAPIEKTISKAKGQPREPQVYTLPPSRDELTKNQVS LTCLVKGFYPSDIAVEWESNGQPENNYKTTPPVLDSDGSFFLYSKLTVDKSRWQQGNVFSC SVMHEALHNHYTQKSLSLSPGK***ASTGSAVTGVPVKGQDTVKGRVPFNGQDPVKGQVSVKGQ DKVKAQEPVKGPVSTKPGSCPIILIRCAMLNPPNRCLKDTDCPGIKKCCEGSCGMACFVPQ** (SEQ ID NO:23)

[00139] An exemplary Elafin-Fc fusion protein is the Elafin-hFc1-SLPI. As shown below, the SLPI polypeptide (SEQ ID NO: 39) portion of the fusion protein is shown in bold, with the WAP domain underlined, the Elafin (SEQ ID NO: 5) polypeptide portion of the fusion protein is shown in bold and italics, the WAP domain is underlined, the IgG-Fc polypeptide portion of the fusion protein is italicized (SEQ ID NO: 7).

Elafin-hFc1-SLPI (human IgG1)

AVTGVPVKGQDTVKGRVPFNGQDPVKGQVSVKGQDKVKAQEPVKGPVSTKPGSCPIILIRC AMLNPPNRCLKDTDCPGIKKCCEGSCGMACFVPQ*EPKSCDKTHTCPPCPAPELLGGPSVFL FPPKPKDTLMISRTPEVTCVVVDVSHEDPEVKFNWYVDGVEVHNAKTKPREEQYNSTYRVV SVLTVLHQDWLNGKEYKCKVSNKALPAPIEKTISKAKGQPREPQVYTLPPSRDELTKNQVS LTCLVKGFYPSDIAVEWESNGQPENNYKTTPPVLDSDGSFFLYSKLTVDKSRWQQGNVFSC SVMHEALHNHYTQKSLSLSPGK*ASTGS**SGKSFKAGVCPPKKSAQCLRYKKPECQSDWQCPG KKRCCPDTCGIKCLDPVDTPNPTRRKPGKCPVTYGQCLMLNPPNFCEMDGQCKRDLKCCMG LCGKSCVSPVKA** (SEQ ID NO:24)

[00140] An exemplary SLPI-Fc fusion protein is the SLPI-hFc1-Elafin. As shown below, the SLPI (SEQ ID NO: 39) portion of the fusion protein is shown in bold, with the WAP domain underlined, the Elafin (SEQ ID NO: 5) polypeptide portion of the fusion protein is shown in bold and italics, the WAP domain is underlined, and the IgG-Fc polypeptide portion of the fusion protein is italicized (SEQ ID NO: 7).

SLPI-hFc1-Elafin (human IgG1)

SGKSFKAGVCPPKKSAQCLRYKKPECQSDWQCPGKKRCCPDTCGIKCLDPVDTPNPTRRKP GKCPVTYGQCLMLNPPNFCEMDGQCKRDLKCCMGLCGKSCVSPVKAEPKSCDKTHTCPPCP *APELLGGPSVFLFPPKPKDTLMISRTPEVTCVVVDVSHEDPEVKFNWYVDGVEVHNAKTKP REEQYNSTYRVVSVLTVLHQDWLNGKEYKCKVSNKALPAPIEKTISKAKGQPREPQVYTLP PSRDELTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTTPPVLDSDGSFFLYSKLTVD KSRWQQGNVFSCSVMHEALHNHYTQKSLSLSPGK*ASTGS***AVTGVPVKGQDTVKGRVPFNGQ DPVKGQVSVKGQDKVKAQEPVKGPVSTKPGSCPIILIRCAMLNPPNRCLKDTDCPGIKKCC EGSCGMACFVPQ** (SEQ ID NO:25)

[00141] These exemplary SLPI-Fc and Elafin-Fc fusion proteins were made using the following techniques.

[00142] The genes encoding human SLPI and Elafin were PCR amplified from human spleen cDNA (Zyagen). Specific point mutations within the gene encoding SLPI, Elafin or the Fc region were generated by overlapping PCR. The SLPI or Elafin encoding gene was cloned in frame with a gene encoding the hinge region, followed by a CH2 domain, and a CH3 domain of human IgG1, IgG2, IgG3, IgG4, or IgM into a mammalian expression vector, containing a mammalian secretion signal sequence up stream of the SLPI or Elafin gene insertion site. In some cases, these vectors were further modified, wherein the gene encoding a linker sequence and either SLPI or Elafin was cloned in frame to the 3' end of the CH3 domain, to generate SLPI-Fc-SLPI, Elafin-Fc-Elafin, SLPI-Fc-Elafin, or Elafin-Fc-SLPI. These expression vectors were transfected into mammalian cells (specifically HEK293 or CHO cells) and grown for several days in 8% CO_2 at 37° C. The recombinant SLPI-Fc and Elafin-Fc fusion proteins were purified from the expression cell supernatant by protein A chromatography. Figure 1B shows a reducing SDS-PAGE gel of the Elafin-Fc (SEQ ID NO:21, lane 1) and SLPI-Fc (SEQ ID NO:16, lane 2) fusion

proteins. Figure 1D shows a reducing SDS-PAGE gel of the Elafin-Fc-SLPI (SEQ ID NO:24). The proteins were visualized by staining with coomassie blue.

[00143] To monitor human Neutrophil Elastase (NE) activity a fluorescent microplate assay was used. Inhibitory activity was measured by a concomitant decrease in the residual NE activity using the following assay. This assay buffer is composed of 100 mM Tris pH 7.4, 500 mM NaCl, and 0.0005% Triton X-100. Human NE is used at a final concentration of 5 nM (but can also be used from 1-20 nM). The fluorescent peptide substrate AAVP-AMC is used at a final concentration of 100 μM in the assay. The Gemini EM plate reader from Molecular Devices is used to read the assay kinetics using excitation and emission wavelengths of 370 nm and 440 nm respectively, and a cutoff of 420 nm. The assay is read for 10 min at room temperature scanning every 5 to 10 seconds. The Vmax per second corresponds to the residual NE activity, which is plotted for each concentration of inhibitor. The intercept with the x-axis indicates the concentration of inhibitor needed to fully inactivate the starting concentration of NE in the assay. Human serum derived AAT (sdAAT) was used as a positive control for NE inhibition in these assays. The Elafin-Fc and SLPI-Fc fusion proteins display potent inhibition of NE (Figure 1C). The Elafin-Fc-SLPI fusion protein also was a potent inhibitor of NE (Figure 1E).

[00144] Furthermore, the SLPI-Fc fusion protein displayed a longer serum half life in rats compared to *E.coli* produced unmodified SLPI (Figure 1F), demonstrating that the fusion proteins of the invention have improved pharmacokinetic properties and are a superior therapeutic format over unmodified versions of SLPI and Elafin, for treating numerous human inflammatory conditions

Example 2: SLPI-TNFα Targeting Molecule Fusion Proteins

[00145] The studies presented herein describe several, non-limiting examples of recombinant SLPI derivatives comprising human SLPI fused to an anti-TNFα antibody or a derivative of a TNFα receptor. These examples are provided below to further illustrate different features of the present invention. The examples also illustrate useful methodology for practicing the invention. These examples do not and are not intended to limit the claimed invention.

[00146] The fusion proteins below include cytokine targeting polypeptide sequences that are from or are derived from (i) the anti-TNFα antibody D2E7 (also known as Adalimumab or Humira®), or (ii) the extracellular domain of Type 2 TNFα Receptor

(TNFR2-ECD). The SLPI polypeptide portion of the fusion protein is in bold text, the WAP domain is underlined, the antibody constant regions (CH1-hinge-CH2-CH3, or CL) are italicized, and D2E7-VH, D2E7-VK, and TNFR2-ECD are shaded in grey and in bold text. While these examples include a hinge sequence and/or a linker sequence, fusion proteins of the invention can be made using any hinge sequence and/or a linker sequence suitable in length and/or flexibility. Alternatively fusion proteins can be made without using a hinge and/or a linker sequence. For example, the polypeptide components can be directly attached.

[00147] An exemplary SLPI-TNFα Targeting Molecule fusion protein is D2E7-Light Chain-SLPI $(G_3S)_2$ Linker. As shown below the SLPI polypeptide portion of the fusion protein is in bold text (SEQ ID NO: 2), the WAP domain is underlined, the antibody constant regions (CH1-hinge-CH2-CH3, or CL) are italicized (SEQ ID NO: 43), and D2E7-VK is shaded in grey and in bold text (SEQ ID NO: 42).

D2E7-Light Chain-SLPI $(G_3S)_2$ Linker

DIQMTQSPSSLSASVGDRVTITCRASQGIRNYLAWYQQKPGKAPKLLIYAASTLQSGVPSR FSGSGSGTDFTLTISSLQPEDVATYYCQRYNRAPYTFGQGTKVEIK*RTVAAPSVFIFPPSD EQLKSGTASVVCLLNNFYPREAKVQWKVDNALQSGNSQESVTEQDSKDSTYSLSSTLTLSK ADYEKHKVYACEVTHQGLSSPVTKSFNRGEC*GGGSGGGS**SGKSFKAGVCPPKKSAQCLRYK KPECQSDWQCPGKKRCCPDTCGIKCLDPVDTPNPTRRKPGKCPVTYGQCLMLNPPNFCEMD GQCKRDLKCCMGMCGKSCVSPVKA** (SEQ ID NO: 26)

[00148] An exemplary SLPI-TNFα Targeting Molecule fusion protein is D2E7-Light Chain-SLPI ASTGS Linker. As shown below the SLPI polypeptide portion of the fusion protein is in bold text (SEQ ID NO: 2), the WAP domain is underlined, the antibody constant regions (CH1-hinge-CH2-CH3, or CL) are italicized (SEQ ID NO: 43), and D2E7-VK is shaded in grey and in bold text (SEQ ID NO: 42).

D2E7-Light Chain-SLPI ASTGS Linker

DIQMTQSPSSLSASVGDRVTITCRASQGIRNYLAWYQQKPGKAPKLLIYAASTLQSGVPSR FSGSGSGTDFTLTISSLQPEDVATYYCQRYNRAPYTFGQGTKVEIK*RTVAAPSVFIFPPSD EQLKSGTASVVCLLNNFYPREAKVQWKVDNALQSGNSQESVTEQDSKDSTYSLSSTLTLSK ADYEKHKVYACEVTHQGLSSPVTKSFNRGEC***ASTGSSGKSFKAGVCPPKKSAQCLRYKKPE**

CQSDWQCPGKKRCCPDTCGIKCLDPVDTPNPTRRKPGKCPVTYGQCLMLNPPNFCEMDGQC KRDLKCCMGMCGKSCVSPVKA (SEQ ID NO: 27)

[00149] An exemplary SLPI-TNFα Targeting Molecule fusion protein is D2E7-Heavy Chain-SLPI $(G_3S)_2$ Linker. As shown below the SLPI polypeptide portion of the fusion protein is in bold text (SEQ ID NO: 2), the WAP domain is underlined, the antibody constant regions (CH1-hinge-CH2-CH3, or CL) are italicized (SEQ ID NO: 45), and D2E7-VH is shaded in grey and in bold text (SEQ ID NO: 44).

D2E7-Heavy Chain-SLPI $(G_3S)_2$ Linker

EVQLVESGGGLVQPGRSLRLSCAASGFTFDDYAMHWVRQAPGKGLEWVSAITWNSGHIDYA DSVEGRFTISRDNAKNSLYLQMNSLRAEDTAVYYCAKVSYLSTASSLDYWGQGTL*VTVSSA STKGPSVFPLAPSSKSTSGGTAALGCLVKDYFPEPVTVSWNSGALTSGVHTFPAVLQSSGL YSLSSVVTVPSSSLGTQTYICNVNHKPSNTKVDKKVEPKSCDKTHTCPPCPAPELLGGPSV FLFPPKPKDTLMISRTPEVTCVVVDVSHEDPEVKFNWYVDGVEVHNAKTKPREEQYNSTYR VVSVLTVLHQDWLNGKEYKCKVSNKALPAPIEKTISKAKGQPREPQVYTLPPSRDELTKNQ VSLTCLVKGFYPSDIAVEWESNGQPENNYKTTPPVLDSDGSFFLYSKLTVDKSRWQQGNVF SCSVMHEALHNHYTQKSLSLSPGK*GGGSGGGS**SGKSFKAGVCPPKKSAQCLRYKKPECQSD WQCPGKKRCCPDTCGIKCLDPVDTPNPTRRKPGKCPVTYGQCLMLNPPNFCEMDGQCKRDL KCCMGMCGKSCVSPVKA** (SEQ ID NO: 28)

[00150] An exemplary SLPI-TNFα Targeting Molecule fusion protein is D2E7-Heavy Chain-SLPI ASTGS Linker. As shown below the SLPI polypeptide portion of the fusion protein is in bold text (SEQ ID NO: 2), the WAP domain is underlined, the antibody constant regions (CH1-hinge-CH2-CH3, or CL) are italicized (SEQ ID NO: 45), and D2E7-VH is shaded in grey and in bold text (SEQ ID NO: 44).

D2E7-Heavy Chain-SLPI ASTGS Linker

EVQLVESGGGLVQPGRSLRLSCAASGFTFDDYAMHWVRQAPGKGLEWVSAITWNSGHIDYA DSVEGRFTISRDNAKNSLYLQMNSLRAEDTAVYYCAKVSYLSTASSLDYWGQGTL*VTVSSA STKGPSVFPLAPSSKSTSGGTAALGCLVKDYFPEPVTVSWNSGALTSGVHTFPAVLQSSGL YSLSSVVTVPSSSLGTQTYICNVNHKPSNTKVDKKVEPKSCDKTHTCPPCPAPELLGGPSV FLFPPKPKDTLMISRTPEVTCVVVDVSHEDPEVKFNWYVDGVEVHNAKTKPREEQYNSTYR VVSVLTVLHQDWLNGKEYKCKVSNKALPAPIEKTISKAKGQPREPQVYTLPPSRDELTKNQ*

VSLTCLVKGFYPSDIAVEWESNGQPENNYKTTPPVLDSDGSFFLYSKLTVDKSRWQQGNVF
*SCSVMHEALHNHYTQKSLSLSPGK*ASTGS**SGKSFKAGVCPPKKSAQCLRYKKPECQSDWQC**
PGKKRCCPDTCGIKCLDPVDTPNPTRRKPGKCPVTYGQCLMLNPPNFCEMDGQCKRDLKCC
MGMCGKSCVSPVKA (SEQ ID NO: 29)

[00151] An exemplary SLPI-TNFα Targeting Molecule fusion protein is TNFR2-ECD-Fc1-SLPI(G_3S)$_2$ Linker. As shown below, the SLPI polypeptide portion of the fusion protein is in bold text, (SEQ ID NO: 2), the WAP domain is underlined, the Fc polypeptide portion is italicized (SEQ ID NO: 47), and the TNFR2-ECD is shaded in grey and in bold text (SEQ ID NO: 46).

TNFR2-ECD-Fc1-SLPI(G_3S)$_2$ Linker

LPAQVAFTPYAPEPGSTCRLREYYDQTAQMCCSKCSPGQHAKVFCTKTSDTVCDSCEDSTY
TQLWNWVPECLSCGSRCSSDQVETQACTREQNRICTCRPGWYCALSKQEGCRLCAPLRKCR
PGFGVARPGTETSDVVCKPCAPGTFSNTTSSTDICRPHQICNVVAIPGNASMDAVCTSTSP
TRSMAPGAVHLPQPVSTRSQHTQPTPEPSTAPSTSFLLPMGPSPPAEGSTGDEPKSCDKTH
TCPPCP*APELLGGPSVFLFPPKPKDTLMISRTPEVTCVVVDVSHEDPQVKFNWYVDGVQVH*
NAKTKPREQQYNSTYRVVSVLTVLHQNWLDGKEYKCKVSNKALPAPIEKTISKAKGQPREP
QVYTLPPSREEMTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTTPPVLDSDGSFFLY
*SKLTVDKSRWQQGNVFSCSVMHEALHNHYTQKSLSLSPGK*GGGSGGGS**SGKSFKAGVCPPK**
KSAQCLRYKKPECQSDWQCPGKKRCCPDTCGIKCLDPVDTPNPTRRKPGKCPVTYGQCLML
NPPNFCEMDGQCKRDLKCCMGMCGKSCVSPVKA (SEQ ID NO: 30)

[00152] An exemplary SLPI-TNFα Targeting Molecule fusion protein is TNFR2-ECD-Fc1-SLPI ASTGS Linker. As shown below, the SLPI polypeptide portion of the fusion protein is in bold text (SEQ ID NO: 2), the WAP domain is underlined, the Fc polypeptide portion is italicized (SEQ ID NO: 47), and the TNFR2-ECD is shaded in grey and in bold text (SEQ ID NO: 46).

TNFR2-ECD-Fc1-SLPI ASTGS Linker

LPAQVAFTPYAPEPGSTCRLREYYDQTAQMCCSKCSPGQHAKVFCTKTSDTVCDSCEDSTY
TQLWNWVPECLSCGSRCSSDQVETQACTREQNRICTCRPGWYCALSKQEGCRLCAPLRKCR
PGFGVARPGTETSDVVCKPCAPGTFSNTTSSTDICRPHQICNVVAIPGNASMDAVCTSTSP
TRSMAPGAVHLPQPVSTRSQHTQPTPEPSTAPSTSFLLPMGPSPPAEGSTGDEPKSCDKTH

TCPPC*PAPELLGGPSVFLFPPKPKDTLMISRTPEVTCVVVDVSHEDPQVKFNWYVDGVQVH NAKTKPREQQYNSTYRVVSVLTVLHQNWLDGKEYKCKVSNKALPAPIEKTISKAKGQPREP QVYTLPPSREEMTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTTPPVLDSDGSFFLY SKLTVDKSRWQQGNVFSCSVMHEALHNHYTQKSLSLSPGK***ASTGSSGKSFKAGVCPPKKSA QCLRYKKPECQSDWQCPGKKRCCPDTCGIKCLDPVDTPNPTRRKPGKCPVTYGQCLMLNPP NFCEMDGQCKRDLKCCMGMCGKSCVSPVKA** (SEQ ID NO: 31)

[00153] These exemplary SLPI-TNFα targeting molecule fusion proteins were made using the following techniques.

[00154] The genes encoding the variable heavy (VH) and variable kappa (VK) regions of the anti-TNFα antibody, D2E7, were generated by gene synthesis. The D2E7-VH gene was cloned in frame with a gene encoding a human IgG1 antibody heavy chain constant region, consisting of a CH1 domain, a hinge domain, a CH2 domain, and a CH3 domain, into a mammalian expression vector, containing a mammalian secretion signal sequence up stream of the VH domain insertion site (D2E7-HC). The D2E7-VK gene was cloned in frame with a human antibody kappa light chain constant (CL) domain, into a mammalian expression vector, containing a mammalian secretion signal sequence up stream of the VK domain insertion site (D2E7-LC). The SLPI encoding gene and the adjacent 5' linker sequence were cloned in frame into the 3' end of either, the CH3 domain of the D2E7 heavy chain gene (D2E7-HC-SLPI), or the CL domain of the D2E7 light chain gene (D2E7-LC-SLPI) coding sequences in the above described mammalian expression vectors. The extracellular domain of the TNFα Receptor 2 (TNFR2-ECD) was generated by gene synthesis and cloned in frame with a gene encoding the hinge region, followed by a CH2 domain and a CH3 domain of human IgG1 (hFc1) into a mammalian expression, containing a mammalian secretion signal sequence up stream of the TNFR2-ECD insertion site. The SLPI encoding gene and the adjacent 5' linker sequence were cloned in frame into the 3' end of the gene encoding TNFR2-ECD-hFc1 into a mammalian expression vector (TNFR2-ECD-hFc1-SLPI).

[00155] The D2E7-HC-SLPI expression vector was co-transfected with either the D2E7-LC or the D2E7-LC-SLPI expression vector into mammalian cells (specifically HEK293 or CHO cells) to generate the D2E7 antibody with SLPI fused to the C-terminus of the heavy chain or to the C-terminus of both the heavy chain and light chain, respectively.

The D2E7-LC-SLPI was co-transfected with the D2E7-HC expression vector into mammalian cells to generate the D2E7 antibody with SLPI fused to the C-terminus of the light chain. The TNFR2-hFc1-SLPI expression vector was transfected into mammalian cells. Transfected cells were grown for several days in 8% CO_2 at 37° C.

[00156] The recombinant SLPI-TNFα targeting fusion proteins were purified from the expression cell supernatant by protein A chromatography. Figure 2B shows a reducing SDS-PAGE gel of the D2E7 antibody alone (lane 1), the D2E7 antibody with SLPI fused to the light chain (SEQ ID NO: 27 co-transfected with D2E7 heavy chain, lane 2), the D2E7 antibody with SLPI fused to the heavy chain (SEQ ID NO: 29 co-transfected with D2E7 light chain, lane 3). Arrows denote modified (SLPI fused) and unmodified (no SLPI) heavy and light chains. The proteins were visualized by staining with coomassie blue.

[00157] The purified SLPI-TNFα targeting molecule fusion proteins were tested for activity by determining their ability to inhibit neutrophil elastase. Human serum derived AAT (sdAAT) was used as a positive control in these assays. (Figure 2C). Relative to serum derived AAT, the D2E7-antibody-SLPI fusion proteins show similar inhibition of neutrophil elastase, indicating that the inhibitory capacity of SLPI has not been compromised by its fusion to an antibody. The NE inhibition assays were conducted as described above.

Example 3 AAT-Fc-SLPI and AAT-Fc-Elafin

[00158] The studies presented herein describe several, non-limiting examples of recombinant AAT derivatives comprising human AAT fused a WAP domain containing protein. These examples are provided below to further illustrate different features of the present invention. The examples also illustrate useful methodology for practicing the invention. The AAT polypeptide portion of the fusion protein is shown in bold text and shaded in grey, the Fc portion is italicized, the SLPI and Elafin portion are in bold text, and the WAP domain containing polypeptide is underlined. While these examples include a hinge sequence and/or a linker sequence, fusion proteins of the invention can be made using any hinge sequence and/or a linker sequence suitable in length and/or flexibility. Alternatively fusion proteins can be made without using a hinge and/or a linker sequence. For example, the polypeptide components can be directly attached.

[00159] An exemplary AAT-Fc-SLPI fusion protein is AAT-hFc1-SLPI (human IgG1 Fc). As shown below, the AAT polypeptide portion of the fusion protein is shown in bold text and shaded in grey (SEQ ID NO: 13), the Fc portion is italicized (SEQ ID NO: 7), the SLPI portion is in bold text (SEQ ID NO: 2), and the WAP domain containing polypeptide is underlined (SEQ ID NO: 3).

AAT-hFc1-SLPI (human IgG1 Fc)

EDPQGDAAQKTDTSHHDQDHPTFNKITPNLAEFAFSLYRQLAHQSNSTNIFFSPVSIATAF
AMLSLGTKADTHDEILEGLNFNLTEIPEAQIHEGFQELLRTLNQPDSQLQLTTGNGLFLSE
GLKLVDKFLEDVKKLYHSEAFTVNFGDTEEAKKQINDYVEKGTQGKIVDLVKELDRDTVFA
LVNYIFFKGKWERPFEVKDTEEEDFHVDQVTTVKVPMMKRLGMFNIQHCKKLSSWVLLMKY
LGNATAIFFLPDEGKLQHLENELTHDIITKFLENEDRRSASLHLPKLSITGTYDLKSVLGQ
LGITKVFSNGADLSGVTEEAPLKLSKAVHKAVLTIDEKGTEAAGAMFLEAIPMSIPPEVKF
NKPFVFLMIEQNTKSPLFMGKVVNPTQK*EPKSCDKTHTCPPC**PAPELLGGPSVFLFPPKPK*
DTLMISRTPEVTCVVVDVSHEDPEVKFNWYVDGVEVHNAKTKPREEQYNSTYRVVSVLTVL
HQDWLNGKEYKCKVSNKALPAPIEKTISKAKGQPREPQVYTLPPSRDELTKNQVSLTCLVK
GFYPSDIAVEWESNGQPENNYKTTPPVLDSDGSFFLYSKLTVDKSRWQQGNVFSCSVMHEA
*LHNHYTQKSLSLSPGK**ASTGS**SGKSFKAGVCPPKKSAQCLRYKKPECQSDWQCPGKKRCCP*
DTCGIKCLDPVDTPNPTRRKPGKCPVTYGQCLMLNPPNFCEMDGQCKRDLKCCMGMCGKSC
VSPVKA (SEQ ID NO: 32)

[00160] An exemplary AAT-Fc-Elafin fusion protein is AAT-hFc1-Elafin. As shown below, the AAT polypeptide portion of the fusion protein is shown in bold text and shaded in grey (SEQ ID NO: 13), the Fc portion is italicized (SEQ ID NO: 7), the Elafin portion are in bold text (SEQ ID NO: 5), and the WAP domain containing polypeptide is underlined (SEQ ID NO: 6).

AAT-hFc1-Elafin (human IgG1 Fc)

EDPQGDAAQKTDTSHHDQDHPTFNKITPNLAEFAFSLYRQLAHQSNSTNIFFSPVSIATAF
AMLSLGTKADTHDEILEGLNFNLTEIPEAQIHEGFQELLRTLNQPDSQLQLTTGNGLFLSE
GLKLVDKFLEDVKKLYHSEAFTVNFGDTEEAKKQINDYVEKGTQGKIVDLVKELDRDTVFA
LVNYIFFKGKWERPFEVKDTEEEDFHVDQVTTVKVPMMKRLGMFNIQHCKKLSSWVLLMKY
LGNATAIFFLPDEGKLQHLENELTHDIITKFLENEDRRSASLHLPKLSITGTYDLKSVLGQ

LGITKVFSNGADLSGVTEEAPLKLSKAVHKAVLTIDEKGTEAAGAMFLEAIPMSIPPEVKF
NKPFVFLMIEQNTKSPLFMGKVVNPTQKEPKSCDKTHTCPPC*PAPELLGGPSVFLFPPKPK*
DTLMISRTPEVTCVVVDVSHEDPEVKFNWYVDGVEVHNAKTKPREEQYNSTYRVVSVLTVL
HQDWLNGKEYKCKVSNKALPAPIEKTISKAKGQPREPQVYTLPPSRDELTKNQVSLTCLVK
GFYPSDIAVEWESNGQPENNYKTTPPVLDSDGSFFLYSKLTVDKSRWQQGNVFSCSVMHEA
*LHNHYTQKSLSLSPGK****ASTGS***AVTGVPVKGQDTVKGRVPFNGQDPVKGQVSVKGQDKVKAQ
EPVKGPVSTKPGSCPIILIRCAMLNPPNRCLKDTDCPGIKKCCEGSCGMACFVPQ (SEQ
ID NO: 33)

[00161] The genes encoding the SLPI and Elafin were PCR amplified from human spleen cDNA (Zyagen). These genes and flanking linker sequences were cloned in frame into mammalian expression vectors containing the genes encoding AAT and an Ig Fc region, wherein a mammalian secretion precedes the AAT gene. These expression vectors were transfected into mammalian cells (specifically HEK293 or CHO cells) and grown for several days in 8% CO_2 at 37° C. The recombinant AAT-Fc-WAP domain fusion proteins were purified from the expression cell supernatant by protein A chromatography. A near neutral pH buffer was used (Gentle Ag/Ab Elution Buffer, Thermo Scientific) to elute the AAT-Fc-WAP domain fusion protein from the protein A resin. Figure 3B shows a reducing SDS-PAGE gel of the purified fusion proteins: AAT-Fc-Elafin (SEQ ID NO: 33, lane 1) and AAT-Fc-SLPI (SEQ ID NO: 32, lane 2).

[00162] The purified AAT-Fc-WAP domain fusion proteins were tested for activity by determining their ability to inhibit neutrophil elastase. Human serum derived AAT (sdAAT) was used as a positive control in these assays. (Figure 3C). Relative to serum derived AAT, the AAT-Fc-WAP targeting molecule fusion proteins display enhanced potency of NE inhibition of neutrophil elastase. NE inhibition assays were conducted as described above.

Example 4 SLPI-Albumin and Elafin-Albumin

[00163] The studies presented herein describe several, non-limiting examples of recombinant AAT derivatives comprising human SLPI fused an albumin polypeptide. These examples are provided below to further illustrate different features of the present invention. The examples also illustrate useful methodology for practicing the invention. These examples do not and are not intended to limit the claimed invention. The AAT portion is in

bold text, the albumin portion is italicized, and the WAP domain is underlined. While these examples include a linker sequence, fusion proteins of the invention can be made using any linker sequence suitable in length and/or flexibility. Alternatively fusion proteins can be made without using a linker sequence.

[00164] An exemplary SLPI-Albumin fusion protein is SLPI-HSA. As shown below, the SLPI portion is in bold text (SEQ ID NO: 2), the albumin portion is italicized (SEQ ID NO: 14).

SLPI-HSA

SGKSFKAGVCPPKKSAQCLRYKKPECQSDWQCPGKKRCCPDTCGIKCLDPVDTPNPTRRKP GKCPVTYGQCLMLNPPNFCEMDGQCKRDLKCCMGMCGKSCVSPVKAASTGS*DAHKSEVAHR FKDLGEENFKALVLIAFAQYLQQCPFEDHVKLVNEVTEFAKTCVADESAENCDKSLHTLFG DKLCTVATLRETYGEMADCCAKQEPERNECFLQHKDDNPNLPRLVRPEVDVMCTAFHDNEE TFLKKYLYEIARRHPYFYAPELLFFAKRYKAAFTECCQAADKAACLLPKLDELRDEGKASS AKQRLKCASLQKFGERAFKAWAVARLSQRFPKAEFAEVSKLVTDLTKVHTECCHGDLLECA DDRADLAKYICENQDSISSKLKECCEKPLLEKSHCIAEVENDEMPADLPSLAADFVESKDV CKNYAEAKDVFLGMFLYEYARRHPDYSVVLLLRLAKTYETTLEKCCAAADPHECYAKVFDE FKPLVEEPQNLIKQNCELFEQLGEYKFQNALLVRYTKKVPQVSTPTLVEVSRNLGKVGSKC CKHPEAKRMPCAEDYLSVVLNQLCVLHEKTPVSDRVTKCCTESLVNRRPCFSALEVDETYV PKEFNAETFTFHADICTLSEKERQIKKQTALVELVKHKPKATKEQLKAVMDDFAAFVEKCC KADDKETCFAEEGKKLVAASQAALGL* (SEQ ID NO: 34)

[00165] An exemplary SLPI-Albumin fusion protein is SLPI-HSA Domain 3. As shown below, the SLPI portion is in bold text (SEQ ID NO: 2), and the albumin portion is italicized (SEQ ID NO: 15).

SLPI-HSA Domain 3

SGKSFKAGVCPPKKSAQCLRYKKPECQSDWQCPGKKRCCPDTCGIKCLDPVDTPNPTRRKP GKCPVTYGQCLMLNPPNFCEMDGQCKRDLKCCMGMCGKSCVSPVKAASTGS*EEPQNLIKQN CELFEQLGEYKFQNALLVRYTKKVPQVSTPTLVEVSRNLGKVGSKCCKHPEAKRMPCAEDY LSVVLNQLCVLHEKTPVSDRVTKCCTESLVNRRPCFSALEVDETYVPKEFNAETFTFHADI CTLSEKERQIKKQTALVELVKHKPKATKEQLKAVMDDFAAFVEKCCKADDKETCFAEEGKK LVA*

(SEQ ID NO: 35)

[00166] An exemplary SLPI-Albumin fusion protein is Elafin-HSA. As shown below, the Elafin portion is in bold text (SEQ ID NO: 5), the albumin portion is italicized (SEQ ID NO: 14), and the WAP domain is underlined.

SLPI-HSA

AVTGVPVKGQDTVKGRVPFNGQDPVKGQVSVKGQDKVKAQEPVKGPVSTKPGSCPIILIRC
AMLNPPNRCLKDTDCPGIKKCCEGSCGMACFVPQASTGS*DAHKSEVAHRFKDLGEENFKAL*
VLIAFAQYLQQCPFEDHVKLVNEVTEFAKTCVADESAENCDKSLHTLFGDKLCTVATLRET
YGEMADCCAKQEPERNECFLQHKDDNPNLPRLVRPEVDVMCTAFHDNEETFLKKYLYEIAR
RHPYFYAPELLFFAKRYKAAFTECCQAADKAACLLPKLDELRDEGKASSAKQRLKCASLQK
FGERAFKAWAVARLSQRFPKAEFAEVSKLVTDLTKVHTECCHGDLLECADDRADLAKYICE
NQDSISSKLKECCEKPLLEKSHCIAEVENDEMPADLPSLAADFVESKDVCKNYAEAKDVFL
GMFLYEYARRHPDYSVVLLLRLAKTYETTLEKCCAAADPHECYAKVFDEFKPLVEEPQNLI
KQNCELFEQLGEYKFQNALLVRYTKKVPQVSTPTLVEVSRNLGKVGSKCCKHPEAKRMPCA
EDYLSVVLNQLCVLHEKTPVSDRVTKCCTESLVNRRPCFSALEVDETYVPKEFNAETFTFH
ADICTLSEKERQIKKQTALVELVKHKPKATKEQLKAVMDDFAAFVEKCCKADDKETCFAEE
GKKLVAASQAALGL
(SEQ ID NO: 36)

[00167] An exemplary Elafin-Albumin fusion protein is Elafin-HSA domain 3. As shown below, the Elafin portion is in bold text (SEQ ID NO: 5), the albumin portion is italicized (SEQ ID NO: 15), and the WAP domain is underlined (SEQ ID NO: 6).

Elafin-HSA Domain 3

AVTGVPVKGQDTVKGRVPFNGQDPVKGQVSVKGQDKVKAQEPVKGPVSTKPGSCPIILIRC
AMLNPPNRCLKDTDCPGIKKCCEGSCGMACFVPQASTGS*EEPQNLIKQNCELFEQLGEYKF*
QNALLVRYTKKVPQVSTPTLVEVSRNLGKVGSKCCKHPEAKRMPCAEDYLSVVLNQLCVLH
EKTPVSDRVTKCCTESLVNRRPCFSALEVDETYVPKEFNAETFTFHADICTLSEKERQIKK
QTALVELVKHKPKATKEQLKAVMDDFAAFVEKCCKADDKETCFAEEGKKLVA (SEQ ID NO:37)

[00168] The gene encoding human serum albumin (HSA) was PCR amplified from human liver cDNA (Zyagen). A mammalian expression vector was generated, wherein gene encoding HSA or the domain 3 of HSA, was cloned in frame to the 3' end of the SLPI

or Elafin encoding gene, containing a mammalian secretion signal sequence up stream of SLPI or Elafin.

[00169] These expression vectors were transfected into mammalian cells (specifically HEK293 or CHO cells) and grown for several days in 8% CO_2 at 37° C. The recombinant SLPI-HSA and Elafin-HSA fusion proteins were purified from the expression cell supernatant using the phenyl-sepharose.

Other Embodiments

[00170] While the invention has been described in conjunction with the detailed description thereof, the foregoing description is intended to illustrate and not limit the scope of the invention, which is defined by the scope of the appended claims. Other aspects, advantages, and modifications are within the scope of the following claims.

What is claimed is:

1. An isolated fusion protein comprising at least one human whey acidic protein (WAP) domain-containing polypeptide operably linked to a second polypeptide, wherein the second polypeptide comprises at least one the following:

an immunoglobulin Fc polypeptide or an amino acid sequence that is derived from an immunoglobulin Fc polypeptide;

a cytokine targeting polypeptide or a sequence derived from a cytokine targeting polypeptide;

a serpin polypeptide or a sequence derived from a serpin polypeptide; or

an albumin polypeptide or an amino acid sequence that is derived from a serum albumin polypeptide.

2. An isolated fusion protein comprising at least one human secretory leukocyte proteinase inhibitor (SLPI) polypeptide operably linked to a second polypeptide, wherein the second polypeptide comprises at least one of the following:

an immunoglobulin Fc polypeptide;

a cytokine targeting polypeptide;

an alpha-1 antitrypsin (AAT) polypeptide;

an alpha-1 antitrypsin (AAT) polypeptide and an immunoglobulin Fc polypeptide; and

a human albumin (HSA) polypeptide.

3. An isolated fusion protein comprising human at least one human Elafin polypeptide operably linked to a second polypeptide, wherein the second polypeptide comprises at least one of the following:

an immunoglobulin Fc polypeptide;

a cytokine targeting polypeptide;

an alpha-1 antitrypsin (AAT) polypeptide;

an alpha-1 antitrypsin (AAT) polypeptide and an immunoglobulin Fc polypeptide; and

an human albumin (HSA) polypeptide.

4. The isolated fusion protein of claim 2, wherein the human SLPI polypeptide is a full-length SLPI polypeptide or derived from a human SLPI polypeptide.

5. The isolated fusion protein of any one of claims 2-4, wherein SLPI polypeptide comprises an amino acid sequence selected the group consisting of SEQ ID NO: 1, 2, and 3.

6. The isolated fusion protein of claim 3, wherein the human Elafin polypeptide is a full-length Elafin polypeptide or derived from a human Elafin polypeptide.

7. The isolated fusion protein of any one of claims 3 and 6, wherein Elafin polypeptide comprises an amino acid sequence selected the group consisting of SEQ ID NO: 4, 5, and 6.

8. The isolated fusion protein of any one of claims 1-6, wherein the immunoglobulin Fc polypeptide is a human Fc polypeptide.

9. The isolated fusion protein of claim 8, wherein human Fc polypeptide is a human IgM polypeptide or a human IgG polypeptide.

10. The isolated fusion protein of claim 9, wherein the human IgG Fc polypeptide is a human IgG1 polypeptide, a human IgG2 Fc polypeptide, human IgG3 Fc polypeptide, or human IgG4 Fc polypeptide.

11. The isolated fusion protein of any one of claims 1-3, wherein the immunoglobulin Fc polypeptide comprises an amino acid sequence selected from the group consisting of SEQ ID NO: 7, 8, 9, 10, and 11.

12. The isolated fusion protein of claim 1, wherein the WAP domain containing polypeptide and the immunoglobulin Fc polypeptide are operably linked via a hinge region, a linker region, or both a hinge region and linker region.

13. The isolated fusion protein of any one of claims 2-4, wherein the SLPI polypeptide and the immunoglobulin Fc polypeptide are operably linked via a hinge region, a linker region, or both a hinge region and linker region.

14. The isolated fusion protein of any one of claims 3 or 6, wherein the Elafin polypeptide and the immunoglobulin Fc polypeptide are operably linked via a hinge region, a linker region, or both a hinge region and linker region.

15. The isolated fusion protein of any one of claims 12-14, wherein the hinge region, the linker region or both the hinge region and the linker region comprise a peptide sequence.

16. The isolated fusion protein of claim 1, wherein the albumin polypeptide is a human serum albumin (HSA) polypeptide or is derived from a HSA polypeptide.

17. The isolated fusion protein of any one of claims 2, 3 or 16, wherein the HSA polypeptide comprises the amino acid sequence of SEQ ID NO: 14 or the amino acid sequence of SEQ ID NO: 15.

18. The isolated fusion protein of any one of claims 2, 3 or 16, wherein the HSA polypeptide comprises domain 3 of HSA.

19. The isolated fusion protein of claim 1, wherein the WAP-domain containing polypeptide is operably linked to HSA via an albumin binding polypeptide.

20. The isolated fusion protein of claim 19, wherein the albumin binding polypeptide is an antibody or antibody fragment or derived from an antibody or antibody fragment.

21. The isolated fusion protein of claims 20, wherein the antibody or antibody fragment or chimeric, humanized, or fully human.

22. The isolated fusion protein of claims 19, wherein the albumin binding polypeptide is a peptide.

23. The isolated fusion protein of claim 19, wherein the albumin binding polypeptide is Domain 3 of *Streptococcal* Protein G or a sequence derived from Domain 3 of *Streptococcal* Protein G.

24. The isolated fusion protein of claim 1, wherein the WAP-domain containing polypeptide is covalently linked to a HSA polypeptide.

25. The isolated fusion protein of claim 1, wherein the WAP-domain containing polypeptide is non-covalently linked to a HSA polypeptide.

26. The isolated fusion protein of claim 1, claim 2, or claim 3, wherein the cytokine targeting polypeptide is a cytokine receptor polypeptide or a derivative of a cytokine receptor polypeptide, a cytokine targeting polypeptide that binds a cytokine receptor, or a cytokine targeting polypeptide binds a human cytokine.

27. The isolated fusion protein of claim 26, wherein the cytokine receptor is a human cytokine receptor polypeptide.

28. The isolated fusion protein of claim 27, wherein the human cytokine receptor polypeptide comprises of multiple subunits.

29. The isolated fusion protein of claim 27, wherein the human cytokine receptor is a receptor for TNFα, IgE, IL-12, IL-23, IL-6, IL-1α, IL-1β, IL-17, IL-13, the p40 subunit of IL-12 and IL-23, IL-4, IL-10, IL-2, IL-18, IL-27, or IL-32.

30. The isolated fusion protein of claim 26, wherein the cytokine targeting polypeptide is an antibody or an antibody fragment.

31. The isolated fusion protein of claim 30, wherein the antibody is chimeric, humanized, or fully human.

32. The isolated fusion protein of claim 26, wherein the human cytokine is TNFα, IgE, IL-12, IL-23, IL-6, IL-1α, IL-1β, IL-17, IL-13, the p40 subunit of IL-12 and IL-23, IL-4, IL-10, IL-2, IL-18, IL-27, or IL-32.

33. The isolated fusion protein of claim 32, wherein the cytokine is human TNFα.

34. The isolated fusion protein of claim 2 or claim 3, wherein AAT polypeptide comprises the amino acid sequence of SEQ ID NO: 13 or SEQ ID NO: 38.

35. The isolated fusion protein of claim 1, wherein the fusion protein comprises a serpin polypeptide, a WAP domain-containing polypeptide and an immunoglobulin Fc polypeptide such that at least two of the serpin polypeptide, the WAP domain-containing polypeptide and the immunoglobulin Fc polypeptide are operably linked via a hinge region, a linker region, or both a hinge region and linker region.

36. The isolated fusion protein of claim 2, wherein the fusion protein comprises an AAT polypeptide, a SLPI polypeptide and an immunoglobulin Fc polypeptide such that at least two of the AAT polypeptide, the SLPI polypeptide and the immunoglobulin Fc polypeptide are operably linked via a hinge region, a linker region, or both a hinge region and linker region.

37. The isolated fusion protein of claim 35 or claim 36, wherein the hinge region, the linker region or both the hinge region and the linker region comprise a peptide sequence.

38. The isolated fusion protein of any one of claim 1, claim 2 or claim 3, wherein the Fc polypeptide is modified to enhance FcRn binding.

39. The isolated fusion protein of any one of claims 1-3, wherein the immunoglobulin Fc polypeptide comprising at least one of the following mutations: Met252Tyr, Ser254Thr, Thr256Glu or Met428Leu and Asn434Ser.

40. The isolated fusion protein of any one of claims 1-3, where the fusion protein comprises an amino acid sequence selected from SEQ ID NO: 16, SEQ ID NO: 17, SEQ ID NO: 18, SEQ ID NO: 19, SEQ ID NO: 20, SEQ ID NO: 21, SEQ ID NO: 22, SEQ ID NO: 23, SEQ ID NO: 24, SEQ ID NO: 25, SEQ ID NO: 26, SEQ ID NO: 27, SEQ ID NO: 28,

and SEQ ID NO: 29, SEQ ID NO: 30, SEQ ID NO: 31, SEQ ID NO: 32, SEQ ID NO: 33, SEQ ID NO: 34, SEQ ID NO: 35, SEQ ID NO: 36, and SEQ ID NO: 37.

41. A method of treating or alleviating a symptom of a disease or disorder associated with aberrant serine protease expression or activity in a subject in need thereof, the method comprising administering a fusion protein according to any one of the previous claims.

42. A method of treating or alleviating a symptom of an inflammatory disease or disorder in a subject in need thereof, the method comprising administering a fusion protein according to any one of the previous claims.

43. A method of treating or alleviating a symptom of an infectious disease or disorder in a subject in need thereof, the method comprising administering a fusion protein according to any one of the previous claims.

44. The method of any one of claims 41-43, wherein the subject is a human.

FIGURE 1A

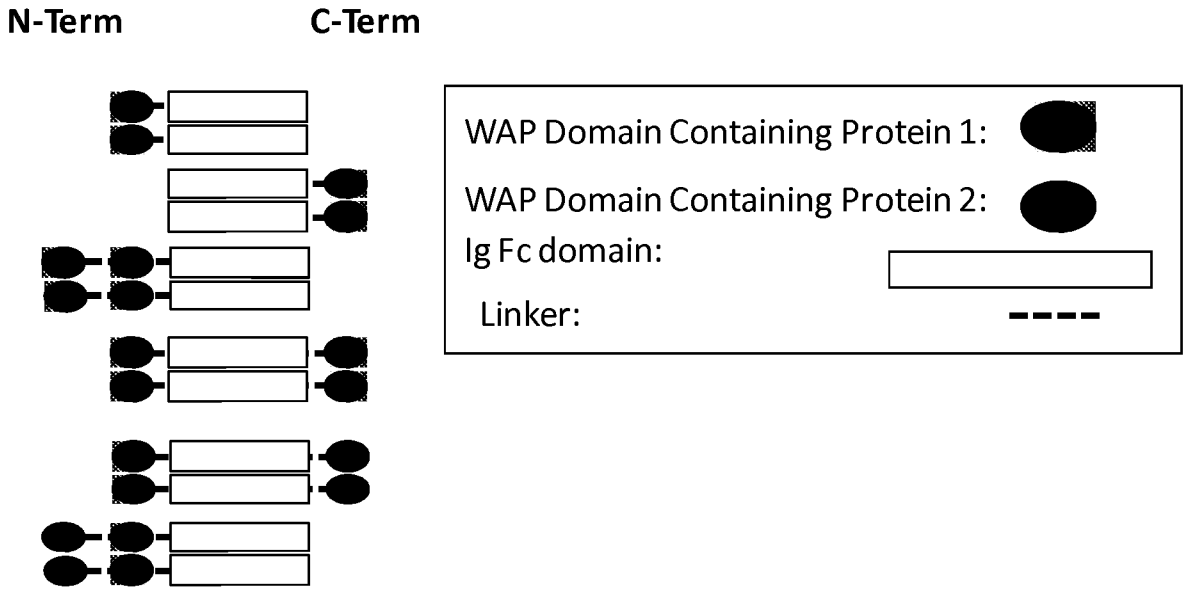


FIGURE 1B

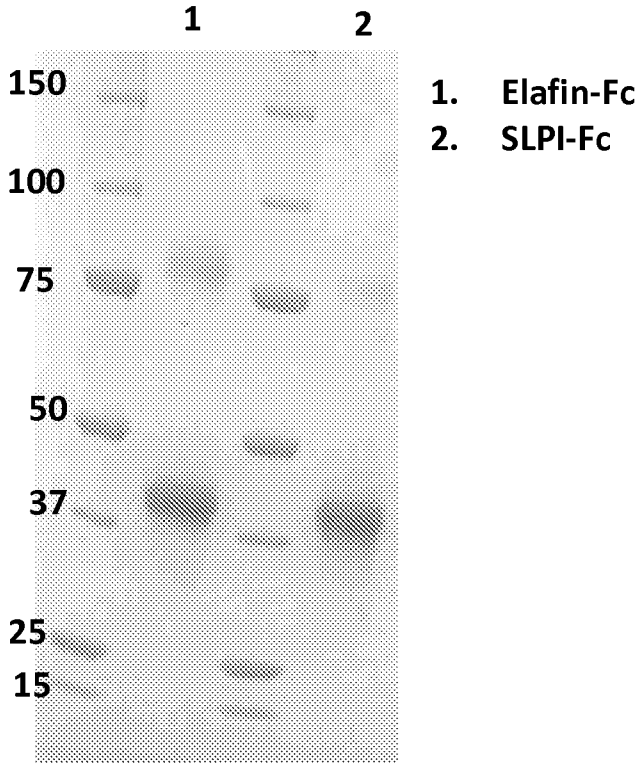


FIGURE 1C

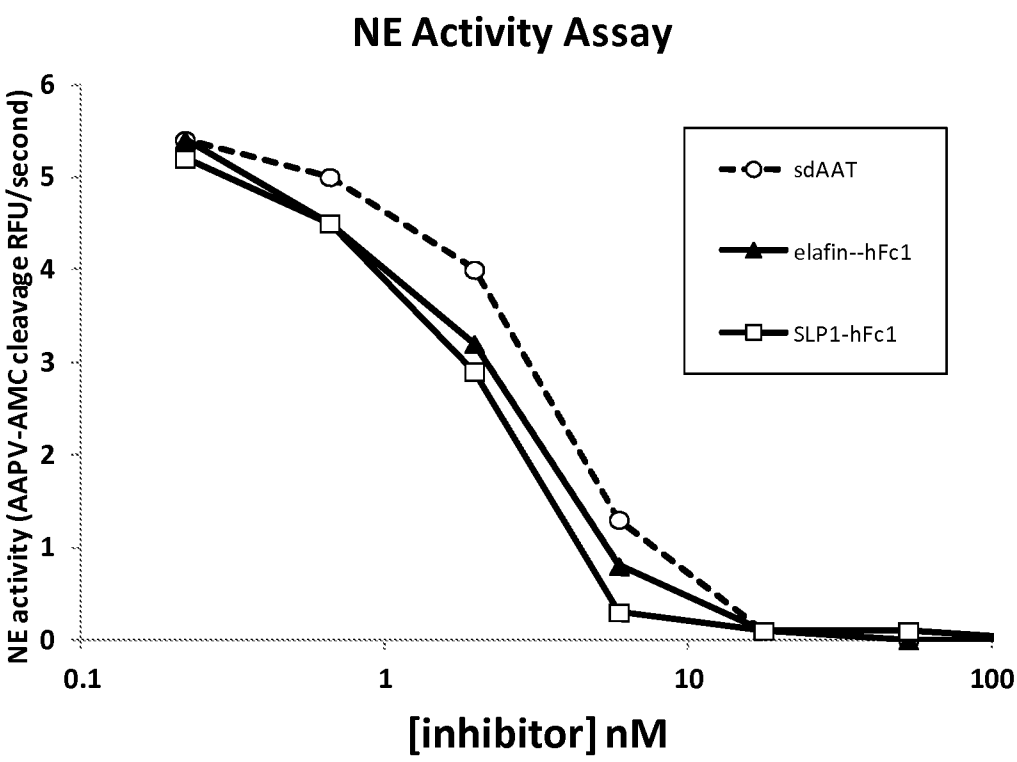


FIGURE 1D

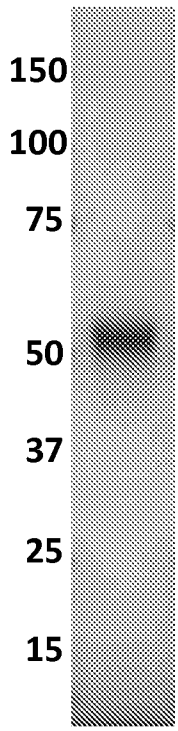


FIGURE 1E

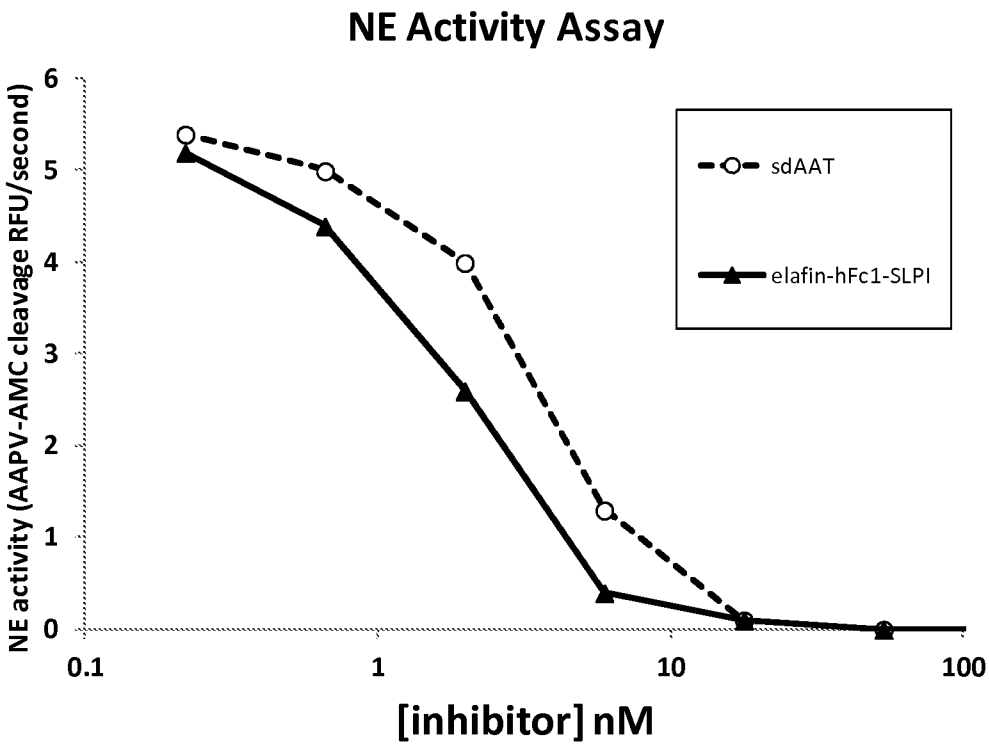


FIGURE 1F

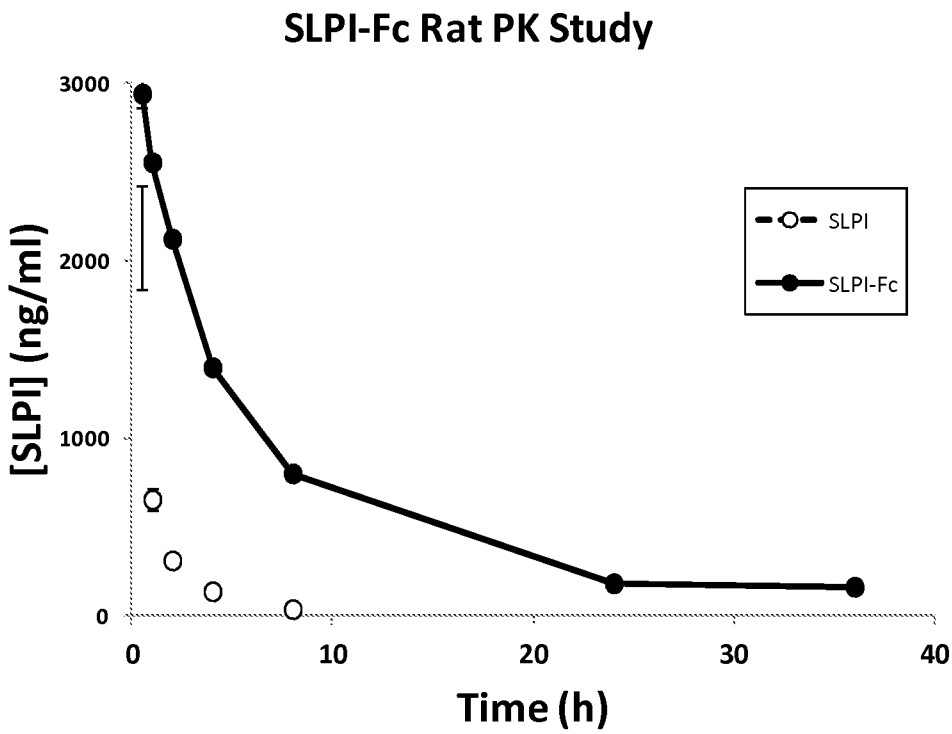
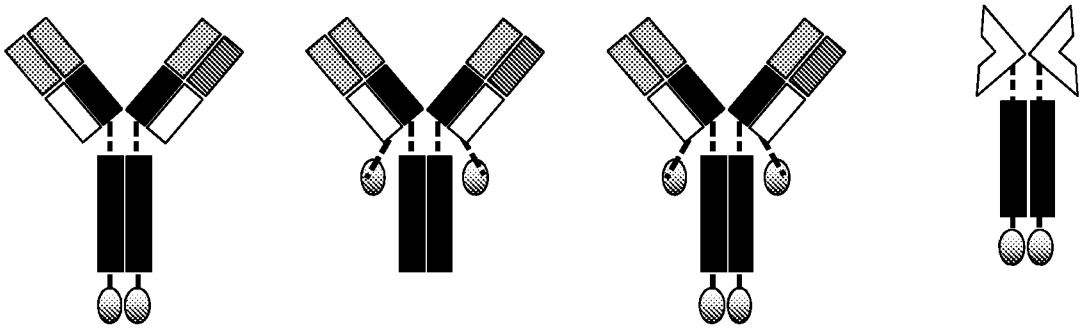


FIGURE 2A



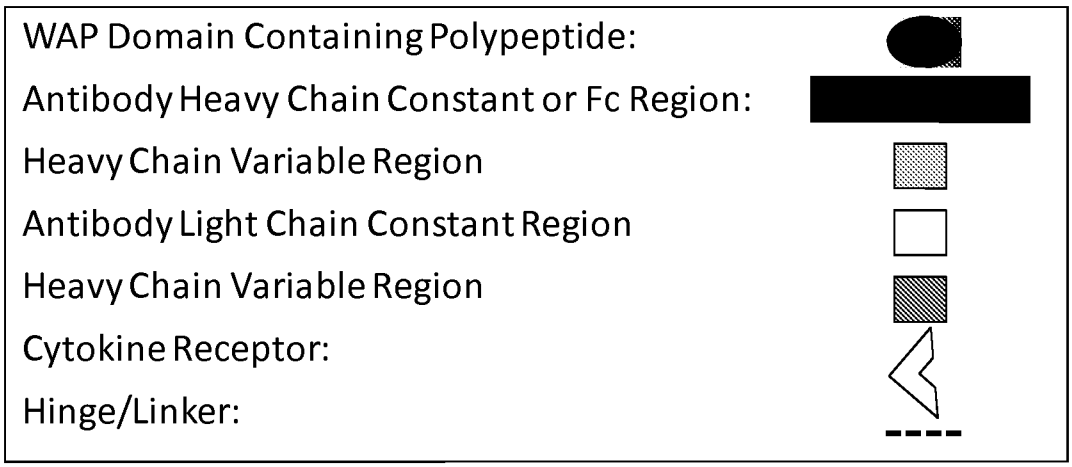


FIGURE 2B

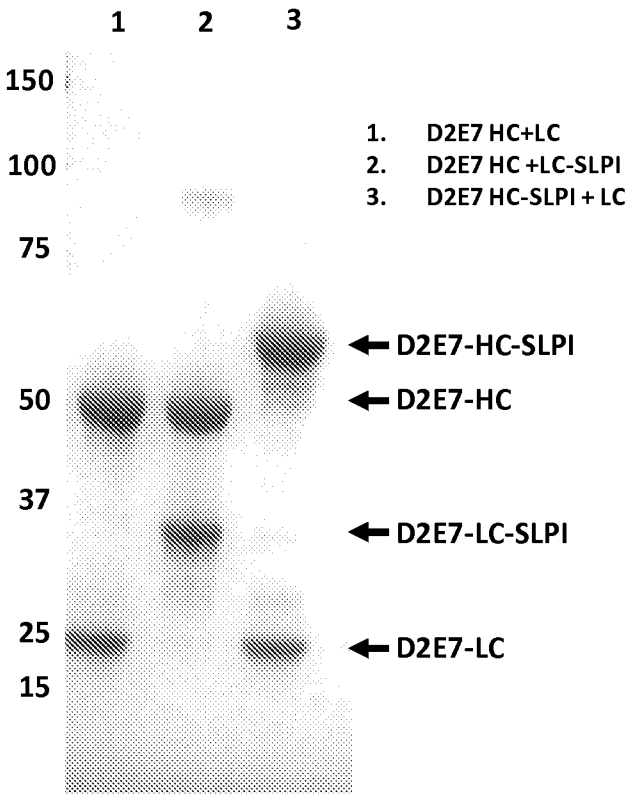


FIGURE 2C

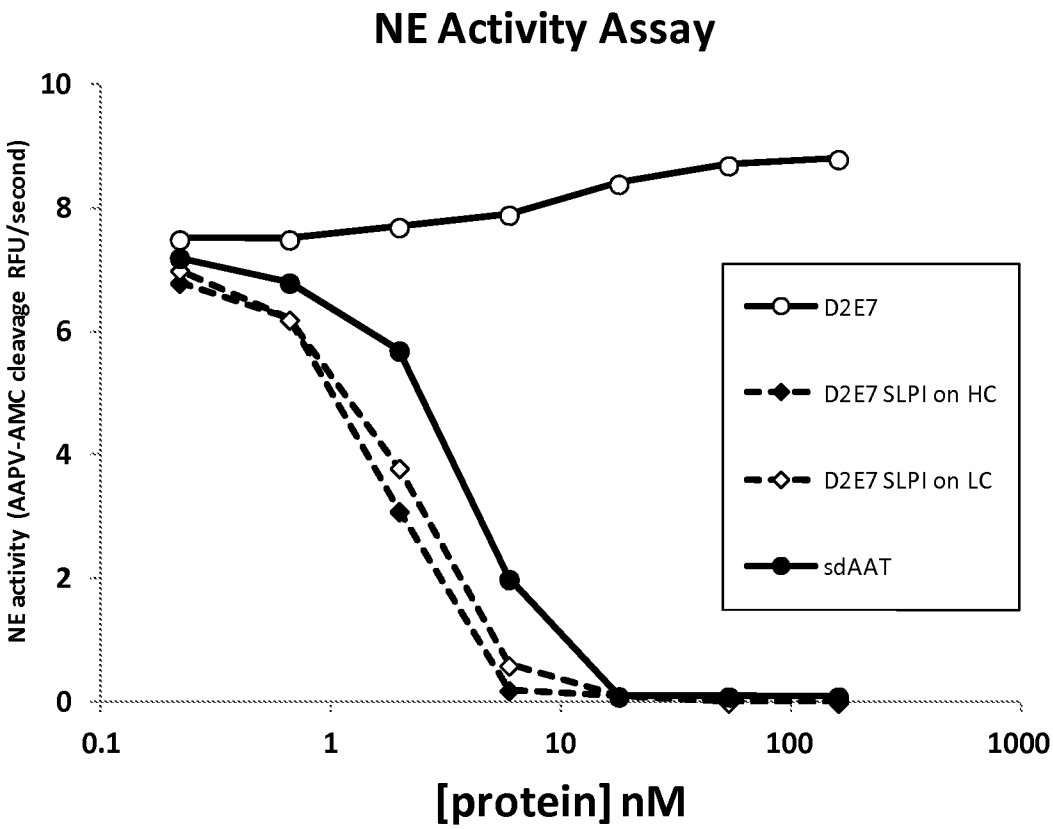


FIGURE 3A

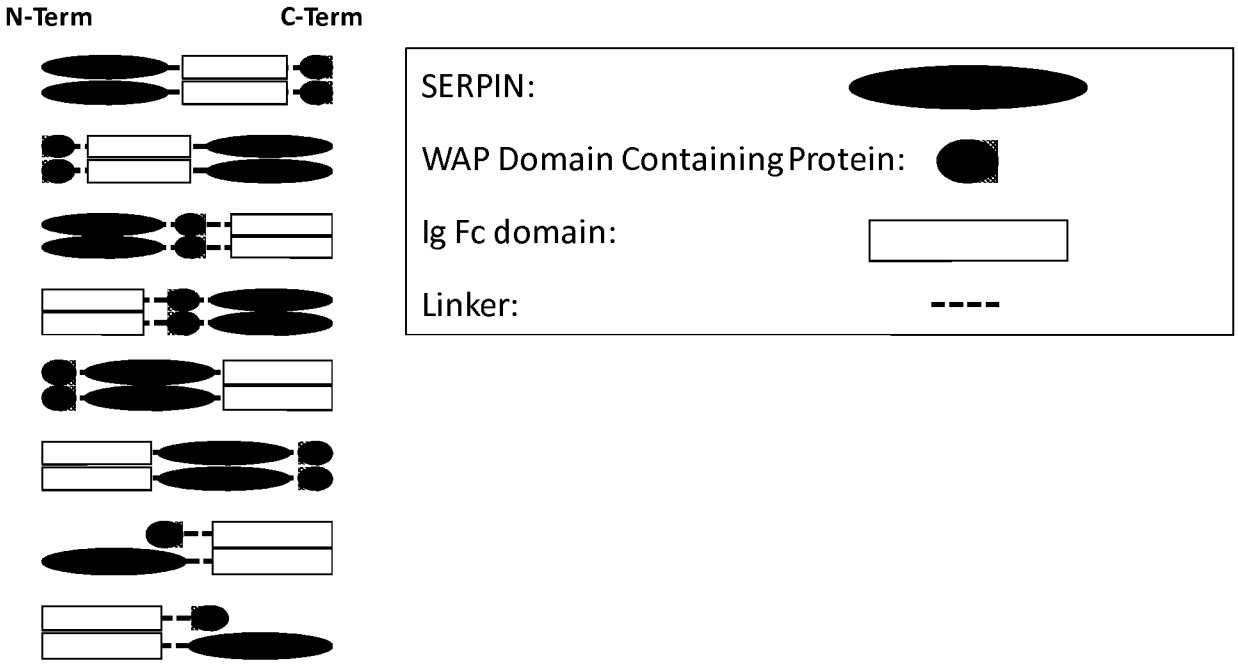


FIGURE 3B

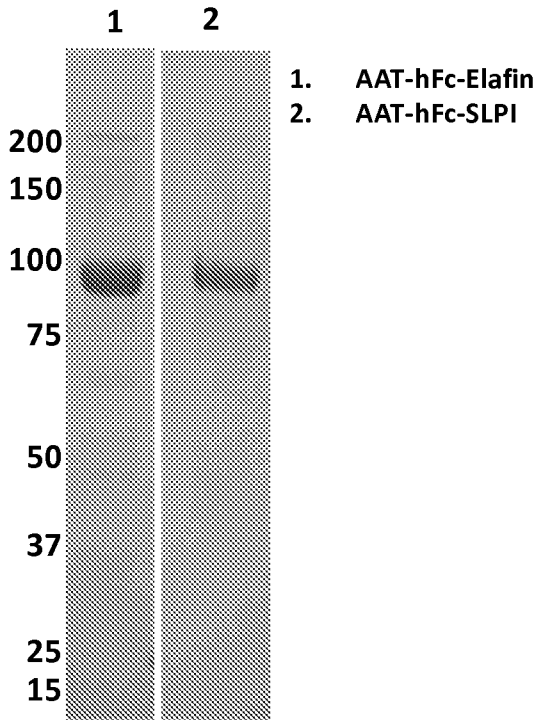


FIGURE 3C

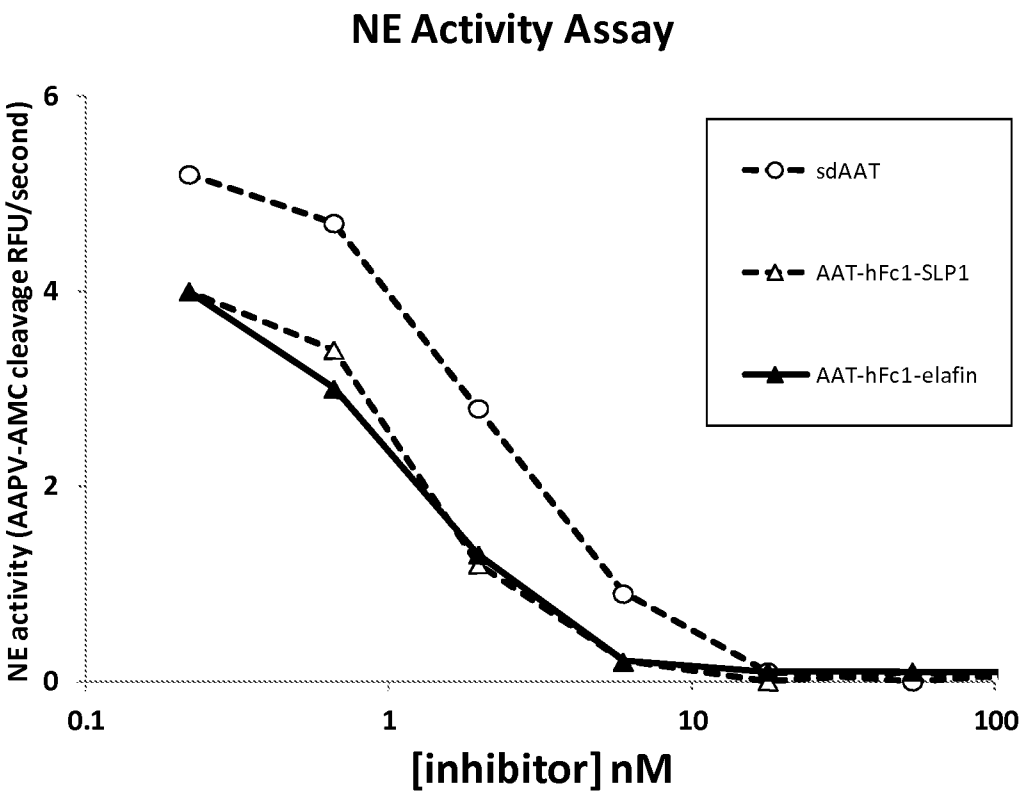
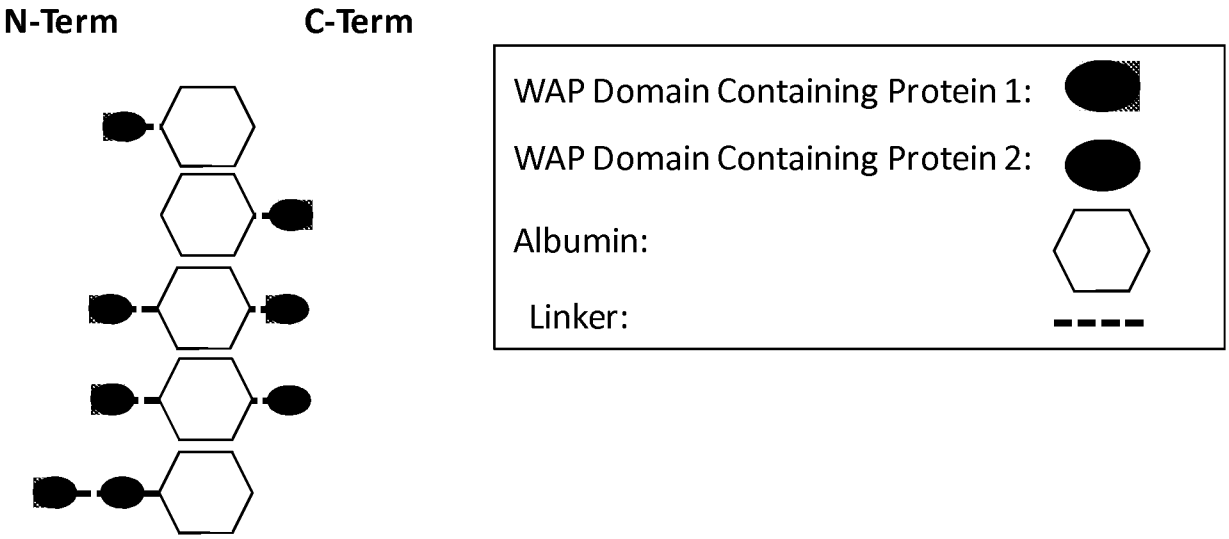


FIGURE 4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