

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

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
1 September 2011 (01.09.2011)

PCT

(10) International Publication Number
WO 2011/106697 A1

(51) International Patent Classification:

A61K 38/19 (2006.01) *A61P 27/02* (2006.01)
A61K 39/395 (2006.01)

(21) International Application Number:

PCT/US2011/026316

(22) International Filing Date:

25 February 2011 (25.02.2011)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

61/308,091	25 February 2010 (25.02.2010)	US
61/329,845	30 April 2010 (30.04.2010)	US
61/331,278	4 May 2010 (04.05.2010)	US

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

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

Published:

— with international search report (Art. 21(3))

— with sequence listing part of description (Rule 5.2(a))

(54) Title: THERAPEUTIC COMPOSITIONS FOR THE TREATMENT OF DRY EYE DISEASE

(57) Abstract: Described herein are materials and methods of treating dry eye disease in a subject.



WO 2011/106697 A1

THERAPEUTIC COMPOSITIONS FOR THE TREATMENT OF DRY EYE DISEASE

FIELD OF THE INVENTION

[0001] This invention relates generally to the field of ophthalmology.

FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0002] This invention was made with Government support under Grant No EY-12963 awarded by the National Institute of Health. The Government has certain rights in the invention.

BACKGROUND OF THE INVENTION

[0003] Dry Eye Disease (DED) is a relatively common condition characterized by inadequate tear film protection of the cornea. Dry eye symptoms have traditionally been managed with eyelid hygiene, topical antibiotics (erythromycin or bacitracin ointments), oral tetracyclines (tetracycline, doxycycline, or minocycline), anti-inflammatory compounds (cyclosporine) and corticosteroids which are often time consuming, frustrating, and frequently ineffective or variably effective treatments.

[0004] Tens of millions of people (mostly women) are affected worldwide by dry eye. 10 million people in US are affected with severe dry eyes and more than 3.2 million women and 1.6 million men above the age of 50 years being affected by dry eye in the US. DED is a potentially disabling disease adversely impacting the vision-related quality of life. It leads to ocular discomfort, a degradation in visual performance (reading speed, contrast sensitivity), and a loss of productivity. Current therapeutic options are limited and costly. Topical cyclosporine-A (Restasis®) is the only approved treatment for DED in US (only). Despite the high incidence of DED, there is currently no consistently effective treatment for this condition and it still remains a therapeutic challenge. As such, there is a need for new therapeutic modalities to treat DED.

SUMMARY OF THE INVENTION

[0005] The present invention discloses a novel method for the treatment of dry eye disease in humans comprising administration of an anti-lymphangiogenic agent to the human subject. In particular, the present invention discloses a novel method for the

treatment of dry eye disease in humans. In some embodiments, the method comprises locally administering an anti-lymphangiogenic agent to the ocular surface of the human. Preferably, the amount of the anti-lymphangiogenic agent employed is effective to inhibit the binding of VEGF-C and/or VEGF-D ligand to VEGFR-3 or the stimulatory effect of VEGF-C and/or VEGF-D on VEGFR-3.

[0006] The present invention is based on novel evidence for the selective growth of lymphatic vessels in DED cornea. Additionally, significant increase in both caliber and extent of lymphatics in DED corneas is accompanied by over expression of lymphangiogenic receptor VEGFR-3, further correlating DED with lymphangiogenesis.

[0007] An anti-lymphangiogenic agent of the invention is selected from the group consisting of: a nucleic acid molecule, an aptamer, an antisense molecule, an RNAi molecule, a protein, a peptide, a cyclic peptide, an antibody or antibody fragment, a polysaccharide, and a small molecule. The anti-lymphangiogenic agent described herein can be administered purely as a prophylactic treatment to prevent dry eye disease in subjects at risk for developing dry eye disease, or as a therapeutic treatment to subjects afflicted with dry eye disease, for the purpose of inhibiting lymphangiogenesis in the eye of a subject in need thereof.

[0008] In one preferred embodiment of the invention, the anti-lymphangiogenic agent is an inhibitor of VEGF-C or VEGF-D mediated signal transduction by VEGFR-2 or VEGFR-3. In a particularly preferred embodiment, the anti-lymphangiogenic agent is an inhibitor of VEGF-C or VEGF-D mediated signal transduction by VEGFR-3.

[0009] In one aspect of the invention, the inhibitor of VEGF-C or VEGF-D mediated signal transduction by VEGFR-2 or VEGFR-3 is a molecule such as but not restricted to an antibody, a small molecule or a peptide that prevents binding of VEGF-C or VEGF-D to the receptors VEGFR-2 or VEGFR-3.

[0010] In another aspect of the invention, the inhibitor of VEGF-C or VEGF-D mediated signal transduction is a VEGFR-2 or VEGFR-3 soluble receptor. Soluble receptors of VEGFR-2 or VEGFR-3 can be administered directly. Alternatively, increase in the secretion of VEGFR-2 or VEGFR-3 is accomplished by inserting the VEGFR-2 or VEGFR-3 soluble receptors genes into the genome of corneal cells. This could be epithelial cells, keratocytes, fibroblasts, endothelial cells, or bone marrow-derived cells. Methods to

introduce genes into a genome of a cell are well-known in the art. Genes are introduced in the genome of corneal cells using viral or non-viral vectors. Viral vectors include for example adenoviruses, retroviruses or lentiviruses. Non-viral vectors include, for example, liposomes such as cationic lipids, nanoparticles, lipoplexes and polyplexes (complexes of polymers with DNA).

[0011] In one embodiment of the invention, the anti-lymphangiogenic agent is administered in combination with an anti-inflammatory agent such as, but not limited to, a composition inhibiting the activity of an inflammatory cytokine selected from the group comprising IL-1, IL-17, TNF- α and IL-6.

[0012] Exemplary functional blockers of IL-1 are described in WO/2009/025763. Exemplary functional blockers of TNF- α include, but are not limited to, recombinant and/or soluble TNF- α receptors, monoclonal antibodies, and small molecule antagonists and/or inverse agonists. One or more commercially-available TNF- α blocking agents are reformulated for topical administration in this embodiment. Exemplary commercial TNF- α blocking agents used for reformulation include, but are not limited to, etanercept/Enbrel, infliximab/Remicade, and adalimumab/Humira.

[0013] In one embodiment of the invention, the anti-lymphangiogenic agent is administered in combination with an antibiotic. Exemplary antibiotic compositions used for combination-therapy with antagonists of IL-mediated inflammation include but are not limited to, amikacin, gentamicin, kanamycin, neomycin, netilmicin, streptomycin, tobramycin, teicoplanin, vancomycin, azithromycin, clarithromycin, clarithromycin, dirithromycin, erythromycin, roxithromycin, troleandomycin, amoxicillin, ampicillin, azlocillin, carbenicillin, cloxacillin, dicloxacillin, flucoxacillin, meziocillin, nafcillin, penicillin, piperacillin, ticarcillin, bacitracin, colistin, polymyxin B, ciprofloxacin, enoxacin, gatifloxacin, levofloxacin, lomefloxacin, moxifloxacin, norfloxacin, oflaxacin, trovafloxacin, mafenide, sulfacetamide, sulfamethizole, sulfasalazine, sulfisoxazole, trimethoprim, cotrimoxazole, demeclocycline, soxycycline, minocycline, oxytetracycline, or tetracycline.

[0014] In one embodiment, the composition of the invention is locally applied to the ocular tissue, alternatively the composition of the invention is applied to the eyelids, the ocular surface, the meibomian glands or the lacrimal glands.

[0015] The composition can be in the form of a solid, a paste, an ointment, a gel, a liquid, an aerosol, a mist, a polymer, a film, an emulsion, or a suspension.

[0016] Optionally, the composition further contains a compound selected from the group consisting of a physiological acceptable salt, poloxamer analogs with carbopol, carbopol/hydroxypropyl methyl cellulose (RP MC), carbopol-methyl cellulose, carboxymethylcellulose (CMC), hyaluronic acid, cyclodextrin, and petroleum.

[0017] In one embodiment, described herein is a method of inhibiting dry eye disease in a subject at risk for developing dry eye disease comprising identifying a subject as being at risk for developing dry eye disease and administering an anti-lymphangiogenic agent to the subject. The amount of the anti-lymphangiogenic agent administered to the subject is preferably in an amount effective to inhibit the development of dry eye disease in the subject.

[0018] In another embodiment, described herein is a method of selecting a therapeutic regimen for a subject in need thereof comprising screening a subject for one or more symptoms of dry eye disease and prescribing for the subject administration of a composition comprising an anti-lymphangiogenic agent described herein. In another embodiment, described herein is a method of treating a subject affected with dry eye disease comprising identifying a subject as having one or more symptoms of dry eye disease and administering a composition comprising an anti-lymphangiogenic agent to the subject.

[0019] In some embodiments, the methods described herein further comprise prescribing (or administering) a standard of care regimen for the treatment of dry eye disease. In the context of methods described herein, "standard of care" refers to a treatment that is generally accepted by clinicians for a certain type of patient diagnosed with a type of illness. For dry eye disease, for example, an aspect of the invention is to improve standard of care therapy with co-therapy with anti-lymphangiogenic agents described herein that inhibit lymphangiogenesis.

[0020] Another aspect described herein is a method of treating a human subject with dry eye disease that has been hypo-responsive to a standard of care treatment for dry eye disease comprising administering an anti-lymphangiogenic agent described herein. For example, such a method comprises administering to such a subject a therapeutically

effective amount of a composition that comprises an anti-lymphangiogenic agent described herein. Such a method optionally includes a step, prior to the administering step, of selecting for treatment a subject with dry eye disease that is hypo-responsive to a standard of care regimen for the treatment of the dry eye disease. The term “hypo-responsive” embraces subjects that failed to respond adequately to a standard of care treatment and subjects that initially responded, but for whom the standard of care treatment has become less effective over time.

[0021] In one embodiment, methods described herein optionally comprise administering a VEGFR-2 inhibitor product to the subject. The “VEGFR-2 inhibitor product” can be any molecule that acts with specificity to reduce VEGF-C/VEGFR-2, VEGF-D/VEGFR-2 or VEGF/VEGFR-2 interactions, e.g., by blocking VEGF-C or VEGF-D binding to VEGFR-2, by blocking VEGF binding to VEGFR-2 or by reducing expression of VEGFR-2. In one embodiment, the VEGFR-2 inhibitor inhibits VEGF-C and VEGF-D binding to VEGFR-2. In another embodiment, the VEGFR-2 inhibitor inhibits binding of VEGF to VEGFR-2. The VEGFR-2 inhibitor can be a polypeptide comprising a soluble VEGFR-2 extracellular domain fragment (amino acids 20-764 of SEQ ID NO: 51) that binds VEGF or VEGF-C or VEGF-D; VEGFR-2 anti-sense polynucleotides or short-interfering RNA (siRNA); anti-VEGFR-2 antibodies; a VEGFR-2 inhibitor polypeptide comprising an antigen-binding fragment of an anti-VEGFR-2 antibody that inhibits binding between VEGFR-2 and VEGF or VEGF-C or VEGF-D; an aptamer that inhibits binding between VEGFR-2 and VEGF; an aptamer that inhibits binding between VEGFR-2 and VEGF-C; an aptamer that inhibits binding between VEGFR-2 and VEGF-D; or a fusion protein comprising the soluble VEGFR-2 polypeptide fragment fused to an immunoglobulin constant region fragment (Fc). In some embodiments, a VEGFR-2 polypeptide fragment is fused to alkaline phosphatase (AP).

[0022] In another embodiment, the methods described herein optionally comprise administering one or more anti-inflammatory agents to the subject. In another embodiments, the methods described herein optionally further comprise administering a tyrosine kinase inhibitor that inhibits VEGFR-2 and/or VEGFR-3 activity.

[0023] Dry eye disease may be attributable to a number of factors, and treatment of subjects who have developed dry eye disease due to a variety of specific factors is contemplated. In some variations, the DED to be treated is DED caused by any condition

other than an alloimmune response. Alloimmune responses may result, for example, in some corneal transplant patients. More specifically, in some variations, the DED to be treated is an autoimmune DED or a DED associated with Sjogren's syndrome. In some variations, the DED is due to excessively fast tear evaporation (evaporative dry eyes) or inadequate tear production. In some variations, the dry eye disease is attributable to one or more causes selected from: aging, contact lens usage and medication usage. In some variations, the dry eye disease is a complication of LASIK refractive surgery. In other variations, the DED arises in a subject who has not had eye surgery of any kind, e.g., treatment of subjects in whom the DED is caused by LASIK surgery, corneal transplant surgery, or other ocular surgeries.

[0024] In some variations, the invention is directed to prophylaxis, to prevent DED disease or its symptoms from developing. Prophylaxis may be appropriate, for example, in the context of subjects who have suffered an eye trauma such as infection, injury, chemical exposure, inflammation, or other situations that have been shown to cause or predispose individuals to DED. In some variations, the prophylaxis is continued until the trauma or the observable effects of the trauma have resolved, or for a limited duration, e.g., 1, 2, 3, or 4 weeks thereafter.

[0025] In a preferred embodiment, the mammalian subject is a human subject. Practice of methods of the invention in other mammalian subjects, especially mammals that are conventionally used as models for demonstrating therapeutic efficacy in humans (e.g., primate, porcine, canine, or rabbit animals), is also contemplated.

[0026] In addition to the foregoing, the following paragraphs are also considered aspects of the invention:

[0027] 1. A method of treating dry eye disease (DED) in a human comprising:

[0028] administering a composition comprising at least one anti-lymphangiogenic agent and a pharmaceutically acceptable carrier to the human, in an amount effective to treat dry eye disease.

[0029] 2. The method of claim 1, wherein the anti-lymphangiogenic agent is administered to the eye of the human.

[0030] 3. The method of paragraph 1, wherein the anti-lymphangiogenic agent is an inhibitor of VEGF-C or VEGF-D mediated signal transduction by VEGFR-2 or VEGFR-3.

[0031] 4. An anti-lymphangiogenic agent for use in the treatment of dry eye disease.

[0032] 5. Use of at least one anti-lymphangiogenic agent in a composition comprising a pharmaceutically acceptable carrier for administering the eye of a human, for the treatment of dry eye disease.

[0033] 6. The method or use of paragraph 1 or 5, wherein the DED is an autoimmune DED or a DED associated with Sjogren's syndrome.

[0034] 7. The method or use of any one of paragraphs 1-3 and 5, wherein the DED is DED due to excessively fast tear evaporation (evaporative dry eyes) or inadequate tear production.

[0035] 8. The method or use of any one of paragraphs 1-3 and 5, wherein the dry eye disease is attributable to one or more causes selected from: aging, contact lens usage and medication usage.

[0036] 9. The method or use of any one of paragraphs 1-3 and 5, wherein the dry eye disease is a complication of LASIK refractive surgery.

[0037] 10. The method or use of any one of paragraphs 1-3 and 5, wherein the at least one anti-lymphangiogenic agent is purified or isolated.

[0038] 11. The method or use of any one of paragraphs 1-3 and 5, wherein said at least one anti-lymphangiogenic agent comprises a member selected from the group consisting of: a nucleic acid molecule, an aptamer, an antisense molecule, an RNAi molecule, a protein, a peptide, a cyclic peptide, an antibody or antibody fragment, a polysaccharide, or a small molecule.

[0039] 12. The method or use of any one of paragraphs 1-3 and 5-11, wherein said at least one anti-lymphangiogenic agent comprises a member selected from the group consisting of a VEGFR-3 inhibitor, a VEGF-D inhibitor and a VEGF-C inhibitor.

[0040] 13. The method or use of any one of paragraphs 1-3 and 5-11, wherein the at least one anti-lymphangiogenic agent comprises a member selected from the group

consisting of a VEGF-C antibody, a VEGF-D antibody, a VEGF-R3 antibody, and a polypeptide comprising a soluble VEGFR-3 fragment that binds VEGF-C or VEGF-D.

[0041] 14. The method or use of paragraph 13, wherein the at least one anti-lymphangiogenic agent comprises a VEGF-C antibody.

[0042] 15. The method or use of paragraph 14, wherein the antibody comprises a heavy chain variable region set forth in amino acids 1-118 of SEQ ID NO: 48.

[0043] 16. The method or use of paragraph 14, wherein antibody comprises a heavy chain comprising the amino acid sequence of SEQ ID NO: 48.

[0044] 17. The method or use of paragraph 14, wherein the VEGF-C antibody is selected from the group consisting of antibodies 69D09, 103, MM0006-2E65 and 193208.

[0045] 18. The method or use of any one of paragraphs 1-3 and 5-11, wherein the at least one anti-lymphangiogenic agent comprises an antibody that competitively inhibits the binding of antibody 69D09 to VEGF-C.

[0046] 19. The method or use of any one of paragraphs 1-3 and 5-11, wherein the at least one anti-lymphangiogenic agent comprises a VEGF-D antibody.

[0047] 20. The method or use of paragraph 19, wherein the VEGF-D antibody is selected from the group consisting of antibodies 2F8, 4A5(VD1), 4E10, 5F12, 4H4, 3C10 28AT743.288.48, MM0001-7E79, RM0007-8C35, 78902, 78939 and 90409.

[0048] 21. The method or use of any one of paragraphs 1-3 and 5-11, wherein the at least one anti-lymphangiogenic agent comprises a soluble VEGFR-3 fragment that binds VEGF-C or VEGF-D.

[0049] 22. The method or use of any one of paragraphs 1-3 and 5-11, wherein the at least one anti-lymphangiogenic agent comprises a human or humanized antibody.

[0050] 23. The method or use of any one of paragraphs 1-3 and 5-11, wherein the at least one anti-lymphangiogenic agent comprises a VEGFR-2 inhibitor.

[0051] 24. The method or use of any one of paragraphs 1-3 and 5-11 wherein the at least one anti-lymphangiogenic agent comprises a tyrosine kinase inhibitor that inhibits the activity of VEGFR-3.

- [0052] 25. The method or use of any one of paragraphs 1-3 and 5-24, further comprising administering an anti-inflammatory agent to the subject.
- [0053] 26. The method or use of paragraph 25, further comprising administering cyclosporine to the subject.
- [0054] 27. The method or use of any one of paragraphs 1-3 and 5-26, wherein said composition further comprises a molecule that inhibits an activity of an inflammatory cytokine selected from the group consisting of IL-1, IL-7, IL23, IL-6 and TNF- α .
- [0055] 28. The method or use of any one of paragraphs 1-3 and 5-27, wherein the method further comprises administering an antibiotic to the human.
- [0056] 29. The use of any one of paragraphs 5-27 further including the use of an antibiotic for the treatment of the dry eye disease.
- [0057] 30. The method or use of paragraph 28 or 29, wherein the antibiotic is selected from the group consisting of amikacin, gentamicin, kanamycin, neomycin, netilmicin, streptomycin, tobramycin, teicoplanin, vancomycin, azithromycin, clarithromycin, clarithromycin, dirithromycin, erythromycin, roxithromycin, troleandomycin, amoxicillin, ampicillin, azlocillin, carbenicillin, cloxacillin, dicloxacillin, flucozaccillin, meziocillin, nafcillin, penicillin, piperacillin, ticarcillin, bacitracin, colistin, polymyxin B, ciprofloxacin, enoxacin, gatifloxacin, levofloxacin, lomefloxacin, moxifloxacin, norfloxacin, oflazacin, trovafloxacin, mafenide, sulfacetamide, sulfamethizole, sulfasalazine, sulfisoxazole, trimethoprim, cotrimoxazole, demeclocycline, soxycycline, minocycline, oxytetracycline, or tetracycline.
- [0058] 31. The method or use of any one of paragraphs 1-3 and 5-27, wherein the eye comprises a tissue or gland in or around the eye selected from the group consisting of ocular tissue, eyelids of the subject, ocular surface, meibomian gland and or lacrimal gland of the human.
- [0059] 32. The method of any one of paragraphs 1-3 and 5-27, wherein said composition is administered topically to the eye.
- [0060] 33. The use according to any one of paragraphs 5-27, wherein the composition is formulated for topical administration.

[0061] 34. The method or use of any one of paragraphs 1-3 and 5-33, wherein said composition is in the form of a solid, a paste, an ointment, a gel, a liquid, an aerosol, a mist, a polymer, a film, an emulsion, or a suspension.

[0062] 35. The method or use of any one of paragraphs 1-3 and 5-34, wherein the composition further comprises a compound selected from the group consisting of physiological acceptable salt, poloxamer analogs with carbopol, carbopol/hydroxypropyl methyl cellulose (RP MC), carbopol-methyl cellulose, carboxymethylcellulose (CMC), hyaluronic acid, cyclodextrin, and petroleum.

[0063] Additional aspects, features and variations of the invention will be apparent from the entirety of this application, including the detailed description, and all such features are intended as aspects of the invention. It should be understood, however, that the detailed description and the specific examples are given by way of illustration, and that the many various changes and modifications that will be apparent to those familiar with the field of the invention are also part of the invention.

[0064] Aspects of the invention described with the term “comprising” should be understood to include the elements explicitly listed, and optionally, additional elements. Aspects of the invention described with “a” or “an” should be understood to include “one or more” unless the context clearly requires a narrower meaning.

[0065] Moreover, features of the invention described herein can be re-combined into additional embodiments that also are intended as aspects of the invention, irrespective of whether the combination of features is specifically mentioned above as an aspect or embodiment of the invention. Also, only those limitations that are described herein as critical to the invention should be viewed as such; variations of the invention lacking features that have not been described herein as critical are intended as aspects of the invention.

[0066] With respect to aspects of the invention that have been described as a set or genus, every individual member of the set or genus is intended, individually, as an aspect of the invention, even if, for brevity, every individual member has not been specifically mentioned herein. When aspects of the invention that are described herein as being selected from a genus, it should be understood that the selection can include mixtures of two or more members of the genus. Similarly, with respect to aspects of the invention that

have been described as a range, such as a range of values, every sub-range within the range is considered an aspect of the invention.

[0067] In addition to the foregoing, the invention includes, as an additional aspect, all embodiments of the invention narrower in scope in any way than the variations specifically described herein. Although the applicant(s) invented the full scope of the claims appended hereto, the claims appended hereto are not intended to encompass within their scope the prior art work of others. Therefore, in the event that statutory prior art within the scope of a claim is brought to the attention of the applicants by a Patent Office or other entity or individual, the applicant(s) reserve the right to exercise amendment rights under applicable patent laws to redefine the subject matter of such a claim to specifically exclude such statutory prior art or obvious variations of statutory prior art from the scope of such a claim. Variations of the invention defined by such amended claims also are intended as aspects of the invention.

DESCRIPTION OF THE DRAWINGS

[0068] Figure 1: Representative whole mount corneal immunofluorescence micrographs showing lymphatics (CD31^{lo}/LYVE-1^{hi}) in normal and dry eye (DE) at day 14 (20x magnification).

[0069] Figure 2: Representative whole mount corneal immunofluorescence micrographs showing lymphatics (CD31^{lo}/LYVE-1^{hi}) in normal and dry eye (DE) at days 6, 10 and 14 (100x magnification).

[0070] Figure 3: Quantification of lymphatics in dry eye (DE) corneas. Morphometric analysis of corneal lymphangiogenesis in normal and DE days 6, 10 and 14 (100x magnification). Morphometric evaluation showed significant increase in lymphatic area (LA) in dry eye compared to normal corneas (Figure 3a). Significant increase in lymphatic caliber (LC) in dry eye compared to normal corneas was noticed only at day 14 (Figure 3b). Data from a representative experiment of three performed is shown as mean \pm S.E.M and each group consists of four to five mice.

[0071] Figure 4: Analysis of lymphangiogenic-specific growth factors. Real-time PCR analysis showing transcript levels of VEGF-A, VEGF-C and VEGF-D in the dry eye corneas at different time points. A significant increase in VEGF-D was seen at day 6 whereas VEGF-A and VEGF-C increased significantly only by day 14. Data from a

representative experiment of three performed is shown as mean \pm S.E.M and each group consists of four to five mice.

[0072] Figure 5: Analysis of lymphangiogenic-specific growth factor receptors. Real-time PCR analysis showing transcript levels of VEGFR-2 and VEGFR-3 in the dry eye corneas at different time points. Significant increase in VEGFR-3 was seen earliest at day 6 but VEGFR-2 increased significantly later in disease at day 14. Data from a representative experiment of three performed is shown as mean \pm S.E.M and each group consists of four to five mice.

[0073] Figure 6: Enumeration of corneal CD11b⁺/LYVE-1⁺ cells. A significant increase in the number of both CD11b⁺ and double stained CD11^{hi}/LYVE-1⁺ cells in the dry eye corneas as compared to normal. Data from a representative experiment of three performed is shown as mean \pm S.E.M and each group consists of four to five mice.

[0074] Figure 7: Increased homing of mature MHC-II+CD11b⁺ APC in the draining LN of DED mice. Flow cytometric analysis of draining lymph nodes showing significant increase in the frequencies of mature MHC-II⁺ CD11b⁺ APC in DED mice compared with normal mice. Data from a representative experiment of two performed is shown and each group consists of three mice.

[0075] Figure 8: Analysis of lymphangiogenic-specific growth factors and their receptors. Real-time PCR analysis showing transcript levels of VEGF-A, VEGF-C, VEGF-D, VEGFR-2 and VEGFR-3 in the dry eye corneas.

[0076] Figure 9: Analysis of proinflammatory cytokines in conjunctiva. Real-time PCR analysis showing expression of cytokines IL-1 α , IL-1 β , IL-6, IL-17. The levels of all four cytokines in the conjunctiva showed significantly decreased expression in anti-VEGF-C treated DED mice as compared to those of untreated DED mice

[0077] Figure 10: Analysis of inflammatory cytokines in draining lymph nodes. Real-time PCR analysis for IL-17 (Th17 cells) and IFN- γ (Th1 cells). Draining lymph nodes of anti-VEGF-C treated DED mice showed significantly decreased induction of T-cell mediated autoimmune response compared untreated DED mice.

[0078] Figure 11: Enumeration of CD11b⁺ cells in DED corneas. Treatment with anti-VEGF-C antibodies significantly decreased infiltration of CD11b⁺ cells (30%) in the DED corneas (day 14).

[0079] Figure 12: Epifluorescent microscopic image of corneal wholemounts immunostained with CD31 and LYVE-1.

[0080] Figure 13: Quantification of number of infiltrating CD11b⁺ cells per mm² of cornea.

[0081] Figure 14: In vivo blockade of VEGF-C ameliorates clinical signs of DED. Corneal fluorescein staining (CFS) score is used as readout for the clinical signs of dry eye inflammation, in anti-VEGF-C Ab-treated and untreated mice. CFS scores were significantly decreased in the group treated with anti-VEGF-C antibody at days 5, 9 and 13 vs the untreated group. Data shown as mean \pm S.E.M and each group consisted of 3 - 4 mice.

DETAILED DESCRIPTION

Dry eye disease

[0082] Keratoconjunctivitis sicca (KCS), also called keratitis sicca, sicca syndrome, xerophthalmia, dry eye syndrome (DES), dry eye disease (DED), or simply dry eyes, is an eye disease caused by decreased tear production or increased tear film evaporation commonly found in humans and some animals. Typical symptoms of keratoconjunctivitis are dryness, burning and a sandygritty eye irritation that gets worse as the day goes on.

[0083] In the context of the present invention the term "dry eye condition" denotes any condition or syndrome which results in the manifestation of dry eye symptoms. It includes an already existing condition as well as pseudo dry eye conditions, i.e. conditions high predisposition of developing dry eye syndromes. Dry eye disease may be as a result of another underlying condition causing dry eye, for example, Sjogren's syndrome, menopause or rheumatoid arthritis. Dry eye may also be a complication of inflammation, e.g. Blepharitis or of a foreign body in the eye. Dry eye may also be the result of infection, or a side effect of medications, or exposure to toxins, chemicals, or other substances may cause a symptom or condition of dry eye. Dry eye conditions may be manifested by one or more ophthalmologic clinical symptoms as known in the art. Examples of dry eye symptoms

include, but are not limited to, foreign body sensation, burning, itching, irritation, redness, eye pain, blurred vision and/or degraded vision.

[0084] Keratoconjunctivitis sicca is characterized by inadequate tear film protection of the cornea because of either inadequate tear production or abnormal tear film constitution, which results in excessively fast evaporation or premature destruction of the tear film. The tear film is constituted by 3 layers: (1) a lipid layer, produced by the Meibomian glands; (2) an aqueous layer, produced by the main and accessory lacrimal glands; and (3) a hydrophilic mucin layer, produced by the conjunctival goblet cells. Any abnormality of 1 of the 3 layers produces an unstable tear film and symptoms of keratitis sicca.

[0085] Sjogren's syndrome and autoimmune diseases associated with Sjogren's syndrome are also conditions associated with aqueous tear deficiency. Drugs such as isotretinoin, sedatives, diuretics, tricyclic antidepressants, antihypertensives, oral contraceptives, antihistamines, nasal decongestants, beta-blockers, phenothiazines, atropine, and pain relieving opiates such as morphine can cause or worsen this condition. Infiltration of the lacrimal glands by sarcoidosis or tumors, or postradiation fibrosis of the lacrimal glands can also cause this condition.

[0086] Keratoconjunctivitis sicca can also be caused by abnormal tear composition resulting in rapid evaporation or premature destruction of the tears. When caused by rapid evaporation, it is termed evaporative dry eyes. In this, although the tear gland produces a sufficient amount of tears, the rate of evaporation of the tears is too rapid. There is a loss of water from the tears that results in tears that are too "salty" or hypertonic. As a result, the entire conjunctiva and cornea cannot be kept covered with a complete layer of tears during certain activities or in certain environments.

[0087] Aging is one of the most common causes of dry eyes. About half of all people who wear contact lenses complain of dry eyes. There are two potential connections between contact lens usage and dry eye. Traditionally, it has been believed that soft contact lenses, which float on the tear film that covers the cornea, absorb the tears in the eyes. However, it is also now known that contact lens usage damages corneal nerve sensitivity, which may lead to decreased lacrimal gland tear production and dry eye. The effect of contact lenses on corneal nerve sensitivity is well established for hard contact lenses as well as soft and rigid gas permeable contact lenses. The connection between this loss in nerve sensitivity

and tear production is the subject of current research. Dry eyes also occur or get worse after LASIK and other refractive surgeries. The corneal nerves stimulate tear secretion. Dry eyes caused by these procedures usually resolves after several months. Persons who are thinking about refractive surgery should consider this.

[0088] A variety of approaches can be taken to treat dry eyes. These can be summarized as: avoidance of exacerbating factors, tear stimulation and supplementation, increasing tear retention, eyelid cleansing and treatment of eye inflammation. Application of artificial tears every few hours can provide temporary relief. Inflammation occurring in response to tears film hypertonicity can be suppressed by mild topical steroids or with topical immunosuppressants such as cyclosporine. Consumption of dark-fleshed fish containing dietary omega-3 fatty acids is associated with a decreased incidence of dry eyes syndrome in women. Early experimental work on omega-3 has shown promising results when used in a topical application (Rashid S et al (2008). Arch Ophthalmol 126 (2): 219-225).

[0089] DED is increasingly recognized as an immune-mediated disorder. Desiccating stress in DED initiates an immune-based inflammation response that is sustained by the ongoing interplay between the ocular surface and various pathogenic immune cells, primarily the CD4+ cells in the conjunctiva and the CD11b+ monocytic cells in the corneal. Desiccating stress induces secretion of inflammatory cytokines, especially IL-1, TNF- α and IL-6 by ocular tissues, which facilitates the activation and migration of resident antigen presenting cells (APCs) toward the regional draining lymph nodes (LNs). In the LNs, these APCs stimulate naive T-cells, leading to the expansion of IL-17 secreting Th17 cells and interferon (IFN)- γ -secreting Th1 cells. Once these effectors are generated in the LNs, they migrate to the ocular surface and secrete effector cytokines.

VEGF Family of Growth Factors

[0090] VEGF (Vascular Endothelial Growth Factor) is a sub-family of growth factors, specifically the platelet-derived growth factor family of cystine-knot growth factors. They are important signaling proteins involved in both vasculogenesis (the de novo formation of the embryonic circulatory system) and angiogenesis (the growth of blood vessels from pre-existing vasculature). Members of the platelet-derived growth factor family include the Placenta growth factor (PlGF), VEGF-A (also known as VEGF), VEGF-B, VEGF-C, VEGF-D and VEGF-E.

[0091] VEGF-A, VEGF-C and VEGF-D exert their effects by variously binding to and activating two structurally related membrane receptor tyrosine kinases, VEGF receptor-1 (VEGFR-1 or Flt-1), VEGFR-2 (flk-1 or KDR), and VEGFR-3 (Flt-4). Members of the VEGF family may also interact with the structurally distinct receptor neuropilin-1. Binding of a VEGF to these receptors initiates a signaling cascade, resulting in effects on gene expression and cell survival, proliferation, and migration.

[0092] VEGF-A binds to VEGFR-1 (Flt-1) and to VEGFR-2 (KDR/Flk-1). VEGFR-2 appears to mediate almost all of the known cellular responses to VEGF-A. The function of VEGFR-1 is less well-defined, although it is thought to modulate VEGFR-2 signaling. VEGF-A is believed to play a central role in the development of new blood vessels (angiogenesis) and the survival of immature blood vessels (vascular maintenance).

[0093] VEGF-C and VEGF-D are ligands for VEGFR-2 and VEGFR-3 and are involved in the mediation of lymphangiogenesis.

Lymphangiogenesis

[0094] Lymphangiogenesis refers to formation of lymphatic vessels, particularly from pre-existing lymphatic vessels, but as used herein, the term applies to formation of lymph vessels under any condition. It also applies to the enlargement of lymphatic vessels, commonly known as lymphatic hyperplasia.. Lymphangiogenesis plays an important physiological role in homeostasis, metabolism and immunity. Lymphatic vessel formation has also been implicated in a number of pathological conditions including neoplasm metastasis, oedema, rheumatoid arthritis, psoriasis and impaired wound healing.

[0095] The normal human cornea is avascular, thus suppressing the afferent lymphatic and efferent vascular arms or the immune cycle. Inflammation however negates this immune and angiogenic privileged state of the cornea and giving the corneal and ocular surface the potential to mount an immune response. Our results show that corneal lymphatics play an important role in mediating the corneal inflammation in dry eyes. Inhibition of corneal lymphangiogenesis decreases ocular surface inflammation in a well characterized mouse model of DED.

[0096] Lymphangiogenesis is regulated to a large extent by VEGF-C and VEGF-D. Lymphangiogenesis appears to be regulated by signaling mediated by VEGFR-3, particularly upon specifically binding its ligands, VEGF-C and VEGF-D.

[0097] During embryogenesis, lymphatic endothelial cell sprouting, proliferation and survival is promoted by VEGF-C. Lymphatic vessels fail to develop in mice in which VEGF-C is absent (*Vegfc* knockout mice), and such mice develop severe edema. Indeed, absence of VEGF-C is embryonic lethal. Lymphatic vessel hypoplasia and lymphedema is exhibited in the skin of mice hemizygous for *Vegfc* (i.e. mice possessing one functional allele).

[0098] Embryonic lymphangiogenesis is also partly regulated by VEGF-D, similar to VEGF-C. However, lymphangiogenesis during embryonic development is not dependent upon VEGF-D, as demonstrated by *Vegfd* knockout mice. The lymphatic system in *Vegfd* knockout mice is relatively normal and *Vegfd* knockout mice are viable and fertile. The absolute abundance of lymphatic vessels in the lung is, however, reduced by approximately 30% compared to wild-type mice.

[0099] Lymphatic vessels express VEGFR-3, the receptor for VEGF-C and VEGF-D, and both VEGF-C and VEGF-D signal predominantly through VEGFR-3. It is also becoming apparent that lymphatic vessels variously express VEGFR-2. VEGF-C and VEGF-D are synthesized as prepro-polypeptides and are proteolytically processed by proprotein convertases. In humans, mature proteolytically processed forms of VEGF-C and VEGF-D bind to VEGFR-2 and VEGFR-3. In mice, mature VEGF-D binding is restricted to VEGFR-3.

[00100] VEGF-C and VEGF-D exist as homodimers, and it has been suggested that they may exist as VEGF-C–VEGF-D heterodimers. In addition to lymphatic vessels, VEGFR-3 is also expressed on blood vessel endothelial cells during development, thereby accounting for the severe vasculogenic and angiogenic defects observed during early embryogenesis in models comprising inactive VEGFR-3 signaling. The lymphatic system possesses almost exclusive expression of VEGFR-3 in healthy tissues in adulthood, because VEGFR-3 expression in blood vessels declines following birth and during adolescence. Thus, only lymphangiogenesis is inhibited in adults by inhibition of the VEGF-C—VEGF-D–VEGFR-3 signaling axis.

[00101] Lymphatic vessels express neuropilin-2 (NRP-2), which can bind VEGF-C or VEGF-D. In lymphangiogenesis, NRP-2 is thought to act as a co-receptor to increase the binding affinity of VEGF-C or VEGF-D to VEGFR-3. NRP-2 is required for

lymphangiogenesis. Proliferation of lymphatic vessel endothelial cells was reduced and lymphatic vessels and capillaries failed to develop in *Nrp2* knockout mice in which NRP-2 is absent. Similarly, NRP-1 is capable of binding VEGF-C and VEGF-D.

[00102] Defective lymphatic capillaries are the underlying cause of Milroy disease and other rare hereditary forms of lymphedema in humans. Tyrosine kinase-inactivating point mutations of the VEGFR-3 gene have been identified as a major cause of Milroy disease, and VEGF-C and VEGF-D therapy has shown promising efficacy in preclinical animal models. However, previous work has only demonstrated lymphatic capillary reconstitution, whereas effects on the collecting lymphatic vessels that are more commonly damaged in lymphedema have not been addressed.

[00103] Lymphatic vessel growth in adult tissues can be induced by Angiopoietin-1 (ANG-1) through its binding to the tunica interna endothelial cell kinase receptor 2 (TIE-2 or TEK). Lymphatic vessel sprouting that was induced by ANG-1 was inhibited by an inhibitor of VEGFR-3. Furthermore, VEGFR-3 was up-regulated by ANG-1 binding to TIE-2. TIE-2 expressed on lymphatic vascular endothelial cells may also be agonized by ANG-2 and ANG-3.

[00104] VEGF-C and VEGF-D may act as ligands for integrins. Specifically, VEGF-C and VEGF-D have been shown to act as ligands for integrin $\alpha 9 \beta 1$. Cell adherence and cell migration were promoted by each of VEGF-C and VEGF-D in cells expressing integrin $\alpha 9 \beta 1$. The effect could be blocked by an anti-integrin $\alpha 9 \beta 1$ antibody or siRNA directed to integrin $\alpha 9 \beta 1$.

[00105] Thus, in lymphangiogenesis, VEGFR-3 appears to be central. VEGFR-3 specifically binds and is activated by ligands VEGF-C and VEGF-D. VEGF-C and VEGF-D are synthesized as prepro-polypeptides and are activated by proteolytic processing by proprotein convertases. VEGF-C and VEGF-D also bind specifically to NRP-2, which is thought to be a co-receptor for VEGFR-3. Both lymphangiogenesis and VEGFR-3 are up-regulated when ANG-1 specifically binds to TIE-2. It is thought that binding of VEGF-C or VEGF-D to integrins, particularly integrin $\alpha 9 \beta 1$, also performs a role in lymphangiogenesis.

[00106] Lymphangiogenesis is mediated primarily by the interaction of growth factors VEGF-C and VEGF-D on VEGFR-2 and VEGFR-3, and in particular on VEGFR-3.

VEGF-A also contributes, albeit indirectly, to lymphangiogenesis by recruiting VEGF-C and VEGF-D secreting macrophages. Inhibition of VEGF-C and VEGF-D signaling pathways would thus constitute a new approach to the treatment of DED. The invention is however not restricted to the inhibition of VEGF-C and VEGF-D signaling pathways and according to the present invention, other anti-lymphangiogenic agents can be used to reduce the signs and symptoms of DED.

Anti-lymphangiogenic agents

[00107] Persons skilled in the art will appreciate from the foregoing that inhibition of lymphangiogenesis can occur at a variety of biological points comprising any one or more of the interactions described. For example, inhibition may occur by targeting VEGF-D, VEGF-C or VEGFR-3.

[00108] An “anti-lymphangiogenic agent” as described herein refers to any substance that partially or fully blocks, neutralizes, reduces, inhibits or antagonizes a biological activity of a molecular component of signaling mediated by VEGFR-3 or lymphangiogenesis. Alternatively, an anti-lymphangiogenic agent is any substance that partially or fully blocks, neutralizes, reduces, inhibits or antagonizes a VEGF-C or VEGF-D biological activity. Thus, “inhibition” is the corresponding state elicited by an inhibitor. A molecular component of signaling mediated by VEGFR-3 or lymphangiogenesis includes VEGFR-3, VEGFR-2, VEGF-C, VEGF-D, proprotein convertases, neuropilin-1 (NRP-1), neuropilin-2 (NRP-2), angiopoietin-1 (ANG-1), tunica interna endothelial cell kinase receptor (TIE-2) or integrin $\alpha 9\beta 1$.

[00109] It is envisaged that practice of the invention extends to any inhibitor known now or in the future.

[00110] Suitable classes of inhibitor molecules that target VEGF-C or VEGF-D or signaling mediated by VEGFR-3, or lymphangiogenesis include antibodies, polypeptides, peptides, peptide mimetics, nucleic acid molecules, and small molecules. Such classes of inhibitor molecules are suitable also for inhibiting binding of ligands, for example VEGF-C or VEGF-D, to integrins, particularly integrin $\alpha 9\beta 1$.

[00111] Suitable VEGF-C, VEGF-D, VEGFR-3-mediated signaling or lymphangiogenesis antibody inhibitors include antagonist and neutralizing antibodies or antibody fragments.

[00112] Polypeptide, peptide, or peptide mimetic VEGF-C or VEGF-D inhibitors, VEGFR-3-mediated signaling inhibitors or lymphangiogenesis inhibitors include fragments or amino acid sequence variants of native polypeptide or peptide components of VEGF-C, VEGF-D, VEGFR-3-mediated signaling or lymphangiogenesis.

[00113] Nucleic acid molecule inhibitors of VEGF-C or VEGF-D activity, VEGFR-3-mediated signaling or lymphangiogenesis include antisense molecules, nucleic acids in triple-helix formation, small interfering RNA (siRNA), and ribozymes.

[00114] Small molecule inhibitors of VEGF-C or VEGF-D, VEGFR-3-mediated signaling or lymphangiogenesis include organic and inorganic molecules.

[00115] Inhibitors of VEGF-C or VEGF-D activity, VEGFR-3-mediated signaling or lymphangiogenesis according to the present invention may exert their effects by interacting with any one or more of VEGFR-3, VEGFR-2, VEGF-C, VEGF-D, proprotein convertases, NRP-1, NRP-2, ANG-1, TIE-2 or integrins, particularly integrin $\alpha 9\beta 1$, in their DNA, RNA or polypeptide forms.

[00116] Inhibition of VEGF-C or VEGF-D activity, VEGFR-3-mediated signaling or lymphangiogenesis according to the present invention may occur via inhibition of ligand availability for receptor binding, inhibition of receptor availability for ligand binding, inhibition of receptor tyrosine kinase activity, or inhibition of co-receptor interaction.

[00117] As used herein, "availability" refers to the potential or actual amount of a molecule that performs some function in VEGF-C or VEGF-D activity, VEGFR-3-mediated signaling or lymphangiogenesis and is present in a biological system. Availability may be relative or absolute. For example, if all copies of a gene encoding a polypeptide involved in lymphangiogenesis were rendered non-functional by genetic mutation and no functioning polypeptide was synthesized, then there would be no availability of the polypeptide in an absolute sense. Alternatively, if the same gene was present with one functioning copy and 50% of the polypeptide was synthesized, there would be reduced or inhibited availability in a relative sense. Similarly, other mechanisms may be envisaged where availability is affected. Receptors may be transcribed or translated to a lesser degree when compared with a control, or the receptor may be targeted by an antibody that binds specifically to the ligand binding site, thereby reducing or inhibiting receptor availability for ligand binding. Analogously, if ligand synthesis is targeted by an antisense inhibitor, or

if an antibody inhibitor or soluble receptor inhibitor specifically binds to the ligand, then there will be reduction or inhibition of ligand availability for receptor binding.

[00118] The term "specific binding" or "specifically binds" or "specific for" refers to binding where a molecule binds to a particular polypeptide or epitope on a particular polypeptide without substantially binding to any other polypeptide or polypeptide epitope. Such binding is measurably different from a non-specific interaction. Specific binding can be measured, for example, by determining binding of a molecule compared to binding of a control molecule, which generally is a molecule of similar structure that does not have binding activity. For example, specific binding can be determined by competition with a control molecule that is similar to the target, for example, an excess of non-labeled target. In this case, specific binding is indicated if the binding of the labeled target to a probe is competitively inhibited by excess unlabeled target. As used herein, specific binding is used in relation to the interaction between the molecular components of VEGF-C or VEGF-D activity, VEGFR-3-mediated signaling or lymphangiogenesis. Specific binding is also used in relation to the interaction between the molecular components of VEGF-C or VEGF-D activity, VEGFR-3-mediated signaling or lymphangiogenesis and agents that partially or fully block, neutralize, reduce or antagonize a biological activity of a molecule that facilitates VEGFR-3-mediated signaling or lymphangiogenesis. Specific binding also applies to the interaction between the molecular components of VEGF-C or VEGF-D activity and agents that partially or fully block, neutralize, reduce or antagonize VEGF-C or VEGF-D biological activity.

[00119] In particular, specific binding refers to a molecule having a K_d at least 2-fold less for the particular polypeptide or epitope on a particular polypeptide than it does for a non-specific target. Preferably, specific binding refers to a molecule having a K_d at least 4-fold, 6-fold, 8-fold or 10-fold less for the particular polypeptide or epitope on a particular polypeptide than it does for a non-specific target. Alternatively, specific binding can be expressed as a molecule having a K_d for the target of at least about 10^{-4} M, alternatively at least about 10^{-5} M, alternatively at least about 10^{-6} M, alternatively at least about 10^{-7} M, alternatively at least about 10^{-8} M, alternatively at least about 10^{-9} M, alternatively at least about 10^{-10} M, alternatively at least about 10^{-11} M, alternatively at least about 10^{-12} M, or less.

[00120] The person skilled in the art will appreciate that there exist many mechanisms for inhibiting VEGF-C or VEGF-D activity, VEGFR-3-mediated signaling or lymphangiogenesis. The principal aim is to reduce receptor signaling. Some examples will be described below, but such a list is not intended to be limiting.

[00121] Antibody Inhibitors

[00122] The term "antibody" is used in the broadest sense and specifically covers, for example, polyclonal antibodies, monoclonal antibodies (including antagonist and neutralizing antibodies), antibody compositions with polyepitopic specificity, single chain antibodies, and fragments of antibodies, provided that they exhibit the desired biological or immunological activity.

[00123] An "antibody inhibitor" will specifically bind to a particular polypeptide or epitope on a particular polypeptide without substantially binding to any other polypeptide or polypeptide epitope. Such binding will partially or fully block, neutralize, reduce or antagonize VEGF-C or VEGF-D activity or a biological activity of a molecule that facilitates VEGFR-3-mediated signaling or lymphangiogenesis. Such target molecules include VEGFR-3, VEGFR-2, VEGF-C and VEGF-D, for example.

[00124] An "isolated antibody" is one which has been identified and separated and/or recovered from a component of its natural environment. Contaminant components of its natural environment are materials which would interfere with diagnostic or therapeutic uses for the antibody, and may include enzymes, hormones, and other proteinaceous or non-proteinaceous solutes. Generally, the antibody will be purified (1) to greater than 95% by weight of antibody as determined by the Lowry method, and most preferably more than 99% by weight, (2) to a degree sufficient to obtain at least 15 residues of N terminal or internal amino acid sequence by use of a spinning cup sequenator, or (3) to homogeneity by SDS PAGE under reducing or non-reducing conditions using Coomassie blue or, preferably, silver stain. An isolated antibody includes the antibody *in situ* within recombinant cells since at least one component of the antibody's natural environment will not be present. Ordinarily, however, isolated antibody will be prepared by at least one purification step.

[00125] Where antibody fragments are used, the smallest inhibitory fragment that specifically binds to the binding domain of the target protein is preferred.

[00126] Polyclonal Antibodies

[00127] Polyclonal antibodies are preferably raised in animals by multiple subcutaneous (s.c.) or intraperitoneal (i.p.) injections of the relevant antigen and an adjuvant. It may be useful to conjugate the relevant antigen (especially when synthetic peptides are used) to a protein that is immunogenic in the species to be immunized. For example, the antigen can be conjugated to keyhole limpet hemocyanin (KLH), serum albumin, bovine thyroglobulin, or soybean trypsin inhibitor, using a bifunctional or derivatizing agent, e.g., maleimidobenzoyl sulfosuccinimide ester (conjugation through cysteine residues), N-hydroxysuccinimide (through lysine residues), glutaraldehyde, succinic anhydride, SOCl_2 , or $\text{R}^1\text{N}=\text{C}=\text{NR}$, where R and R^1 are different alkyl groups.

[00128] In one protocol for generating polyclonal antibodies, animals are immunized against the antigen, immunogenic conjugate, or derivative, by combining the antigen, conjugate or derivative with 3 volumes of Freund's complete adjuvant and injecting the solution intradermally at multiple sites. One month later, the animals are boosted with 1/5 to 1/10 the original amount of peptide or conjugate in Freund's complete adjuvant by subcutaneous injection at multiple sites. Seven to 14 days later, the animals are bled and the serum is assayed for antibody titer. Animals are boosted until the titer plateaus. Conjugates also can be made in recombinant cell culture as protein fusions. Also, aggregating agents such as alum are suitably used to enhance the immune response.

[00129] Monoclonal Antibodies

[00130] The term "monoclonal antibody" as used herein refers to an antibody obtained from a population of substantially homogeneous antibodies, i.e., the individual antibodies comprising the population are identical except for possible naturally occurring mutations that may be present in minor amounts. Monoclonal antibodies are highly specific, being directed against a single antigenic site. Furthermore, in contrast to polyclonal antibody preparations which include different antibodies directed against different determinants (epitopes), each monoclonal antibody is directed against a single determinant on the antigen. In addition to their specificity, the monoclonal antibodies are advantageous in that they may be synthesized uncontaminated by other antibodies. The modifier "monoclonal" is not to be construed as requiring production of the antibody by any particular method.

[00131] Monoclonal antibodies may be made using the hybridoma method in which a mouse or other appropriate host animal, such as a hamster, is immunized to elicit lymphocytes that produce or are capable of producing antibodies that will specifically bind to the protein used for immunization. Alternatively, lymphocytes may be immunized *in vitro*. After immunization, lymphocytes are isolated and then fused with a myeloma cell line using a suitable fusing agent, such as polyethylene glycol, to form a hybridoma cell.

[00132] The hybridoma cells thus prepared are seeded and grown in a suitable culture medium, which preferably contains one or more substances that inhibit the growth or survival of the unfused, parental myeloma cells (also referred to as fusion partner).

[00133] Culture medium in which hybridoma cells are growing is assayed for production of monoclonal antibodies directed against the antigen. Preferably, the binding specificity of monoclonal antibodies produced by hybridoma cells is determined by immunoprecipitation or by an *in vitro* binding assay, such as radioimmunoassay (RIA) or enzyme-linked immunosorbent assay (ELISA).

[00134] Once hybridoma cells that produce antibodies of the desired specificity, affinity, and/or activity are identified, the clones may be subcloned by limiting dilution procedures and grown by standard methods. In addition, the hybridoma cells may be grown *in vivo* as ascites tumors in an animal e.g., by i.p. injection of the cells into mice.

[00135] The monoclonal antibodies secreted by the subclones are suitably separated from the culture medium, ascites fluid, or serum by conventional antibody purification procedures such as, for example, affinity chromatography (e.g., using protein A or protein G-Sepharose) or ion-exchange chromatography, hydroxyapatite chromatography, gel electrophoresis, or dialysis.

[00136] DNA encoding the monoclonal antibodies is readily isolated and sequenced using conventional procedures. The hybridoma cells serve as a preferred source of such DNA. Once isolated, the DNA may be placed into expression vectors, which are then transfected into host cells such as *E. coli* cells, simian COS cells, Chinese Hamster Ovary (CHO) cells, or myeloma cells that do not otherwise produce antibody protein, to obtain the synthesis of monoclonal antibodies in the recombinant host cells.

[00137] Monoclonal antibodies or antibody fragments can be isolated from antibody phage libraries. High affinity (nM range) human antibodies can be generated by chain

shuffling, as well as combinatorial infection and *in vivo* recombination as a strategy for constructing very large phage libraries. Thus, these techniques are viable alternatives to traditional monoclonal antibody hybridoma techniques for isolation of monoclonal antibodies.

[00138] The DNA that encodes the antibody may be modified to produce chimeric or fusion antibody polypeptides. The monoclonal antibodies used herein include "chimeric" antibodies in which a portion of the heavy and/ or light chain is identical with or homologous to corresponding sequences in antibodies derived from a particular species or belonging to a particular antibody class or subclass, while the remainder of the chain(s) is identical with or homologous to corresponding sequences in antibodies derived from another species or belonging to another antibody class or subclass, as well as fragments of such antibodies, so long as they exhibit the desired biological activity.

[00139] Human and Humanized Antibodies

[00140] The anti-VEGF-C, anti-VEGF-D, anti-VEGFR-3-mediated signaling or anti-lymphangiogenesis antibodies used in the invention may comprise humanized antibodies or human antibodies. Generally, a "humanized antibody" is an antibody of non-human origin that has been modified using recombinant DNA techniques to circumvent the problem of a human's immune system reacting to an antibody as a foreign antigen. The standard procedure of producing monoclonal antibodies produces mouse antibodies. Although murine antibodies are very similar to human ones, there are differences. Consequently, the human immune system recognizes mouse antibodies as foreign, rapidly removing them from circulation and causing systemic inflammatory effects. "Humanized" forms of non-human (e.g., rodent) antibodies are chimeric antibodies that contain a reduced percentage of sequence derived from the non-human antibody. Various forms of humanized anti-VEGF-C, anti-VEGF-D, anti-VEGFR-3-mediated signaling or anti-lymphangiogenesis antibodies are contemplated. Humanized antibodies may be intact antibodies, such as intact IgG₁ antibodies, antibody chains or fragments thereof (such as Fv, Fab, Fab', F(ab')₂, or other antigen-binding subsequences of antibodies). Humanized antibodies include human antibodies (recipient antibody) in which residues from a complementary determining region (CDR) of the recipient are replaced by residues from a CDR of a non-human species (donor antibody) such as mouse, rat or rabbit having the desired specificity, affinity and capacity. In some instances, Fv framework residues of the human antibody are replaced by

corresponding non-human residues. Humanized antibodies may also comprise residues which are found neither in the recipient antibody nor in the imported CDR or framework sequences. In general, the humanized antibody will comprise substantially all of at least one, and typically two, variable domains, in which all or substantially all of the CDR regions correspond to those of a non-human antibody and all or substantially all of the FR regions are those of a human antibody consensus sequence. The humanized antibody optimally also will comprise at least a portion of an antibody constant region (Fc), typically that of a human antibody.

[00141] Various humanization strategies have been described in the prior art and it is envisaged that practice of the invention extends to the use of both known humanization strategies and any new strategies to be developed in the future. Examples of known humanization strategies include those described by Studnicka (US 5,869,619) and Padlan (1991, *Molec. Immunol.*, 28, 489-498), Winter (US 5,225,539) and Jones et al (1986, *Nature*, 321, 522-525), Queen *et al.* (US 5,693,761) and Foote (US 6,881,557).

[00142] As an alternative to humanization, human antibodies can be generated. For example, it is now possible to produce transgenic animals (e.g., mice) that are capable, upon immunization, of producing a full repertoire of human antibodies in the absence of endogenous immunoglobulin production.

[00143] Alternatively, phage display technology can be used to produce human antibodies and antibody fragments *in vitro*, from immunoglobulin variable (V) domain gene repertoires from unimmunized donors. Phage display can be performed in a variety of formats. Several sources of V-gene segments can be used for phage display.

[00144] Antibody fragments

[00145] "Antibody fragments" comprise a portion of an antibody, preferably the antigen binding or variable region of the intact antibody. Examples of antibody fragments include Fab, Fab', F(ab')₂, and Fv fragments; diabodies; linear antibodies; single chain antibody molecules; and multispecific antibodies formed from antibody fragments. Antibody fragments of particular interest are fragments that retain antigen-binding properties of the whole antibody, and are useful as inhibitors for practicing the invention.

[00146] Papain digestion of antibodies produces two identical antigen binding fragments, called "Fab" fragments, and a residual "Fc" fragment, a designation reflecting the ability to

crystallize readily. Each Fab fragment is monovalent with respect to antigen binding, i.e., it has a single antigen binding site. Pepsin treatment of an antibody yields a single large $F(ab')_2$ fragment which roughly corresponds to two disulfide linked Fab fragments having divalent antigen binding activity and is still capable of cross linking antigen. Fab' fragments differ from Fab fragments by having additional residues at the carboxy terminus of the C_{H1} domain including one or more cysteines from the antibody hinge region. Fab'-SH is the designation herein for Fab' in which the cysteine residue(s) of the constant domains bear a free thiol group. $F(ab')_2$ antibody fragments originally were produced as pairs of Fab' fragments which have hinge cysteines between them. Other chemical couplings of antibody fragments are also known.

[00147] "Fv" is the minimum antibody fragment which contains a complete antigen recognition binding site. This fragment consists of a dimer of one heavy and one light chain variable region domain in tight, non covalent association. From the folding of these two domains emanate six hypervariable loops (3 loops each from the H and L chain) that contribute the amino acid residues for antigen binding and confer antigen binding specificity to the antibody. However, even a single variable domain (or half of an Fv comprising only three CDRs specific for an antigen) has the ability to recognize and bind antigen, although at a lower affinity than the entire binding site.

[00148] "Single chain Fv" abbreviated as "scFv" are antibody fragments that comprise the VH and VL antibody domains connected into a single polypeptide chain. Preferably, the scFv polypeptide further comprises a polypeptide linker between the VH and VL domains which enables the scFv to form the desired structure for antigen binding.

[00149] In certain circumstances there are advantages of using antibody fragments, rather than whole antibodies. The smaller size of the fragments allows for rapid clearance from the circulation.

[00150] Various techniques have been developed for the production of antibody fragments. Traditionally, these fragments were derived via proteolytic digestion of intact antibodies. However, these fragments can now be produced directly by recombinant host cells. Fab, Fv and ScFv antibody fragments can all be expressed in and secreted from *E. coli*, thus allowing the facile production of large amounts of these fragments. Antibody fragments can be isolated from the antibody phage libraries. Alternatively, Fab'-SH

fragments can be directly recovered from *E. coli* and chemically coupled to form $F(ab')_2$ fragments. According to another approach, $F(ab')_2$ fragments can be isolated directly from recombinant host cell culture. Fab and $F(ab')_2$ fragment with increased *in vivo* half-life comprising a salvage receptor binding epitope residues also may be used.

[00151] Other techniques for the production of antibody fragments will be apparent to the skilled practitioner. The antibody of choice is a single chain Fv fragment (scFv). Fv and scFv are the only species with intact combining sites that are devoid of constant regions; thus, they are suitable for reduced nonspecific binding during *in vivo* use. The antibody fragment may also be a "linear antibody", which may be monospecific or bispecific. The inhibitor also maybe a polypeptide or protein comprising an antibody or antibody fragment linked to another entity to form a fusion protein.

[00152] Bispecific Antibodies

[00153] Bispecific antibodies are antibodies that have binding specificities for at least two different epitopes. Bispecific antibodies can be prepared as full length antibodies or antibody fragments (e.g., $F(ab')_2$ bispecific antibodies).

[00154] Methods for making bispecific antibodies are known in the art. Traditional production of full length bispecific antibodies is based on the co-expression of two immunoglobulin heavy chain-light chain pairs, where the two chains have different specificities.

[00155] According to a different approach, antibody variable domains with the desired binding specificity (antibody-antigen combining sites) are fused to immunoglobulin constant domain sequences.

[00156] Bispecific antibodies include cross-linked or "heteroconjugate" antibodies. Heteroconjugate antibodies are composed of two covalently joined antibodies. It is contemplated that the antibodies may be prepared *in vitro* using known methods in synthetic protein chemistry, including those involving crosslinking agents. For example, one of the antibodies in the heteroconjugate can be coupled to avidin, the other to biotin. Heteroconjugate antibodies may be made using any convenient cross-linking methods. Suitable cross-linking agents and cross-linking techniques are well known in the art.

[00157] Techniques for generating bispecific antibodies from antibody fragments have also been described in the literature. For example, bispecific antibodies can be prepared using chemical linkage.

[00158] Recent progress has facilitated the direct recovery of Fab'-SH fragments from *E. coli*, which can be chemically coupled to form bispecific antibodies. Various techniques for making and isolating bispecific antibody fragments directly from recombinant cell culture have also been described.

[00159] The term "diabodies" refers to small antibody fragments prepared by constructing scFv fragments with short linkers (about 5 to 10 residues) between the VH and VL domains such that inter chain but not intra chain pairing of the V domains is achieved, resulting in a bivalent fragment, i.e., fragment having two antigen binding sites. Bispecific diabodies are heterodimers of two "crossover" scFv fragments in which the VH and VL domains of the two antibodies are present on different polypeptide chains.

[00160] According to an alternative "diabody" technology for making bispecific antibody fragments, the fragments comprise a VH connected to a VL by a linker which is too short to allow pairing between the two domains on the same chain. Accordingly, the VH and VL domains of one fragment are forced to pair with the complementary VL and VH domains of another fragment, thereby forming two antigen-binding sites. Another strategy for making bispecific antibody fragments by the use of single-chain Fv (scFv) dimers has also been reported.

[00161] Antibodies with more than two valencies are contemplated for use in the invention. For example, trispecific antibodies can be prepared.

[00162] Exemplary multivalent antibodies and binding constructs that are suitable inhibitors for practicing the invention include those described in International Patent Application No. PCT/US2005/007742 (published as WO 2005/087812 on 22 September 2005) or US Patent Publication No. 2005/0282233, filed March 7, 2005, published December 22, 2005, both incorporated herein by reference in their entirety. These documents describe, for example, an antibody substance that specifically binds to first and second growth factors selected from the group consisting of human vascular endothelial growth factor-A (VEGF-A), human vascular endothelial growth factor-B (VEGF-B), human vascular endothelial growth factor-C (VEGF-C), human vascular endothelial growth

factor-D (VEGF-D), human vascular endothelial growth factor-E (VEGF-E), human placental growth factor (PIGF), human platelet-derived growth factor-A (PDGF-A), human platelet-derived growth factor-B (PDGF-B), human platelet-derived growth factor-C (PDGF-C), and human platelet-derived growth factor-D (PDGF-D), wherein each of said growth factors binds and stimulates phosphorylation of at least one receptor tyrosine kinase, and wherein the antibody substance inhibits the first and second growth factors to which it binds from stimulating phosphorylation of said receptor tyrosine kinases. Of particular interest for the present invention are bi-specific antibody substances that bind two of VEGF-C, VEGF-D, and VEGF-A, for example. These documents also describe an antibody substance produced by a process comprising: (a) screening a library of antibody molecules to identify at least one antibody molecule that binds to a first growth factor selected from the group consisting of human vascular endothelial growth factor-A (VEGF-A), human vascular endothelial growth factor-B (VEGF-B), human vascular endothelial growth factor-C (VEGF-C), human vascular endothelial growth factor-D (VEGF-D), human vascular endothelial growth factor-E (VEGF-E), human placental growth factor (PIGF), human platelet-derived growth factor-A (PDGF-A), human platelet-derived growth factor-B (PDGF-B), human platelet-derived growth factor-C (PDGF-C), and human platelet-derived growth factor-D (PDGF-D), wherein each of said growth factors binds and stimulates phosphorylation of at least one receptor tyrosine kinase; (b) screening molecule(s) identified in (a) to identify at least one molecule that binds to a second growth factor selected from said group; (c) screening molecule(s) identified in step (b) to identify at least one molecule that inhibits the first and second growth factors to which it binds from stimulating phosphorylation of said receptor tyrosine kinases, wherein the antibody substance comprises a molecule identified in step (C).

[00163] A multivalent antibody may be internalized (and/ or catabolized) faster than a bivalent antibody by a cell expressing an antigen to which the antibodies bind. Antibodies that may be used in the present invention can be multivalent antibodies (which are other than of the IgM class) with three or more antigen binding sites (e.g. tetravalent antibodies), which can be readily produced by recombinant expression of nucleic acid encoding the polypeptide chains of the antibody. The multivalent antibody can comprise a dimerization domain and three or more antigen binding sites. A preferred dimerization domain comprises an Fc region or a hinge region. In this scenario, the antibody will comprise an Fc

region and three or more antigen binding sites amino-terminal to the Fc region. A preferred multivalent antibody comprises three to about eight, but preferably four, antigen binding sites. The multivalent antibody comprises at least one polypeptide chain (and preferably two polypeptide chains), wherein the polypeptide chain(s) comprise two or more variable domains. For instance, the polypeptide chain(s) may comprise $VD1-(X_1)_n-VD2-(X_2)_n-Fc$, wherein VD1 is a first variable domain, VD2 is a second variable domain, Fc is one polypeptide chain of an Fc region, X_1 and X_2 represent an amino acid or polypeptide, and n is 0 or 1. For instance, the polypeptide chain(s) may comprise: V_H-C_H1 -flexible linker- V_H-C_H1 -Fc region chain; or $V_H-C_H1-V_H-C_H1$ -Fc region chain. A multivalent antibody preferably further comprises at least two (and preferably four) light chain variable domain polypeptides. A multivalent antibody may, for instance, comprise from about two to about eight light chain variable domain polypeptides. The light chain variable domain polypeptides contemplated here comprise a light chain variable domain and, optionally, further comprise a CL domain.

[00164] Peptide and Peptide Mimetic Inhibitors

[00165] In another embodiment, the inhibitor of VEGF-D activity, VEGFR-3—mediated signaling or lymphangiogenesis is a peptide or peptide mimetic. The peptide or peptide mimetic may reduce receptor availability for native ligand binding.

[00166] As used herein, “peptide mimetic” and “peptidomimetic” are used interchangeably.




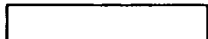

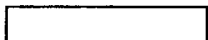
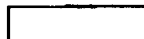
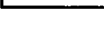

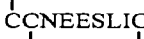
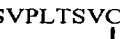


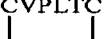
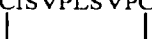
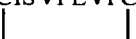
[00167] A peptide inhibitor is a peptide that binds specifically to a component of VEGF-C or VEGF-D activity, VEGFR-3-mediated signaling or lymphangiogenesis and inhibits or neutralizes the function of that component in the process of VEGF-C or VEGF-D activity, VEGFR-3-mediated signaling or lymphangiogenesis. Peptide inhibitors may be chemically synthesized using known peptide synthesis methodology or may be prepared and purified using recombinant technology. The preferred length of peptide inhibitors of VEGF-C or VEGF-D activity, VEGFR-3-mediated signaling or lymphangiogenesis is from about 6, 7, 8, 9 or 10 amino acid residues to about 100 amino acid residues. It is contemplated that longer peptides may prove useful. Peptide inhibitors may be identified without undue experimentation using well known techniques. In this regard, it is noted that techniques for

screening peptide libraries for peptides that are capable of specifically binding to a polypeptide target are well known in the art.

[00168] For any of the foregoing peptides, one preferred variation involves peptides that have been modified to comprise an intramolecular bond between two non-adjacent amino acid residues of the primary sequence, thereby forming a cyclic peptide. For example, in one variation, the peptide comprises a pair of cysteine residues, such as amino- and carboxy-terminal cysteines, and the intramolecular bond comprises a disulfide bond between the cysteines. However, organic chemists and peptide chemists are capable of synthesizing intramolecular bonds between a wide variety of amino acids using conventional techniques.

[00169] Exemplary peptidomimetic inhibitors of the VEGF-C and/or VEGF-D signaling pathways suitable for practicing the invention include those described in U.S. Patent No. 7,045,133 (May 16, 2006), incorporated herein by reference in its entirety. That patent describes, for example, monomeric monocyclic peptide inhibitors based on loop 1, 2 or 3 of VEGF-D. A preferred peptide interferes with at least the activity of VEGF-D and VEGF-C mediated by VEGF receptor-2 and VEGF receptor-3 (VEGFR-3). A particularly preferred peptide interferes with the activity of VEGF-D, VEGF-C and VEGF mediated by VEGFR-2 and the activity of VEGF-D and VEGF-C mediated by VEGFR-3. The patent also describes a dimeric bicyclic peptide inhibitor which comprises two monomeric monocyclic peptides, each individually based on loop 1, 2 or 3 of VEGF-D, linked together. Such dimeric bicyclic peptides may comprise two monomeric monocyclic peptides which are the same or different. (See, for example, Table 1-3 of the '133 patent.) Exemplary peptides in Table 1 are reproduced below:

TABLE 1

Sequence and predicted and actual molecular masses (determined by mass spectrometry) of peptides synthesized				
num- ber	sequence	mass predicted	mass actual [M + H]	
1	CASELGKSTNTFC (SEQ ID NO:5) 	1358.52	1360	
2	CNEESLIC (SEQ ID NO:6) 	908.02	909.5	
3	CISVPLTSVPC (SEQ ID NO:7) 	1116.37	1117.6	
4	 CASELGKSTNTFCCKPPC (SEQ ID NO:8) CASELGKSTNTFCCKPPC (SEQ ID NO:8) 	2793.18	2793.9	
5	 CASELGKSTNTFCCKPPC (SEQ ID NO:8);  CCNEESLIC (SEQ ID NO:9); 	3566.09	3567.1	
6	 CCNEESLIC (SEQ ID NO:9)  CCNEESLIC (SEQ ID NO:9) 	2019.6	2020.8	
7	CSVPLTSVC (SEQ ID NO:10) 	905.41	907	
8	CVPLTSC (SEQ ID NO:11) 	719.32	720.5	
9	CVPLTC (SEQ ID NO:12) 	632.28	633.6	
10	CISVPLSVPC (SEQ ID NO:13) 	1014.5	1015.4	
11	CISVPLVPC (SEQ ID NO:14) 	927.47	928.3	

[00170]

[00171] Additional peptide inhibitors useful for practicing this invention are described in U.S. Patent No. 7,611,711 (November 3, 2009), incorporated herein by reference in its entirety. This patent describes peptides that bind VEGFR-3 and inhibit VEGFR-3 ligands (VEGF-C and -D) from binding and stimulating the receptor. For example, in one embodiment, the invention provides an isolated peptide comprising the formula: $X_1X_2X_3X_4X_5X_6X_7X_8$ (SEQ ID NO: 1), wherein X_1 through X_8 are amino acid residues, wherein the peptide binds to VEGFR3, and wherein X_1 through X_8 are defined as follows: the amino acid residue at X_1 is a glycine residue or a conservative substitution thereof; the amino acid residue at X_2 is a tyrosine residue or a conservative substitution thereof; the amino acid residue at X_3 is a tryptophan residue or a conservative substitution thereof; the amino acid residue at X_4 is a leucine residue or a conservative substitution thereof; the amino acid residue at X_5 is a threonine residue or a conservative substitution thereof; the amino acid residue at X_6 is an isoleucine residue or a conservative substitution thereof; the amino acid residue at X_7 is a tryptophan residue or a conservative substitution thereof; and the amino acid residue at X_8 is a glycine residue or a conservative substitution thereof. Preferred peptides are from 6 to 100 amino acids in length, e.g., 6, 7, 8, 9, 10, 11, 12, . . . 97, 98, 99, or 100 amino acids in length. The peptides may be made cyclic by the formation of at least one bond between non-adjacent amino acids. For example, in one variation, the peptides are formed with terminal cysteines which can be made to form an intramolecular disulfide bond. Thus, in one preferred embodiment, the peptide further comprises amino- and carboxy-terminal cysteine residues. For example, the peptide may comprise the amino acid sequence: $CX_1X_2X_3X_4X_5X_6X_7X_8C$ (SEQ ID NO: 2), wherein $X_1X_2X_3X_4X_5X_6X_7X_8$ are defined as above, and C represents cysteine. In an alternative embodiment, additional residues are attached to X_1 or X_8 , within the terminal cysteines.

[00172] Preferred conservative substitutions for these peptide molecules include any of the following, in any combination: the conservative substitution at position X_1 is selected from isoleucine, valine, leucine, alanine, cysteine, phenylalanine, proline, tryptophan, tyrosine, norleucine and methionine; the conservative substitution at position X_2 is selected from isoleucine, valine, leucine, alanine, cysteine, glycine, phenylalanine, proline, tryptophan, norleucine and methionine; the conservative substitution at position X_3 is selected from isoleucine, valine, leucine, alanine, cysteine, glycine, phenylalanine, proline, tyrosine, norleucine and methionine; the conservative substitution at position X_4 is selected

from isoleucine, valine, alanine, cysteine, glycine, phenylalanine, proline, tryptophan, tyrosine, norleucine and methionine; the conservative substitution at position X₅ is selected from asparagine, glutamine, and serine; the conservative substitution at position X₆ is selected from valine, leucine, alanine, cysteine, glycine, phenylalanine, proline, tryptophan, tyrosine, norleucine or methionine; the conservative substitution at position X₇ is selected from isoleucine, valine, leucine, alanine, cysteine, glycine, phenylalanine, proline, tyrosine, norleucine and methionine; and the conservative substitution at position X₈ is selected from isoleucine, valine, leucine, alanine, cysteine, phenylalanine, proline, tryptophan, tyrosine, norleucine and methionine.

[00173] In on preferred embodiments, the invention provides an isolated peptide comprising the sequence Y₁GYWLTIWGY₂ (SEQ ID NO: 3), wherein Y₁ and Y₂ are amino acids. In one variation, the peptide is made cyclic by a bond between Y₁ and Y₂. In a specific preferred embodiment, the peptide comprises the sequence CGYWLTIWGC (SEQ ID NO: 4). Other specific examples of peptides described in that patent include peptides that comprise any of the following sequences: SGYWWDTWTF (SEQ ID NO: 15), SCYWRDTWTF (SEQ ID NO: 16), KVGWSSPDW (SEQ ID NO: 17), FVGWTKVLG (SEQ ID NO: 18), YSSMRWRH (SEQ ID NO: 19), RWRGNAYPG (SEQ ID NO: 20), SAVFRGRWL (SEQ ID NO: 21), WFSASLRFR (SEQ ID NO: 22), WQLGRNWI (SEQ ID NO: 23), VEVQITQE (SEQ ID NO: 24), AGKASSLW (SEQ ID NO: 25), RALDSALA (SEQ ID NO: 26), YGFEEAAW (SEQ ID NO: 27), YGFLWGM (SEQ ID NO: 28), SRWRILG (SEQ ID NO: 29), HKWQKRQ (SEQ ID NO: 30), MDPWGGW (SEQ ID NO: 31), RKVWDIR (SEQ ID NO: 32), VWDHGV (SEQ ID NO: 33), CWQLGRNWIC (SEQ ID NO: 34), CVEVQITQEC (SEQ ID NO: 35), CAGKASSLWC (SEQ ID NO: 36), CRALDSALAC (SEQ ID NO: 37), CYGFEEAWC (SEQ ID NO: 38), CYGFLWGMC (SEQ ID NO: 39), CSRWRILGC (SEQ ID NO: 40), CHKWQKRQC (SEQ ID NO: 41), CMDPWGGWC (SEQ ID NO: 42), CRKVWDIRC (SEQ ID NO: 43), CVWDHGV (SEQ ID NO: 44), and CGQMCTVWCSSGC (SEQ ID NO: 45), and conservative substitution-analogs thereof, wherein the peptide binds human VEGFR-3. Preferred peptides comprise these exact amino acid sequences, or sequences in which only one or only two conserved substitutions have been introduced. In another preferred variation, the peptides are preferred with

amino- and carboxy- terminal cysteines, which permit formation of cyclic molecules and dimers and multimers.

[00174] Nucleic Acid Molecules

[00175] Antisense Molecules

[00176] In yet another embodiment, the inhibitor of VEGF-C or VEGF-D activity, VEGFR-3-mediated signaling or lymphangiogenesis is an antisense molecule that reduces transcription and/ or translation of a component of VEGF-C or VEGF-D activity, VEGFR-3-mediated signaling or lymphangiogenesis, thereby reducing VEGF-C or VEGF-D activity, VEGFR-3-mediated signaling or lymphangiogenesis.

[00177] The antisense molecule comprises RNA or DNA prepared using antisense technology, where, for example, an antisense RNA or DNA molecule acts to block directly the translation of mRNA by hybridizing to targeted mRNA and preventing protein translation. Binding of antisense or sense oligonucleotides to target nucleic acid sequences results in the formation of duplexes that block transcription or translation of the target sequence by one of several means, including enhanced degradation of the duplexes, premature termination of transcription or translation, or by other means. The antisense oligonucleotides thus may be used to reduce or block expression of a component of VEGF-C or VEGF-D activity, VEGFR-3-mediated signaling or lymphangiogenesis, and thus VEGF-C or VEGF-D activity, VEGFR-3-mediated signaling or lymphangiogenesis. Such oligonucleotides can also be delivered to cells such that the antisense RNA or DNA may be expressed *in vivo* to inhibit production of components of VEGF-C or VEGF-D activity, VEGFR-3-mediated signaling or lymphangiogenesis.

[00178] Inhibitors of VEGF-C or VEGF-D activity or signaling mediated by VEGFR-3, or lymphangiogenesis include antisense or sense oligonucleotides comprising a single-stranded nucleic acid sequence (either RNA or DNA) capable of binding to target mRNA (sense) or DNA (antisense) sequences. Such a fragment generally comprises about 10 to 40 nucleotides in length, preferably at least about 14 nucleotides, preferably from about 14 to 30 nucleotides.

[00179] Antisense or sense oligonucleotides further comprise oligonucleotides having modified sugar-phosphodiester backbones that are resistant to endogenous nucleases, or are covalently linked to other moieties that increases affinity of the oligonucleotide for a target

nucleic acid sequence, or intercalating agents to modify binding specificities of the antisense or sense oligonucleotide for the target nucleotide sequence.

[00180] Antisense materials and methods are further described below, e.g., in the context of VEGFR-2 inhibitors. This discussion below also is applicable to antisense materials and methods for other targets, including VEGFR-3, VEGF-C, and VEGF-D.

[00181] Small Interfering RNA (siRNA)

[00182] In one embodiment, it is envisaged that siRNA will inhibit VEGF-C or VEGF-D activity, VEGFR-3-mediated signaling or lymphangiogenesis. "siRNA" or "RNAi" are double-stranded RNA molecules, typically about 21 nucleotides in length, that are homologous to a gene or polynucleotide that encodes the target gene and interfere with the target gene's expression. Interfering RNA materials and methods are further described below, e.g., in the context of VEGFR-2 inhibitors. This discussion below also is applicable to interfering RNA directed to other targets, including VEGFR-3, VEGF-C, and VEGF-D.

[00183] Nucleic Acid Molecules in Triple-Helix Formation

[00184] In another embodiment, the inhibitor of VEGF-C or VEGF-D activity, VEGFR-3-mediated signaling or lymphangiogenesis comprises nucleic acid molecules in triple-helix formation. Nucleic acid molecules in triple-helix formation used to inhibit transcription should be single-stranded and composed of deoxynucleotides. A DNA oligonucleotide is designed to be complementary to a region of the gene involved in transcription. The base composition of these oligonucleotides is designed such that it promotes triple-helix formation via Hoogsteen base-pairing rules, which generally require sizeable stretches of purines or pyrimidines on one strand of a duplex.

[00185] Ribozymes

[00186] In a related embodiment, the inhibitor of VEGF-C or VEGF-D activity, VEGFR-3-mediated signaling or lymphangiogenesis is a ribozyme that reduces transcription of a component of VEGF-C or VEGF-D activity or signaling mediated by VEGFR-3, or a lymphangiogenic component.

[00187] A "ribozyme" is an enzymatic RNA molecule capable of catalyzing the specific cleavage of RNA. Ribozymes act by sequence-specific hybridization to the complementary

target RNA, followed by endonucleolytic cleavage. Specific ribozyme cleavage sites within a potential RNA target can be identified by known techniques.

[00188] Small Molecule Inhibitors

[00189] In a further embodiment, the inhibitor of VEGF-C or VEGF-D activity, VEGFR-3-mediated signaling or lymphangiogenesis is a small molecule.

[00190] A “small molecule” is defined herein to have a molecular weight below about 2000 daltons, and preferably below about 500 Daltons. Potential inhibitors of VEGF-C or VEGF-D activity, VEGFR-3-mediated signaling or lymphangiogenesis include small molecules that bind to the active site, the receptor binding site, or growth factor or other relevant binding site of components of VEGF-C or VEGF-D activity or VEGFR-3-mediated signaling, or lymphangiogenesis, thereby blocking the normal biological activity of VEGF-C or VEGF-D, VEGFR-3-mediated signaling or lymphangiogenesis. Examples of small molecules include, but are not limited to, synthetic non-peptidyl organic or inorganic compounds.

[00191] Small molecule inhibitors of VEGF-C or VEGF-D activity, VEGFR-3-mediated signaling or lymphangiogenesis may be identified without undue experimentation using known techniques and chemically synthesized using known methodology. In this regard, it is noted that techniques for screening organic molecule libraries for molecules that are capable of binding to a polypeptide target are known in the art.

[00192] Inhibition of Receptor Availability for Ligand Binding

[00193] Antibody Inhibitors

[00194] In one embodiment, the inhibitor of VEGF-C or VEGF-D activity, VEGFR-3-mediated signaling or lymphangiogenesis is an antibody. In a preferred embodiment, the inhibitor of VEGF-C or VEGF-D activity, VEGFR-3-mediated signaling or lymphangiogenesis is an anti-VEGFR-3 antibody that reduces VEGFR-3 availability for ligand binding.

[00195] Suitable antibodies for use in the methods of the invention and means for their production are disclosed in WO2000/021560 and WO1995/021868 and include a polyclonal or a monoclonal antibody that binds specifically to VEGFR-3 and blocks its signaling, a fragment of such an antibody, a chimeric antibody, a humanized antibody, and

a bispecific antibody that binds specifically to VEGFR-3 and blocks its signaling and also binds to another antigen.

[00196] In a preferred embodiment, the antibody inhibitor is a humanized antibody. In another embodiment, the antibody inhibitor of VEGF-C or VEGF-D activity, VEGFR-3-mediated signaling or lymphangiogenesis comprises a Fab, Fab', or F(ab')₂ fragment, or a single chain Fv (scFv) fragment.

[00197] Persons skilled in the art will appreciate that in particular embodiments, the monoclonal antibody may comprise antibody 9D9F9, disclosed in WO2000/021560 or 2E11D11 disclosed in WO2003/006104. Alternatively monoclonal antibodies that specifically bind to VEGFR-3 and may be used according to the invention include antibodies MM0003-7G63, RM0003-5F63, C28G5, KLT9, ZMD.251, mF4-31C1 and hF4-3C5. A particularly preferred monoclonal antibody is hF4-3C5, a fully-humanized antagonist antibody to human VEGFR-3.

[00198] In an alternative embodiment, the inhibitor may comprise a bispecific antibody, particularly a diabody, that binds specifically to and neutralizes each of VEGFR-3 and a second target. One example of such a diabody is that derived from antibodies hF4-3C5 and IMC-1121, which binds specifically to and neutralizes each of VEGFR-3 and VEGFR-2.

[00199] An inhibitor of VEGF-C or VEGF-D activity, VEGFR-3-mediated signaling or lymphangiogenesis according to the present invention also includes in one embodiment an antibody, as described above, that inhibits or neutralizes the receptor tyrosine kinase activity of VEGFR-3.

[00200] Peptide and Peptide Mimetic Inhibitors

[00201] The person skilled in the art will appreciate that particular inhibitors of VEGF-C or VEGF-D activity, VEGFR-3-mediated signaling or lymphangiogenesis that can be employed in a particular embodiment of the present invention are disclosed in WO2000/021560, WO2001/052875, and WO2002/057299, which are incorporated herein by reference. In one embodiment, the inhibitor of VEGF-C or VEGF-D activity, VEGFR-3-mediated signaling or lymphangiogenesis comprises a peptide. Such a peptide to be used as an inhibitor of VEGF-C or VEGF-D activity, VEGFR-3-mediated signaling or lymphangiogenesis can be generated by random peptide synthesis, by recombinant means from random oligonucleotides, or a peptide may be selected from a phage display library,

according to the disclosure of WO2002/057299 and WO2000/021560 and methods standard in the art. Such a peptide can be identified with the aid of the VEGFR-3 extracellular domain.

[00202] In a particular embodiment, the peptide inhibitor of VEGF-C or VEGF-D activity, VEGFR-3-mediated signaling or lymphangiogenesis comprises the amino acid sequence GYWX₁X₂X₃W (SEQ ID NO: 46), wherein X₁, X₂, and X₃ comprise amino acids and wherein the peptide binds VEGFR-3, according to WO2002/057299. In a related embodiment, the peptide inhibitor comprises the amino acid sequence GYWX₁X₂X₃WX₄ (SEQ ID NO: 47), wherein X₄ comprises an amino acid. In another embodiment, either of the preceding peptides may further comprise an amino- and carboxy-terminus cysteine residue. In a particular embodiment, the peptide comprises a cyclic peptide. In an alternative embodiment, the peptide comprises a peptide dimer that binds to VEGFR-3, and in a preferred form, the peptides comprising the dimer are the same, according to WO2002/057299.

[00203] In one embodiment, the peptidomimetic inhibitor is a monomeric monocyclic peptide inhibitor or dimeric bicyclic peptide inhibitor. Preferably, such peptidomimetic inhibitors are based on the peptide sequence of exposed loops of growth factor proteins, for example, loops 1, 2, and 3 of VEGF-D. In a preferred embodiment, the peptidomimetic inhibitor comprises any one of: CASELGKSTNTFC (SEQ ID NO 5); CNEESLIC (SEQ ID NO: 6); or CISVPLTSVPC (SEQ ID NO: 7).

[00204] In one embodiment, the peptide mimetic inhibitor is prepared by the methods disclosed in WO2001/052875 and WO2002/057299. Peptides that may be used as inhibitors of VEGF-D activity, VEGFR-3—mediated signaling or lymphangiogenesis are disclosed in WO2000/021560. Such peptides include a polypeptide comprising a fragment or analog of a vertebrate VEGF-C polypeptide, wherein the polypeptide and fragment or analog are capable of binding to VEGFR-3, but do not activate signaling, and a polypeptide comprising a fragment or analog of a vertebrate VEGF-C or VEGF-D polypeptide, wherein the polypeptide and fragment or analog are capable of binding to VEGFR-3, but do not activate signaling.

[00205] The person skilled in the art will appreciate that inhibitors of VEGF-D activity, VEGFR-3-mediated signaling or lymphangiogenesis inhibitors according to

WO2002/057299 include peptides comprising the sequence $Y_1GYWLTIWGY_2$ (SEQ ID NO: 3), wherein Y_1 and Y_2 are amino acids. In one variation, the peptide is made cyclic by a bond between Y_1 and Y_2 . In a specific preferred embodiment, the peptide comprises the sequence CGYWLTIWGC (SEQ ID NO: 4). Other peptide inhibitors comprise any of the following amino acid sequences: SGYWWDTW (SEQ ID NO: 15), SCYWRDTWF (SEQ ID NO: 16), KVGWSSPDW (SEQ ID NO: 17), FVGWTKVLG (SEQ ID NO: 18), YSSMRWRH (SEQ ID NO: 19), RWRGNAYPG (SEQ ID NO: 20), SAVFRGRWL (SEQ ID NO: 21), WFSASLRFR (SEQ ID NO: 22), WQLGRNWI (SEQ ID NO: 23), VEVQITQE (SEQ ID NO: 24), AGKASSLW (SEQ ID NO: 25), RALDSALA (SEQ ID NO: 26), YGFEEAW (SEQ ID NO: 27), YGFLWGM (SEQ ID NO: 28), SRWRILG (SEQ ID NO: 29), HKWQKRQ (SEQ ID NO: 30), MDPWGGW (SEQ ID NO: 31), RKVWDIR (SEQ ID NO: 32), VWDHGV (SEQ ID NO: 33), CWQLGRNWIC (SEQ ID NO: 34), CVEVQITQEC (SEQ ID NO: 35), CAGKASSLWC (SEQ ID NO: 36), CRALDSALAC (SEQ ID NO: 37), CYGFEEAWC (SEQ ID NO: 38), CYGFLWGMC (SEQ ID NO: 39), CSRWRILGC (SEQ ID NO: 40), CHKWQKRQC (SEQ ID NO: 41), CMDPWGGWC (SEQ ID NO: 42), CRKVWDIRC (SEQ ID NO: 43), CVWDHGV (SEQ ID NO: 44), CGQMCTVWCSSGC (SEQ ID NO: 45), or conservative substitutions-variants thereof. Preferred peptides comprise these exact amino acid sequences, or sequences in which only one or only two conserved substitutions have been introduced. In another preferred variation, the peptides comprise amino- and carboxy-terminal cysteines, which permit formation of cyclic molecules and dimers and multimers. In yet another variation, peptide inhibitors include the amino acid sequence $GYWX_1X_2X_3W$ (SEQ ID NO: 46), wherein X_1 , X_2 , and X_3 comprise amino acids, the amino acid sequence $GYWX_1XZX_3WX_4$ (SEQ ID NO: 47), wherein X_4 comprises an amino acid. In still another variation, these peptides further comprise amino- and carboxy-terminal cysteine residues.

[00206] Nucleic Acid Inhibitors

[00207] In a preferred embodiment, the invention envisages use of a VEGFR-3 antisense RNA, as disclosed in WO2000/021560, to inhibit the translation of VEGFR-3–encoding mRNA to eliminate or downregulate levels of VEGFR-3. Similarly, siRNA or nucleic acids in triple helix formation could be used to reduce VEGFR-3 availability for ligand binding.

[00208] Small Molecule Inhibitors

[00209] In a preferred embodiment, the small molecule is a small molecule inhibitor of receptor tyrosine kinase activity. In a more preferred embodiment, the small molecule comprises PTK787/ ZK22854, AZP2171, ZK991, KRN633, MAZ51, sorafenib, sunitinib (SU11248), axitinib (AG013736), vandetanib (ZD6474), or 3-(indole-3-yl)-4-(3,4,5-trimethoxyphenyl)-1H-pyrrole-2,5-dione.

[00210] Inhibition of Ligand Availability for Receptor Binding

[00211] Antibody Inhibitors

[00212] According to one embodiment, inhibition of VEGF-C or VEGF-D activity, VEGFR-3-mediated signaling or lymphangiogenesis can be achieved using antibodies that specifically bind and neutralize ligands for VEGFR-3, that is, VEGF-C and/ or VEGF-D. Antibodies similar to anti-VEGFR-3 antibodies described above are contemplated. Suitable antibodies and their means for production are disclosed in WO2000/021560. The person skilled in the art will appreciate that antibodies that bind specifically to VEGF-D and may be used according to the invention include monoclonal antibodies 2F8, 4A5 (also known as VD1), 4E10, 5F12, 4H4 and 3C10 disclosed in WO2000/037025. A particularly preferred antibody is 4A5, and in particular, a humanized version thereof. In another embodiment, the chimeric or humanized antibody comprises SEQ ID NO: 56 and SEQ ID NO: 57, or the antibody comprises any one of SEQ ID NOs: 58 to 60 and any one of SEQ ID NOs: 61 to 63, as disclosed in WO2005/087177. Alternatively monoclonal antibodies that may be used according to the invention include 28AT743.288.48, MM0007-7E79, RM0007-8C35, 78902, 78923, 78939, and 90409.

[00213] Similarly, monoclonal antibodies that bind VEGF-C may be employed. The anti-VEGF-C antibodies will specifically bind to human VEGF-C or a biologically active fragment thereof, e.g. the mature fully-processed form. Such binding will partially or fully block, neutralize, reduce or antagonize VEGF-C activity. Suitable examples of such antibodies include antibodies 103, MM0006-2E65 and 193208. Further examples of such antibodies are found in US 7,208,582 and US 7,109,308.

[00214] One example of an anti-VEGF-C antibody is a monoclonal antibody that competitively inhibits the binding to VEGF-C of monoclonal anti-VEGF-C antibody 69D09 produced by hybridoma ATCC PTA-4095 or having the heavy and light chain amino acid sequences as follows:

SEQ ID NO: 48

<u>EVRLLES</u> GGG	<u>LVQPGG</u> SLRL	<u>SCAASG</u> FTFR	<u>PRAMAW</u> VRQA	<u>PGKGLE</u> WVSS
10	20	30	40	50
<u>ISAQGAS</u> YY	<u>ADSVKGR</u> FTI	<u>SRDNSK</u> NTLY	<u>LQMNSL</u> RAED	<u>TAVYYC</u> ARDL
60	70	80	90	100
<u>SVSGFG</u> PWGR	<u>GTMTIV</u> SSAS	<u>TKGPSV</u> FPLA	<u>PSSKST</u> SGGT	<u>AALGCL</u> VKDY
110	120	130	140	150
<u>FPEPVT</u> SWN	<u>SGALTSG</u> VHT	<u>FPAVLQ</u> SSGL	<u>YSLSSV</u> VTVP	<u>SSSLGT</u> QTYI
160	170	180	190	200
<u>CNVNHK</u> PSNT	<u>KVDKRVE</u> PKS	<u>CDKTHI</u> CPPC	<u>PAPELL</u> GGPS	<u>VFLFPP</u> KPKD
210	220	230	240	250
<u>TLMISRT</u> PEV	<u>TCVVVD</u> VSHE	<u>DPEVKF</u> NWYV	<u>DGVEVH</u> NAKT	<u>KPREEQ</u> YNST
260	270	280	290	300
<u>YRVVSV</u> LTVL	<u>HQDWLN</u> GKEY	<u>KCKVSN</u> KALP	<u>APIEKT</u> ISKA	<u>KGQPRE</u> PQVY
310	320	330	340	350
<u>TLPPSRE</u> EMT	<u>KNQVSL</u> TCLV	<u>KGFYPS</u> DIIV	<u>EWESNG</u> QPEN	<u>NYKITP</u> FPVLD
360	370	380	390	400
<u>SDGSFF</u> LYSK	<u>LTVDKSR</u> WQQ	<u>GNVFSC</u> SVMH	<u>EALHNY</u> HTQK	<u>SLSLSP</u> GK
410	420	430	440	448

Sequence of anti-VEGF-C antibody heavy chain

SEQ ID NO: 49

<u>SYELTQ</u> PPSS	<u>SGTPGQ</u> RVTI	<u>SCSGSS</u> SNIG	<u>RHTVSW</u> YQQV	<u>PGTAPK</u> LLIY
10	20	30	40	50
<u>SDDHRP</u> SGVP	<u>DRFSASK</u> SGT	<u>SASLTIT</u> GLQ	<u>SEDEAD</u> YYCA	<u>AWDDSL</u> NGPW
60	70	80	90	100
<u>VFGGGT</u> KLIV	<u>LGQPKA</u> PSV	<u>TLFPSP</u> SEEL	<u>QANKAT</u> LVCL	<u>ISDFYP</u> GAVT
110	120	130	140	150
<u>VAWKAD</u> SSPV	<u>KAGVET</u> TTPS	<u>KQSNNK</u> YAAS	<u>SYLSLT</u> PEQW	<u>KSHRSY</u> SCQV
160	170	180	190	200
<u>THEGST</u> VEKT	<u>VAPTECS</u>			
210	217			

Sequence of anti-VEGF-C antibody light chain

[00215] Another example of an anti-VEGF-C antibody is a monoclonal antibody that binds to the same epitope as the monoclonal anti-VEGF-C antibody 69D09 produced by hybridoma ATCC PTA-4095 or a monoclonal antibody having the heavy and light chain amino acid sequences shown above. In one embodiment, the anti-VEGF-C antibody is a

fully-human anti-VEGF-C monoclonal antibody, including but not limited to 69D09 antibody or fragment thereof. The anti-VEGF-C antibody may be a humanized antibody.

[00216] Preferably, the anti-VEGF-C antibody is a human antibody produced by deposited hybridoma ATC PTA-4095 (also referred to herein as "VGX-100") or having the heavy and light chain amino acid sequences shown above.

[00217] Alternatively, antibodies may bind proprotein convertases, enzymes responsible for processing VEGF-C and VEGF-D from their prepro-forms to their activated forms, and reduce, inhibit or neutralize such activity thereby limiting the amount of proteolytically processed ligand available for binding to VEGFR-3. Again, antibodies corresponding with anti-VEGFR-3 antibodies described above are envisaged. Such antibodies are disclosed in WO05/112971 and include neutralizing antibodies to inhibit the biological action of proprotein convertases.

[00218] Peptide Inhibitors

[00219] Inhibitors of VEGF-C or VEGF-D activity, VEGFR-3-mediated signaling or lymphangiogenesis as used in the present invention include inhibitors of proprotein convertases. As noted, one class of inhibitor of proprotein convertases comprises antibodies. Another class of inhibitor of proprotein convertases includes peptide inhibitors.

[00220] Peptide inhibitors of proprotein convertases are disclosed in WO05/112971 and include prosegments of proprotein convertases, inhibitory variants of anti-trypsin and peptidyl haloalkylketone inhibitors.

[00221] Representative inhibitory prosegments of proprotein convertases include the inhibitory prosegments of PC5A (also known as PC6A), PC5B (also known as PC6B), PACE4, PCl (also known as PC3), PC2, PC4, PC7 and Furin. A representative inhibitory variant of anti-trypsin is α -1 antitrypsin Portland, an engineered variant of naturally occurring antitrypsin that inhibits multiple proprotein convertases. Representative peptidyl halomethyl ketone inhibitors include decanoyl-Arg-Val-Lys-Arg-chloromethylketone (Dec-RVKR-CMK), decanoyl-Phe-Ala-Lys-Arg-chloromethylketone (Dec-FAKR-CMK), decanoyl-Arg-Glu-Ile-Arg-chloromethylketone (Dec-REIR-CMK), and decanoyl-Arg-Glu-Lys-Arg-chloromethylketone (Dec-REKR-CMK). These inhibitors of proprotein convertases, such as Dec-RVKR-CMK or the inhibitory prosegments of proprotein convertases, can be used to block the activation of VEGF-C and VEGF-D and thereby

inhibit VEGF-C or VEGF-D activity, VEGFR-3-mediated signaling or lymphangiogenesis induced by partially processed or fully processed VEGF-C or VEGF-D.

[00222] Soluble Receptors

[00223] According to another embodiment, VEGF-C or VEGF-D activity, VEGFR-3-mediated signaling or lymphangiogenesis can be inhibited using soluble receptors that bind VEGFR-3 ligands. Soluble receptors capable of binding VEGF-C and VEGF-D, thereby inhibiting VEGF-C or VEGF-D activity or signaling via VEGFR-3, are disclosed in WO2000/023565, WO2000/021560, WO2002/060950 and WO2005/087808. Such inhibitors of VEGF-D activity, VEGFR-3-mediated signaling or lymphangiogenesis inhibitors include soluble VEGFR-2, VEGFR-3, NRP-1, and NRP-2.

[00224] According to one embodiment, soluble receptor constructs useful for practicing the present invention are described in International Patent Application No. PCT/US02/01784, filed January 22, 2002 (WO 2002/060950, published August 8, 2002), incorporated here by reference in its entirety, and in International Patent Application No. PCT/US2005/007741, filed March 7, 2005 (WO 2005/087808, published September 22, 2005), incorporated here by reference in its entirety. As described therein, the receptor tyrosine kinases that bind the VEGF or PDGF family of ligands include an extracellular domain, a hydrophobic transmembrane domain, and an intracellular domain. The extracellular domain can be used as a ligand trap by formulating it as a soluble formulation, optionally fused with an additional component, such as polyethylene glycol or an antibody constant region to improve serum half-life.

[00225] The complete ECD of PDGFRs and VEGFRs is not required for ligand (growth factor) binding. The ECD of VEGFR-1 (R-1) and VEGFR-2 (R-2) consists of seven Ig-like domains and the ECD of VEGFR-3 (R-3) has six intact Ig-like domains--D5 of R-3 is cleaved post-translationally into disulfide linked subunits leaving VEGFR-3. Veikkola, T., *et al.*, *Cancer Res.* 60:203-212 (2000). In general, receptor fragments of at least the first three Ig-like domains for this family are sufficient to bind ligand. The PDGFRs have five Ig-like domains.

[00226] Table 1A: Immunoglobulin-like domains for VEGFR-2 and VEGFR-3

	R-2	R-2	R-3	R-3
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	SEQ ID NO: 50 positions	SEQ ID NO: 51 positions	SEQ ID NO: 54 positions	SEQ ID NO: 55 positions
D1	145-316	48-105	158-364	47-115
D2	436-610	145-203	479-649	154-210
D3	724-931	241-310	761-961	248-314
D4	1039-1204	346-401	1070-1228	351-403
D5	1321-1600	440-533	1340-1633	441-538
D6	1699-1936	566-645	1739-1990	574-657
D7	2050-2221	683-740	2102-2275	695-752

[00227] Soluble receptor constructs for use as a ligand trap for VEGF-C or -D preferably comprise at least one Ig-like domain of a VEGFR as described in Table 2, to as many as seven. The construct optionally will include sequence before the most N-terminally positioned Ig-like domain, optionally will include sequence beyond the most C-terminally positioned Ig-like domain, and optionally will include sequence between the Ig-domains as well. Variants, *e.g.*, with one or more amino acid substitutions, additions, or deletions of an amino acid residue, are also contemplated. Likewise, chimeras, *e.g.*, combinations of Ig-like domains from different receptors, are contemplated. In some embodiments, the soluble receptor comprises a receptor fragment comprising at least the first three Ig-like domains of a receptor tyrosine kinase.

[00228] In one embodiment, referring specifically to the VEGFR-3 sequence, soluble receptors are contemplated in which the soluble receptor polypeptide comprises a portion of a mammalian, preferably human, VEGFR-3 extracellular domain (EC) wherein the portion binds to at least one VEGFR-3 ligand and comprises at least the first, second and third Ig-like domains of the VEGFR-3-EC, and wherein the polypeptide lacks VEGFR-3 Ig-like domains 4-7 and preferably any transmembrane domain.

[00229] In another embodiment, referring specifically to the VEGFR-3 sequence, soluble receptors are contemplated in which the soluble receptor polypeptide comprises an amino acid sequence at least 90, 91, 92, 93, 94, or 95% identical to a VEGFR-3 fragment,

wherein the VEGFR-3 fragment comprises an amino acid sequence consisting of a portion of SEQ ID NO: 53, wherein the carboxy-terminal residue of the fragment is selected from the group consisting of positions 211 to 247 of SEQ ID NO: 53, and wherein the fragment and the polypeptide bind VEGF-C or VEGF-D. In some variations, the fragment has an amino terminal amino acid selected from the group consisting of positions of 1 to 47 of SEQ ID NO: 53. In some variations, the VEGFR-3 fragment used to make the soluble receptor has an amino terminal residue selected from the group consisting of positions 1 to 47 of SEQ ID NO: 53, and a carboxy-terminal residue selected from the group consisting of positions 226 to 775 of SEQ ID NO: 53, wherein VEGFR-3 fragment binds at least one of VEGF-C and VEGF-D. Specific peptides include a fragment of R-3 defined by positions 1-226, positions 1-229, and positions 1-329, positions 47-224, positions 47-225, positions 47-226, positions 47-227, positions 47-228, positions 47-229, positions 47-230, positions 47-231, positions 47-232, positions 47-236, positions 47-240, positions 47-245, positions 47-314, positions 47-210, and positions 47-247.

[00230] Soluble receptors that bind VEGF-C and -D can also be constructed from a VEGFR-2 amino acid sequence. Referring to the human VEGFR-2 sequence (SEQ ID NO: 51), exemplary R2 fragments for use in a soluble receptor have an amino terminal residue selected from the group consisting of positions 1 to 118 of SEQ ID NO: 51, and a carboxy-terminal residue selected from the group consisting of positions 326 to 764 of SEQ ID NO: 51, wherein VEGFR-2 fragment binds at least one of VEGF-C and VEGF-D (and may also bind VEGF-A or other VEGF's). In some variations, the amino terminal residue from the VEGFR-2 sequence is selected from the group consisting of positions 1 to 192 of SEQ ID NO: 51, and the carboxy terminal residue is selected from the group consisting of positions 393 to 764 of SEQ ID NO: 51. In still other variations, the amino-terminal residue is selected from the group consisting of positions 1 to 48 of SEQ ID NO: 51, and a carboxy terminal residue selected from the group consisting of positions 214 to 764 of SEQ ID NO: 51. In some embodiments, the soluble receptor based on VEGFR-2 comprises a VEGFR-2 sequence selected from positions 24-326, positions 118-326, positions 118-220, positions 118-226, and positions 118-232, positions 106-240, positions 112-234, positions 114-220, positions 115-220, positions 116-222, positions 117-220, positions 118-221, positions 118-222, positions 118-223, positions 118-224, positions 118-228, positions 48-203, positions 145-310 and positions 48-310.

[00231] As described in WO 2005/087808, these or other exemplary soluble receptor constructs can be combined to make multivalent binding constructs. The receptor fragments, binding constructs, and other peptide molecules may be fused to heterologous peptides to confer various properties, *e.g.*, increased solubility, modulation of clearance, targeting to particular cell or tissue types. In some embodiments, the receptor fragment is linked to a Fc domain of IgG or other immunoglobulin. In some embodiments, a receptor fragment is fused to alkaline phosphatase (AP). Methods for making Fc or AP fusion constructs are found in WO 02/060950.

[00232] Nucleic Acid Inhibitors

[00233] In another embodiment of the invention, antisense oligonucleotides are used as inhibitors of proprotein convertases. The antisense oligonucleotides preferably inhibit expression of proprotein convertases by inhibiting transcription or translation of proprotein convertases. In a further embodiment, the antagonizing agent is small interfering RNAs (siRNA, also known as RNAi, RNA interference nucleic acids). Also contemplated are methods of inhibiting the target gene expression or target protein function utilizing ribozymes and triplex-forming nucleic acid molecules.

[00234] Similarly, in a related embodiment, antisense, siRNA and ribozyme inhibitors directed to VEGF-C and/or VEGF-D are included as inhibitors of VEGF-C or VEGF-D activity, VEGFR-3-mediated signaling or lymphangiogenesis exerting their effects by reducing transcription and/ or translation of VEGF-C and VEGF-D.

[00235] Peptide and Peptide Mimetic Inhibitors

[00236] According to one embodiment, the inhibitor to be used in the invention comprises a peptide that reduces the availability of ligand to bind to VEGFR-3. Such a peptide can be generated by random peptide synthesis, by recombinant means from random oligonucleotides, or a peptide may be selected from a phage display library by methods standard in the art. In a particular embodiment, the peptide will be derived from VEGFR-3 or VEGFR-2 and will bind specifically to VEGF-C or VEGF-D such that the ligand available for binding to native VEGFR-3 is reduced. Such a peptide may be identified with the aid of the VEGF-C or VEGF-D.

[00237] Small Molecule Inhibitors

[00238] In one embodiment, the small molecule inhibitor is a small molecule inhibitor of a proprotein convertase. In a particular embodiment, the proprotein convertase is furin and the small molecule comprises B3 (CCG8294, naphthofluorescein disodium) or a derivative of 2,5-dideoxystreptamine.

[00239] Tyrosine Kinase Inhibitors

[00240] In another embodiment, the anti-lymphangiogenic agent is a tyrosine kinase inhibitor that inhibits VEGFR-3 activity, which means an inhibitor of receptor tyrosine kinase activity that selectively or non-selectively reduces the tyrosine kinase activity of a VEGFR-3 receptor. Such an inhibitor generally reduces VEGFR-3 tyrosine kinase activity without significantly effecting the expression of VEGFR-3 and without effecting other VEGFR-3 activities such as ligand-binding capacity. A VEGFR-3 kinase inhibitor can be a molecule that directly binds the VEGFR-3 catalytic domain, for example, an ATP analog. A VEGFR-3 kinase inhibitor can bind the VEGFR-3 catalytic domain through one or more hydrogen bonds similar to those anchoring the adenine moiety of ATP to VEGFR-3 (Engl et al., J. Biol. Chem. 271:26157-26164 (1996); Tong et al., Nature Struct. Biol. 4:311-316 (1997); and Wilson et al., Chem. Biol. 4:423-431 (1997)). A VEGFR-3 kinase inhibitor also can bind the hydrophobic pocket adjacent to the adenine binding site (Mohamedi et al., EMBO J. 17:5896-5904 (1998); Tong et al., supra, 1997; and Wilson et al., supra, 1997).

[00241] VEGFR-3 kinase inhibitors useful in the invention include specific VEGFR-3 kinase inhibitors such as indolinones that differentially block VEGF-C and VEGF-D induced VEGFR-3 kinase activity compared to that of VEGFR-2. Such specific VEGFR-3 kinase inhibitors, for example, MAE106 and MAZ51 can be prepared as described in Kirkin et al., Eur. J. Biochem. 268:5530-5540 (2001). Additional VEGFR-3 kinase inhibitors, including specific, selective and non-selective inhibitors, are known in the art or can be identified using one of a number of well known methods for assaying for receptor tyrosine kinase inhibition.

[00242] As an example, a VEGFR-3 kinase inhibitor can be identified using a well known ELISA assay to analyze production of phosphorylated tyrosine as described, for example in Hennequin et al., J. Med. Chem. 42:5369-5389 (1999) and Wedge et al., Cancer Res. 60:970-975 (2000). Such an assay can be used to screen for molecules that inhibit VEGFR-3 in preference to other vascular endothelial growth factor receptors such as

VEGFR-1 and in preference to unrelated tyrosine kinases such as fibroblast growth factor receptor1 (FGFR1). Briefly, molecules to be screened can be incubated for 20 minutes at room temperature with a cytoplasmic receptor domain in a HEPES (pH 7.5) buffered solution containing 10 mM MnCl_2 and 2 μM ATP in 96-well plates coated with a poly(Glu, Ala, Tyr) 6:3:1 random copolymer substrate (SIGMA; St. Louis, Mo.). Phosphorylated tyrosine can be detected by sequential incubation with mouse IgG anti-phosphotyrosine antibody (Upstate Biotechnology; Lake Placid, N.Y.), a horseradish peroxidase-linked sheep anti-mouse immunoglobulin antibody (Amersham; Piscataway, N.J.), and 2,2'azino-bis (3-ethylbenzthiazoline-6-sulfonic acid) (Roche Molecular Biochemicals, Indianapolis, Ind.). In such an in vitro kinase assay, the source of VEGFR-3 can be, for example, a lysate prepared from an insect cell infected with recombinant baculovirus containing a cytoplasmic receptor domain, for example, encoding residues 798 to 1363 of human VEGFR-3.

[00243] The term VEGFR-3 kinase inhibitor, as used herein, encompasses specific, selective and non-selective inhibitors of VEGFR-3. A specific VEGFR-3 kinase inhibitor reduces the tyrosine kinase activity of VEGFR-3 in preference to the activity of most or all unrelated receptor tyrosine kinases such as FGFR1 and in preference to the activity of the vascular endothelial growth factor receptors, VEGFR-1 and VEGFR-2. A selective VEGFR-3 kinase inhibitor reduces the tyrosine kinase activity of VEGFR-3 in preference to most or all unrelated receptor tyrosine kinases such as FGFR1. Such a selective VEGFR-3 inhibitor can have an IC_{50} for inhibition of an isolated VEGFR-3 cytoplasmic domain that is, for example, at least 10-fold less than the IC_{50} for both VEGFR-1 and VEGFR-2. In particular embodiments, the invention provides a selective VEGFR-3 kinase inhibitor having an IC_{50} for inhibition of an isolated VEGFR-3 cytoplasmic domain that is at least 20-fold, 30-fold, 40-fold, 50-fold, 100-fold, 200-fold, 300-fold, 400-fold or 500-fold less than the IC_{50} for both VEGFR-1 and VEGFR-2. In contrast, a non-selective VEGFR-3 kinase inhibitor reduces the tyrosine kinase activity of VEGFR-1 or VEGFR-2 or both to a similar extent as VEGFR-3.

[00244] Antibody Inhibitors Affecting Ligand—Receptor Complex

[00245] In one embodiment, the invention includes use of bispecific antibodies, as described above, as inhibitors of VEGF-C or VEGF-D activity, VEGFR-3—mediated signaling or lymphangiogenesis, specifically inhibiting ligand-receptor complexes.

[00246] Suitable antibodies and their means for production are disclosed in WO2000/021560 and include a bispecific antibody that binds specifically to an epitope or epitopes derived from a VEGFR-3-(VEGFR-3 ligand) complex (receptor-ligand complex) and blocks VEGFR-3 signaling.

[00247] Inhibition of Co-Receptor Interaction

[00248] Antibody Inhibitors Affecting Co-Receptors of VEGFR-3

[00249] In a further embodiment, inhibitors of VEGF-C or VEGF-D activity, VEGFR-3-mediated signaling or lymphangiogenesis include antibodies, as described above, that bind specifically to and reduce, inhibit or neutralize co-receptor binding to VEGFR-3. Such antibodies may be directed to a co-receptor, a ligand-co-receptor binary complex, a co-receptor-receptor binary complex, or a ligand—co-receptor-receptor ternary complex. Co-receptors include NRP-1 and NRP-2. The person skilled in the art will understand that monoclonal antibodies that specifically bind NRP-1 or NRP-2 and may be used according to the invention include antibodies 1B3, 3G6-2C5, AD5-17F6, 446915, 446921, 130603, 130604, 96009, 3B8, 54, 257103, 257107, A-12, and C-9. Alternatively, a bispecific antibody which specifically binds to NRP-2 receptor and a VEGF-C polypeptide, as disclosed in WO2003/029814, may be used according to the invention.

[00250] Peptide Inhibitors Affecting Co-Receptors of VEGFR-3

[00251] In another embodiment, a peptide inhibitor comprising a peptide dimer may target one or more receptors and/ or co-receptors. Co-receptors include NRP-1 and NRP-2. As disclosed in WO2002/057299, in a particular embodiment, the peptide dimer comprises one peptide that binds VEGFR-3 and a second peptide that binds to any one of VEGFR-1, VEGFR-2, NRP-1, or NRP-2.

[00252] Small Molecule and Nucleic Acid Inhibitors Affecting Co-Receptors of VEGFR-3

[00253] According to the present invention, it is also envisaged that small molecules, antisense molecules, siRNA and ribozymes, as described above, can be utilized as inhibitors of VEGF-D activity, VEGFR-3—mediated signaling or lymphangiogenesis by targeting co-receptors that interact with VEGFR-3. Such co-receptors include NRP-1 and NRP-2.

[00254] Inhibition of Downstream Signaling

[00255] Alternatively, an inhibitor of VEGF-C or VEGF-D activity, VEGFR-3—mediated signaling or lymphangiogenesis according to any of the foregoing descriptions may disrupt downstream intracellular VEGFR-3 signaling, as disclosed in WO2000/021560.

[00256] Therapeutic Uses of the Anti-Lymphangiogenic Agents

[00257] In yet another embodiment, the invention provides numerous methods of using the anti-lymphangiogenic agents described herein. Generally speaking, the anti-lymphangiogenic agents described herein are useful for inhibiting cellular processes that are mediated through signal transduction through VEGFR-2 or VEGFR-3 for prophylaxis or therapy of dry eye disease.

[00258] Thus, in one variation, described herein is a method of prophylaxis or therapy for dry eye disease comprising administering to a subject in need of prophylaxis or therapy for dry eye disease a composition comprising an anti-lymphangiogenic agent. Preferably, the amount of the anti-lymphangiogenic agent employed is effective to inhibit the binding of VEGF-C and/or VEGF-D ligand to VEGFR-3 or the stimulatory effect of VEGF-C and/or VEGF-D on VEGFR-3.

[00259] Dose response studies permit accurate determination of a proper quantity of anti-lymphangiogenic agent to employ. Effective quantities can be estimated, for example, from measurements of the binding affinity of a polypeptide for a target receptor, of the quantity of receptor present on target cells, of the expected dilution volume (e.g., patient weight and blood volume for in vivo embodiments), and of polypeptide clearance rates. For example, existing literature regarding dosing of anti-VEGF-C antibodies known also provides guidance for dosing of the anti-lymphangiogenic agents described herein.

[00260] The anti-lymphangiogenic agent described herein can be administered purely as a prophylactic treatment to prevent dry eye disease in subjects at risk for developing dry eye disease, or as a therapeutic treatment to subjects afflicted with dry eye disease, for the purpose of inhibiting lymphangiogenesis in the eye of a subject in need thereof.

[00261] Subjects who are at risk for developing dry eye disease include subjects considering or who have already undergone refractive surgery; subjects over the age of

sixty five; female subjects experiencing hormonal changes brought on by pregnancy, lactation, oral contraceptives, menstruation and post-menopause; subjects afflicted with rheumatoid arthritis, diabetes, thyroid abnormalities, asthma, cataracts, glaucoma or lupus; subjects taking medication(s) that decrease the body's ability to produce lubricating tears such as decongestants, antidepressants, antihistamines, blood pressure medication, oral contraceptives, diuretics, ulcer medication, tranquilizers and beta blockers; subjects that wear contact lenses; subjects exposed to environmental conditions that increase tear evaporation such as smoke, fluorescent light, air pollution, wind, heat, air conditioning and dry climates; and subjects that are heavy computer users (i.e., subjects that spend hours staring at computer displays that ignore their normal blinking process).

[00262] In one embodiment, described herein is a method of inhibiting dry eye disease in a subject at risk for developing dry eye disease comprising identifying a subject as being at risk for developing dry eye disease and administering an anti-lymphangiogenic agent to the subject. The amount of the anti-lymphangiogenic agent administered to the subject is preferably in an amount effective to inhibit the development of dry eye disease in the subject.

[00263] In another embodiment, described herein is a method of selecting a therapeutic regimen for a subject in need thereof comprising screening a subject for one or more symptoms of dry eye disease and prescribing for the subject administration of a composition comprising an anti-lymphangiogenic agent described herein. In another embodiment, described herein is a method of treating a subject affected with dry eye disease comprising identifying a subject as having one or more symptoms of dry eye disease and administering a composition comprising an anti-lymphangiogenic agent to the subject. Symptoms associated with dry eye disease include, but are not limited to, foreign body sensation, burning, itching, irritation, redness, eye pain, blurred vision, degraded vision, excessive tearing, dryness and a sandygritty eye irritation that gets worse as the day goes on.

[00264] In some embodiments, the methods described herein do not include administering an anti-lymphangiogenic agent as described herein to a subject that has undergone corneal transplant surgery.

[00265] In some embodiments, the methods described herein further comprise prescribing (or administering) a standard of care regimen for the treatment of dry eye disease. In the context of methods described herein, "standard of care" refers to a treatment that is generally accepted by clinicians for a certain type of patient diagnosed with a type of illness. For dry eye disease, for example, an aspect of the invention is to improve standard of care therapy with co-therapy with anti-lymphangiogenic agents described herein that inhibit lymphangiogenesis. Exemplary standard of care regimens for dry eye disease include, but are not limited to, eyelid hygiene, topical antibiotics (including, but not limited to erythromycin or bacitracin ointments), oral tetracyclines (tetracycline, doxycycline, or minocycline), anti-inflammatory compounds (including, but not limited to, cyclosporine) and corticosteroids.

[00266] Also contemplated are methods of treating a subject with dry eye disease that is hypo-responsive to a standard of care regimen for the treatment of dry eye disease comprising administering an anti-lymphangiogenic agent to the subject in an amount effective to treat dry eye disease.

[00267] In a preferred embodiment, the mammalian subject is a human subject. Practice of methods of the invention in other mammalian subjects, especially mammals that are conventionally used as models for demonstrating therapeutic efficacy in humans (e.g., primate, porcine, canine, or rabbit animals), is also contemplated.

[00268] Combination Therapy

[00269] Combination therapy embodiments of the invention include products and methods. Exemplary combination products include two or more agents formulated as a single composition or packaged together in separate compositions, e.g., as a unit dose package or kit. Exemplary combination methods include prescribing for administration, or administration of two or more agents simultaneously or in tandem.

[00270] A combination of an anti-lymphangiogenic agent with one or more additional therapeutic agents in the methods described herein may reduce the amount of either agent needed as a therapeutically effective dosage, and thereby reduce any negative side effects the agents may induce *in vivo*. Combination therapy preferably results in improved efficiency compared to either agent alone. Additional therapeutics or second agents contemplated for use in combination with an anti-lymphangiogenic agent described herein

include a VEGFR-2 inhibitor product, a tyrosine kinase inhibitor that inhibits VEGFR-2 and/or VEGFR-3 signaling, an anti-inflammatory agent; an immunosuppressive agent (e.g., cyclosporine), an angiogenesis inhibitor, an antibiotic, and a standard of care regimen for the treatment of dry eye disease.

[00271] A. Standard of Care for Regimen for Treatment of Dry Eye Disease

[00272] In one embodiment, methods described herein optionally comprise administering a standard of care therapeutic to the subject. In some embodiments, the standard of care therapeutic and the anti-lymphangiogenic agent are co-administered in a single composition. In other embodiments, the standard of care therapeutic is administered as a separate composition from the anti-lymphangiogenic agent.

[00273] In the context of methods of the invention, "standard of care" refers to a treatment that is generally accepted by clinicians for a certain type of patient diagnosed with a type of illness. For dry eye disease, for example, an aspect of the invention is to improve standard of care therapy with co-therapy with anti-lymphangiogenic agents described herein that inhibit lymphangiogenesis. Exemplary standard of care regimens for dry eye disease include, but are not limited to, eyelid hygiene, topical antibiotics (including, but not limited to erythromycin or bacitracin ointments), oral tetracyclines (tetracycline, doxycycline, or minocycline), anti-inflammatory compounds (including, but not limited to, cyclosporine) and corticosteroids.

[00274] B. VEGFR-2 Inhibitor Product(s)

[00275] In one embodiment, methods described herein optionally comprise administering a VEGFR-2 inhibitor product to the subject. In some embodiments, the VEGFR-2 inhibitor product and the anti-lymphangiogenesis agent are co-administered in a single composition. In other embodiments, the VEGFR-2 inhibitor product is administered as a separate composition from the anti-lymphangiogenesis agent. cDNA and amino acid sequences of human VEGFR-2 are set forth in SEQ ID NOs: 50 and 51, respectively. The "VEGFR-2 inhibitor product" can be any molecule that acts with specificity to reduce VEGF-C/VEGFR-2, VEGF-D/VEGFR-2 or VEGF/VEGFR-2 interactions, e.g., by blocking VEGF-C or VEGF-D binding to VEGFR-2, by blocking VEGF binding to VEGFR-2 or by reducing expression of VEGFR-2. In one embodiment, the VEGFR-2 inhibitor inhibits VEGF-C and VEGF-D binding to VEGFR-2. In another embodiment, the

VEGFR-2 inhibitor inhibits binding of VEGF to VEGFR-2. The VEGFR-2 inhibitor can be a polypeptide comprising a soluble VEGFR-2 extracellular domain fragment (amino acids 20-764 of SEQ ID NO: 51) that binds VEGF or VEGF-C or VEGF-D; VEGFR-2 anti-sense polynucleotides or short-interfering RNA (siRNA); anti-VEGFR-2 antibodies; a VEGFR-2 inhibitor polypeptide comprising an antigen-binding fragment of an anti-VEGFR-2 antibody that inhibits binding between VEGFR-2 and VEGF or VEGF-C or VEGF-D; an aptamer that inhibits binding between VEGFR-2 and VEGF; an aptamer that inhibits binding between VEGFR-2 and VEGF-C; an aptamer that inhibits binding between VEGFR-2 and VEGF-D; or a fusion protein comprising the soluble VEGFR-2 polypeptide fragment fused to an immunoglobulin constant region fragment (Fc). In some embodiments, a VEGFR-2 polypeptide fragment is fused to alkaline phosphatase (AP). Methods for making Fc or AP fusion constructs are found in WO 02/060950, the disclosure of which is incorporated herein by reference in its entirety.

[00276] A number of VEGFR-2 antibodies have been described, see for example, U.S. Patent No. 6,334,339 and U.S. Patent Publication Nos. 2002/0064528, 2005/0214860, and 2005/0234225 (all of which are incorporated herein by reference in their entireties). Antibodies are useful for modulating VEGFR-2/VEGF interactions due to the ability to easily generate antibodies with relative specificity, and due to the continued improvements in technologies for adopting antibodies to human therapy. Thus, the invention contemplates use of antibodies (e.g., monoclonal and polyclonal antibodies, single chain antibodies, chimeric antibodies, bifunctional/bispecific antibodies, humanized antibodies, human antibodies, and complementary determining region (CDR)-grafted antibodies, including compounds which include CDR sequences which specifically recognize a polypeptide of the invention) specific for VEGFR-2. Human antibodies can also be produced using various techniques known in the art, including phage display libraries [Hoogenboom and Winter, *J. Mol. Biol.*, 227:381 (1991); Marks et al., *J. Mol. Biol.*, 222:581 (1991)]. The techniques of Cole et al. and Boerner et al. are also available for the preparation of human monoclonal antibodies (Cole et al., *Monoclonal Antibodies and Cancer Therapy*, Alan R. Liss, p. 77 (1985) and Boerner et al., *J. Immunol.*, 147(1):86-95 (1991)). Similarly, human antibodies can be made by introducing of human immunoglobulin loci into transgenic animals, e.g., mice in which the endogenous immunoglobulin genes have been partially or completely inactivated. Upon challenge,

human antibody production is observed, which closely resembles that seen in humans in all respects, including gene rearrangement, assembly, and antibody repertoire. This approach is described, for example, in U.S. Pat. Nos. 5,545,807; 5,545,806; 5,569,825; 5,625,126; 5,633,425; 5,661,016, and in the following scientific publications: Marks et al., *Bio/Technology* 10, 779-783 (1992); Lonberg et al., *Nature* 368 856-859 (1994); Morrison, *Nature* 368, 812-13 (1994); Fishwild et al., *Nature Biotechnology* 14, 845-51 (1996); Neuberger, *Nature Biotechnology* 14, 826 (1996); Lonberg and Huszar, *Intern. Rev. Immunol.* 13:65-93 (1995).

[00277] VEGFR-2 antibody fragments, including Fab, Fab', F(ab')₂, Fv, scFv, are also contemplated. The term "specific for," when used to describe antibodies of the invention, indicates that the variable regions of the antibodies of the invention recognize and bind the polypeptide of interest exclusively (i.e., able to distinguish the polypeptides of interest from other known polypeptides of the same family, by virtue of measurable differences in binding affinity, despite the possible existence of localized sequence identity, homology, or similarity between family members). It will be understood that specific antibodies may also interact with other proteins (for example, *S. aureus* protein A or other antibodies in ELISA techniques) through interactions with sequences outside the variable region of the antibodies, and in particular, in the constant region of the molecule. Screening assays to determine binding specificity of an antibody of the invention are well known and routinely practiced in the art. For a comprehensive discussion of such assays, see Harlow et al. (Eds), *Antibodies A Laboratory Manual*; Cold Spring Harbor Laboratory; Cold Spring Harbor, NY (1988), Chapter 6. Antibodies of the invention can be produced using any method well known and routinely practiced in the art.

[00278] In another embodiment, methods described herein optionally comprise administering an anti-sense VEGFR-2 nucleic acid molecule to the subject. Anti-sense VEGFR-2 nucleic acid molecules are useful therapeutically to inhibit the translation of VEGFR-2-encoding mRNAs where the therapeutic objective involves a desire to eliminate the presence of VEGFR-2 or to downregulate its levels. VEGFR-2 anti-sense RNA, for example, could be useful as a VEGFR-2 antagonizing agent in the treatment of diseases in which VEGFR-2 is involved as a causative agent, e.g., inflammatory diseases.

[00279] An antisense nucleic acid comprises a nucleotide sequence that is complementary to a "sense" nucleic acid encoding a protein (e.g., complementary to the

coding strand of a double-stranded cDNA molecule or complementary to an mRNA sequence). (See, e.g., the VEGFR-3 cDNA sequence of SEQ ID NO: 9). Methods for designing and optimizing antisense nucleotides are described in Lima *et al.*, (*J Biol Chem* ;272:626-38. 1997) and Kurreck *et al.*, (*Nucleic Acids Res.* ;30:1911-8. 2002). In specific aspects, antisense nucleic acid molecules are provided that comprise a sequence complementary to at least about 10, 25, 50, 100, 250 or 500 nucleotides or an entire VEGFR-2 coding strand, or to only a portion thereof. Nucleic acid molecules encoding fragments, homologs, derivatives and analogs of a VEGFR-2 or antisense nucleic acids complementary to a VEGFR-2 nucleic acid sequence are also contemplated.

[00280] In one embodiment, an antisense nucleic acid molecule is antisense to a “coding region” of the coding strand of a nucleotide sequence encoding a VEGFR-2 protein. The term “coding region” refers to the region of the nucleotide sequence comprising codons which are translated into amino acid residues. In another embodiment, the antisense nucleic acid molecule is antisense to a “conceding region” of the coding strand of a nucleotide sequence encoding the VEGFR-2. The term “conceding region” refers to 5' and 3' sequences which flank the coding region that are not translated into amino acids (i.e., also referred to as 5' and 3' untranslated regions).

[00281] Antisense nucleic acids of the invention can be designed according to the rules of Watson and Crick or Hoogsteen base pairing. The antisense nucleic acid molecule can be complementary to the entire coding region of VEGFR-2 mRNA, but more preferably is an oligonucleotide that is antisense to only a portion of the coding or noncoding region of VEGFR-2 mRNA. An antisense oligonucleotide can be, for example, about 5, 10, 15, 20, 25, 30, 35, 40, 45, or 50 nucleotides in length. An antisense nucleic acid of the invention can be constructed using chemical synthesis or enzymatic ligation reactions using procedures known in the art. For example, an antisense nucleic acid (e.g., an antisense oligonucleotide) can be chemically synthesized using naturally occurring nucleotides or variously modified nucleotides designed to increase the biological stability of the molecules or to increase the physical stability of the duplex formed between the antisense and sense nucleic acids (e.g., phosphorothioate derivatives and acridine substituted nucleotides can be used).

[00282] Examples of modified nucleotides that can be used to generate the antisense nucleic acid include: 5-fluorouracil, 5-bromouracil, 5-chlorouracil, 5-iodouracil,

hypoxanthine, xanthine, 4-acetylcytosine, 5-(carboxyhydroxymethyl) uracil, 5-carboxymethylaminomethyl-2-thiouridine, 5-carboxymethylaminomethyluracil, dihydrouracil, beta-D-galactosylqueosine, inosine, N6-isopentenyladenine, 1-methylguanine, 1-methylinosine, 2,2-dimethylguanine, 2-methyladenine, 2-methylguanine, 3-methylcytosine, 5-methylcytosine, N6-adenine, 7-methylguanine, 5-methylaminomethyluracil, 5-methoxyaminomethyl-2-thiouracil, beta-D-mannosylqueosine, 5'-methoxycarboxymethyluracil, 5-methoxyuracil, 2-methylthio-N6-isopentenyladenine, uracil-5-oxyacetic acid (v), wybutoxosine, pseudouracil, queosine, 2-thiocytosine, 5-methyl-2-thiouracil, 2-thiouracil, 4-thiouracil, 5-methyluracil, uracil-5-oxyacetic acid methylester, uracil-5-oxyacetic acid (v), 5-methyl-2-thiouracil, 3-(3-amino-3-N-2-carboxypropyl) uracil, (acp3)w, and 2,6-diaminopurine. Alternatively, the antisense nucleic acid can be produced biologically using an expression vector into which a nucleic acid has been subcloned in an antisense orientation.

[00283] The antisense nucleic acid molecules of the invention are typically administered to a subject or generated *in situ* such that they hybridize with or bind to cellular mRNA and/or genomic DNA encoding VEGFR-2 to thereby inhibit expression of the protein (e.g., by inhibiting transcription and/or translation). The hybridization can be by conventional nucleotide complementarity to form a stable duplex, or, for example, in the case of an antisense nucleic acid molecule that binds to DNA duplexes, through specific interactions in the major groove of the double helix.

[00284] In still another embodiment, VEGFR-2 RNA can be used for induction of RNA interference (RNAi), using double stranded (dsRNA) (Fire *et al.*, *Nature* 391: 806-811, 1998) or short-interfering RNA (siRNA) sequences (Yu *et al.*, *Proc Natl Acad Sci U S A.* 99:6047-52, 2002). "RNAi" is the process by which dsRNA induces homology-dependent degradation of complimentary mRNA. In one embodiment, a nucleic acid molecule of the invention is hybridized by complementary base pairing with a "sense" ribonucleic acid of the invention to form the double stranded RNA. The dsRNA antisense and sense nucleic acid molecules are provided that correspond to at least about 20, 25, 50, 100, 250 or 500 nucleotides or an entire VEGFR-2 coding strand, or to only a portion thereof. In an alternative embodiment, the siRNAs are 30 nucleotides or less in length, and more preferably 21- to 23-nucleotides, with characteristic 2- to 3- nucleotide 3'-overhanging ends, which are generated by ribonuclease III cleavage from longer dsRNAs. See e.g.

Tuschl T. (*Nat Biotechnol.* 20:446-48. 2002). Preparation and use of RNAi compounds is described in U.S. Patent Publication No. 2004/0023390, the disclosure of which is incorporated herein by reference in its entirety.

[00285] Intracellular transcription of small RNA molecules can be achieved by cloning the siRNA templates into RNA polymerase III (Pol III) transcription units, which normally encode the small nuclear RNA (snRNA) U6 or the human RNase P RNA H1. Two approaches can be used to express siRNAs: in one embodiment, sense and antisense strands constituting the siRNA duplex are transcribed by individual promoters (Lee, *et al. Nat. Biotechnol.* 20, 500-505. 2002); in an alternative embodiment, siRNAs are expressed as stem-loop hairpin RNA structures that give rise to siRNAs after intracellular processing (Brummelkamp *et al. Science* 296:550-553. 2002) (incorporated herein by reference).

[00286] The dsRNA/siRNA is most commonly administered by annealing sense and antisense RNA strands *in vitro* before delivery to the organism. In an alternate embodiment, RNAi may be carried out by administering sense and antisense nucleic acids of the invention in the same solution without annealing prior to administration, and may even be performed by administering the nucleic acids in separate vehicles within a very close timeframe. Nucleic acid molecules encoding fragments, homologs, derivatives and analogs of a VEGFR-2 or antisense nucleic acids complementary to a mVEGFR-2 nucleic acid sequence are also contemplated.

[00287] Aptamers are another nucleic acid based method for interfering with the interaction of VEGFR-2 or VEGFR-3 and their respective ligands VEGF-A and/or VEGF-C and/or VEGF-D. Aptamers are DNA or RNA molecules that have been selected from random pools based on their ability to bind other molecules. Aptamers have been selected which bind nucleic acid, proteins, small organic compounds, and even entire organisms. Methods and compositions for identifying and making aptamers are known to those of skill in the art and are described e.g., in U.S. Patent No. 5,840,867 and U.S. Patent No. 5,582,981 each incorporated herein by reference.

[00288] Recent advances in the field of combinatorial sciences have identified short polymer sequences with high affinity and specificity to a given target. For example, SELEX technology has been used to identify DNA and RNA aptamers with binding properties that rival mammalian antibodies, the field of immunology has generated and

isolated antibodies or antibody fragments which bind to a myriad of compounds and phage display has been utilized to discover new peptide sequences with very favorable binding properties. Based on the success of these molecular evolution techniques, it is certain that molecules can be created which bind to any target molecule. A loop structure is often involved with providing the desired binding attributes as in the case of: aptamers which often utilize hairpin loops created from short regions without complimentary base pairing, naturally derived antibodies that utilize combinatorial arrangement of looped hyper-variable regions and new phage display libraries utilizing cyclic peptides that have shown improved results when compared to linear peptide phage display results. Thus, sufficient evidence has been generated to suggest that high affinity ligands can be created and identified by combinatorial molecular evolution techniques. For the present invention, molecular evolution techniques can be used to isolate binding constructs specific for ligands described herein. For more on aptamers, See generally, Gold, L., Singer, B., He, Y.Y., Brody, E., "Aptamers As Therapeutic And Diagnostic Agents," J. Biotechnol. 74:5-13 (2000). Relevant techniques for generating aptamers may be found in U.S. Pat. No. 6,699,843, which is incorporated by reference in its entirety.

[00289] In some embodiments, the aptamer may be generated by preparing a library of nucleic acids; contacting the library of nucleic acids with a growth factor, wherein nucleic acids having greater binding affinity for the growth factor (relative to other library nucleic acids) are selected and amplified to yield a mixture of nucleic acids enriched for nucleic acids with relatively higher affinity and specificity for binding to the growth factor. The processes may be repeated, and the selected nucleic acids mutated and re-screened, whereby a growth factor aptamer is identified.

[00290] In yet another variation, the VEGFR-2 inhibitor product comprises a soluble extracellular domain fragment of VEGFR-1 that binds VEGF and inhibits VEGF binding to VEGFR-2. cDNA and amino acid sequences of VEGFR-1 are set forth in SEQ ID NOs: 18 and 19. Exemplary extracellular domain fragments of VEGFR-1 are described in U.S. Patent Publication No. 2006/0030000 and International Patent Publication No. WO 2005/087808, the disclosures of which are incorporated herein by reference in their entireties.

[00291] C. Anti-inflammatory Agents

[00292] In another embodiment, the methods described herein optionally comprise administering one or more anti-inflammatory agents to the subject. In some embodiments, the anti-inflammatory agent and the anti-lymphangiogenic agent are co-administered in a single composition. In other embodiments, the anti-inflammatory agent is administered as a separate composition from the anti-lymphangiogenic agent. Combinations involving an anti-lymphangiogenic agent, a VEGFR-2 inhibitor, and an anti-inflammatory agent are specifically contemplated. As used herein, the term “anti-inflammatory agent” refers generally to any agent that reduces inflammation or swelling in a subject. A number of exemplary anti-inflammatory agents are recited herein, but it will be appreciated that there may be additional suitable anti-inflammatory agents not specifically recited herein, but which are encompassed by the present invention.

[00293] In one variation, the anti-inflammatory agent is a non-steroidal anti-inflammatory drug (NSAID). Exemplary NSAIDs include, but are not limited to: aspirin, SulfasalazineTM, AsacolTM, DipendiumTM, PentasaTM, AnaproxTM, Anaprox DSTM (naproxen sodium); AnsaTMid (flurbiprofen); ArthroTMtec (diclofenac sodium + misoprostil); CataTMflam/VoltaTMren (diclofenac potassium); ClinorilTM (sulindac); DayproTM (oxaprozin); DisalcidTM (salsalate); DolobidTM (diflunisal); EC NaprosynTM (naproxen sodium); FeldeneTM (piroxicam); IndocinTM, Indocin SRTM (indomethacin); LodineTM, Lodine XLTM (etodolac); MotrinTM (ibuprofen); NaprelanTM (naproxen); NaprosynTM (naproxen); OrudisTM, (ketoprofen); OruvailTM (ketoprofen); RelafenTM (nabumetone); TolectinTM, (tolmetin sodium); TrilisateTM (choline magnesium trisilicylate); Cox-1 inhibitors; Cox-2 Inhibitors such as VioxxTM (rofecoxib); ArcoxiaTM (etoricoxib), CelebrexTM (celecoxib); MobicTM (meloxicam); BextraTM (valdecoxib), DynastatTM paracoxib sodium; PrexigeTM (lumiracoxib), and nabumetone. Additional suitable NSAIDs, include, but are not limited to, the following: 5-aminosalicylic acid (5-ASA, mesalamine, lesalazine), ε-acetamidocaproic acid, S-adenosylmethionine, 3-amino-4-hydroxybutyric acid, amixetrine, anitrazafen, antrafenine, bendazac, bendazac lysinate, benzydamine, beprozine, broperamole, bucolome, buefzolac, ciproquazone, cloximate, dazidamine, deboxamet, detomidine, difenpyramide, difenpyramide, difisalamine, difazol, emorfazone, fanetizole mesylate, fenflumizole, floctafenine, flumizole, flunixin, fluproquazone, fopirtoline, fosfosal, guaimesal, guaiazolene, isonixirn, lefetamine HCl, leflunomide, lofemizole, lotifazole, lysin clonixinate, meseclazone, nabumetone, nictindole,

nimesulide, orgotein, orpanoxin, oxaceprolm, oxapadol, paranyline, perisoxal, perisoxal citrate, pifoxime, piproxen, pirazolac, pirfenidone, proquazone, proxazole, thielavin B, tiflamizole, timegadine, tolectin, tolpadol, tryptamid and those designated by company code number such as 480156S, AA861, AD1590, AFP802, AFP860, AI77B, AP504, AU8001, BPPC, BW540C, CHINOIN 127, CN100, EB382, EL508, F1044, FK-506, GV3658, ITF182, KCNTEI6090, KME4, LA2851, MR714, MR897, MY309, ONO3144, PR823, PV102, PV108, R830, RS2131, SCR152, SH440, SIR133, SPAS510, SQ27239, ST281, SY6001, TA60, TAI-901 (4-benzoyl-1-indancarboxylic acid), TVX2706, U60257, UR2301 and WY41770.

[00294] In another variation, the anti-inflammatory agent can be a compound that inhibits the interaction of inflammatory cytokines with their receptors. Examples of cytokine inhibitors useful in combination with the specific binding agents of the invention include, for example, antagonists (such as antibodies) of TGF- α (e.g., Remicade), as well as antagonists (such as antibodies) directed against interleukins involved in inflammation. Such interleukins are described herein and preferably include, but are not limited to, IL-1, IL-2, IL-3, IL-4, IL-5, IL-6, IL-8, IL-9, IL-12, IL-13, IL-17, and IL-18. See Feghali, et al., *Frontiers in Biosci.*, 2:12-26 (1997).

[00295] In another variation, the anti-inflammatory agent is a corticosteroid. Exemplary corticosteroids include, but are not limited to, difluroasone diacetate, clobetasol propionate, halobetasol propionate, betamethasone, betamethasone dipropionate, budesonide, cortisone, dexamethasone, fluocinonide, halcinonide desoximethasone, triamcinolone, fluticasone propionate, fluocinolone acetonide, flurandrenolide, mometasone furoate, betamethosone, fluticasone propionate, fluocinolone acetonide, aclometasone dipropionate, methylprednisolone, prednisolone, prednisone, triamcinolone, desonide and hydrocortisone.

[00296] In another variation, the anti-inflammatory agent is cyclosporine.

[00297] D. Antibiotics

[00298] In another embodiment, the methods described herein optionally further comprise administering an antibiotic to the subject. In some embodiments, the antibiotic and the anti-lymphangiogenic agent are co-administered in a single composition. In other embodiments, the antibiotic is administered as a separate composition from the anti-

lymphangiogenic agent. Exemplary antibiotics include, but are not limited to, tetracycline, aminoglycosides, penicillins, cephalosporins, sulfonamide drugs, chloramphenicol sodium succinate, erythromycin, vancomycin, lincomycin, clindamycin, nystatin, amphotericin B, amantidine, idoxuridine, p-amino salicylic acid, isoniazid, rifampin, antinomycin D, mithramycin, daunomycin, adriamycin, bleomycin, vinblastine, vincristine, procarbazine, and imidazole carboxamide.

[00299] D. Tyrosine Kinase Inhibitors

[00300] In another embodiment, the methods described herein optionally further comprise administering a tyrosine kinase inhibitor that inhibits VEGFR-2 and/or VEGFR-3 activity. It is contemplated that VEGFR-3 tyrosine kinase inhibitors would be useful in combination therapy embodiments where the anti-lymphangiogenic agent is not a VEGFR-3 tyrosine kinase inhibitor.

[00301] Exemplary tyrosine kinase inhibitors for use in the methods described herein include, but are not limited to, AEE788 (TKI, VEGFR-2, EGFR: Novartis); ZD6474 (TKI, VEGFR-1, -2, -3, EGFR: Zactima: AstraZeneca); AZD2171 (TKI, VEGFR-1, -2: AstraZeneca); SU 11248 (TKI, VEGFR-1, -2, PDGFR: Sunitinib: Pfizer); AG13925 (TKI, VEGFR-1, -2: Pfizer); AG013736 (TKI, VEGFR-1, -2: Pfizer); CEP-7055 (TKI, VEGFR-1, -2, -3: Cephalon); CP-547,632 (TKI, VEGFR-1, -2: Pfizer); GW7S6024 (TKI, VEGFR-1, -2, -3: GlaxoSmithKline); GW786034 (TKI, VEGFR-1, -2, -3: GlaxoSmithKline); sorafenib (TKI, Bay 43-9006, VEGFR-1, -2, PDGFR: Bayer/Onyx); SU4312 (TKI, VEGFR-2, PDGFR: Pfizer); AMG706 (TKI, VEGFR-1, -2, -3: Amgen); XL647 (TKI, EGFR, HER2, VEGFR, ErbB4: Exelixis); XL999 (TKI, FGFR, VEGFR, PDGFR, Flt-3: Exelixis); PKC412 (TKI, KIT, PDGFR, PKC, FLT3, VEGFR-2: Novartis); AEE788 (TKI, EGFR, VEGFR2, VEGFR-1: Novartis); OSI-030 (TKI, c-kit, VEGFR: OSI Pharmaceuticals); OS1-817 (TKI c-kit, VEGFR: OSI Pharmaceuticals); DMPQ (TKI, ERGF, PDGFR, ErbB2, p56, pkA, pkC); MLN518 (TKI, Flt3, PDGFR, c-KIT (T53518: Millennium Pharmaceuticals); lestaurinib (TKI, FLT3, CEP-701, Cephalon); ZD 1839 (TKI, EGFR: gefitinib, Iressa: AstraZeneca); OSI-774 (TKI, EGFR: Erlotinib: Tarceva: OSI Pharmaceuticals); lapatinib (TKI, ErbB-2, EGFR, and GD-2016: Tykerb: GlaxoSmithKline).

[00302] In some embodiments, the methods described herein further comprise administering a tyrosine kinase inhibitor that inhibits angiogenesis to the subject. Exemplary anti-angiogenic tyrosine kinase inhibitors and their targets are provided below in Table 2.

Table 2. Antiangiogenic tyrosine kinase receptor inhibitors and their targets						
Agent	VEGFR-1	VEGFR-2	VEGFR-3	PDGFR	EGFR	Other targets
Vandetanib		•			•	RET
Sunitinib	•	•	•	•		KIT, FLT3, RET
Axitinib	•	•	•			
Sorafenib	•	•	•	•		KIT, RAF, FLT3
Vatalanib	•	•	•	•		KIT
Cediranib	•	•	•	•		KIT
Motesanib	•	•	•	•		KIT, RET
Pazopanib	•	•	•	•		KIT
BIBF 1120		•		•		FGFR

Abbreviations: FGFR, fibroblast-like growth factor receptor; FLT3, FMS-like tyrosine kinase 3; KIT, stem cell factor receptor; RET, glial cell line-derived neurotrophic factor receptor; VEGFR, vascular endothelial growth factor receptor.

[00303] E. Administration of the Combination Therapy

[00304] Combination therapy with one or more of the additional agents described herein may be achieved by administering to a subject a single composition or pharmacological formulation that includes the anti-lymphangiogenic agent and the one or more additional agents, or by administering to the subject two (or more) distinct compositions or formulations, at the same time, wherein one composition includes an anti-lymphangiogenic agent and the other includes a second agent.

[00305] Alternatively, the combination therapy employing an anti-lymphangiogenic agent described herein may precede or follow the second agent treatment by intervals ranging from minutes to weeks. In embodiments where the second agent and the anti-lymphangiogenic agent are administered separately, one would generally ensure that a significant period of time did not expire between the times of each delivery, such that the agent and the anti-lymphangiogenic agent would still be able to exert an advantageously combined effect. In such instances, it is contemplated that one would administer both modalities within about 12-24 hours of each other and, more preferably, within about 6-12 hours of each other, with a delay time of only about 12 hours being most preferred. In some situations, it may be desirable to extend the time period for treatment significantly, however, where several days (2, 3, 4, 5, 6 or 7) to several weeks (1, 2, 3, 4, 5, 6, 7 or 8)

lapse between the respective administrations. Repeated treatments with one or both agents is specifically contemplated.

Formulations and Pharmaceutically acceptable carriers

[00306] Some exemplary ophthalmic viscosity enhancers that can be used in the present formulation include: carboxymethyl cellulose sodium; methylcellulose; hydroxypropyl cellulose; hydroxypropylmethyl cellulose; hydroxyethyl cellulose; polyethylene glycol 300; polyethylene glycol 400; polyvinyl alcohol; and providone.

[00307] Some natural products, such as veegum, alginates, xanthan gum, gelatin, acacia and tragacanth, may also be used to increase the viscosity of ophthalmic solutions.

[00308] A tonicity is important because hypotonic eye drops cause an edema of the cornea, and hypertonic eye drops cause deformation of the cornea. The ideal tonicity is approximately 300 mOsm. The tonicity can be achieved by methods described in Remington: The Science and Practice of Pharmacy, known to those versed in the art.

[00309] Suitable ophthalmic carriers are known to those skilled in the art and all such conventional carriers may be employed in the present invention. Exemplary compounds incorporated to facilitate and expedite transdermal delivery of topical compositions into ocular or adnexal tissues include, but are not limited to, alcohol (ethanol, propanol, and nonanol), fatty alcohol (lauryl alcohol), fatty acid (valeric acid, caproic acid and capric acid), fatty acid ester (isopropyl myristate and isopropyl n-hexanoate), alkyl ester (ethyl acetate and butyl acetate), polyol (propylene glycol, propanedione and hexanetriol), sulfoxide (dimethylsulfoxide and decylmethylsulfoxide), amide (urea, dimethylacetamide and pyrrolidone derivatives), surfactant (sodium lauryl sulfate, cetyltrimethylammonium bromide, polaxamers, spans, tweens, bile salts and lecithin), terpene (d-limonene, alphaterpeneol, 1,8-cineole and menthone), and alkanone (N-heptane and N-nonane). Moreover, topically-administered compositions comprise surface adhesion molecule modulating agents including, but not limited to, a cadherin antagonist, a selectin antagonist, and an integrin antagonist. Thus, a particular carrier may take the form of a sterile, ophthalmic ointment, cream, gel, solution, or dispersion. Also including as suitable ophthalmic carriers are slow release polymers, e.g., "Ocusert" polymers, "Hydron" polymers, etc.

[00310] Stabilizers may also be used such as, for example, chelating agents, e.g., EDTA. Antioxidants may also be used, e.g., sodium bisulfite, sodium thiosulfite, 8-hydroxy quinoline or ascorbic acid. Sterility typically will be maintained by conventional ophthalmic preservatives, e.g., chlorbutanol, benzalkonium chloride, cetylpyridium chloride, phenyl mercuric salts, thimerosal, etc., for aqueous formulations, and used in amounts which are nontoxic and which generally vary from about 0.001 to about 0.1% by weight of the aqueous solution. Conventional preservatives for ointments include methyl and propyl parabens. Typical ointment bases include white petrolatum and mineral oil or liquid petrolatum. However, preserved aqueous carriers are preferred. Solutions may be manually delivered to the eye in suitable dosage form, e.g., eye drops, or delivered by suitable microdrop or spray apparatus typically affording a metered dose of medicament. Examples of suitable ophthalmic carriers include sterile, substantially isotonic, aqueous solutions containing minor amounts, i.e., less than about 5% by weight hydroxypropylmethylcellulose, polyvinyl alcohol, carboxymethylcellulose, hydroxyethylcellulose, glycerine and EDTA. The solutions are preferably maintained at substantially neutral pH and isotonic with appropriate amounts of conventional buffers, e.g., phosphate, borate, acetate, tris.

[00311] In some embodiments, penetration enhancers are added to the ophthalmologic carrier.

Routes of Administration

[00312] The composition containing the anti-lymphangiogenic agent can be administered to a patient by a variety of means depending, in part, on the type of agent to be administered and the history, risk factors and symptoms of the patient. Routes of administration suitable for the methods of the invention include both systemic and local administration. Thus, in one embodiment, a method of treating dry eye disease is practiced by systemic administration of a pharmaceutical composition comprising the anti-lymphangiogenic agent. In another embodiment, a method of the invention is practiced by local administration of a pharmaceutical composition comprising the anti-lymphangiogenic agent. In further embodiments, a pharmaceutical composition comprising the anti-lymphangiogenic agent is administered topically, or by local injection, or is released from an intraocular or periocular implant.

[00313] As used herein, the term "systemic administration" means a mode of administration resulting in delivery of a pharmaceutical composition to essentially the whole body of the patient. Exemplary modes of systemic administration include, without limitation, intravenous injection and oral administration. The term "local administration," as used herein, means a mode of administration resulting in significantly more pharmaceutical composition being delivered to and about the eyes than to regions distal from the eyes.

[00314] Systemic and local routes of administration useful in the methods of the invention encompass, without limitation, oral gavage; intravenous injection; intraperitoneal injection; intramuscular injection; subcutaneous injection; transdermal diffusion and electrophoresis; topical eye drops and ointments; periocular and intraocular injection including subconjunctival injection; extended release delivery devices including locally implanted extended release devices; and intraocular and periocular implants including bioerodible and reservoir-based implants.

[00315] In some embodiments, an ophthalmic composition containing an anti-lymphangiogenic agent is administered topically to the eye. The ophthalmic composition can be for example, an ophthalmic solution (ocular drops). In other embodiments, the ophthalmic composition containing the anti-lymphangiogenic agent is injected directly into the eye. In a further embodiment, the ophthalmic composition containing the anti-lymphangiogenic agent is released from an intraocular or periocular implant such as a bioerodible or reservoir-based implant.

[00316] In some embodiments, the ophthalmic composition comprising an anti-lymphangiogenic agent is administered locally in an extended release formulation. For example, an ophthalmic composition containing an anti-lymphangiogenic agent can be administered via an intraocular or periocular implant, which can be, for example, bioerodible or reservoir-based. As used herein, the term "implant" refers to any material that does not significantly migrate from the insertion site following implantation. An implant can be biodegradable, non-biodegradable, or composed of both biodegradable and non-biodegradable materials; a non-biodegradable implant can include, if desired, a refillable reservoir. Implants useful in the methods of the invention include, for example, patches, particles, sheets, plaques, microcapsules and the like, and can be of any shape and size compatible with the selected site of insertion, which can be, without limitation, the

posterior chamber, anterior chamber, suprachoroid or subconjunctiva. It is understood that an implant useful in the invention generally releases the implanted pharmaceutical composition at an effective dosage to the eye of the patient over an extended period of time. A variety of ocular implants and extended release formulations suitable for ocular release are well known in the art, as described, for example, in U.S. Pat. Nos. 5,869,079 and 5,443,505.

[00317] In instances where the anti-lymphangiogenic agent is a nucleic acid molecule, administration of a pharmaceutical composition containing the nucleic acid molecule can be carried out using one of numerous methods well known in the art of gene therapy. Such methods include, but are not limited to, lentiviral transformation, adenoviral transformation, cytomegaloviral transformation, microinjection and electroporation.

[00318] In some embodiments, the anti-lymphangiogenic agents are administered to the subject in a liquid or gel suspension in the form of drops, spray or gel. In yet another embodiment, the anti-lymphangiogenic agents are injected directly into the lacrimal tissues or onto the eye surface.

[00319] In other embodiments, the anti-lymphangiogenic agents are applied to the eye via liposomes. In still other embodiments, the anti-lymphangiogenic agents are infused into the tear film via a pump-catheter system. In still another embodiment, the anti-lymphangiogenic agents are contained within a continuous or selective-release device, for example, membranes such as, but not limited to, those employed in the Ocusert™ System (Alza Corp., Palo Alto, Calif.). As an additional embodiment, the anti-lymphangiogenic agents are contained within, carried by, or attached to contact lenses which are placed on the eye. In yet another embodiment, the anti-lymphangiogenic agents are contained within a swab or sponge which can be applied to the ocular surface. Another embodiment of the present invention involves the active compound contained within a liquid spray which can be applied to the ocular surface.

[00320] All publications and patents mentioned herein are hereby incorporated by reference in their entirety as if each individual publication or patent was specifically and individually indicated to be incorporated by reference. In case of conflict, the present application, including any definitions herein, will control.

EXAMPLES

Materials and Methods

Experimental Dry Eye Murine Model

[00321] Eight to ten week- old female C57BLI6 mice (Charles River Laboratory, Wilmington, MA) were used in accordance with the standards in the ARVO Statement for the Use of Animals in Ophthalmic and Vision Research. The research protocol was approved by the Schepens Eye Research Institute Animal Care and Use Committee. Dry eye was induced in murine eyes using a Controlled Environment Chamber (CEC) which exposes the mice to high-flow desiccated air. To achieve maximum ocular surface dryness, the conditions in CEC were supplemented with topical application of 1% atropine sulfate (Falcon Pharma, Fort Worth, Texas) twice for the first 48 hours and subcutaneous injections of 0.1ml of 5mg/ml of scopolamine hydrobromide (Sigma- Aldrich, St. Louis, MO) three times a day, for the entire duration of the experiment.

[00322] RNA Isolation and Molecular analysis using Real Time Polymerase Chain Reaction

[00323] Five mice (10 eyes) were included in each group. Two corneas were pooled together to equal as one sample and stored at -80°C in Trizol (Invitrogen, Carlsbad, California; catalog No.15596026) until future use. Total RNA was isolated from these corneas using the RNeasy microkit (Qiagen, Valencia, CA; catalog No. 74004). Equal amounts of RNA were used to synthesize cDNA using SuperScript™ III Reverse Transcriptase (Invitrogen, Carlsbad, CA; catalog No.18080) according to the manufacturer's recommendations. Real-Time PCR was performed using FAM-MGB dye labeled predesigned primers (Applied Biosystem, Foster City, CA) for GAPDH (assay ID.Mm999999 15_gl), VEGF-A (Mm00437304_ml), VEGF-C (Mrn00437313_ml), VEGF-D (Mm00438965_ml), VEGFR-2 (Mm00440099_ml), VEGFR-3 (Mm00433337_ml). 2.5 µl of cDNA was loaded in each well and assays were performed in duplicate. The GAPDH gene was used as the endogenous reference for each reaction. The results were normalized by the cycle threshold (CT) of GAPDH and the relative mRNA level in the normal mice was used as the normalized control.

[00324] Immunohistochemistry

[00325] The following primary antibodies were used for immunohistochemical staining: rat anti-mouse CD11b-FITC for monocytes/macrophages (BD Pharmingen, San Diego,

California, 1:100), goat anti-mouse CD31 FITC as pan-endothelial marker (Santa Cruz Biotechnology, Santa Cruz, California, 1: 100) and purified rabbit anti-mouse LYVE-1 as lymphatic endothelial marker (Abeam, MA, USA, 1:400). Respective isotypes were used as negative controls. Rhodamine conjugated goat anti-rabbit (BD Pharmingen, San Diego, California, 1:100) was the secondary antibody used.

[00326] Freshly excised corneas were washed in PBS, fixed in acetone for 15 minutes and then double stained with CD31 and LYVE-1 as described previously. To analyze infiltration of CD11b⁺/LYVE-1 cells, corneas from three mice from each group were taken and cells were counted in 5-6 areas in the periphery (0.5 μ m area from the limbus) of each cornea in a masked fashion, using epifluorescence microscope (model E800; Nikon, Melville, NY) at 40X magnification. The mean number of cells was obtained by averaging the total number of cells in all the areas studied and the result was expressed as the number of positive cells per mm².

[00327] Morphometry of Lymphangiogenesis in the Cornea

[00328] Morphology of lymphatics was analyzed using an automated image analysis program written with Matlab (The Mathworks, Inc., Natick, MA). Lymphatics were isolated from digitized images with this program using standard computer vision techniques for image segmentation, including background isolation and subtraction, edge detection, and k-means clustering. This segmentation process generated binary images in which lymphatic vessels are represented by 1s and all other image content is represented by 0s. The resultant isolated lymphatic vessels were analyzed morphologically using two metrics, Lymphatic Area (LA) and Lymphatic Caliber (LC). LA represents the total surface area of the lymphatic vessels when projected into the plane of the image. LC is a summary measure of the diameters of the lymphatic vessels present. LC was measured using a computational technique that generates the largest diameter circle centered at each pixel inside a lymphatic vessel. The mean value across all pixels within lymphatic vessels was taken as an estimate of the mean LC for a given image.

[00329] Flow Cytometry

[00330] Draining LNs from DED (day 10) and normal mice were collected. Single cell suspension of LN cells was stained with the anti-CD11b-FITC and anti-IAb (MHC-II)-PE.

Stained LN cells were then analyzed on an EPICS XL flow cytometer (Beckman Coulter). All the antibodies with their matched isotype controls were purchased from eBioscience.

[00331] Studies involving inhibition of corneal neo-lymphangiogenesis using an anti-VEGF-C antibody (Example 5 onwards)

[00332] Anti-VEGF-C antibodies (VGX-100; Vegenics Limited, Australia) were administered intraperitoneally daily from day 1 to day 10 to DED mice. Mice were assessed clinically using corneal fluorescent staining. Tissues from cornea, conjunctiva and draining lymph nodes were examined for cellular and molecular pathological changes. In vivo blockade of VEGF-C suppresses corneal lymphangiogenesis and ameliorates clinical signs of DED.

[00333] Statistical Analysis

[00334] A two-tailed Student's t-test was performed and P-values less than 0.05 were deemed statistically significant. Results are presented as the mean \pm SEM of at least three experiments.

[00335] Example 1: Demonstration and Quantification of lymphatics in dry eye corneas

[00336] To determine whether DED induces growth of lymphatics into the cornea, and whether lymphatic growth is paralleled by growth of blood vessels, corneal whole mounts were double stained for CD31 (pan-endothelial marker) and LYVE-1 (lymphatic vascular endothelial marker) at days 0, 6, 10 and 14 and quantified for lymphangiogenesis. Blood vessels were identified as CD31^{hi}/LYVE-1⁻ and lymph vessels were identified as CD31^{lo}/LYVE-1^{hi}. A significant increase in lymphatic area LA is seen in DED mice (Figure 1 b). Morphometric analysis revealed small buds of lymphatic vessels arising from the limbal vascular arcade at an early time point (day 6), which increased in caliber (LC) and area (LA), and advanced towards the center of the cornea with DED progression (Figures 1 and 2). A significant increase in LA (Figure 3a) was seen as early as day 6 ($P < 0.01$) which continued until day 14 ($P < 0.0001$). However, LC (Figure 3b) was significantly increased from the normal only by day 14 ($P < 0.02$). Remarkably, these lymphatics were not accompanied by growth of blood vessels at any given time point.

[00337] Example 2: Expression levels of different VEGF's and VEGFR's in dry eye corneas

[00338] The development of lymphatic vessels is regulated by factors common to both hemangiogenesis and lymphangiogenesis. VEGF-C and VEGF-D are the classic lymphangiogenic factors and act by binding to their receptors VEGFR-2 and VEGFR-3, which are expressed on lymphatic endothelial cells. To determine the molecular mechanisms of lymphangiogenesis in DED, expression of different vascular endothelial growth factors and their receptors were quantified at indicated time points in the cornea using real time PCR. Amongst the VEGF species (Figure 4), lymphangiogenic specific VEGF-D was not only the earliest to increase at day 6 (- 2 folds; $P < 0.03$) but also showed the maximum increase in expression at day 14 (- 3 folds; $P < 0.03$). Significant increased transcript expression of VEGF-A and VEGF-C was seen only by day 14 ($P < 0.03$ for both). Similarly levels of lymphangiogenic specific VEGFR-3 were first to show a significant increase at day 6 (- 4 folds; $P < 0.01$) and continued to rise until day 14 (- 8 folds; $P < 0.01$). Though an overall trend toward increased expression was noticed with VEGFR-2 (primarily specific for blood vessel growth), significant increase ($P < 0.05$) was appreciated only by day 14 (Figure 5).

[00339] Example 3: Enumeration of CD11b/LYVE-1 positive cells in dry eye corneas

[00340] The normal cornea has a resident population of bone marrow-derived CD11b⁺ monocyticmacrophage-lineage cells and the development of DED increases the number of CD11b⁺ cells in the cornea. The role of macrophages in inflammatory lymphangiogenesis is well established. These CD11b⁺ macrophages may also express various lymphatic endothelial markers, such as LYVE-1. To see what proportion of these CD11b⁺ cells had lymphangiogenic potential, whole mount corneal tissues were double stained with CD11b and LYVE-1 at day 14. There was a significant increase in the number of both CD11b⁺ ($P < 0.02$) and CD11b⁺ / LYVE-1⁺ ($P < 0.0001$) cells in dry eye as compared to normal corneas (Figure 6). In DED, about 25% of the CD11b⁺ cells were positive for LYVE-1 where as only 4% of the CD11b⁺ cells were positive for LYVE-1 in the normal corneas.

[00341] Example 4: Role of APC homing

[00342] It was next investigated whether corneal lymphangiogenesis in DED is associated with the increased homing of APC in the draining LN. Using flow cytometry, the frequencies of mature APC (MHC-II+CD11b⁺) in the draining LN of normal and DED mice were analysed (Figure 7). Data showed a significant increase in the frequency of

MHC-II+CD11b⁺ APC in the LN cells of DED mice compared to those in the LN of normal mice (Range: 14.9-19.5% vs. 10- 13.5%, $p<0.05$).

[00343] Example 5: Effect of *in vivo* blockade of pro-lymphangiogenic VEGF-C on Dry Eye Disease.

[00344] Dry eye was induced in murine eyes as described in the materials and methods.

[00345] Real-time PCR was performed to quantify expression of different VEGF growth factors (VEGF-A, VEGF-C, VEGF-D) and their receptors (VEGFR-2, VEGFR-3) in the cornea at days 6, 10 and 14 (Figure 8) and to determine the levels of proinflammatory cytokines. IL-1 α , IL-1 β , IL-6, IL-17 in the conjunctiva showed significantly decreased expression in anti-VEGF-C treated DED mice as compared to those of untreated DED mice (Figure 9). Draining lymph nodes of anti-VEGF-C treated DED mice showed significantly decreased induction of T-cell mediated autoimmune response compared untreated DED mice as determined by Real-time PCR analysis for IL-17 (Th17 cells) and IFN- γ (Th1 cells) (Figure 10).

[00346] Enumeration of CD11b⁺/LYVE-I⁺ monocytic cells was done in the DED corneas at day 14 as described previously (Figures 11). Treatment with anti-VEGF-C antibodies significantly decreased infiltration of CD11b⁺ cells (30%) in the DED corneas.

[00347] To determine whether DED induces growth of lymphatics into the cornea, and whether lymphatic growth is paralleled by growth of blood vessels, corneal whole mounts were double stained for CD31 (pan-endothelial marker) and LYVE-I (lymphatic vascular endothelial marker) at days 0, 6, 10 and 14 and quantified for lymphangiogenesis as described previously. Lymphatics were seen growing toward the center of DED corneas (Figure 12). Morphometric analysis showed significant increase in both lymphatic area ($P<0.0001$) and lymphatic caliber ($P<0.02$) at day 14 of disease (Figure 13). These lymphatics were not accompanied by any new blood vessels. Lymphangiogenic specific VEGF-D and VEGFR-3 were the earliest to increase at day 6 followed by increase in VEGF-C, VEGF-A and VEGFR-2. Increased recruitment of CD11b⁺/ LYVE-I⁺ monocytic cells to the cornea was also seen with disease.

[00348] These results demonstrate that low-grade inflammation associated with dry eye is an inducer of lymphangiogenesis without accompanied hemangiogenesis.

[00349] Clinical Relevance: Demonstration of selective lymphatic growth into dry eye corneas provides an important mechanistic link to adaptive (T cell-mediated) immunity by delineating how corneal antigen trafficking can occur to the lymphoid tissues.

[00350] Dry eye disease (DED) once thought to be solely due to deficiency of tears, is increasingly being recognized as an immune-mediated disorder. DED affects many millions of people with a wide spectrum of seminal features ranging from mild ocular discomfort to sight-threatening corneal complications such as persistent epithelial defects and sterile stromal ulceration. In the United States alone, more than 3.2 million women and 1.6 million men above the age of 50 years are affected by this potentially disabling disease adversely impacting the vision-related quality of life.

[00351] Clinically significant DED is associated with ocular surface inflammation, although the precise immunopathogenesis is not known. There is strong evidence regarding T cell involvement in the pathogenesis of DED in both animal models and humans. Recently, we illustrated T cell activation in the regional lymph nodes of dry eye mice, coincident with acquisition of specific chemokine markers which help in the homing of T cells to the inflamed ocular surface. Further we demonstrated induction of autoimmunity in the draining lymph nodes of dry eye mice due to impaired Treg function and generation of pathogenic Th17 cells. These Th17 cells were found to be resistant to Treg mediated suppression, leading to unrestrained generation of pathogenic T cells and sustained ocular surface inflammation. Accordingly, much of the work to date has focused on understanding immunological phenomena occurring in the lymphoid compartment and the effector responses thereby generated, leaving unanswered the question as to how naive T cells in the draining lymph nodes get primed to the ocular surface antigen(s) that drive immunity in DED.

[00352] The draining lymph nodes are critical sites for induction of immunity and their role in generation of alloimmunity has been well established in corneal transplantation. The enhanced survival rate of corneal transplants in mice with excised cervical lymph nodes implicates the importance of functional flow of antigen presenting cells (APCs) from the ocular surface to the draining lymphoid tissue as a necessary component of alloimmunity and graft rejection. However, little is known about the pathway that allows trafficking of corneal APCs to the draining lymph nodes where they prime naive T cells to corneal antigens and generate autoimmune responses in dry eye.

[00353] Emphasis is now being given to the importance of pathological angiogenesis (hem- and lymphangiogenesis) in various corneal diseases such as different forms of keratitis, chemical burns, graft vs host disease etc., but to date there is no data regarding corneal angiogenesis in DED. A plausible reason could be that most of the above mentioned conditions except DED are accompanied by in-growth of clinically visible blood vessels into the cornea. Traditionally it has been thought that lymphatics and blood vessels which serve as afferent and efferent arms of the immune response respectively are always coexistent in pathological states. The present work provides the first evidence for selective lymphangiogenesis occurring in DED cornea using a murine model. Herein, we attempt to determine the growth of lymphatic vessels into the cornea with the progression of DED, discuss the pathophysiologic implications of corneal lymphangiogenesis in dry eye and the potential of antilymphangiogenic therapy for ameliorating DED.

[00354] DISCUSSION

[00355] Lymphangiogenesis in the postnatal period is primarily a response to inflammation and is seen in various pathological states as diverse as tumor metastasis, wound healing and transplantation. Lymphatics play an important role in generating immuno-inflammatory responses by directing the antigen bearing immunocytes (e.g. dendritic cells) from the periphery to the draining lymph nodes where T cells are primed and expanded. The normal human cornea is avascular, thus suppressing the afferent lymphatic and efferent vascular arms of the immune cycle. Inflammation however negates this "immune" and "angiogenic" privileged state of the cornea and gives it the potential to mount an immune response.

[00356] Angiogenesis in the cornea is now extensively being studied in various pathological models such as transplantation. Whereas corneal blood vessels have long been thought to be an important risk factor for immune rejection in corneal transplantation, it is only recently after unveiling of new lymphatic specific markers, that the significance of lymphangiogenesis in corneal alloimmunity has been characterized. Despite recognizing the role of inflammatory angiogenesis in the eye, little has hitherto been studied regarding angiogenic mechanisms in DED. Desiccating stress in DED initiates an immune-based inflammatory response that is sustained by the ongoing interplay between the ocular surface and various pathogenic immune cells, primarily the CD4⁺ T cells in the conjunctiva and CDI 1b ÷ monocytic cells in the cornea. Desiccating stress induces secretion of

inflammatory cytokines, especially interleukin (IL)-1, tumor necrosis factor- α , and IL-6 by ocular surface tissues, which facilitate the activation and migration of resident APCs toward the regional draining LN. Our data on frequencies of mature APC in the LN also suggest increased trafficking of mature APC in

[00357] the LN of DED mice (Fig 7). In the LN, these APCs stimulate naive T cells, leading to the

[00358] expansion of IL-17 secreting Th17 cells and interferon (IFN)- γ -secreting Th1 cells. Once these effectors are generated in the LN, they migrate to the ocular surface and secrete effector cytokines. Recent work has provided evidence for the induction of T cell mediated autoimmune responses in the regional lymph nodes of DED mice. But what has remained unanswered is how corneal APCs can traffic to the draining lymphoid compartment in order to initiate the immune cycle in DED.

[00359] Interestingly, to date there has been no published data on this important facet of immunity in DED. The data presented herein clearly demonstrates the development of lymphatic vessels in the setting of the dry eye state. These lymphatic vessels increase both in caliber and area while advancing toward the corneal center with progression of dry eye. Remarkably, these lymphatic vessels are not accompanied by growth of blood vessels. Various spatio-temporal studies examining relation between new blood and lymphatic vessels have led to the belief that a preexisting blood vascular bed is necessary to guide lymphangiogenesis. The current study refutes the general perception of wound healing models in skin where growth of lymphatic vessels follows that of blood vessels by several days. This is also in contrast to other robust models of corneal inflammation where there is either parallel outgrowth of blood and lymphatic vessels or the blood vessels are precedent over the lymphatics. This provides the first evidence of selective 'natural' (non pharmacologically induced) lymphangiogenesis in a disease model that is dissociated from hemangiogenesis.

[00360] Lymphangiogenesis is mediated primarily by the interaction of growth factors VEGF-C and VEGF-D on VEGFR-2 and VEGFR-3. VEGF-A also contributes, albeit indirectly, to lymphangiogenesis by recruiting VEGF-C and VEGF-D secreting macrophages. In the present study, dry eye induction led to the up-regulation of all the VEGF growth factors and their receptors. Though the rise in levels of VEGF-A, VEGF-C

and VEGFR-2 occurred at later time points (day 14), it is noteworthy, that VEGF-D and VEGFR-3 (which are both largely specific to lymphangiogenesis) increased as early as day 6 of disease. The functional relevance of the early rise of VEGF-D is highlighted in a recent study where VEGF-D, via its action on VEGFR-3, was shown to be a critical modifier of VEGF-C driven early sprouting and migration of lymphatic endothelial cells. Macrophages also seem to play a crucial role in lymphangiogenesis. Under normal physiological conditions, all ocular tissues except the central cornea are rich in bone marrow derived LYVE-1⁺ macrophages which may serve as precursor cells for de novo formation of lymphatics. In the present study, we noticed significantly increased number of CD11b⁺/LYVE-1⁺ cells in the peripheral corneas after exposure to desiccating stress, suggesting that either these cells infiltrate into or multiply from pre-existing CD11b⁺ LYVE-1⁺ cells in the cornea, and contribute to lymphangiogenesis. Alternatively, there is a possibility of upregulation of LYVE-1 in the previous CD11b⁺/LYVE-1⁻ cells.

[00361] In summary, presented herein is novel evidence for the selective growth of lymphatic (but not blood) vessels in dry eye disease providing new insights into the pathophysiology of the disease. The findings suggest that these newly formed corneal lymphatics may serve as potential conduits for migration of corneal APCs to lymphoid tissues where they generate autoreactive Th17 and Th1 cells in DED. This study not only provides a link between ocular surface inflammation and the generation of T cell mediated immunity in the lymphoid compartment, but also offers an example of how lymphangiogenesis and hemangiogenesis can be 'naturally' dissociated in a pathological state. The severing of the 'eye-lymphatic axis' in other immune-mediated conditions, such as transplant rejection, has been shown to hold promise as a strategy of suppressing alloimmunity without inhibiting needed innate host defense mechanisms. Similarly, a strategy targeting prolymphangiogenic factors such as VEGF-C or VEGF-D may prove effective in ameliorating dry eye disease.

[00362] Example 7: Blockade of prolymphangiogenic VEGF-C suppresses dry eye disease

[00363] Effect of in vivo blockade of pro-lymphangiogenic VEGF-C on Dry Eye Disease Rationale: Dry eye disease (DED) is an immune-mediated disorder whose precise pathogenesis remains largely unknown. While it has been clearly established that in DED generation of pathogenic CD4⁺ T cells (Th1/Th17) primarily occur in the draining lymph

nodes, the mechanisms of trafficking of corneal antigen presenting cells (APC) to lymphoid tissues where they activate and expand pathogenic CD4⁺ T cell subsets, were still not well understood prior to the invention described herein. The present invention provides evidence for the selective growth of lymphatic (but not blood) vessels in DED cornea. Data shows a significant increase in both caliber and extent of lymphatics in DED corneas which was also confirmed using real-time PCR by showing a highly significant over-expression of lymphangiogenic receptor VEGFR-3 (in contrast to a non-statistically significant increase in hemangiogenic receptor VEGFR-2 expression). This study not only provides a link between ocular surface inflammation and the generation of T-cell mediated immunity in the lymphoid compartment, but also offers an example of how lymphangiogenesis and hemangiogenesis can be 'naturally' dissociated in a pathological state. Data suggests that these corneal lymphatics may serve as conduits for migration of corneal APCs to lymphoid tissues where they activate autoreactive T cells in DED.

[00364] Immunopathogenesis of DED: The pathogenesis is not fully understood. Ocular surface inflammation sustained by ongoing activation and infiltration of pathogenic immune cells. Strong evidence of T cell involvement. Recent work draining lymphoid tissue primary site for activation and generation of auto reactive effector T cells in DED (Chauhan et al; Role of Th17 cells in the immunopathogenesis of dry eye disease. *Mucosal Immunol.* 2009; 2(4):375-376.).

[00365] Expression levels of VEGF's and VEGFR's in DE corneas using RT PCR has demonstrated an increased transcript expression of VEGF-C, VEGF-D, and VEGFR-3. Thus, targeting pro-lymphangiogenic VEGF-C/D has therapeutic implications in DED.

[00366] Corneal lymphatics play an important role in mediating the corneal inflammation in dry eyes. Experiments: To validate this, inhibition of corneal neolymphangiogenesis was performed in a well characterized mouse model of DED described above. To see if inhibition of corneal neolymphangiogenesis could decrease ocular surface inflammation, anti-VEGF-C antibodies were administered i.p. daily from day -1 to day 10 to DED mice and assessed clinically using corneal fluorescein staining.

[00367] Methods (as described previously): Induction of Dry Eye Disease. Experimental Dry Eye Murine Model. Assessment of Corneal Surface: Corneal Fluorescein Staining. Immunohistochemistry: Monocyte/macrophage marker - CD11b; Pan-endothelial marker -

CD31; Lymphatic endothelial marker - LYVE-1; Blood vessels: CD31^{hi}/LYVE-1; Lymph vessels: CD31^{lo}/LYVE-1^{hi}. Morphometry of Lymphangiogenesis: Automated image analysis program written using Mat lab. Lymphatic Area (LA) - total surface area of the lymphatic vessels when projected into the plane of the image. Lymphatic Caliber (LC) - measure of the diameters of the lymphatic vessels.

[00368] Anti-VEGF-C antibody and treatment regimen. Experimental design: Three groups: Normal, DE group treated with IP normal Saline (Untreated) and DE group treated with anti-VEGF-C antibody (VGX-100; a gift from Vegenics, Australia). Daily IP application of anti-VEGF-C antibody /Normal saline from day -1 to day 13. Dose: 400 pg (20mg/kg) in 100 μ l of Normal Saline.

[00369] The results are presented in Figure 14. Results: The data clearly shows a significant decrease in disease severity in anti-VEGF-C-treated group compared to the untreated group. In conclusion, suppression of lymphatic growth with VEGF-C blockade led to significant improvement in DED reflected by decrease in: corneal epitheliopathy; corneal infiltration of CD11b⁺ cells; expression of pro-lymphangiogenic growth factors and receptors (VEGF-C, -D, R3) in DE corneas; and mRNA expression levels of pro-inflammatory cytokines in the conjunctiva.

[00370] Those skilled in the art will recognize, or be able to ascertain using no more than routine experimentation, many equivalents to the specific embodiments of the invention described herein. While specific embodiments of the subject invention have been discussed, the above specification is illustrative and not restrictive. Many variations of the invention will become apparent to those skilled in the art upon review of this specification. The full scope of the invention should be determined by reference to the claims, along with their full scope of equivalents, and the specification, along with such variations. Such equivalents are intended to be encompassed by the following claims.

What is claimed is:

1. A method of treating dry eye disease (DED) in a human comprising:
administering a composition comprising at least one anti-lymphangiogenic agent and a pharmaceutically acceptable carrier to the human, in an amount effective to treat dry eye disease.
2. The method of claim 1, wherein the anti-lymphangiogenic agent is administered to the eye of the human.
3. The method of claim 1, wherein the anti-lymphangiogenic agent is an inhibitor of VEGF-C or VEGF-D mediated signal transduction by VEGFR-2 or VEGFR-3.
4. An anti-lymphangiogenic agent for use in the treatment of dry eye disease.
5. Use of at least one anti-lymphangiogenic agent in a composition comprising a pharmaceutically acceptable carrier for administering to the eye of a human, for the treatment of dry eye disease.
6. The method or use of claim 1 or 5, wherein the DED is an autoimmune DED or a DED associated with Sjogren's syndrome.
7. The method or use of any one of claims 1-3 and 5, wherein the DED is DED due to excessively fast tear evaporation (evaporative dry eyes) or inadequate tear production.
8. The method or use of any one of claims 1-3 and 5, wherein the dry eye disease is attributable to one or more causes selected from: aging, contact lens usage and medication usage.
9. The method or use of any one of claims 1-3 and 5, wherein the dry eye disease is a complication of LASIK refractive surgery.
10. The method or use of any one of claims 1-3 and 5, wherein the at least one anti-lymphangiogenic agent is purified or isolated.
11. The method or use of any one of claims 1-3 and 5, wherein said at least one anti-lymphangiogenic agent comprises a member selected from the group consisting of: a nucleic acid molecule, an aptamer, an antisense molecule, an RNAi molecule, a protein, a

peptide, a cyclic peptide, an antibody or antibody fragment, a polysaccharide, or a small molecule.

12. The method or use of any one of claims 1-3 and 5-11, wherein said at least one anti-lymphangiogenic agent comprises a member selected from the group consisting of a VEGFR-3 inhibitor, a VEGF-D inhibitor and a VEGF-C inhibitor.

13. The method or use of any one of claims 1-3 and 5-11, wherein the at least one anti-lymphangiogenic agent comprises a member selected from the group consisting of a VEGF-C antibody, a VEGF-D antibody, a VEGF-R3 antibody, and a polypeptide comprising a soluble VEGFR-3 fragment that binds VEGF-C or VEGF-D.

14. The method or use of claim 13, wherein the at least one anti-lymphangiogenic agent comprises a VEGF-C antibody.

15. The method or use of claim 14, wherein the antibody comprises a heavy chain variable region set forth in amino acids 1-118 of SEQ ID NO: 48.

16. The method or use of claim 14, wherein antibody comprises a heavy chain comprising the amino acid sequence of SEQ ID NO: 48.

17. The method or use of claim 14, wherein the VEGF-C antibody is selected from the group consisting of antibodies 69D09, 103, MM0006-2E65 and 193208.

18. The method or use of any one of claims 1-3 and 5-11, wherein the at least one anti-lymphangiogenic agent comprises an antibody that competitively inhibits the binding of antibody 69D09 to VEGF-C.

19. The method or use of any one of claims 1-3 and 5-11, wherein the at least one anti-lymphangiogenic agent comprises a VEGF-D antibody.

20. The method or use of claim 19, wherein the VEGF-D antibody is selected from the group consisting of antibodies 2F8, 4A5(VD1), 4E10, 5F12, 4H4, 3C10 28AT743.288.48, MM0001-7E79, RM0007-8C35, 78902, 78939 and 90409.

21. The method or use of any one of claims 1-3 and 5-11, wherein the at least one anti-lymphangiogenic agent comprises a soluble VEGFR-3 fragment that binds VEGF-C or VEGF-D.

22. The method or use of any one of claims 1-3 and 5-11, wherein the at least one anti-lymphangiogenic agent comprises a human or humanized antibody.

23. The method or use of any one of claims 1-3 and 5-11, wherein the at least one anti-lymphangiogenic agent comprises a VEGFR-2 inhibitor.

24. The method or use of any one of claims 1-3 and 5-11 wherein the at least one anti-lymphangiogenic agent comprises a tyrosine kinase inhibitor that inhibits the activity of VEGFR-3.

25. The method or use of any one of claims 1-3 and 5-24, further comprising administering an anti-inflammatory agent to the subject.

26. The method or use of claim 25, further comprising administering cyclosporine to the subject.

27. The method or use of any one of claims 1-3 and 5-26, wherein said composition further comprises a molecule that inhibits an activity of an inflammatory cytokine selected from the group consisting of IL-1, IL-7, IL23, IL-6 and TNF- α .

28. The method or use of any one of claims 1-3 and 5-27, wherein the method further comprises administering an antibiotic to the human.

29. The use of any one of claims 5-27 further including the use of an antibiotic for the treatment of the dry eye disease.

30. The method or use of claim 28 or 29, wherein the antibiotic is selected from the group consisting of amikacin, gentamicin, kanamycin, neomycin, netilmicin, streptomycin, tobramycin, teicoplanin, vancomycin, azithromycin, clarithromycin, clarithromycin, dirithromycin, erythromycin, roxithromycin, troleandomycin, amoxicillin, ampicillin, azlocillin, carbenicillin, cloxacillin, dicloxacillin, flucoxacillin, mezlocillin, nafcillin, penicillin, piperacillin, ticarcillin, bacitracin, colistin, polymyxin B, ciprofloxacin, enoxacin, gatifloxacin, levofloxacin, lomefloxacin, moxifloxacin, norfloxacin, ofloxacin, trovafloxacin, mafenide, sulfacetamide, sulfamethizole, sulfasalazine, sulfisoxazole, trimethoprim, cotrimoxazole, demeclocycline, soxycycline, minocycline, oxytetracycline, or tetracycline.

31. The method or use of any one of claims 1-3 and 5-27, wherein the eye comprises a tissue or gland in or around the eye selected from the group consisting of

ocular tissue, eyelids of the subject, ocular surface, meibomian gland and or lacrimal gland of the human.

32. The method of any one of claims 1-3 and 5-27, wherein said composition is administered topically to the eye.

33. The use according to any one of claims 5-27, wherein the composition is formulated for topical administration.

34. The method or use of any one of claims 1-3 and 5-33, wherein said composition is in the form of a solid, a paste, an ointment, a gel, a liquid, an aerosol, a mist, a polymer, a film, an emulsion, or a suspension.

35. The method or use of any one of claims 1-3 and 5-34, wherein the composition further comprises a compound selected from the group consisting of physiological acceptable salt, poloxamer analogs with carbopol, carbopol/hydroxypropyl methyl cellulose (RP MC), carbopol-methyl cellulose, carboxymethylcellulose (CMC), hyaluronic acid, cyclodextrin, and petroleum.

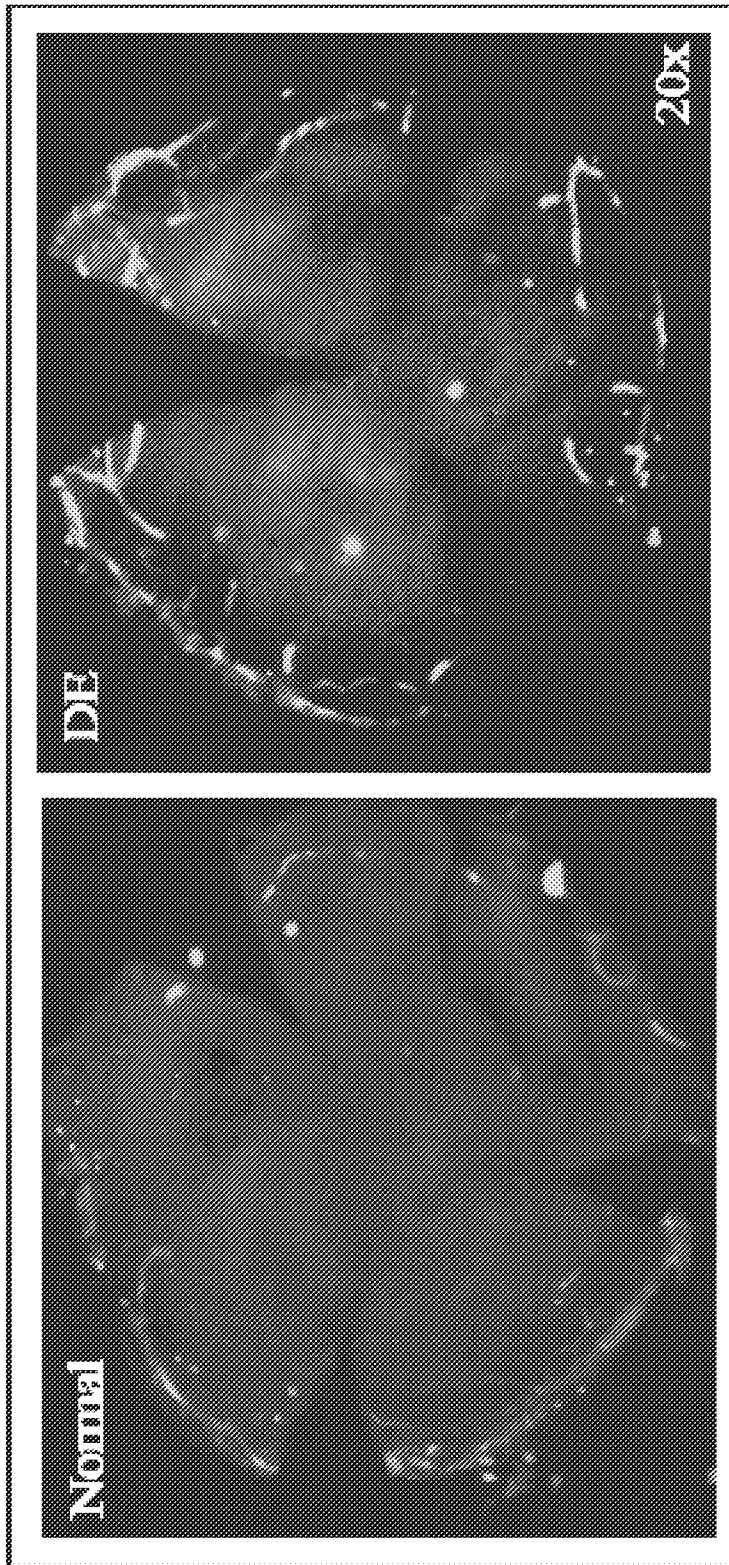


Figure 1

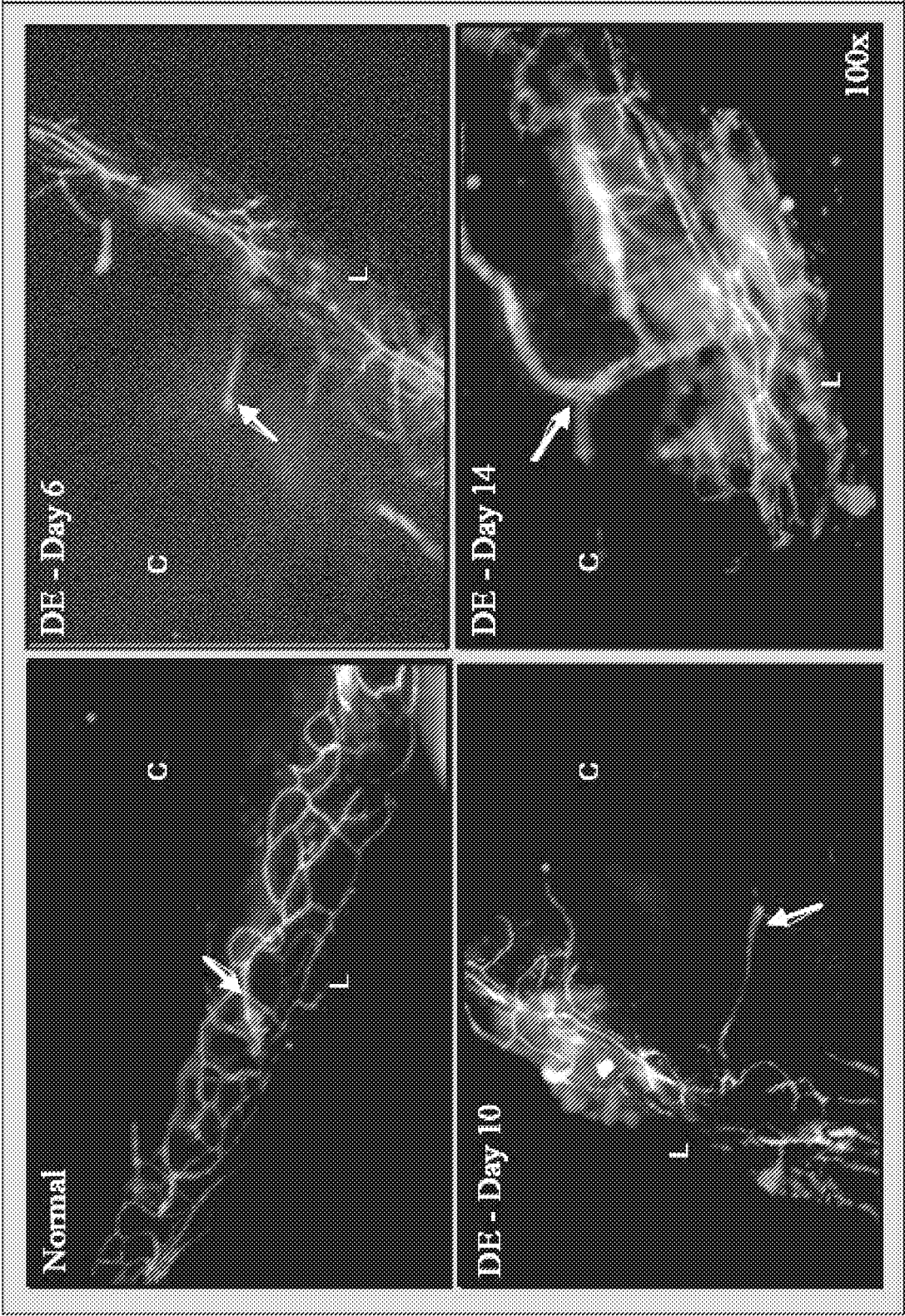


Figure 2

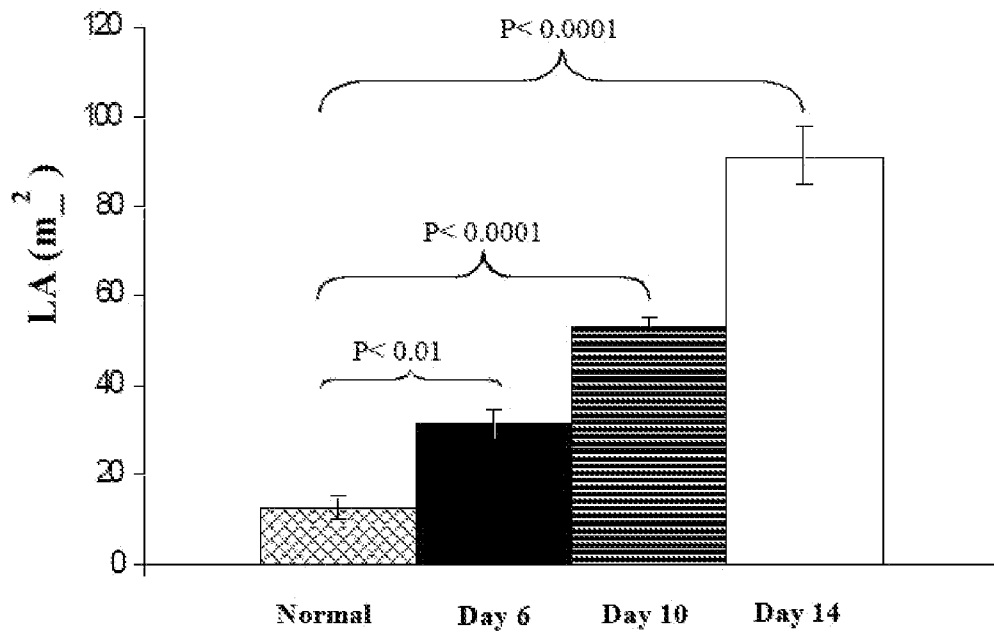


Figure 3a

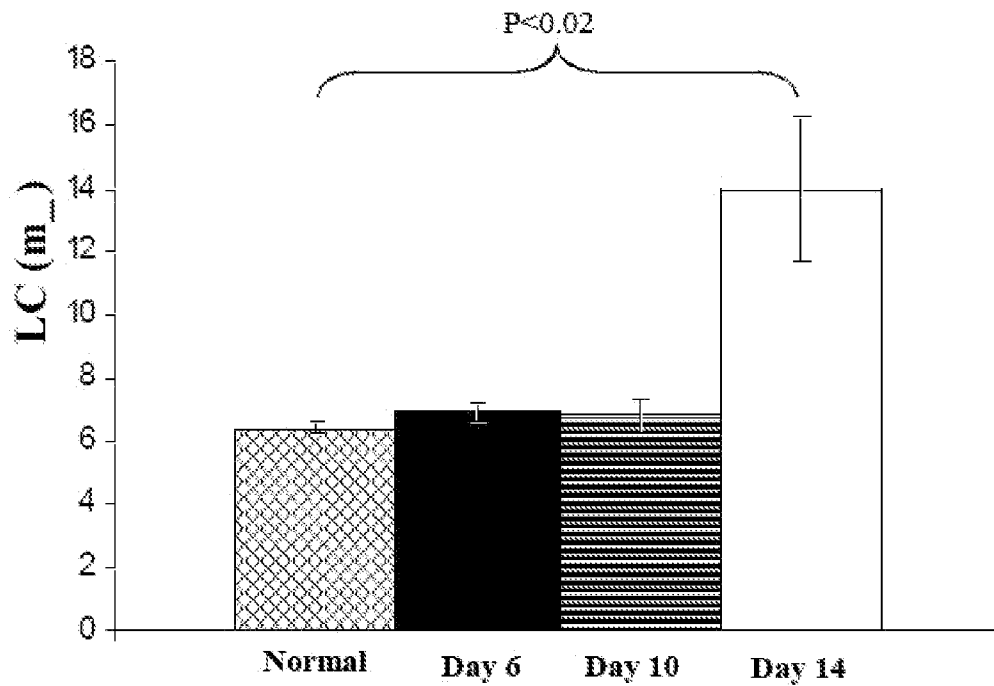


Figure 3b

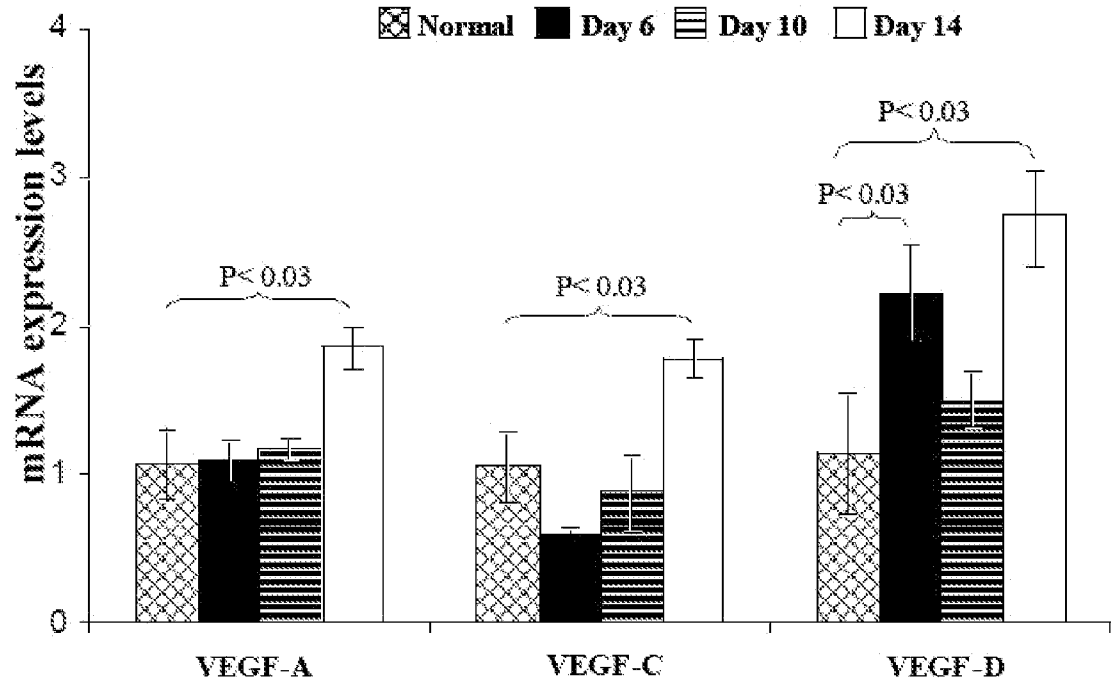


Figure 4

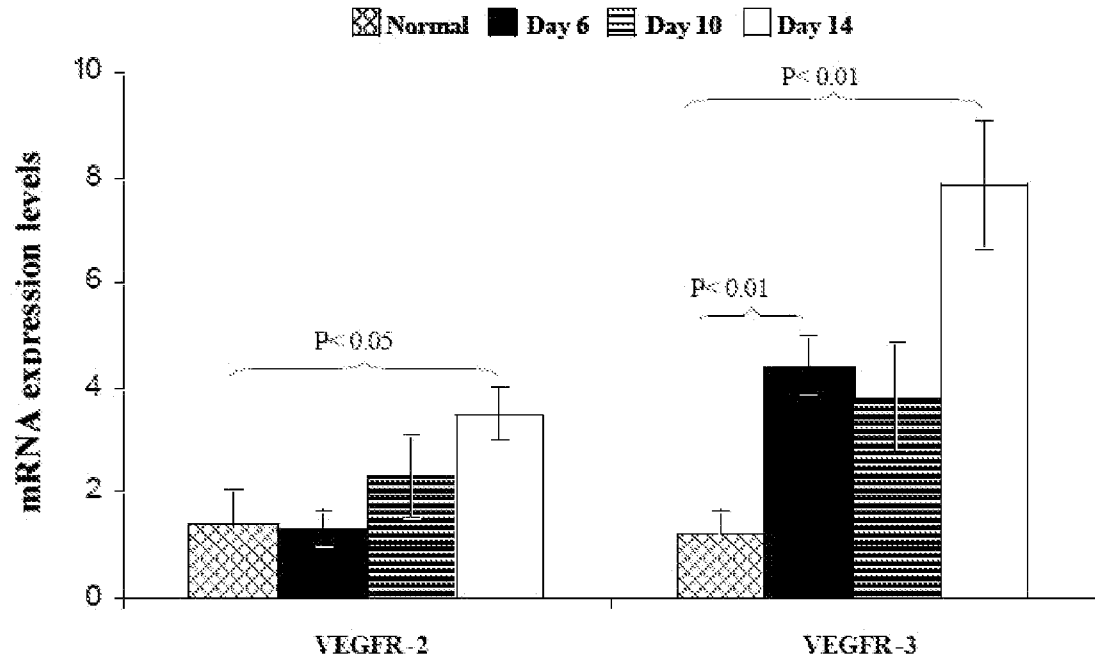


Figure 5

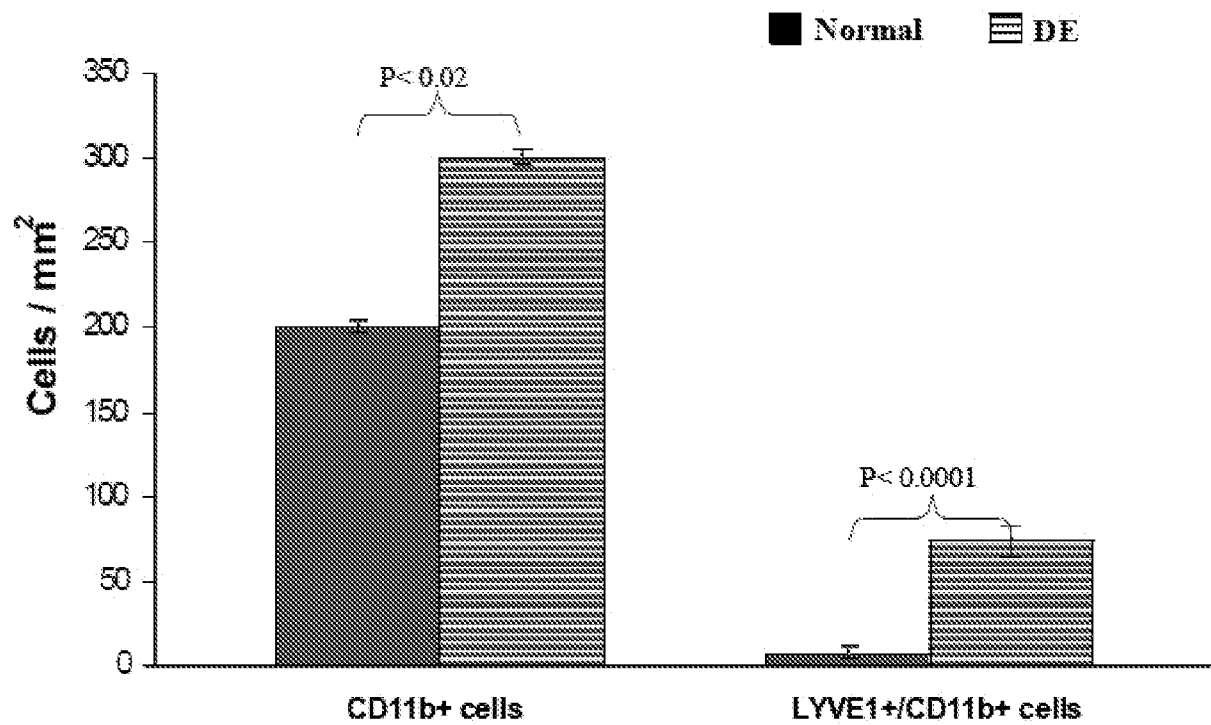


Figure 6

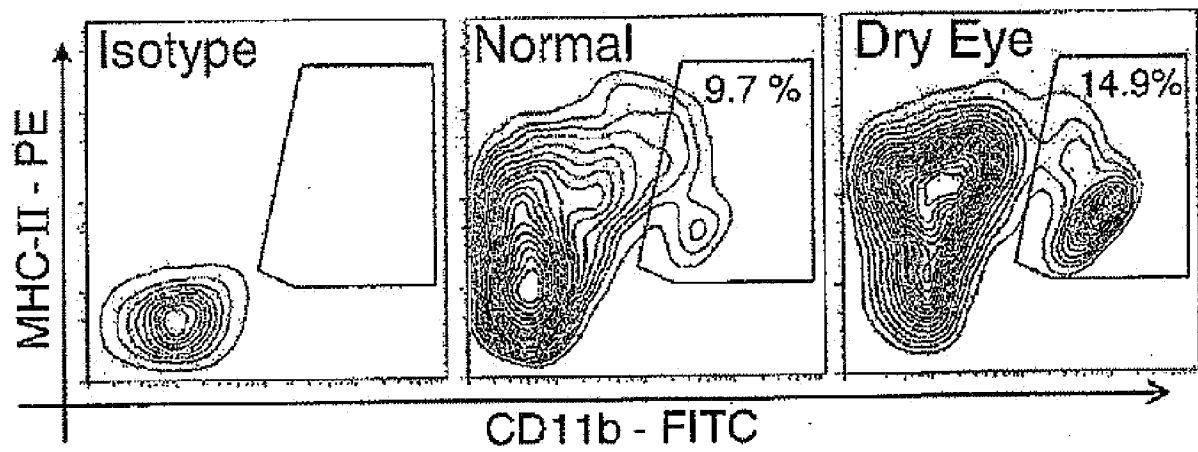


Figure 7

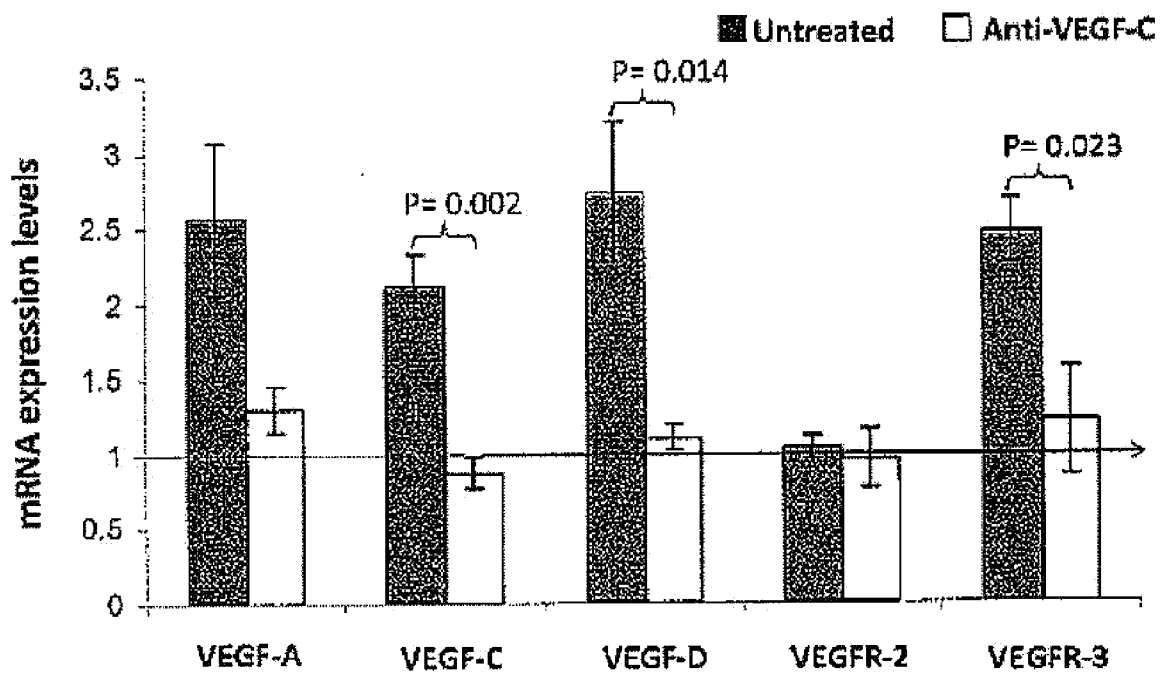


Figure 8

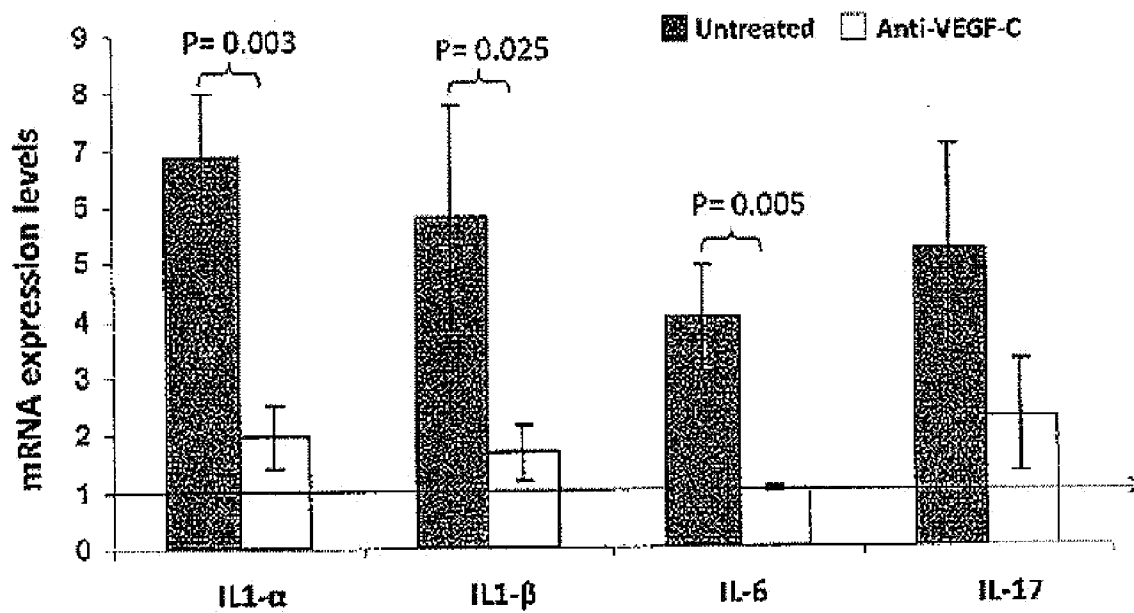


Figure 9

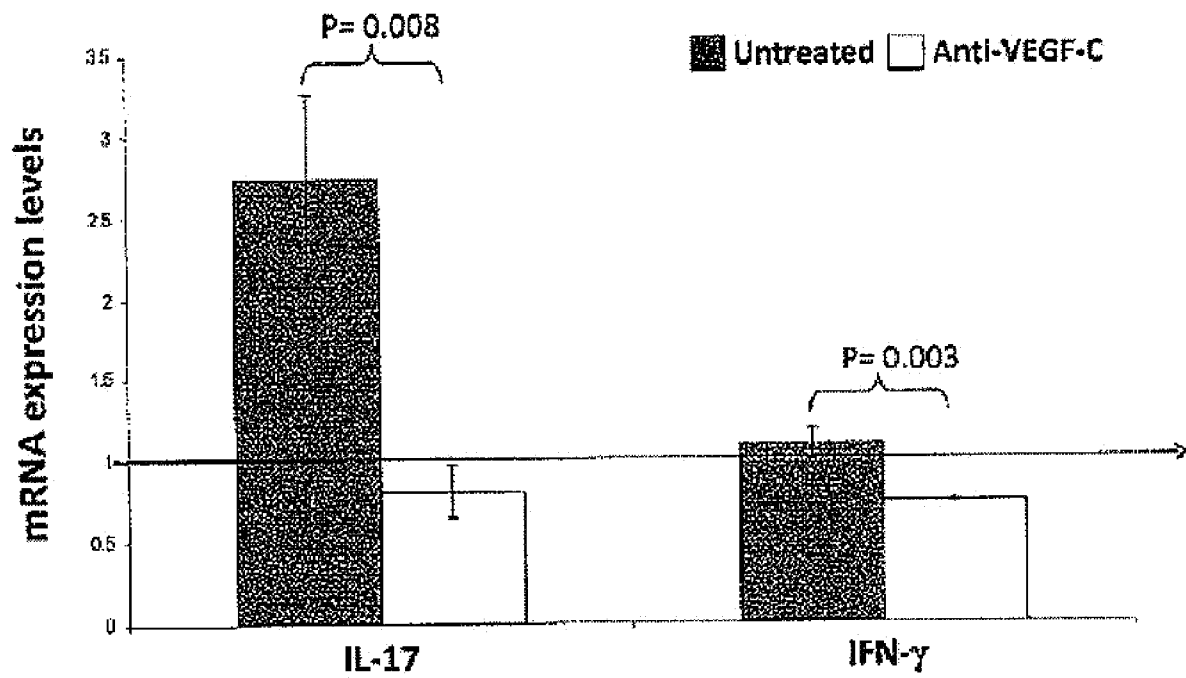


Figure 10

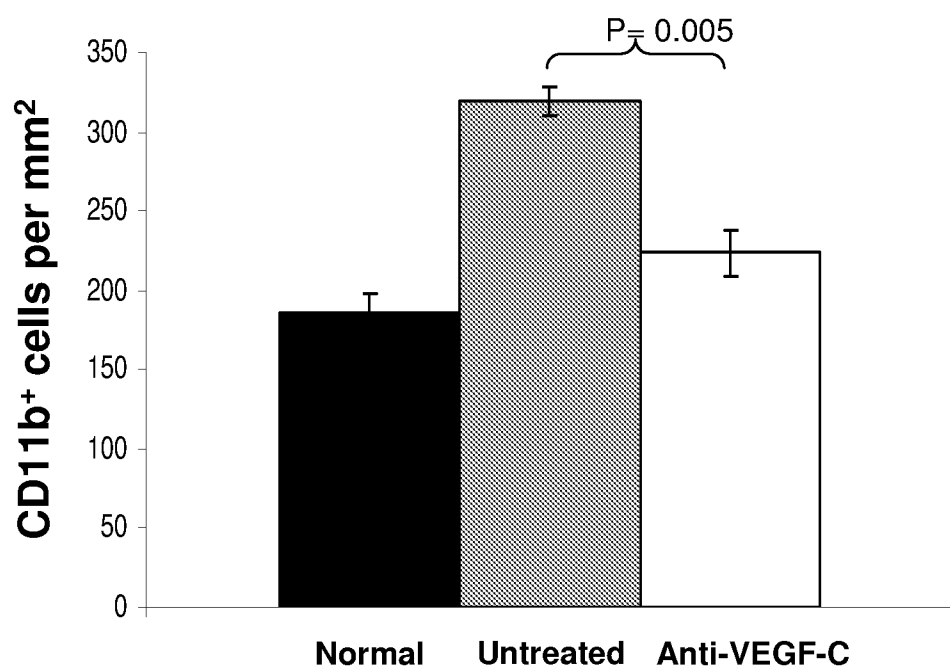
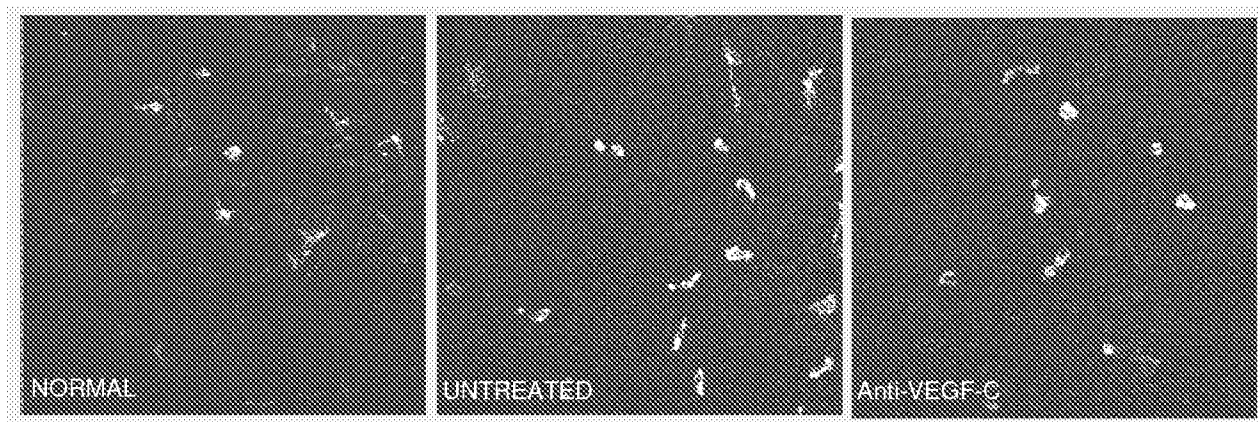
FIGURE 11

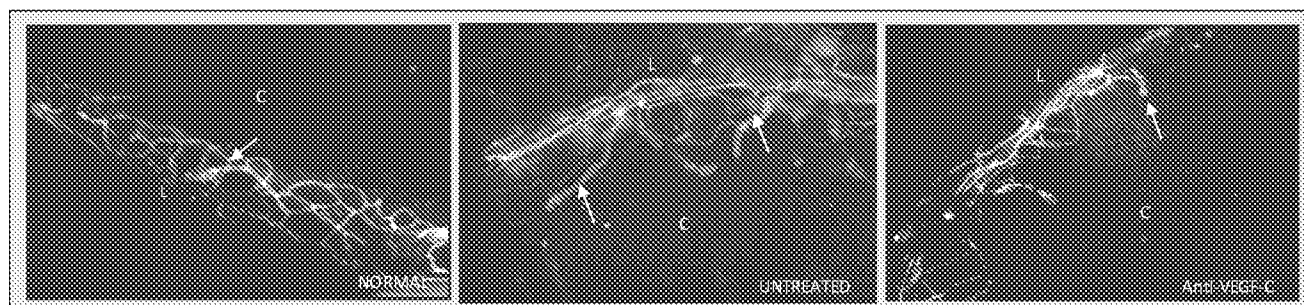
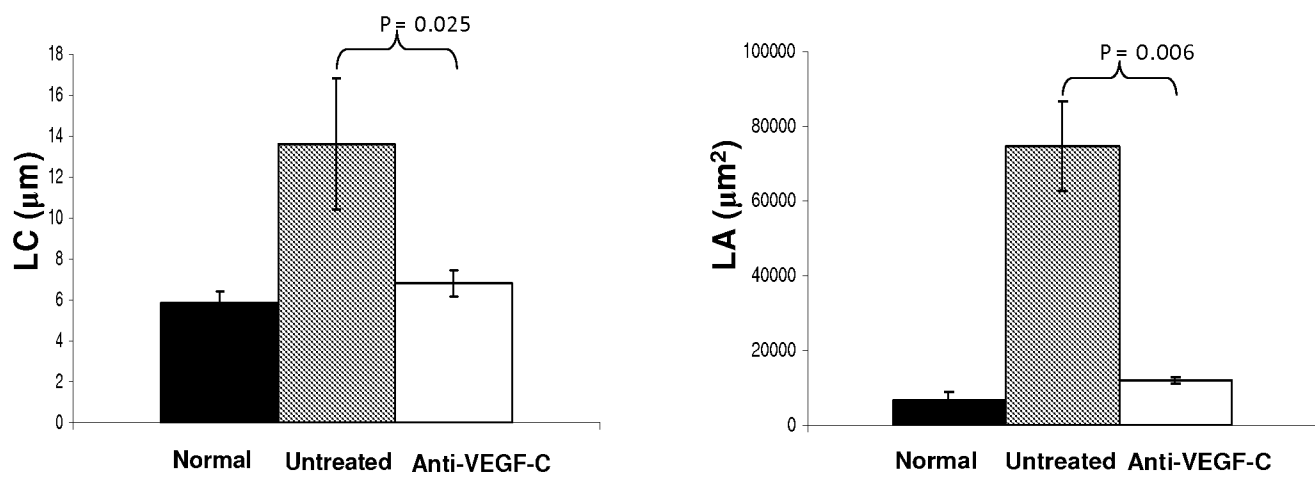
FIGURE 12

FIGURE 13

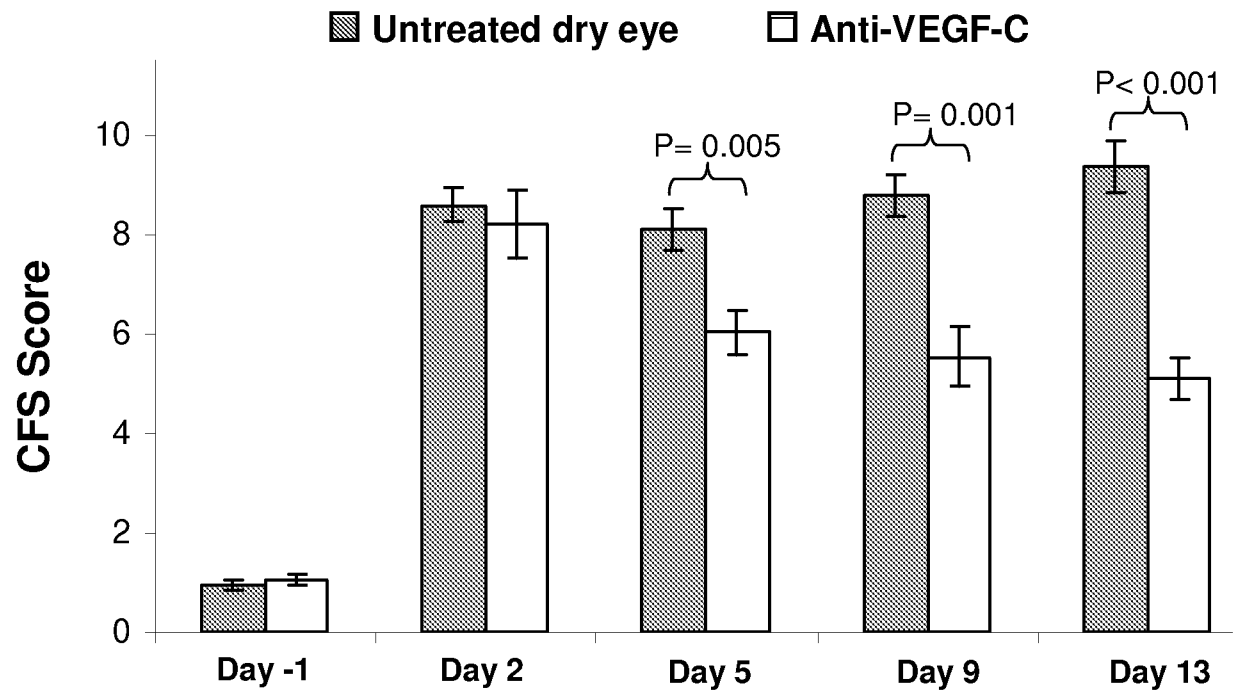


Figure 14

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2011/026316

A. CLASSIFICATION OF SUBJECT MATTER

INV. A61K38/19 A61K39/395 A61P27/02
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

A61K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, BIOSIS, COMPENDEX, EMBASE, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Y	paragraphs [0011] - [0016], [0023], [0030], [0073]; claims 1,5,7,28,29; figure 13	13-21,24
X	WO 2009/060198 A1 (PEREGRINE PHARMACEUTICALS INC [US]; AFFITECH AS [NO]; OWEN DEBORAH JAN) 14 May 2009 (2009-05-14) page 16, line 21 - line 29 page 60, line 29 - page 61, line 14 page 177, line 13	1-6,8, 10,11, 22,23, 31-35
Y	WO 03/072029 A2 (ALLERGAN INC [US]) 4 September 2003 (2003-09-04) page 57, lines 1-8; claims 1,13,20	13-21,24
	-/--	



Further documents are listed in the continuation of Box C.



See patent family annex.

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search

10 May 2011

Date of mailing of the international search report

24/05/2011

Name and mailing address of the ISA/

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Authorized officer

Bochelen, Damien

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2011/026316

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Y	----- WO 2005/087177 A2 (LUDWIG INST CANCER RES [US]; ACHEN MARC G [AU]; STACKER STEPHEN [AU];) 22 September 2005 (2005-09-22) examples 5-7	13,24
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International application No

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