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DESCRIPTION

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of priority to United States provisional application serial number 62/143,579, filed April 6, 2015.

BACKGROUND

[0002] The transforming growth factor-beta (TGF-beta) superfamily contains a variety of growth factors that share common sequence elements and structural motifs. These proteins are known to exert biological effects on a large variety of cell types in both vertebrates and invertebrates. Members of the superfamily perform important functions during embryonic development in pattern formation and tissue specification and can influence a variety of differentiation processes, including adipogenesis, myogenesis, chondrogenesis, cardiogenesis, hematopoiesis, neurogenesis, and epithelial cell differentiation. The family is divided into two general phylogenetic clades: the more recently evolved members of the superfamily, which includes TGF-betas, activins, and nodal and the clade of more distantly related proteins of the superfamily, which includes a number of BMPs and GDFs [Hinck (2012) FEBS Letters 586:1860-1870]. TGF-beta family members have diverse, often complementary biological effects. By manipulating the activity of a member of the TGF-beta family, it is often possible to cause significant physiological changes in an organism. For example, the Piedmontese and Belgian Blue cattle breeds carry a loss-of-function mutation in the GDF8 (also called myostatin) gene that causes a marked increase in muscle mass [Grobet et al. (1997) Nat Genet 17(1):71-4]. Furthermore, in humans, inactive alleles of GDF8 are associated with increased muscle mass and, reportedly, exceptional strength [Schuelke et al. (2004) N Engl J Med 350:2682-8].

[0003] Changes in fibrosis, muscle, bone, fat, red blood cells, and other tissues may be achieved by enhancing or inhibiting intracellular signaling (e.g., SMAD 1, 2, 3, 5, and/or 8) that is mediated by ligands of the TGF-beta family. Thus, there is a need for agents that regulate the activity of various ligands of the TGF-beta superfamily.

SUMMARY OF THE PRESENT DISCLOSURE

[0004] In a first aspect, the present invention provides a soluble recombinant heteromultimer comprising an ALK7 polypeptide and an ActRIIB polypeptide, wherein the ALK7 polypeptide comprises an amino acid sequence that is at least 85% identical to amino acids 28-92 of SEQ ID NO: 9, and wherein the ActRIIB polypeptide comprises an amino acid sequence that is at least 85% identical to amino acids 29-109 of SEQ ID NO: 1, wherein the ALK7 polypeptide is a fusion protein further comprising a heterologous domain, wherein the ActRIIB polypeptide is a

fusion protein further comprising a heterologous domain, and wherein the heteromultimer binds to one or more of activin A, activin B, and GDF 11. The ALK7 polypeptide may comprise an amino acid sequence that is at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identical to a polypeptide that: a. begins at any one of amino acids 21, 22, 23, 24, 25, 26, 27, or 28 of SEQ ID NO: 9, and b. ends at any one of amino acids 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, or 113 of SEQ ID NO: 9. The ActRIIB polypeptide may comprise an amino acid sequence that is at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identical to a polypeptide that: a. begins at any one of amino acids 20, 21, 22, 23, 24, 25, 26, 27, 28, or 29 of SEQ ID NO: 1, and b. ends at any one of amino acids 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133, or 134 of SEQ ID NO: 1. The heterologous domain may comprise an Fc immunoglobulin domain. The Fc immunoglobulin domain may comprise one or more amino acid modifications that promotes heterodimer formation and/or that inhibit homodimer formation. The heterologous domain may comprise an Fc immunoglobulin domain from an IgG immunoglobulin. The fusion protein may further comprise a linker domain positioned between the ALK7 domain and the heterologous domain. The ALK7 polypeptide may comprise one or more modified amino acid residues selected from the group consisting of: a glycosylated amino acid, a PEGylated amino acid, a farnesylated amino acid, an acetylated amino acid, a biotinylated amino acid, an amino acid conjugated to a lipid moiety, and an amino acid conjugated to an organic derivatizing agent. The heteromultimer may bind to activin A, activin B, activin C, activin E, activin AB, activin AC, activin AE, activin BC, activin BE, GDF8, GDF11, nodal, BMP5, BMP6, GDF3, and/or BMP10. The heteromultimer may inhibit activin A, activin B, activin C, activin E, activin AB, activin AC, activin AE, activin BC, activin BE, GDF8, GDF11, nodal, BMP5, BMP6, GDF3, and/or BMP10 signaling in a cell-based assay. The heteromultimer may be an ALK7:ActRIIB heterodimer. The heteromultimer may bind to activin B.

[0005] In another aspect, the present invention provides a pharmaceutical preparation comprising the heteromultimer of the first aspect. The pharmaceutical preparation may be substantially pyrogen-free and/or further comprises an additional active agent. The pharmaceutical preparation may comprise less than about 10%, 9%, 8%, 7%, 6%, 5%, 4%, 3%, 2%, or less than about 1% ALK7 homomultimers and/or less than about 10%, 9%, 8%, 7%, 6%, 5%, 4%, 3%, 2%, or less than about 1% ActRIIB homomultimers.

[0006] As described herein, it has been discovered that an ALK7:ActRIIB heterodimer protein complex is a unique antagonist of ligands of the TGF-beta superfamily, exhibiting a different ligand-binding profile/selectivity compared to corresponding ActRIIB and ALK7 homodimers. In particular, an exemplary ALK7:ActRIIB heterodimer displays enhanced binding to activin AC, activin C, and BMP5 compared to either homodimer, retains strong binding to activin B as observed with ActRIIB homodimer, and exhibits reduced binding to GDF11, GDF8, activin A, BMP10, BMP6, GDF3, and BMP9. In particular, ALK7:ActRIIB heterodimer displays low to no observable affinity for BMP9, whereas this ligand binds strongly to ActRIIB homodimer. See Figure 6. These results therefore demonstrate that ALK7:ActRIIB heterodimers are a more selective antagonists (inhibitors) of certain ligands of the TGF-beta superfamily compared to

ActRIIB homodimers. Accordingly, an ALK7:ActRIIB heterodimer will be more useful than an ActRIIB homodimer in certain applications where such selective antagonism is advantageous. Examples include therapeutic applications where it is desirable to antagonize one or more of activin B, activin AC, activin C, and BMP5 with decreased antagonism of one or more of activin A, BMP10, BMP6, GDF3, and BMP9. Moreover, an ALK7:ActRIIB heterodimer was shown to have therapeutic effects in a mouse model of kidney disease as well as a beneficial catabolic effects on adipose cells. Therefore, while not wishing to be bound to a particular mechanism of action, it is expected that ALK7:ActRIIB heteromultimers, as well as variants thereof, that bind to/inhibit at least one or more of activin (e.g., activin A, activin B, activin AB, activin C, activin E, activin AC, activin AE, activin BC and activin BE), GDF8, GDF11, BMP10, BMP6, BMP5, GDF3, and/or nodal will be useful agents for treating kidney disease, particularly certain disorders of kidney disease such as inflammation and fibrosis, and/or promoting beneficial catabolic effects on adipose tissue. Furthermore, it is expected that other antagonists (inhibitors), or combinations of antagonists, that mimic the binding/inhibitory properties of the ALK7:ActRIIB heterodimers as well as agents that directly or indirectly antagonize ALK7 and/or ActRIIB receptors, agents that directly or indirectly antagonize ALK7 and/or ActRIIB-binding ligands, agents that directly or indirectly antagonize downstream signaling mediator (e.g., Smads), and/or agents that directly or indirectly antagonize TGF β superfamily co-receptors (e.g., Cripto or Cryptic) will have similar biological effects. These antagonistic mimetic are collectively referred to herein as "ALK7:ActRIIB antagonists" or "ALK7:ActRIIB inhibitors".

[0007] Therefore, the present disclosure provides, in part, heteromultimer complexes (heteromultimers) comprising at least one ALK7 polypeptide and at least one ActRIIB polypeptide (ALK7:ActRIIB heteromultimers). Preferably, ALK7 polypeptides comprise a ligand-binding domain of an ALK7 receptor, for example, a portion of the ALK7 extracellular domain. Similarly, ActRIIB polypeptides generally comprise a ligand-binding domain of an ActRIIB receptor, for example, a portion of the ActRIIB extracellular domain. Preferably, such ALK7 and ActRIIB polypeptides, as well as resultant heteromultimers thereof, are soluble.

[0008] In certain aspects, an ALK7:ActRIIB heteromultimer comprises an ALK7 amino acid sequence that is at least 70% identical to a polypeptide that begins at any one of amino acids 21-28 of SEQ ID NO: 9 (e.g., amino acids 21, 22, 23, 24, 25, 26, 27, or 28) and ends at any one of amino acids 92-113 of SEQ ID NO: 9 (e.g., amino acids 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, or 113) of SEQ ID NO: 9. For example, ALK7:ActRIIB heteromultimers may comprise an amino acid sequence that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identical to amino acids 28-92 of SEQ ID NO: 9. In other instances, ALK7:ActRIIB heteromultimers may comprise an ALK7 amino acid sequence that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identical to amino acids 21-113 of SEQ ID NO: 9. In other instances, ALK7:ActRIIB heteromultimers may comprise an ALK7 amino acid sequence that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identical to SEQ ID NO: 10. In still other instances, ALK7:ActRIIB heteromultimers may comprise an ALK7 amino acid sequence that is at least 70%, 75%, 80%,

85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identical to SEQ ID NO: 20. In even other instances, ALK7:ActRIIB heteromultimers may comprise an ALK7 amino acid sequence that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identical to SEQ ID NO: 39. In further instances, ALK7:ActRIIB heteromultimers may comprise an ALK7 amino acid sequence that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identical to SEQ ID NO: 43. In further instances, ALK7:ActRIIB heteromultimers may comprise an ALK7 amino acid sequence that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identical to SEQ ID NO: 46.

[0009] In certain aspects, an ALK7:ActRIIB heteromultimer comprises an ActRIIB amino acid sequence that is at least 70% identical to a polypeptide that begins at any one of amino acids 20-29 of SEQ ID NO: 1 (e.g., 20, 21, 22, 23, 24, 25, 26, 27, 28, or 29) and ends at any one of amino acids 109-134 of SEQ ID NO: 1 (109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133, or 134) of SEQ ID NO: 1. For example, ALK7:ActRIIB heteromultimers may comprise an amino acid sequence that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identical to amino acids 29-109 of SEQ ID NO: 1. In further instances, ALK7:ActRIIB heteromultimers may comprise an ActRIIB amino acid sequence that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identical to amino acids 25-131. In other instances, ALK7:ActRIIB heteromultimers may comprise an ActRIIB amino acid sequence that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identical to SEQ ID NO: 2. In still other instances, ALK7:ActRIIB heteromultimers may comprise an ActRIIB amino acid sequence that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identical to SEQ ID NO: 5. In still even other instances, ALK7:ActRIIB heteromultimers may comprise an ActRIIB amino acid sequence that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identical to SEQ ID NO: 6. In certain preferred instances, ALK7:ActRIIB heteromultimers do not comprise an ActRIIB polypeptide comprising an acidic amino acid (e.g., the naturally occurring amino acids E or D or an artificial acidic amino acid) at the position corresponding to L79 of SEQ ID NO: 1.

[0010] Various combinations of the ALK7 and ActRIIB polypeptides described herein are also contemplated with respect to ALK7:ActRIIB heteromultimers. For example, in certain aspects, an ALK7:ActRIIB heteromultimer may comprise, consist essentially of or consist of a) a polypeptide comprising, consisting essentially of, or consisting of an ALK7 amino acid sequence that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identical to amino acids 28-92 of SEQ ID NO: 9; and b) a polypeptide comprising, or consisting essentially of, or consisting of an ActRIIB amino

acid sequence that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identical to amino acids 29-109 of SEQ ID NO: 1. In further aspects, an ALK7:ActRIIB heteromultimer may comprise, consist essentially of or consist of a) a polypeptide comprising, consisting essentially of, or consisting of an ALK7 amino acid sequence that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identical to amino acids 21-113 of SEQ ID NO: 9; and b) a polypeptide comprising, or consisting essentially of, or consisting of an ActRIIB amino acid sequence that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identical to amino acids 25-131 of SEQ ID NO: 1. In other aspects, an ALK7:ActRIIB heteromultimer may comprise, consist essentially of or consist of a) a polypeptide comprising, consisting essentially of, or consisting of an ALK7 amino acid sequence that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identical to SEQ ID NO: 10; and b) a polypeptide comprising, or consisting essentially of, or consisting of an ActRIIB amino acid sequence that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identical to SEQ ID NO: 2. In other aspects, an ALK7:ActRIIB heteromultimer may comprise, consist essentially of or consist of a) a polypeptide comprising, consisting essentially of, or consisting of an ALK7 amino acid sequence that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identical to SEQ ID NO: 20; and b) a polypeptide comprising, or consisting essentially of, or consisting of an ActRIIB amino acid sequence that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identical to SEQ ID NO: 2. In other aspects, an ALK7:ActRIIB heteromultimer may comprise, consist essentially of or consist of a) a polypeptide comprising, consisting essentially of, or consisting of an ALK7 amino acid sequence that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identical to SEQ ID NO: 39; and b) a polypeptide comprising, or consisting essentially of, or consisting of an ActRIIB amino acid sequence that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identical to SEQ ID NO: 2. In other aspects, an ALK7:ActRIIB heteromultimer may comprise, consist essentially of or consist of a) a polypeptide comprising, consisting essentially of, or consisting of an ALK7 amino acid sequence that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identical to SEQ ID NO: 43; and b) a polypeptide comprising, or consisting essentially of, or consisting of an ActRIIB amino acid sequence that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identical to SEQ ID NO: 2. In even other aspects, an ALK7:ActRIIB heteromultimer may comprise, consist essentially of or consist of a) a polypeptide comprising,

consisting essentially of, or consisting of an ALK7 amino acid sequence that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identical to SEQ ID NO: 10; and b) a polypeptide comprising, or consisting essentially of, or consisting of an ActRIIB amino acid sequence that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identical to SEQ ID NO: 3. In even other aspects, an ALK7:ActRIIB heteromultimer may comprise, consist essentially of or consist of a) a polypeptide comprising, consisting essentially of, or consisting of an ALK7 amino acid sequence that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identical to SEQ ID NO: 20; and b) a polypeptide comprising, or consisting essentially of, or consisting of an ActRIIB amino acid sequence that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identical to SEQ ID NO: 3. In even other aspects, an ALK7:ActRIIB heteromultimer may comprise, consist essentially of or consist of a) a polypeptide comprising, consisting essentially of, or consisting of an ALK7 amino acid sequence that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identical to SEQ ID NO: 39; and b) a polypeptide comprising, or consisting essentially of, or consisting of an ActRIIB amino acid sequence that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identical to SEQ ID NO: 3. In even other aspects, an ALK7:ActRIIB heteromultimer may comprise, consist essentially of or consist of a) a polypeptide comprising, consisting essentially of, or consisting of an ALK7 amino acid sequence that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identical to SEQ ID NO: 43; and b) a polypeptide comprising, or consisting essentially of, or consisting of an ActRIIB amino acid sequence that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identical to SEQ ID NO: 3. In other aspects, an ALK7:ActRIIB heteromultimer may comprise, consist essentially of or consist of a) a polypeptide comprising, consisting essentially of, or consisting of an ALK7 amino acid sequence that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identical to SEQ ID NO: 46; and b) a polypeptide comprising, or consisting essentially of, or consisting of an ActRIIB amino acid sequence that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identical to SEQ ID NO: 3. In still other aspects, an ALK7:ActRIIB heteromultimer may comprise, consist essentially of or consist of a) a polypeptide comprising, consisting essentially of, or consisting of an ALK7 amino acid sequence that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identical to SEQ ID NO: 10; and b) a polypeptide comprising, or consisting essentially of, or consisting of an ActRIIB amino acid

sequence that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identical to SEQ ID NO: 6.

[0011] As described herein, ALK7:ActRIIB heteromultimer structures include, for example, heterodimers, heterotrimers, heterotetramers, heteropentamers, and higher order heteromultimer complexes. See, e.g., Figures 1, 2, and 8-10. In certain preferred instances, ALK7:ActRIIB heteromultimers are heterodimers.

[0012] In certain aspects, ALK7 and/or ActRIIB polypeptides may be fusion proteins. For example, in some instances, an ALK7 polypeptide may be a fusion protein comprising an ALK7 polypeptide domain and one or more heterologous (non-ALK7) polypeptide domains. Similarly, in some instances, an ActRIIB polypeptide may be a fusion protein comprising an ActRIIB polypeptide domain and one or more heterologous (non-ActRIIB) polypeptide domains. Optionally, ALK7 polypeptides are connected directly (fused) to one or more heterologous domains, or an intervening sequence, such as a linker, may be positioned between the amino acid sequence of the ALK7 polypeptide and the one or more heterologous domains. Similarly, the ActRIIB polypeptide may be connected directly (fused) to one or more heterologous domains, or an intervening sequence, such as a linker, may be positioned between the amino acid sequence of the ActRIIB polypeptide and the one or more heterologous domains. Linkers may correspond to the roughly 15 amino acid unstructured region at the C-terminal end of the extracellular domain of ActRIIB or ALK7 (the "tail"), or it may be an artificial sequence of between 5 and 15, 20, 30, 50, 100 or more amino acids that are relatively free of secondary structure. A linker may be rich in glycine and proline residues and may, for example, contain repeating sequences of threonine/serine and glycines. Examples of linkers include, but are not limited to, the sequences TGGG (SEQ ID NO: 17), SGGG (SEQ ID NO: 18), TGGGG (SEQ ID NO: 15), SGGGG (SEQ ID NO: 16), GGGGS (SEQ ID NO: 58), GGGG (SEQ ID NO: 14), and GGG (SEQ ID NO: 13). In some instances, the one or more heterologous domains that provide a desirable property to the ALK7 and/or ActRIIB fusion proteins including, for example, improved pharmacokinetics, easier purification, targeting to particular tissues, etc. For example, a heterologous domain of a fusion protein may enhance one or more of in vivo stability, in vivo half-life, uptake/administration, tissue localization or distribution, formation of protein complexes, multimerization of the fusion protein, and/or purification. An ALK7 or ActRIIB fusion protein may include an immunoglobulin Fc domain (wild-type or mutant) or a serum albumin. In some instances, an ALK7 and/or ActRIIB polypeptides may comprise a purification subsequence, such as an epitope tag, a FLAG tag, a polyhistidine sequence, and a GST fusion.

[0013] In certain instances, ALK7:ActRIIB heteromultimers described herein comprise an ALK7 polypeptide covalently, or non-covalently, associated with an ActRIIB polypeptide wherein the ALK7 polypeptide comprises an ALK7 domain and an amino acid sequence of a first member (or second member) of an interaction pair and the ActRIIB polypeptide comprises an ActRIIB polypeptide and an amino acid sequence of a second member (or first member) of the interaction pair. Interaction pairs described herein are designed to promote dimerization or form higher order multimers. See, e.g., Figures 1, 2, and 8-10. In some instances, the

interaction pair may be any two polypeptide sequences that interact to form a complex, particularly a heterodimeric complex although operative instances may also employ an interaction pair that forms a homodimeric sequence. The first and second members of the interaction pair may be an asymmetric pair, meaning that the members of the pair preferentially associate with each other rather than self-associate (i.e., guided interaction pairs). Accordingly, first and second members of an asymmetric interaction pair may associate to form a heterodimeric complex. Alternatively, the interaction pair may be unguided, meaning that the members of the pair may associate with each other or self-associate without substantial preference and thus may have the same or different amino acid sequences. Accordingly, first and second members of an unguided interaction pair may associate to form a homodimer complex or a heterodimeric complex. Optionally, the first member of the interaction action pair (e.g., an asymmetric pair or an unguided interaction pair) associates covalently with the second member of the interaction pair. Optionally, the first member of the interaction action pair (e.g., an asymmetric pair or an unguided interaction pair) associates non-covalently with the second member of the interaction pair. Optionally, the first member of the interaction action pair (e.g., an asymmetric pair or an unguided interaction pair) associates through both covalent and non-covalent mechanisms with the second member of the interaction pair.

[0014] In some instances, ALK7 polypeptides are fusion proteins that comprise an Fc domain of an immunoglobulin. Similarly, in some instances, ActRIIB polypeptides are fusion proteins that comprise an Fc domain of an immunoglobulin. Traditional Fc fusion proteins and antibodies are examples of unguided interaction pairs, whereas a variety of engineered Fc domains have been designed as asymmetric interaction pairs [Spiess et al (2015) Molecular Immunology 67(2A): 95-106]. Therefore, a first member and/or a second member of an interaction pair described herein may comprise a constant domain of an immunoglobulin, including, for example, the Fc portion of an immunoglobulin. For example, a first member of an interaction pair may comprise an amino acid sequence that is derived from an Fc domain of an IgG (IgG1, IgG2, IgG3, or IgG4), IgA (IgA1 or IgA2), IgE, or IgM immunoglobulin. Such immunoglobulin domains may comprise one or more amino acid modifications (e.g., deletions, additions, and/or substitutions) that promote ALK7:ActRIIB heteromultimer formation. For example, the first member of an interaction pair may comprise, consist essentially of, or consist of an amino acid sequence that is at least 70%, 75%, 80%, 85%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99% or 100% identical to any one of SEQ ID NOs: 23-37. Similarly, a second member of an interaction pair may comprise an amino acid sequence that is derived from an Fc domain of an IgG (IgG1, IgG2, IgG3, or IgG4), IgA (IgA1 or IgA2), IgE, or IgM. Such immunoglobulin domains may comprise one or more amino acid modifications (e.g., deletions, additions, and/or substitutions) that promote ALK7:ActRIIB heteromultimer formation. For example, the second member of an interaction pair may comprise, consist essentially of, or consist of an amino acid sequence that is at least 70%, 75%, 80%, 85%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99% or 100% identical to any one of SEQ ID NOs: 23-37. In some instances, a first member and a second member of an interaction pair comprise Fc domains derived from the same immunoglobulin class and subtype. In other instances, a first member and a second member of an interaction pair comprise Fc domains derived from different immunoglobulin classes or subtypes.

[0015] In some instances, an ALK7:ActRIIB heterodimer comprises i) an ALK7 polypeptide comprising, consisting essentially of, or consisting of an amino acid sequence that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identical to SEQ ID NO: 76, and ii) an ActRIIB polypeptide comprising, consisting essentially of, or consisting of an amino acid sequence that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identical to SEQ ID NO: 73. In other instances, an ALK7:ActRIIB heterodimer comprises i) an ALK7 polypeptide comprising, consisting essentially of, or consisting of an amino acid sequence that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identical to SEQ ID NO: 80, and ii) an ActRIIB polypeptide comprising, consisting essentially of, or consisting of an amino acid sequence that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identical to SEQ ID NO: 78.

[0016] Optionally, a first member and/or a second member of an interaction pair (e.g., an asymmetric pair or an unguided interaction pair) comprise a modified constant domain of an immunoglobulin, including, for example, a modified Fc portion of an immunoglobulin. For example, protein complexes of the disclosure may comprise a first modified Fc portion of an IgG comprising, consisting essentially of, or consisting of an amino acid sequence that is at least 80%, 85%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% identical to an amino acid sequence selected from the group: SEQ ID NOs: 23-37 and a second modified Fc portion of an IgG, which may be the same or different from the amino acid sequence of the first modified Fc portion of the IgG, comprising, consisting essentially of, or consisting of an amino acid sequence that is at least 80%, 85%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% identical to an amino acid sequence selected from the group: SEQ ID NOs: 23-37. In some instances, ALK7:ActRIIB heteromultimers comprise, consist essentially of, or consist of: a) an ALK7 (or ActRIIB) fusion protein comprising an immunoglobulin domain that comprises an amino acid sequence that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identical to SEQ ID NO: 23, optionally wherein the immunoglobulin domain comprises a positively charged amino acid (e.g., K, R, or H) at the positions corresponding to residues 134 and 177 of SEQ ID NO: 23, and further optionally wherein the immunoglobulin domain does not comprise a positively charged amino acid (e.g., K, R, or H) at the position corresponding to residue 225 of SEQ ID NO: 23, and b) an ActRIIB (or ALK7) fusion protein comprising an immunoglobulin domain that comprises, consisting essentially of, or consisting of an amino acid sequence that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identical to SEQ ID NO: 24, optionally wherein the immunoglobulin domain comprises a negatively charged (e.g., D or E) amino acid at the positions corresponding to residues 170 and 187 of SEQ ID NO: 24, and further optionally wherein the immunoglobulin domain comprises a positively charged amino acid (e.g., K, R, or H) at the position corresponding to residue 225 of SEQ ID NO: 24. In other instances, ALK7:ActRIIB heteromultimers comprise, consist essentially of, or consist of: a) an ALK7 (or ActRIIB) fusion protein comprising an immunoglobulin domain that comprises an amino acid sequence that is

at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identical to SEQ ID NO: 27, optionally wherein the immunoglobulin domain comprises a C at the position corresponding to residue 132 of SEQ ID NO: 27 and a W at the position corresponding to residue 144 of SEQ ID NO: 27, and further optionally wherein the immunoglobulin domain does not comprise a positively charged amino acid (e.g., K, R, or H) at the position corresponding to residue 225 of SEQ ID NO: 27, and b) an ActRIIB (or ALK7) fusion protein comprising an immunoglobulin domain that comprises, consisting essentially of, or consisting of an amino acid sequence that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identical to SEQ ID NO: 28, optionally wherein the immunoglobulin domain comprises a S at the position corresponding to residue 144 of SEQ ID NO: 28, an A at the position corresponding to residue 146 of SEQ ID NO: 28, and a V at the position corresponding to residue 185 of SEQ ID NO: 28, and further optionally wherein the immunoglobulin domain does not comprise a positively charged amino acid (e.g., K, R, or H) at the position corresponding to residue 225 of SEQ ID NO: 28.

[0017] Optionally, an ALK7 and/or ActRIIB polypeptide includes one or more modified amino acid residues selected from: a glycosylated amino acid, a PEGylated amino acid, a farnesylated amino acid, an acetylated amino acid, a biotinylated amino acid, an amino acid conjugated to a lipid moiety, and an amino acid conjugated to an organic derivatizing agent. ALK7 and/or ActRIIB polypeptides may comprise at least one N-linked sugar, and may include two, three or more N-linked sugars. Such polypeptides may also comprise O-linked sugars. ALK7 and/or ActRIIB polypeptides may be produced in a variety of cell lines that glycosylate the protein in a manner that is suitable for patient use, including engineered insect or yeast cells, and mammalian cells such as COS cells, CHO cells, HEK cells and NSO cells. In some instances an ALK7 and/or ActRIIB polypeptide is glycosylated and has a glycosylation pattern obtainable from a Chinese hamster ovary cell line. Preferably ALK7:ActRIIB heteromultimer complexes of the disclosure exhibit a serum half-life of at least 4, 6, 12, 24, 36, 48, or 72 hours in a mammal (e.g., a mouse or a human). Optionally, ALK7:ActRIIB heteromultimers may exhibit a serum half-life of at least 6, 8, 10, 12, 14, 20, 25, or 30 days in a mammal (e.g., a mouse or a human).

[0018] In certain aspects, ALK7:ActRIIB heteromultimers of the disclosure bind to one or more TGF-beta superfamily ligands. Optionally, ALK7:ActRIIB heteromultimers bind to one or more of these ligands with a K_D of less than or equal to 10^{-8} , 10^{-9} , 10^{-10} , 10^{-11} , or 10^{-12} M. For example, in some instances, ALK7:ActRIIB heteromultimers bind to activin. In some instances, ALK7:ActRIIB heteromultimers bind to activin A. In some instances, ALK7:ActRIIB heteromultimers bind to activin B. In some instances, ALK7:ActRIIB heteromultimers bind to activin C. In some instances, ALK7:ActRIIB heteromultimers bind to activin AB. In some instances, ALK7:ActRIIB heteromultimers bind to activin AC. In some instances, ALK7:ActRIIB heteromultimers bind to activin BC. In some instances, ALK7:ActRIIB heteromultimers bind to activin E. In some instances, ALK7:ActRIIB heteromultimers bind to activin AE. In some instances, ALK7:ActRIIB heteromultimers bind to activin BE. In some instances, ALK7:ActRIIB heteromultimers bind to GDF11. In some instances, ALK7:ActRIIB heteromultimers bind to GDF8. In some instances, ALK7:ActRIIB heteromultimers bind to BMP6. In some instances,

ALK7:ActRIIB heteromultimers bind to BMP10. In some instances, ALK7:ActRIIB heteromultimers bind to BMP5. In some instances, ALK7:ActRIIB heteromultimers bind to GDF3. In some instances, ALK7:ActRIIB heteromultimers bind to nodal. In some instances, ALK7:ActRIIB heteromultimers do not bind to or do not substantially bind to BMP9. In some instances, the ALK7:ActRIIB heteromultimer binds to BMP10 with weaker affinity compared to a corresponding ActRIIB homomultimer. In some instances, the ALK7:ActRIIB heteromultimer binds to BMP9 with weaker affinity compared to a corresponding ActRIIB homomultimer. In some instances, the ALK7:ActRIIB heteromultimer binds to GDF3 with weaker affinity compared to a corresponding ActRIIB homomultimer. In some instances, the ALK7:ActRIIB heteromultimer binds to BMP6 with weaker affinity compared to a corresponding ActRIIB homomultimer. In some instances, the ALK7:ActRIIB heteromultimer binds to GDF8 with weaker affinity compared to a corresponding ActRIIB homomultimer. In some instances, the ALK7:ActRIIB heteromultimer binds to GDF11 with weaker affinity compared to a corresponding ActRIIB homomultimer. In some instances, the ALK7:ActRIIB heteromultimer binds to activin C with stronger affinity compared to a corresponding ActRIIB homomultimer. In some instances, the ALK7:ActRIIB heteromultimer binds to activin AC with stronger affinity compared to a corresponding ActRIIB homomultimer. In some instances, the ALK7:ActRIIB heteromultimer binds to BMP5 with stronger affinity compared to a corresponding ActRIIB homomultimer.

[0019] In general, ALK7:ActRIIB heteromultimers of the disclosure antagonize (inhibit) one or more activities of at least one TGF-beta superfamily ligand, and such alterations in activity may be measured using various assays known in the art, including, for example, a cell-based assay such as those described herein. In certain aspects, ALK7:ActRIIB heteromultimers may be used to inhibit signaling (e.g., Smad 2/3 and/or Smad 1/5/8 signaling) mediated by one or more TGFβ superfamily ligands in, for example, a cell-based assay. For example, in some instances, ALK7:ActRIIB heteromultimers inhibit activin signaling in a cell-based assay. In some instances, ALK7:ActRIIB heteromultimers inhibit activin A signaling in a cell-based assay. In some instances, ALK7:ActRIIB heteromultimers inhibit activin B signaling in a cell-based assay. In some instances, ALK7:ActRIIB heteromultimers inhibit activin C signaling in a cell-based assay. In some instances, ALK7:ActRIIB heteromultimers inhibit activin AB signaling in a cell-based assay. In some instances, ALK7:ActRIIB heteromultimers inhibit activin AC signaling in a cell-based assay. In some instances, ALK7:ActRIIB heteromultimers inhibit activin BC signaling in a cell-based assay. In some instances, ALK7:ActRIIB heteromultimers inhibit activin E signaling in a cell-based assay. In some instances, ALK7:ActRIIB heteromultimers inhibit activin AE signaling in a cell-based assay. In some instances, ALK7:ActRIIB heteromultimers inhibit activin BE signaling in a cell-based assay. In some instances, ALK7:ActRIIB heteromultimers inhibit GDF11 signaling in a cell-based assay. In some instances, ALK7:ActRIIB heteromultimers inhibit GDF8 signaling in a cell-based assay. In some instances, ALK7:ActRIIB heteromultimers inhibit BMP6 signaling in a cell-based assay. In some instances, ALK7:ActRIIB heteromultimers inhibit BMP10 signaling in a cell-based assay. In some instances, ALK7:ActRIIB heteromultimers inhibit BMP5 signaling in a cell-based assay. In some instances, ALK7:ActRIIB heteromultimers may inhibit GDF3 signaling in a cell-based assay. In some instances, ALK7:ActRIIB heteromultimers may inhibit nodal signaling in a cell-based assay. In some

instances, ALK7:ActRIIB heteromultimers do not inhibit or do not substantially inhibit BMP9 signaling in a cell-based assay. In some instances, ALK7:ActRIIB heteromultimers are weaker inhibitors of BMP9 signaling in a cell-based assay compared to a corresponding ActRIIB homomultimer. In some instances, ALK7:ActRIIB heteromultimers are weaker inhibitors of BMP10 signaling in a cell-based assay compared to a corresponding ActRIIB homomultimer. In some instances, ALK7:ActRIIB heteromultimers are weaker inhibitors of BMP6 signaling in a cell-based assay compared to a corresponding ActRIIB homomultimer. In some instances, ALK7:ActRIIB heteromultimers are weaker inhibitors of GDF3 signaling in a cell-based assay compared to a corresponding ActRIIB homomultimer. In some instances, ALK7:ActRIIB heteromultimers are weaker inhibitors of GDF11 signaling in a cell-based assay compared to a corresponding ActRIIB homomultimer. In some instances, ALK7:ActRIIB heteromultimers are weaker inhibitors of GDF8 signaling in a cell-based assay compared to a corresponding ActRIIB homomultimer. In some instances, ALK7:ActRIIB heteromultimers are weaker inhibitors of activin A signaling in a cell-based assay compared to a corresponding ActRIIB homomultimer. In some instances, ALK7:ActRIIB heteromultimers are stronger inhibitors of activin C signaling in a cell-based assay compared to a corresponding ActRIIB homomultimer. In some instances, ALK7:ActRIIB heteromultimers are stronger inhibitors of activin AC signaling in a cell-based assay compared to a corresponding ActRIIB homomultimer. In some instances, ALK7:ActRIIB heteromultimers are stronger inhibitors of BMP5 signaling in a cell-based assay compared to a corresponding ActRIIB homomultimer.

[0020] Any of the ALK7:ActRIIB heteromultimers as well as ALK7:ActRIIB antagonists described herein may be formulated as a pharmaceutical preparation (compositions). In some instances, pharmaceutical preparations comprise a pharmaceutically acceptable carrier. A pharmaceutical preparation will preferably be pyrogen-free (meaning pyrogen free to the extent required by regulations governing the quality of products for therapeutic use). A pharmaceutical preparation may also include one or more additional compounds such as a compound that is used to treat a disorder/condition described herein. In general, ALK7:ActRIIB heteromultimer pharmaceutical preparations are substantially free of ALK7 and/or ActRIIB homomultimers. For example, in some instances, ALK7:ActRIIB heteromultimer pharmaceutical preparations comprise less than about 10%, 9%, 8%, 7%, 6%, 5%, 4%, 3%, 2%, or less than about 1% ALK7 homomultimers. In some instances, ALK7:ActRIIB heteromultimer pharmaceutical preparations comprise less than about 10%, 9%, 8%, 7%, 6%, 5%, 4%, 3%, 2%, or less than about 1% ActRIIB homomultimers.

[0021] In certain aspects, the disclosure provides nucleic acids encoding an ALK7 or ActRIIB polypeptide as described herein. For example, an ActRIIB nucleic acid may comprise, consists essentially of, or consists of a nucleic acid that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identical to the sequence of 73-396 of SEQ ID NO: 7 or one that hybridizes under stringent conditions to the complement of nucleotides 73-396 of SEQ ID NO: 7. Such a nucleic acid may be one that comprises the sequence of SEQ ID NOs: 8 or 72. In some instances, an ActRIIB nucleic acid comprises, consists essentially of, or consists of a nucleotide sequence that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%,

99%, or 100% identical to any one of SEQ ID Nos: 7, 8, and 72. Similarly, an ALK7 nucleic acid may comprise, consists essentially of, or consists of a nucleic acid that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identical to the sequence of 61-339 of SEQ ID NO: 11 or one that hybridizes under stringent conditions to the complement of nucleotides 61-339 of SEQ ID NO: 11. Such an ALK7 nucleic acid may be one that comprises the sequence of SEQ ID NOs: 12, 22, 41, 45, or 75. In some instances, an ALK7 nucleic acid comprises, consists essentially of, or consists of a nucleotide sequence that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identical to any one of SEQ ID NOs: 11, 12, 22, 41, 45, or 75.

[0022] In certain aspects, the present disclosure provides nucleic acids sequence comprising a coding sequence for and ALK7 polypeptide and a coding sequence for the ActRIIB polypeptide. For example, in some instances, nucleic acids of the disclosure a) comprises, consists essentially of, or consists of a nucleotide sequence that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identical to any one of SEQ ID NOs: 11, 12, 21, 22, 40, 41, 44, 45, or 75, and b) comprises, consists essentially of, or consists of a nucleotide sequence that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identical to any one of SEQ ID Nos: 7, 8, or 72. Preferably, ALK7 and/or ActRIIB nucleic acids are isolated and/or recombinant nucleic acids. Nucleic acids disclosed herein may be operably linked to a promoter for expression. The present disclosure further provides vectors comprising such ALK7 and/or ActRIIB polynucleotides as well as cells (e.g., CHO cells), preferably cells isolated from a human or other vertebrate species, comprising such ALK7 and/or ActRIIB polynucleotides as well as vectors comprising such ALK7 and/or ActRIIB polynucleotides.

[0023] In certain aspects, ALK7 polypeptides and/or ActRIIB polypeptides may be expressed in a mammalian cell line, optionally a cell line that mediates suitably natural glycosylation of the ActRIIB or ALK7 protein so as to diminish the likelihood of an unfavorable immune response in a patient (including the possibility of veterinary patients). Human and CHO cell lines have been used successfully, and it is expected that other common mammalian expression vectors will be useful. Thus the disclosure provides cultured cells comprising any of the nucleic acids disclosed herein. Such cells may be mammalian cells, including CHO cells, NSO cells, HEK cells and COS cells. Other cells may be chosen depending on the species of the intended patient. Other cells are disclosed herein. Cultured cells are understood to mean cells maintained in laboratory or other man-made conditions (e.g., frozen, or in media) and not part of a living organism.

[0024] In certain aspects, the disclosure provides methods for making any of the ALK7 and ActRIIB polypeptides described herein as well as ALK7:ActRIIB heteromultimer complexes comprising such polypeptides. Such a method may include expressing any of the nucleic acids disclosed herein in a suitable cell (e.g., CHO cell or a COS cell). For example, in some instances a method of making a heteromultimer comprising an ALK7 polypeptide and an ActRIIB polypeptide comprises: a) culturing a cell under conditions suitable for expression of an

ALK7 polypeptide and an ActRIIB polypeptide, wherein the cell comprises an ALK7 polynucleotide and an ActRIIB polynucleotide; and b) recovering the heteromultimer so expressed. Alternatively, a method of making a heteromultimer comprising an ALK7 polypeptide and an ActRIIB polypeptide may comprise: a) culturing a first cell under conditions suitable for expression of an ALK7 polypeptide, wherein the first cell comprises an ALK7 polynucleotide; b) recovering the ALK7 polypeptide so expressed; c) culturing a second cell under conditions suitable for expression of an ActRIIB polypeptide, wherein the second cell comprises an ActRIIB polynucleotide; d) recovering the ActRIIB polypeptide so expressed; e) combining the recovered ALK7 polypeptide and the recovered ActRIIB polypeptide under conditions suitable for ALK7:ActRIIB heteromultimer formation; and f) recovering the ALK7:ActRIIB heteromultimer. In certain instances, ALK7 and/or ActRIIB polypeptides are expressed using a TPA leader sequence (e.g., SEQ ID NO: 70). In certain instances, ALK7 and/or ActRIIB polypeptides are expressed in a CHO cell. ALK7 and ActRIIB polypeptides described herein, as well as protein complexes of the same, may be recovered as crude, partially purified, or highly purified fractions using any of the well-known techniques for obtaining protein from cell cultures. In general, such methods result in ALK7:ActRIIB complexes that are substantially free of ALK7 and/or ActRIIB homomultimers. For example, in some instances, methods for producing ALK7:ActRIIB heteromultimers result in less than about 10%, 9%, 8%, 7%, 6%, 5%, 4%, 3%, 2%, or less than about 1% ALK7 homomultimers. In some instances, methods for producing ALK7:ActRIIB heteromultimers result in less than about 10%, 9%, 8%, 7%, 6%, 5%, 4%, 3%, 2%, or less than about 1% ActRIIB homomultimers. In some instances, methods for producing ALK7:ActRIIB heteromultimers result in less than about 10%, 9%, 8%, 7%, 6%, 5%, 4%, 3%, 2%, or less than about 1% ALK7 homomultimers and In some instances, methods for producing ALK7:ActRIIB heteromultimers result in less than about 10%, 9%, 8%, 7%, 6%, 5%, 4%, 3%, 2%, or less than about 1% ActRIIB homomultimers.

[0025] The disclosure further provides methods and ALK7:ActRIIB heteromultimers for use in the treatment or prevention of various activin C-associated diseases and conditions. For example, in some instances, ALK7:ActRIIB heteromultimers may be used to increase fertility, increase sperm production, increase seminiferous tubule volume, decrease prostate inflammation, decrease liver inflammation in a patient in need thereof. In some instances, ALK7:ActRIIB heteromultimers may be used to treat or prevent hepatic cancer, testicular cancer, or prostate cancer. In some instances, ALK7:ActRIIB heteromultimers may be used to decrease levels (e.g., serum levels) of activin C in a patient in need thereof.

[0026] The disclosure further provides methods and ALK7:ActRIIB antagonists (e.g., ALK7:ActRIIB heteromultimers) for use in the treatment or prevention of various ALK7:ActRIIB-associated diseases and conditions associated with, for example, kidney, fat, fibrosis, and other tissues. Such diseases or conditions include, for example, chronic kidney disease or failure, acute kidney disease or failure, patients that have stage 1 kidney disease, patients that have stage 2 kidney disease, patients that have stage 3 kidney disease, patients that have stage 4 kidney disease, patients that have stage 5 kidney disease, non-diabetic kidney diseases, glomerulonephritis, interstitial nephritis, diabetic kidney diseases, diabetic nephropathy, glomerulosclerosis, rapid progressive glomerulonephritis, renal fibrosis, Alport

syndrome, IDDM nephritis, mesangial proliferative glomerulonephritis, membranoproliferative glomerulonephritis, crescentic glomerulonephritis, renal interstitial fibrosis, focal segmental glomerulosclerosis, membranous nephropathy, minimal change disease, pauci-immune rapid progressive glomerulonephritis, IgA nephropathy, polycystic kidney disease, Dent's disease, nephrocytosis, Heymann nephritis, autosomal dominant (adult) polycystic kidney disease, autosomal recessive (childhood) polycystic kidney disease, acute kidney injury, nephrotic syndrome, renal ischemia, podocyte diseases or disorders, proteinuria, glomerular diseases, membranous glomerulonephritis, focal segmental glomerulonephritis, pre-eclampsia, eclampsia, kidney lesions, collagen vascular diseases, benign orthostatic (postural) proteinuria, IgM nephropathy, membranous nephropathy, sarcoidosis, diabetes mellitus, kidney damage due to drugs, Fabry's disease, aminoaciduria, Fanconi syndrome, hypertensive nephrosclerosis, interstitial nephritis, Sickle cell disease, hemoglobinuria, myoglobinuria, Wegener's Granulomatosis, Glycogen Storage Disease Type 1, chronic kidney disease, chronic renal failure, low Glomerular Filtration Rate (GFR), nephroangiosclerosis, lupus nephritis, ANCA-positive pauci-immune crescentic glomerulonephritis, chronic allograft nephropathy, nephrotoxicity, renal toxicity, kidney necrosis, kidney damage, glomerular and tubular injury, kidney dysfunction, nephritic syndrome, acute renal failure, chronic renal failure, proximal tubal dysfunction, acute kidney transplant rejection, chronic kidney transplant rejection, non-IgA mesangioproliferative glomerulonephritis, postinfectious glomerulonephritis, vasculitides with renal involvement of any kind, any hereditary renal disease, any interstitial nephritis, renal transplant failure, kidney cancer, kidney disease associated with other conditions (e.g., hypertension, diabetes, and autoimmune disease), Dent's disease, nephrocytosis, Heymann nephritis, a primary kidney disease, a collapsing glomerulopathy, a dense deposit disease, a cryoglobulinemia-associated glomerulonephritis, an Henoch-Schonlein disease, a postinfectious glomerulonephritis, a bacterial endocarditis, a microscopic polyangitis, a Churg-Strauss syndrome, an anti-GBM-antibody mediated glomerulonephritis, amyloidosis, a monoclonal immunoglobulin deposition disease, a fibrillary glomerulonephritis, an immunotactoid glomerulopathy, ischemic tubular injury, a medication-induced tubulo-interstitial nephritis, a toxic tubulo-interstitial nephritis, an infectious tubulo-interstitial nephritis, a bacterial pyelonephritis, a viral infectious tubulo-interstitial nephritis which results from a polyomavirus infection or an HIV infection, a metabolic-induced tubulo-interstitial disease, a mixed connective disease, a cast nephropathy, a crystal nephropathy which may results from urate or oxalate or drug-induced crystal deposition, an acute cellular tubulo-interstitial allograft rejection, a tumoral infiltrative disease which results from a lymphoma or a post-transplant lymphoproliferative disease, an obstructive disease of the kidney, vascular disease, a thrombotic microangiopathy, a nephroangiosclerosis, an atheroembolic disease, a mixed connective tissue disease, a polyarteritis nodosa, a calcineurin-inhibitor induced-vascular disease, an acute cellular vascular allograft rejection, an acute humoral allograft rejection, early renal function decline (ERFD), end stage renal disease (ESRD), renal vein thrombosis, acute tubular necrosis, renal occlusion, acute interstitial nephritis, established chronic kidney disease, renal artery stenosis, ischemic nephropathy, uremia, drug and toxin-induced chronic tubulointerstitial nephritis, reflux nephropathy, kidney stones, Goodpasture's syndrome, normocytic normochromic anemia, renal anemia, diabetic chronic kidney disease, IgG4-related disease, von Hippel-Lindau syndrome, tuberous sclerosis, nephronophthisis, medullary cystic

kidney disease, renal cell carcinoma, adenocarcinoma, nephroblastoma, lymphoma, leukemia, hyposialylation disorder, chronic cyclosporine nephropathy, renal reperfusion injury, renal dysplasia, azotemia, bilateral arterial occlusion, acute uric acid nephropathy, hypovolemia, acute bilateral obstructive uropathy, hypercalcemic nephropathy, hemolytic uremic syndrome, acute urinary retention, malignant nephrosclerosis, postpartum glomerulosclerosis, scleroderma, non-Goodpasture's anti-GBM disease, microscopic polyarteritis nodosa, allergic granulomatosis, acute radiation nephritis, post-streptococcal glomerulonephritis, Waldenstrom's macroglobulinemia, analgesic nephropathy, arteriovenous fistula, arteriovenous graft, dialysis, ectopic kidney, medullary sponge kidney, renal osteodystrophy, solitary kidney, hydronephrosis, microalbuminuria, uremia, haematuria, hyperlipidemia, hypoalbuminaemia, lipiduria, acidosis, and hyperkalemia. In some instances, the disclosure further provides methods and ALK7:ActRIIB antagonists (e.g., ALK7:ActRIIB heteromultimers) for use in delaying or preventing progression from: stage 1 to stage 2 kidney disease, stage 2 to stage 3 kidney disease, stage 3 to stage 4 kidney disease, or stage 4 to stage 5 kidney disease. In some instances, the disclosure further provides methods and ALK7:ActRIIB antagonists (e.g., ALK7:ActRIIB heteromultimers) for use in preventing or reducing kidney inflammation. In some instances, the disclosure further provides methods and ALK7:ActRIIB antagonists (e.g., ALK7:ActRIIB heteromultimers) for use in preventing or reducing kidney damage. In some instances, the disclosure further provides methods and ALK7:ActRIIB antagonists (e.g., ALK7:ActRIIB heteromultimers) for use in preventing or reducing kidney fibrosis.

[0027] In some instances, the disclosure further provides methods and ALK7:ActRIIB antagonists (e.g., ALK7:ActRIIB heteromultimers) for use in lipolysis activity in a subject in need thereof. In some instances, the disclosure further provides methods and ALK7:ActRIIB antagonists (e.g., ALK7:ActRIIB heteromultimers) for use in decreasing body fat content or reducing the rate of increase in body fat content in a subject in need thereof. In some instances, the disclosure further provides methods and ALK7:ActRIIB antagonists (e.g., ALK7:ActRIIB heteromultimers) for use in treating a disorder or condition associated with undesirable body weight gain in a subject. Such disorders include, for example, obesity (e.g., abdominal obesity); overweight; insulin resistance; metabolic syndrome and other metabolic diseases or conditions; a lipid disorder such as, low HDL levels, high LDL levels, hyperlipidemia, hypertriglyceridemia or dyslipidemia; lipoprotein aberrations; decreased triglycerides; fatty liver disease; non-alcoholic fatty liver disease; hyperglycemia; impaired glucose tolerance (IGT); hyperinsulinemia; high cholesterol (e.g., high LDL levels and/or hypercholesterolemia); cardiovascular disease such as, heart disease including coronary heart disease, congestive heart failure, atherosclerosis; arteriosclerosis, and/or hypertension; Syndrome X; vascular restenosis; neuropathy; and/or other disorders/conditions associated with one or more of the above diseases or conditions, and/or with overweight (e.g., BMI of ≥ 25 kg/m²), or with too much body fat. In some instances, the disclosure provides methods for decreasing body fat content or reducing the rate of increase in body fat content in a subject, comprising administering to a subject in need thereof an effective amount of an ALK7:ActRIIB antagonist, or combination of ALK7:ActRIIB antagonists. In some instances, the disclosure provides methods for treating a disorder associated with undesirable body weight gain in a subject, comprising administering to a subject in need thereof an effective amount of an

ALK7:ActRIIB antagonist, or combination of ALK7:ActRIIB antagonists. In some instances, the disorder associated with undesirable body weight gain in a subject is selected from the group consisting of: obesity, non-insulin dependent diabetes mellitus (NIDDM), cardiovascular disease, hypertension, osteoarthritis, stroke, respiratory problems, and gall bladder disease. In some instances, the disclosure provides methods for reducing cholesterol and/or triglycerides in a patient, comprising administering to a subject patient in need thereof an effective amount of an ALK7:ActRIIB antagonist, or combination of ALK7:ActRIIB antagonists.

[0028] In some instances, the disclosure further provides methods and ALK7:ActRIIB antagonists (e.g., ALK7:ActRIIB heteromultimers) for use in treating and/or ameliorating cancer or a condition associated with cancer. In some instances, the subject has a cancer selected from the group consisting of melanoma, breast, colon, and endometrial, pancreatic, gastric, and uterine cancer. In some instances, the subject has myeloma (e.g., multiple myeloma, plasmacytoma, localized myeloma, and extramedullary myeloma). In some instances, the ALK7:ActRIIB antagonist is administered to treat or prevent lymphatic metastasis, bloodstream metastasis, tumor growth, or tumor invasion.

[0029] In some instances, the disclosure further provides methods and ALK7:ActRIIB antagonists (e.g., ALK7:ActRIIB heteromultimers) for use in treating or preventing fibrosis or a disorder or condition associated with fibrosis in a patient in need thereof. Such disorders or conditions include, for example, pulmonary fibrosis, hypersensitivity pneumonitis, idiopathic fibrosis, tuberculosis, pneumonia, cystic fibrosis, asthma, chronic obstructive pulmonary disease (COPD), emphysema, renal (kidney) fibrosis, renal (kidney) failure, chronic renal (kidney) disease, bone fibrosis, myelofibrosis, rheumatoid arthritis, systemic lupus erythematosus, scleroderma, sarcoidosis, granulomatosis with polyangiitis, Peyronie's disease, liver fibrosis, Wilson's disease, glycogen storage diseases (particularly types III, IV, IX, and X), iron-overload, Gaucher disease, Zellweger syndrome, nonalcoholic and alcoholic steatohepatitis, biliary cirrhosis, sclerosing cholangitis, Budd-Chiari syndrome, surgery-associated fibrosis, Crohn's disease, Duputren's contracture, mediastinal fibrosis, nephrogenic fibrosis, retroperitoneal fibrosis, atrial fibrosis, endomyocardial fibrosis, pancreatic fibrosis.

BRIEF DESCRIPTION OF THE DRAWINGS

[0030]

Figure 1A and 1B show two schematic examples of heteromeric protein complexes comprising type I receptor and type II receptor polypeptides. Figure 1A depicts a heterodimeric protein complex comprising one type I receptor fusion polypeptide and one type II receptor fusion polypeptide, which can be assembled covalently or noncovalently via a multimerization domain contained within each polypeptide chain. Two assembled multimerization domains constitute an interaction pair, which can be either guided or unguided. Figure 1B depicts a heterotetrameric protein complex comprising two heterodimeric complexes as depicted in

Figure 1A. Complexes of higher order can be envisioned.

Figure 2 show a schematic example of a heteromeric protein complex comprising a type I receptor polypeptide (indicated as "I") (e.g. a polypeptide that is at least 70%, 75%, 80%, 85%, 90%, 91%, 92%, 93%, 94%, 95%, 97%, 98%, 99% or 100% identical to an extracellular domain of an ALK7 protein from humans or other species such as those described herein, e.g., SEQ ID Nos: 9, 10, 19, 20, 38, 39, 42, 43, 46, 74, 76, 79, and 80) and a type II receptor polypeptide (indicated as "II") (e.g. a polypeptide that is at least 70%, 75%, 80%, 85%, 90%, 91%, 92%, 93%, 94%, 95%, 97%, 98%, 99% or 100% identical to an extracellular domain of an ActRIIB protein from humans or other species as such as those described herein, e.g., SEQ ID Nos: 1, 2, 3, 4, 5, 6, 71, 73, 77, and 78). In the illustrated instances, the type I receptor polypeptide is part of a fusion polypeptide that comprises a first member of an interaction pair ("C₁"), and the type II receptor polypeptide is part of a fusion polypeptide that comprises a second member of an interaction pair ("C₂"). In each fusion polypeptide, a linker may be positioned between the type I or type II receptor polypeptide and the corresponding member of the interaction pair. The first and second members of the interaction pair may be a guided (asymmetric) pair, meaning that the members of the pair associate preferentially with each other rather than self-associate, or the interaction pair may be unguided, meaning that the members of the pair may associate with each other or self-associate without substantial preference and may have the same or different amino acid sequences. Traditional Fc fusion proteins and antibodies are examples of unguided interaction pairs, whereas a variety of engineered Fc domains have been designed as guided (asymmetric) interaction pairs [e.g., Spiess et al (2015) *Molecular Immunology* 67(2A): 95-106].

Figure 3 shows an alignment of extracellular domains of human ActRIIA (SEQ ID NO: 49) and human ActRIIB (SEQ ID NO: 2) with the residues that are deduced herein, based on composite analysis of multiple ActRIIB and ActRIIA crystal structures, to directly contact ligand indicated with boxes.

Figure 4 shows a multiple sequence alignment of various vertebrate ActRIIB precursor proteins without their intracellular domains (SEQ ID NOs: 50-55) human ActRIIA precursor protein without its intracellular domain (SEQ ID NO: 56), and a consensus ActRII precursor protein (SEQ ID NO: 57).

Figure 5 shows multiple sequence alignment of Fc domains from human IgG isotypes using Clustal 2.1. Hinge regions are indicated by dotted underline. Double underline indicates examples of positions engineered in IgG1 Fc to promote asymmetric chain pairing and the corresponding positions with respect to other isotypes IgG2, IgG3 and IgG4.

Figure 6 shows comparative ligand binding data for an ALK7-Fc:ActRIIB-Fc heterodimeric protein complex compared to ActRIIB-Fc homodimer and ALK7-Fc homodimer. For each protein complex, ligands are ranked by k_{off} , a kinetic constant that correlates well with ligand signaling inhibition, and listed in descending order of binding affinity (ligands bound most tightly are listed at the top). At left, yellow, red, green, and blue lines indicate magnitude of the off-rate constant. Solid black lines indicate ligands whose binding to heterodimer is enhanced or

unchanged compared with homodimer, whereas dashed red lines indicate substantially reduced binding compared with homodimer. As shown, four of the five ligands with strong binding to ActRIIB-Fc homodimer (activin A, BMP10, GDF8, and GDF11) exhibit reduced binding to the ActRIIB-Fc:ALK7-Fc heterodimer, the exception being activin B which retains tight binding to the heterodimer. Similarly, three of four ligands with intermediate binding to ActRIIB-Fc homodimer (GDF3, BMP6, and particularly BMP9) exhibit reduced binding to the ActRIIB-Fc:ALK7-Fc heterodimer, whereas binding to activin AC is increased to become the second strongest ligand interaction with the heterodimer overall. Finally, activin C and BMP5 unexpectedly bind the ActRIIB-Fc:ALK7 heterodimer with intermediate strength despite no binding (activin C) or weak binding (BMP5) to ActRIIB-Fc homodimer. No ligands tested bind to ALK7-Fc homodimer.

Figure 7 shows a multiple sequence alignment of ALK7 extracellular domains derived from various vertebrate species (SEQ ID NOs: 59-64).

Figures 8A-8D show schematic examples of heteromeric protein complexes comprising an ALK7 polypeptide (e.g. a polypeptide that is at least 70%, 75%, 80%, 85%, 90%, 91%, 92%, 93%, 94%, 95%, 97%, 98%, 99% or 100% identical to an extracellular domain of an ALK7 protein from humans or other species such as those described herein, e.g., SEQ ID Nos: 9, 10, 19, 20, 38, 39, 42, 43, 46, 74, 76, 79, and 80) and an ActRIIB polypeptide (e.g. a polypeptide that is at least 70%, 75%, 80%, 85%, 90%, 91%, 92%, 93%, 94%, 95%, 97%, 98%, 99% or 100% identical to an extracellular domain of an ActRIIB protein from humans or other species such as those described herein, e.g., SEQ ID Nos: 1, 2, 3, 4, 5, 6, 71, 73, 77, and 78). In the illustrated instances, the ALK7 polypeptide is part of a fusion polypeptide that comprises a first member of an interaction pair ("C₁"), and the ActRIIB polypeptide is part of a fusion polypeptide that comprises a second member of an interaction pair ("C₂"). Suitable interaction pairs included, for example, heavy chain and/or light chain immunoglobulin interaction pairs, truncations, and variants thereof such as those described herein [e.g., Spiess et al (2015) *Molecular Immunology* 67(2A): 95-106]. In each fusion polypeptide, a linker may be positioned between the ALK7 or ActRIIB polypeptide and the corresponding member of the interaction pair. The first and second members of the interaction pair may be unguided, meaning that the members of the pair may associate with each other or self-associate without substantial preference, and they may have the same or different amino acid sequences. See Figure 8A. Alternatively, the interaction pair may be a guided (asymmetric) pair, meaning that the members of the pair associate preferentially with each other rather than self-associate. See Figure 8B. Complexes of higher order can be envisioned. See Figure 8C and 8D.

Figures 9A-9G show schematic examples of heteromeric protein complexes comprising two ALK7 polypeptides (e.g. polypeptide that are independently at least 70%, 75%, 80%, 85%, 90%, 91%, 92%, 93%, 94%, 95%, 97%, 98%, 99% or 100% identical to an extracellular domain of an ALK7 protein from humans or other species such as those described herein, e.g., SEQ ID Nos: 9, 10, 19, 20, 38, 39, 42, 43, 46, 74, 76, 79, and 80) and two ActRIIB polypeptides (e.g. two polypeptides that are independently at least 70%, 75%, 80%, 85%, 90%, 91%, 92%, 93%, 94%, 95%, 97%, 98%, 99% or 100% identical to an extracellular domain of an ActRIIB protein from humans or other species such as those described herein, e.g., SEQ ID Nos: 1, 2, 3, 4, 5,

6, 71, 73, 77, and 78).

In the illustrated instance 9A, the first ALK7 polypeptide (from left to right) is part of a fusion polypeptide that comprises a first member of an interaction pair ("C₁") and further comprises an additional first member of an interaction pair ("A₁"); and the second ALK7 polypeptide is part of a fusion polypeptide that comprises a second member of an interaction pair ("C₂") and further comprises a first member of an interaction pair ("A₂"). The first ActRIIB polypeptide (from left to right) is part of a fusion polypeptide that comprises a second member of an interaction pair ("B₁"); and the second ActRIIB polypeptide is part of a fusion polypeptide that comprises a second member of an interaction pair ("B₂"). A₁ and A₂ may be the same or different; B₁ and B₂ may be the same or different, and C₁ and C₂ may be the same or different. In each fusion polypeptide, a linker may be positioned between the ALK7 or ActRIIB polypeptide and the corresponding member of the interaction pair as well as between interaction pairs. Figure 9A is an example of an association of unguided interaction pairs, meaning that the members of the pair may associate with each other or self-associate without substantial preference and may have the same or different amino acid sequences.

In the illustrated instance 9B, the first ActRIIB polypeptide (from left to right) is part of a fusion polypeptide that comprises a first member of an interaction pair ("C_i") and further comprises an additional first member of an interaction pair ("A₁"); and the second ActRIIB polypeptide is part of a fusion polypeptide that comprises a second member of an interaction pair ("B₂"). The first ALK7 polypeptide (from left to right) is part of a fusion polypeptide that comprises a second member of an interaction pair ("B_i"); and the second ALK7 polypeptide is part of a fusion polypeptide that comprises a second member of an interaction pair ("C₂") and further comprises a first member of an interaction pair ("A₂"). In each fusion polypeptide, a linker may be positioned between the ALK7 or ActRIIB polypeptide and the corresponding member of the interaction pair as well as between interaction pairs. Figure 9B is an example of an association of guided (asymmetric) interaction pairs, meaning that the members of the pair associate preferentially with each other rather than self-associate.

Suitable interaction pairs included, for example, heavy chain and/or light chain immunoglobulin interaction pairs, truncations, and variants thereof as described herein [e.g., Spiess et al (2015) *Molecular Immunology* 67(2A): 95-106]. Complexes of higher order can be envisioned. See Figure 9C-9F. Using similar methods, particularly those that employ light and/or heavy chain immunoglobulins, truncations, or variants thereof, interaction pairs may be used to produce ALK7:ActRIIB heterodimers that resemble antibody Fab and F(ab')₂ complexes [e.g., Spiess et al (2015) *Molecular Immunology* 67(2A): 95-106]. See Figure 9G.

Figures 10A and 10B show schematic examples of a heteromeric protein complex comprising an ALK7 polypeptide (e.g. a polypeptide that is at least 70%, 75%, 80%, 85%, 90%, 91%, 92%, 93%, 94%, 95%, 97%, 98%, 99% or 100% identical to an extracellular domain of an ALK7 protein from humans or other species as described herein, e.g., SEQ ID Nos: 9, 10, 19, 20, 38, 39, 42, 43, 46, 74, 76, 79, and 80), an ActRIIB polypeptide (e.g. a polypeptide that is at least 70%, 75%, 80%, 85%, 90%, 91%, 92%, 93%, 94%, 95%, 97%, 98%, 99% or 100% identical to an extracellular domain of an ActRIIB protein from humans or other species as such as those described herein, e.g., SEQ ID Nos: 1, 2, 3, 4, 5, 6, 71, 73, 77, and 78), and a ligand-binding

domain of an antibody (e.g., a ligand binding domain derived from an antibody that binds to one or more ALK7:ActRIIB-binding ligands). In the illustrated instances, the ALK7 polypeptide is part of a fusion polypeptide that comprises a first member of an interaction pair ("C₁"), and further comprises an additional first member of an interaction pair ("A₁"). The ActRIIB polypeptide is part of a fusion polypeptide that comprises a second member of an interaction pair ("B₁"). The variable heavy chain (V_H) polypeptide is part of a fusion polypeptide that comprises a second member of an interaction pair ("C₂"), and further comprises a first member of an interaction pair ("A₂"). The variable heavy chain (V_L) polypeptide is part of a fusion polypeptide that comprises a second member of an interaction pair ("B₂"). In each fusion polypeptide, a linker may be positioned between the ALK7 or ActRIIB polypeptide and the corresponding member of the interaction pair, between interaction pairs, and between the V_H and V_L polypeptides and a member of the interaction pair. A₁ and A₂ may be the same or different; B₁ and B₂ may be the same or different, and C₁ and C₂ may be the same or different. Suitable interaction pairs included, for example, constant heavy chain and/or light chain immunoglobulin interaction pairs, truncations, and variants thereof as described herein [e.g., Spiess et al (2015) *Molecular Immunology* 67(2A): 95-106]. Figure 10A is an example of an association of guided (asymmetric) interaction pairs, meaning that the members of the pair associate preferentially with each other rather than self-associate. Figure 10B is an example of an association of unguided interaction pairs, meaning that the members of the pair may associate with each other or self-associate without substantial preference and may have the same or different amino acid sequences.

Such antibody-ALK7:ActRIIB complexes may be useful in situations where it is desirable to further bind/antagonize an agent that is not an ALK7:ActRIIB ligand. Alternatively, such antibody-ALK7:ActRIIB complexes may be useful in situations where it is desirable to further enhance ALK7:ActRIIB ligand binding/antagonism. For example, as demonstrated by the examples herein, an ALK7:ActRIIB heterodimer has high affinity for several ligands including, e.g., activin B and activin AC. In addition, ALK7:ActRIIB heterodimers bind to GDF3 but with weaker affinity. In certain situations where it is desirable to antagonize GDF3 activity in addition to one or more of the high affinity-binding ligands (e.g., activin B and activin AC), GDF3 may be outcompeted for binding to an ALK7:ActRIIB heterodimer. In these situations, addition of binding domain of an anti-GDF3 antibody to the ALK7:ActRIIB heteromultimer complex would improve the capacity of the protein complex to antagonize GDF3 in addition to one or more of the higher affinity ALK7:ActRIIB binding-ligands (e.g., activin B, and activin AC).

Figure 11 shows schematic examples of ALK7:ActRIIB single-trap polypeptides. ALK7:ActRIIB single-trap polypeptides may contain multiple ALK7 domains (e.g., 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 or more domains), having the same or different sequences, and multiple ActRIIB domains (e.g., 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 or more domains), having the same or different sequences. These ALK7 and ActRIIB domains may be arranged in any order and may comprise one or more linker domains positions between one or more of the ALK7 and ActRIIB domains. Such ligand traps may be useful as therapeutic agents to treat or prevent diseases or disorders described herein.

Figure 12A-12D show schematic examples of multimeric protein complexes comprising at least one ALK7:ActRIIB single-chain trap polypeptide. In the illustrated instances 12A and 12B, a first ALK7:ActRIIB single-chain trap polypeptide (from left to right) is part of a fusion polypeptide that comprises a first member of an interaction pair ("C₁"); and a second ALK7:ActRIIB single-chain trap polypeptide is part of a fusion polypeptide that comprises a second member of an interaction pair ("C₂"). C₁ and C₂ may be the same or different. The first and second ALK7:ActRIIB single-chain trap polypeptides may be the same or different. In each fusion polypeptide, a linker may be positioned between the ALK7:ActRIIB single-chain trap polypeptide and the corresponding member of the interaction pair. Suitable interaction pairs included, for example, heavy chain and/or light chain immunoglobulin interaction pairs, truncations, and variants thereof as described herein [e.g., Spiess et al (2015) *Molecular Immunology* 67(2A): 95-106]. Figure 12A is an example of an association of unguided interaction pairs, meaning that the members of the pair may associate with each other or self-associate without substantial preference and may have the same or different amino acid sequences. Figure 12B is an example of an association of guided (asymmetric) interaction pairs, meaning that the members of the pair associate preferentially with each other rather than self-associate. Complexes of higher order can be envisioned. In addition, such ALK7:ActRIIB single-chain trap polypeptides may be similarly be associated, covalently or non-covalently, with one or more ALK7 polypeptides and/or one or more ActRIIB polypeptides. See Figure 12C. Also, such ALK7:ActRIIB single-chain trap polypeptides may be similarly be associated, covalently or non-covalently, with one or more ligand-binding domain of an antibody (e.g., a ligand binding domain of an antibody that binds to one or more ALK7:ActRIIB binding-ligands). See Figure 12D.

Figures 13A-13C shows gene expression profiles of fibrotic genes (Colla1, Col3a1, Fibronectin, PAI-1, CTGF, and α -SMA), inflammatory genes (Tnfa, and MCP1), cytokine genes (Tgfb1, Tgfb2, Tgfb3, and activin A), kidney injury gene (NGAL), Hypoxia-inducible factor 1-alpha (HIF1a), and activin A receptor (Acvr2A) from mouse kidneys subjected to unilateral ureteral obstruction (UUO). Samples from the contralateral, non-surgery kidney were used as a control (Ctrl). Gene expression profiles were obtained at 3 days and 17 days post-surgery. Mice were administered either PBS or an ALK7-Fc:ActRIIB-Fc homodimer at days 3, 7, 10, and 14 post-surgery. Statistics was performed using a one-way ANOVA followed by Tukey analysis. (*) denotes a statistical difference between i) control samples compared to UUO kidneys at 3 days or ii) control samples compared to UUO kidneys at 17 days in mice administered the ALK7-Fc:ActRIIB-Fc homodimer. (\$) denotes a statistical difference between UUO kidneys at 17 days in mice administered only PBS compared with UUO kidneys at 17 days in mice administered the ALK7-Fc:ActRIIB-Fc homodimer. (@) denotes that no transcript was detected.

DETAIL DESCRIPTION OF THE DISCLOSURE

1. Overview

[0031] In part, the present disclosure relates to heteromultimers comprising a TGF β superfamily type I receptor polypeptide and a TGF β superfamily type II receptor polypeptide, uses thereof, and methods of making such heteromultimers. See, e.g., Figures 1 and 2. In certain preferred instances, heteromultimers comprise an extracellular domain of a TGF β superfamily type I receptor polypeptide and an extracellular domain of a TGF β superfamily type II receptor polypeptide. In particular, the disclosure provides heteromultimers comprising an ALK7 polypeptide and an ActRIIB polypeptide. Preferably ALK7 polypeptides comprise a ligand-binding domain of an ALK7 receptor, and ActRIIB polypeptides comprise a ligand-binding domain of an ActRIIB receptor. In certain preferred instances, ALK7:ActRIIB heteromultimers have an altered TGF β superfamily ligand binding profile/specificity compared to a corresponding sample of a homomultimer (e.g., an ALK7:ActRIIB heterodimer compared to an ActRIIB:ActRIIB homodimer or an ALK7:ALK7 homodimer).

[0032] The TGF- β superfamily is comprised of over 30 secreted factors including TGF-betas, activins, nodals, bone morphogenetic proteins (BMPs), growth and differentiation factors (GDFs), and anti-Mullerian hormone (AMH) [Weiss et al. (2013) *Developmental Biology*, 2(1): 47-63]. Members of the superfamily, which are found in both vertebrates and invertebrates, are ubiquitously expressed in diverse tissues and function during the earliest stages of development throughout the lifetime of an animal. Indeed, TGF- β superfamily proteins are key mediators of stem cell self-renewal, gastrulation, differentiation, organ morphogenesis, and adult tissue homeostasis. Consistent with this ubiquitous activity, aberrant TGF-beta superfamily signaling is associated with a wide range of human pathologies including, for example, autoimmune disease, cardiovascular disease, fibrotic disease, and cancer.

[0033] Ligands of the TGF-beta superfamily share the same dimeric structure in which the central 3-1/2 turn helix of one monomer packs against the concave surface formed by the beta-strands of the other monomer. The majority of TGF-beta family members are further stabilized by an intermolecular disulfide bond. This disulfide bond traverses through a ring formed by two other disulfide bonds generating what has been termed a 'cysteine knot' motif [Lin et al. (2006) *Reproduction* 132: 179-190; and Hinck et al. (2012) *FEBS Letters* 586: 1860-1870].

[0034] TGF-beta superfamily signaling is mediated by heteromeric complexes of type I and type II serine/threonine kinase receptors, which phosphorylate and activate downstream SMAD proteins (e.g., SMAD proteins 1, 2, 3, 5, and 8) upon ligand stimulation [Massagué (2000) *Nat. Rev. Mol. Cell Biol.* 1:169-178]. These type I and type II receptors are transmembrane proteins, composed of a ligand-binding extracellular domain with cysteine-rich region, a transmembrane domain, and a cytoplasmic domain with predicted serine/threonine kinase specificity. In general, type I receptors mediate intracellular signaling while the type II receptors are required for binding TGF-beta superfamily ligands. Type I and II receptors form a stable

complex after ligand binding, resulting in phosphorylation of type I receptors by type II receptors.

[0035] The TGF-beta family can be divided into two phylogenetic branches based on the type I receptors they bind and the Smad proteins they activate. One is the more recently evolved branch, which includes, *e.g.*, the TGF-betas, activins, GDF8, GDF9, GDF11, BMP3 and nodal, which signal through type I receptors that activate Smads 2 and 3 [Hinck (2012) FEBS Letters 586:1860-1870]. The other branch comprises the more distantly related proteins of the superfamily and includes, *e.g.*, BMP2, BMP4, BMP5, BMP6, BMP7, BMP8a, BMP8b, BMP9, BMP10, GDF1, GDF5, GDF6, and GDF7, which signal through Smads 1, 5, and 8.

[0036] TGF-beta isoforms are the founding members of the TGF-beta superfamily, of which there are 3 known isoforms in mammals designated as TGF-beta1, TGF-beta2 and TGF-beta3. Mature bioactive TGF-beta ligands function as homodimers and predominantly signal through the type I receptor ALK5, but have also been found to additionally signal through ALK1 in endothelial cells [Goumans et al. (2003) Mol Cell 12(4): 817-828]. TGF-beta1 is the most abundant and ubiquitously expressed isoform. TGF-beta1 is known to have an important role in wound healing, and mice expressing a constitutively active TGF-beta1 transgene develop fibrosis [Clouthier et al. (1997) J Clin. Invest. 100(11): 2697-2713]. TGF-beta1 is also involved in T cell activation and maintenance of T regulatory cells [Li et al. (2006) Immunity 25(3): 455-471]. TGF-beta2 expression was first described in human glioblastoma cells, and is occurs in neurons and astroglial cells of the embryonic nervous system. TGF-beta2 is known to suppress interleukin-2-dependent growth of T lymphocytes. TGF-beta3 was initially isolated from a human rhabdomyosarcoma cell line and since has been found in lung adenocarcinoma and kidney carcinoma cell lines. TGF-beta3 is known to be important for palate and lung morphogenesis [Kubiczkova et al. (2012) Journal of Translational Medicine 10:183].

[0037] Activins are members of the TGF-beta superfamily and were initially discovered as regulators of secretion of follicle-stimulating hormone, but subsequently various reproductive and non-reproductive roles have been characterized. There are three principal activin forms (A, B, and AB) that are homo/heterodimers of two closely related β subunits ($\beta_A\beta_A$, $\beta_B\beta_B$, and $\beta_A\beta_B$, respectively). The human genome also encodes an activin C and an activin E, which are primarily expressed in the liver, and heterodimeric forms containing β_C or β_E are also known. In the TGF-beta superfamily, activins are unique and multifunctional factors that can stimulate hormone production in ovarian and placental cells, support neuronal cell survival, influence cell-cycle progress positively or negatively depending on cell type, and induce mesodermal differentiation at least in amphibian embryos [DePaolo et al. (1991) Proc Soc Ep Biol Med. 198:500-512; Dyson et al. (1997) Curr Biol. 7:81-84; and Woodruff (1998) Biochem Pharmacol. 55:953-963]. In several tissues, activin signaling is antagonized by its related heterodimer, inhibin. For example, in the regulation of follicle-stimulating hormone (FSH) secretion from the pituitary, activin promotes FSH synthesis and secretion, while inhibin reduces FSH synthesis and secretion. Other proteins that may regulate activin bioactivity and/or bind to activin include follistatin (FS), follistatin-related protein (FSRP, also known as FLRG or FSTL3), and α_2 -

macroglobulin.

[0038] As described herein, agents that bind to "activin A" are agents that specifically bind to the β_A subunit, whether in the context of an isolated β_A subunit or as a dimeric complex (e.g., a $\beta_A\beta_A$ homodimer or a $\beta_A\beta_B$ heterodimer). In the case of a heterodimer complex (e.g., a $\beta_A\beta_B$ heterodimer), agents that bind to "activin A" are specific for epitopes present within the β_A subunit, but do not bind to epitopes present within the non- β_A subunit of the complex (e.g., the β_B subunit of the complex). Similarly, agents disclosed herein that antagonize (inhibit) "activin A" are agents that inhibit one or more activities as mediated by a β_A subunit, whether in the context of an isolated β_A subunit or as a dimeric complex (e.g., a $\beta_A\beta_A$ homodimer or a $\beta_A\beta_B$ heterodimer). In the case of $\beta_A\beta_B$ heterodimers, agents that inhibit "activin A" are agents that specifically inhibit one or more activities of the β_A subunit, but do not inhibit the activity of the non- β_A subunit of the complex (e.g., the β_B subunit of the complex). This principle applies also to agents that bind to and/or inhibit "activin B", "activin C", and "activin E". Agents disclosed herein that antagonize "activin AB" are agents that inhibit one or more activities as mediated by the β_A subunit and one or more activities as mediated by the β_B subunit. The same principle also applies to agents that bind to and/or inhibit "activin AC", "activin AE", "activin BC" or "activin BE".

[0039] Nodal proteins have functions in mesoderm and endoderm induction and formation, as well as subsequent organization of axial structures such as heart and stomach in early embryogenesis. It has been demonstrated that dorsal tissue in a developing vertebrate embryo contributes predominantly to the axial structures of the notochord and pre-chordal plate while it recruits surrounding cells to form non-axial embryonic structures. Nodal appears to signal through both type I and type II receptors and intracellular effectors known as SMAD proteins. Studies support the idea that ActRIIA and ActRIIB serve as type II receptors for nodal [Sakuma et al. (2002) *Genes Cells*. 2002, 7:401-12]. It is suggested that Nodal ligands interact with their co-factors (e.g., Cripto or Cryptic) to activate activin type I and type II receptors, which phosphorylate SMAD2. Nodal proteins are implicated in many events critical to the early vertebrate embryo, including mesoderm formation, anterior patterning, and left-right axis specification. Experimental evidence has demonstrated that nodal signaling activates pAR3-Lux, a luciferase reporter previously shown to respond specifically to activin and TGF-beta. However, nodal is unable to induce pTlx2-Lux, a reporter specifically responsive to bone morphogenetic proteins. Recent results provide direct biochemical evidence that nodal signaling is mediated by SMAD2 and SMAD3, which also mediate signaling by TGF-betas and activins. Further evidence has shown that the extracellular protein Cripto or Cryptic is required for nodal signaling, making it distinct from activin or TGF-beta signaling.

[0040] The BMPs and GDFs together form a family of cysteine-knot cytokines sharing the characteristic fold of the TGF-beta superfamily [Rider et al. (2010) *Biochem J.*, 429(1): 1-12]. This family includes, for example, BMP2, BMP4, BMP6, BMP7, BMP2a, BMP3, BMP3b (also known as GDF10), BMP4, BMP5, BMP6, BMP7, BMP8, BMP8a, BMP8b, BMP9 (also known as

GDF2), BMP10, BMP11 (also known as GDF11), BMP12 (also known as GDF7), BMP13 (also known as GDF6), BMP14 (also known as GDF5), BMP15, GDF1, GDF3 (also known as VGR2), GDF8 (also known as myostatin), GDF9, GDF15, and decapentaplegic. Besides the ability to induce bone formation, which gave the BMPs their name, the BMP/GDFs display morphogenetic activities in the development of a wide range of tissues. BMP/GDF homo- and hetero-dimers interact with combinations of type I and type II receptor dimers to produce multiple possible signaling complexes, leading to the activation of one of two competing sets of SMAD transcription factors. BMP/GDFs have highly specific and localized functions. These are regulated in a number of ways, including the developmental restriction of BMP/GDF expression and through the secretion of several specific BMP antagonist proteins that bind with high affinity to the cytokines. Curiously, a number of these antagonists resemble TGF-beta superfamily ligands.

[0041] Growth and differentiation factor-8 (GDF8) is also known as myostatin. GDF8 is a negative regulator of skeletal muscle mass and is highly expressed in developing and adult skeletal muscle. The GDF8 null mutation in transgenic mice is characterized by a marked hypertrophy and hyperplasia of skeletal muscle [McPherron et al. *Nature* (1997) 387:83-90]. Similar increases in skeletal muscle mass are evident in naturally occurring mutations of GDF8 in cattle and, strikingly, in humans [Ashmore et al. (1974) *Growth*, 38:501-507; Swatland and Kieffer, *J. Anim. Sci.* (1994) 38:752-757; McPherron and Lee, *Proc. Natl. Acad. Sci. USA* (1997) 94:12457-12461; Kambadur et al. *Genome Res.* (1997) 7:910-915; and Schuelke et al. (2004) *N Engl J Med*, 350:2682-8]. Studies have also shown that muscle wasting associated with HIV-infection in humans is accompanied by increases in GDF8 protein expression [Gonzalez-Cadavid et al., *PNAS* (1998) 95:14938-43]. In addition, GDF8 can modulate the production of muscle-specific enzymes (e.g., creatine kinase) and modulate myoblast cell proliferation [International Patent Application Publication No. WO 00/43781]. The GDF8 propeptide can noncovalently bind to the mature GDF8 domain dimer, inactivating its biological activity [Miyazono et al. (1988) *J. Biol. Chem.*, 263: 6407-6415; Wakefield et al. (1988) *J. Biol. Chem.*, 263: 7646-7654; and Brown et al. (1990) *Growth Factors*, 3: 35-43]. Other proteins which bind to GDF8 or structurally related proteins and inhibit their biological activity include follistatin, and potentially, follistatin-related proteins [Gamer et al. (1999) *Dev. Biol.*, 208: 222-232].

[0042] GDF11, also known as BMP11, is a secreted protein that is expressed in the tail bud, limb bud, maxillary and mandibular arches, and dorsal root ganglia during mouse development [McPherron et al. (1999) *Nat. Genet.*, 22: 260-264; and Nakashima et al. (1999) *Mech. Dev.*, 80: 185-189]. GDF11 plays a unique role in patterning both mesodermal and neural tissues [Gamer et al. (1999) *Dev Biol.*, 208:222-32]. GDF11 was shown to be a negative regulator of chondrogenesis and myogenesis in developing chick limb [Gamer et al. (2001) *Dev Biol.*, 229:407-20]. The expression of GDF11 in muscle also suggests its role in regulating muscle growth in a similar way to GDF8. In addition, the expression of GDF11 in brain suggests that GDF11 may also possess activities that relate to the function of the nervous system. Interestingly, GDF11 was found to inhibit neurogenesis in the olfactory epithelium [Wu et al. (2003) *Neuron.*, 37:197-207]. Hence, inhibitors of GDF11 may have in vitro and in vivo

applications in the treatment of diseases such as muscle diseases and neurodegenerative diseases (e.g., amyotrophic lateral sclerosis).

[0043] BMP7, also called osteogenic protein-1 (OP-1), is well known to induce cartilage and bone formation. In addition, BMP7 regulates a wide array of physiological processes. For example, BMP7 may be the osteoinductive factor responsible for the phenomenon of epithelial osteogenesis. It is also found that BMP7 plays a role in calcium regulation and bone homeostasis. Like activin, BMP7 binds to type II receptors, ActRIIA and ActRIIB. However, BMP7 and activin recruit distinct type I receptors into heteromeric receptor complexes. The major BMP7 type I receptor observed was ALK2, while activin bound exclusively to ALK4 (ActRIIB). BMP7 and activin elicited distinct biological responses and activated different SMAD pathways [Macias-Silva et al. (1998) J Biol Chem. 273:25628-36].

[0044] As described herein, comparative binding data demonstrated that an ALK7:ActRIIB heterodimer has an altered binding profile (ligand selectivity) compared to either corresponding ActRIIB or ALK7 homodimers. In particular, the ALK7:ActRIIB heterodimer displays enhanced binding to activin C, activin AC, and BMP5 compared to either homodimer, and retains strong binding to activin B as observed with the ActRIIB homodimer. However, the ALK7:ActRIIB heterodimer exhibits reduced binding to GDF11, GDF8, activin A, BMP10, BMP6, GDF3, and BMP9 compared to the ActRIIB homodimer. In particular, BMP9 displays low or no observable affinity for the ALK7:ActRIIB heterodimer, whereas this ligand binds tightly to ActRIIB homodimer.

[0045] These results therefore demonstrate that ALK7:ActRIIB heterodimers are more selective antagonists of activin B, activin C, activin AC, and BMP5 compared to ActRIIB homodimers. Additionally, it is expected that such heterodimers will bind tightly to Activin BC, given the binding to Activins B and C. Additionally, it is expected that such heterodimers will bind to activin E, activin AE and activin BE given the structural similarity between activin C and E. Accordingly, an ALK7:ActRIIB heterodimer may be more useful than an ActRIIB homodimer in certain applications where such selective antagonism is advantageous. Examples include therapeutic applications where it is desirable to retain antagonism of one or more of activin B, activin C, activin AC, activin BC, activin E, activin AE, activin BE and BMP5 but minimize antagonism of one or more of activin A, BMP9, BMP10, GDF3, and BMP6.

[0046] Moreover, ALK7:ActRIIB heterodimers, as described herein, exert beneficial catabolic effects on adipose tissue. Additionally, the ALK7:ActRIIB heterodimers described herein are shown to have potent protective effects in a model of chronic kidney disease, with effects including the inhibition of fibrosis and inflammation. However, unlike ActRIIB homodimer, an ActRIIB:ALK7 heterodimer exhibits only low-affinity or transient binding to BMP9 and so will have little to no concurrent inhibition on processes mediated by BMP9, such as angiogenesis. This novel selectivity will be useful, for example, in treating patients in need of inhibitory effects on fat, or protective effects on the kidney, but not in need of altered angiogenesis.

[0047] The terms used in this specification generally have their ordinary meanings in the art,

within the context of this disclosure and in the specific context where each term is used. Certain terms are discussed below or elsewhere in the specification to provide additional guidance to the practitioner in describing the compositions and methods of the disclosure and how to make and use them. The scope or meaning of any use of a term will be apparent from the specific context in which it is used.

[0048] The terms "heteromer" or "heteromultimer" is a complex comprising at least a first polypeptide chain and a second polypeptide chain, wherein the second polypeptide chain differs in amino acid sequence from the first polypeptide chain by at least one amino acid residue. The heteromer can comprise a "heterodimer" formed by the first and second polypeptide chains or can form higher order structures where one or more polypeptide chains in addition to the first and second polypeptide chains are present. Exemplary structures for the heteromultimer include heterodimers, heterotrimers, heterotetramers and further oligomeric structures. Heterodimers are designated herein as X:Y or equivalently as X-Y, where X represents a first polypeptide chain and Y represents a second polypeptide chain. Higher-order heteromers and oligomeric structures are designated herein in a corresponding manner. In certain instances a heteromultimer is recombinant (e.g., one or more polypeptide components may be a recombinant protein), isolated and/or purified.

[0049] "Homologous," in all its grammatical forms and spelling variations, refers to the relationship between two proteins that possess a "common evolutionary origin," including proteins from superfamilies in the same species of organism, as well as homologous proteins from different species of organism. Such proteins (and their encoding nucleic acids) have sequence homology, as reflected by their sequence similarity, whether in terms of percent identity or by the presence of specific residues or motifs and conserved positions. However, in common usage and in the instant application, the term "homologous," when modified with an adverb such as "highly," may refer to sequence similarity and may or may not relate to a common evolutionary origin.

[0050] The term "sequence similarity," in all its grammatical forms, refers to the degree of identity or correspondence between nucleic acid or amino acid sequences that may or may not share a common evolutionary origin.

[0051] "Percent (%) sequence identity" with respect to a reference polypeptide (or nucleotide) sequence is defined as the percentage of amino acid residues (or nucleic acids) in a candidate sequence that are identical to the amino acid residues (or nucleic acids) in the reference polypeptide (nucleotide) sequence, after aligning the sequences and introducing gaps, if necessary, to achieve the maximum percent sequence identity, and not considering any conservative substitutions as part of the sequence identity. Alignment for purposes of determining percent amino acid sequence identity can be achieved in various ways that are within the skill in the art, for instance, using publicly available computer software such as BLAST, BLAST-2, ALIGN or Megalign (DNASTAR) software. Those skilled in the art can determine appropriate parameters for aligning sequences, including any algorithms needed to achieve maximal alignment over the full length of the sequences being compared. For

purposes herein, however, % amino acid (nucleic acid) sequence identity values are generated using the sequence comparison computer program ALIGN-2. The ALIGN-2 sequence comparison computer program was authored by Genentech, Inc., and the source code has been filed with user documentation in the U.S. Copyright Office, Washington D.C., 20559, where it is registered under U.S. Copyright Registration No. TXU510087. The ALIGN-2 program is publicly available from Genentech, Inc., South San Francisco, Calif., or may be compiled from the source code. The ALIGN-2 program should be compiled for use on a UNIX operating system, including digital UNIX V4.0D. All sequence comparison parameters are set by the ALIGN-2 program and do not vary.

[0052] "Agonize", in all its grammatical forms, refers to the process of activating a protein and/or gene (e.g., by activating or amplifying that protein's gene expression or by inducing an inactive protein to enter an active state) or increasing a protein's and/or gene's activity.

[0053] "Antagonize", in all its grammatical forms, refers to the process of inhibiting a protein and/or gene (e.g., by inhibiting or decreasing that protein's gene expression or by inducing an active protein to enter an inactive state) or decreasing a protein's and/or gene's activity.

[0054] As used herein, unless otherwise stated, "does not substantially bind to X" is intended to mean that an agent has a K_D that is greater than about 10^{-7} , 10^{-6} , 10^{-5} , 10^{-4} , or greater (e.g., no detectable binding by the assay used to determine the K_D) for "X", wherein "X" is a specified agent such as protein or nucleic acid.

[0055] The terms "about" and "approximately" as used in connection with a numerical value throughout the specification and the claims denotes an interval of accuracy, familiar and acceptable to a person skilled in the art. In general, such interval of accuracy is $\pm 10\%$. Alternatively, and particularly in biological systems, the terms "about" and "approximately" may mean values that are within an order of magnitude, preferably ≤ 5 -fold and more preferably ≤ 2 -fold of a given value.

[0056] Numeric ranges disclosed herein are inclusive of the numbers defining the ranges.

[0057] The terms "a" and "an" include plural referents unless the context in which the term is used clearly dictates otherwise. The terms "a" (or "an"), as well as the terms "one or more," and "at least one" can be used interchangeably herein. Furthermore, "and/or" where used herein is to be taken as specific disclosure of each of the two or more specified features or components with or without the other. Thus, the term "and/or" as used in a phrase such as "A and/or B" herein is intended to include "A and B," "A or B," "A" (alone), and "B" (alone). Likewise, the term "and/or" as used in a phrase such as "A, B, and/or C" is intended to encompass each of the following aspects: A, B, and C; A, B, or C; A or C; A or B; B or C; A and C; A and B; B and C; A (alone); B (alone); and C (alone).

[0058] Throughout this specification, the word "comprise" or variations such as "comprises" or "comprising" will be understood to imply the inclusion of a stated integer or groups of integers

but not the exclusion of any other integer or group of integers.

2. ActRIIB:ALK7 Antagonists

[0059] As described herein, it has been discovered that ALK7:ActRIIB heterodimers have a unique ligand-binding profile/selectivity compared to corresponding ActRIIB and ALK7 homodimers. Interestingly, four of the five ligands with the strongest binding to ActRIIB homodimer (activin A, BMP10, GDF8, and GDF11) exhibit reduced binding to the ALK7:ActRIIB heterodimer, the exception being activin B which retains tight binding to the heterodimer. Similarly, three of the four ligands with intermediate binding to ActRIIB homodimer (GDF3, BMP6, and particularly BMP9) exhibit reduced binding to the ALK7:ActRIIB heterodimer, whereas binding to activin AC is increased to become the second strongest ligand interaction with the heterodimer overall. Finally, activin C and BMP5 unexpectedly bind the ALK7:ActRIIB heterodimer with intermediate strength despite no binding (activin C) or weak binding (BMP5) to ActRIIB homodimer. Given the binding to activin B and activin C, it is expected that the ALK7:ActRIIB heterodimer binds tightly to activin BC. The net result is that the ALK7:ActRIIB heterodimer possesses a ligand-binding profile distinctly different from that of either ActRIIB homodimer or ALK7 homodimer, which binds none of the foregoing ligands.

[0060] These results therefore indicate that the ALK7:ActRIIB heteromultimers are more selective antagonist of activin B, activin AC and Activin BC compared to ActRIIB homomultimers. Moreover, ALK7:ActRIIB heterodimer exhibits the unusual property of robust binding to activin C. Accordingly, an ALK7:ActRIIB heteromultimers will be more useful than an ActRIIB homomultimers in certain applications where such selective antagonism is advantageous.

[0061] Moreover, ALK7:ActRIIB heteromultimers are surprisingly effective in ameliorating various complications of kidney disease (e.g., treating or preventing kidney injury, inflammation, and damage) as well as exerting beneficial anabolic adipose cells. Although ALK7:ActRIIB heteromultimers may exert biological effects through a mechanism other than ligand inhibition [e.g., inhibition of one or more of activin B, activin AC, activin C, GDF11, GDF8, activin A, BMP10, BMP6, BMP5, nodal, and GDF3 may be an indicator of the tendency of an agent to inhibit the activities of a spectrum of additional agents, including, perhaps, other members of the TGF-beta superfamily, and such collective inhibition may lead to a desired effect on, for example, kidney disease or a metabolic disorder], other types of TGF-beta superfamily ligand antagonists as well as type I and type II receptor antagonists (e.g., natural ligand traps such as follistatin and Lefty, antibodies, inhibitory nucleic acids, and inhibitory small molecules), or combinations of such antagonists, are expected to be useful in accordance with the methods described herein, particularly those that that mimic the binding/inhibitory properties of the ALK7:ActRIIB heterodimers as well as agents that directly or indirectly antagonize ALK7 and/or ActRIIB receptors, agents that directly or indirectly antagonize ALK7 and/or ActRIIB-binding ligands, agents that directly or indirectly antagonize downstream

signaling mediators (e.g., Smads), and/or agents that directly or indirectly antagonize TGF β superfamily co-receptors (e.g., Cripto or Cryptic) will have similar biological effects. Collectively ALK7:ActRIIB heteromultimers and these alternative antagonists are referred to herein as "ALK7:ActRIIB antagonists" or "ALK7:ActRIIB inhibitors".

A. ALK7:ActRIIB Heteromultimers

[0062] In certain aspects, the present disclosure relates to heteromultimers comprising one or more ALK7 receptor polypeptides (e.g., SEQ ID NOs: 9, 10, 19, 20, 38, 39, 42, 43, 46, 74, 76, 79, and 80) and one or more ActRIIB receptor polypeptides (e.g., SEQ ID NOs: 1, 2, 3, 4, 5, 6, 71, 73, 77, and 78), which are generally referred to herein as "ALK7:ActRIIB heteromultimer complexes" or "ALK7:ActRIIB heteromultimers". Preferably, ALK7:ActRIIB heteromultimers of the disclosure are soluble, for example, a heteromultimer may comprises a soluble portion (domain) of an ALK7 receptor and a soluble portion (domain) of an ActRIIB receptor. In general, the extracellular domains of ALK7 and ActRIIB correspond to a soluble portion of these receptors. Therefore, in some instances, heteromultimers of the disclosure comprise an extracellular domain of an ALK7 receptor and an extracellular domain of an ActRIIB receptor. Example extracellular domains of ALK7 and ActRIIB receptors are disclosed herein and these sequences, as well as fragments, functional variants, and modified forms thereof, may be used in accordance with the disclosure (e.g., ALK7:ActRIIB heteromultimers and uses thereof). ALK7:ActRIIB heteromultimers of the disclosure include, e.g., heterodimers, heterotrimers, heterotetramers and higher order oligomeric structures. See, e.g., Figures 1, 2, and 8-10. In certain preferred instances, heteromultimers of the disclosure are ALK7:ActRIIB heterodimers.

[0063] Preferably, ALK7:ActRIIB heteromultimers of the disclosure bind to one or more TGF-beta superfamily ligands. In some instances, ALK7:ActRIIB heteromultimers bind to one or more of activin (e.g., activin A, activin B, activin C, activin E, activin AB, activin AC, activin AE, activin BC, and activin BE), GDF8, and GDF11. Optionally, in some instances, ALK7:ActRIIB heteromultimers further bind to BMP6. Optionally, in some instances, ALK7:ActRIIB heteromultimers further bind to BMP10. Optionally, in some instances, ALK7:ActRIIB heteromultimers further bind to BMP5. Optionally, in some instances, ALK7:ActRIIB heteromultimers further bind to GDF3. Optionally, in some instances, ALK7:ActRIIB heteromultimers further bind to nodal. Optionally, in some instances, ALK7:ActRIIB heteromultimers further bind to BMP10. Optionally, in some instances, ALK7:ActRIIB heteromultimers do not bind or do not substantially bind to BMP9. In certain preferred instances, ALK7:ActRIIB heteromultimers bind one or more of GDF11, GDF8, activin A, BMP10, BMP6, GDF3, and BMP9 with weaker affinity compared to a corresponding ActRIIB homomultimer. In other preferred instances, ALK7:ActRIIB heteromultimers bind one or more of activin C, activin AC, activin BC, and BMP5 with stronger affinity compared to a corresponding ActRIIB homomultimer. Optionally, ALK7:ActRIIB heteromultimers further bind to one or more of BMP2, BMP2/7, BMP3, BMP4, BMP4/7, BMP7, BMP8a, BMP8b, GDF5, GDF6/BMP13, GDF7, GDF9b/BMP15, GDF15/MIC1, TGF- β 1, TGF- β 2, TGF- β 3, glial cell-derived neurotrophic factor (GDNF), neurturin, artemin, persephin, MIS, and Lefty.

[0064] TGF-beta superfamily ligand-binding ALK7:ActRIIB heteromultimers may be used to inhibit (antagonize) signaling (e.g., Smad 2/3 and/or Smad 1/5/8 signaling) mediated by one or more TGF β superfamily ligands. In particular, ALK7:ActRIIB heteromultimers of the disclosure may be used to inhibit signaling by one or more TGF β superfamily ligands in, for example, a cell-based assay such as those described herein. For example, ALK7:ActRIIB heteromultimers inhibit signaling mediated by one or more of e.g., activin (e.g., activin A, activin B, activin C, activin E, activin AB, activin AC, activin BC, activin AE and activin BE), GDF11, GDF8, BMP10, BMP6, BMP5, nodal, and GDF3 in a cell-based assay. Optionally, in some instances, ALK7:ActRIIB heteromultimers may further inhibit BMP6 signaling in a cell-based assay. Optionally, in some instances, ALK7:ActRIIB heteromultimers may further inhibit GDF3 signaling in a cell-based assay. Optionally, in some instances, ALK7:ActRIIB heteromultimers may further inhibit nodal signaling in a cell-based assay. Optionally, in some instances, ALK7:ActRIIB heteromultimers may further inhibit BMP5 signaling in a cell-based assay. Optionally, in some instances, ALK7:ActRIIB heteromultimers may further inhibit signaling BMP10 signaling in a cell-based assay. Optionally, in some instances, ALK7:ActRIIB heteromultimers do not inhibit or do not substantially inhibit signaling mediated by BMP9 in a cell-based assay. In certain preferred instances, ALK7:ActRIIB heteromultimers have a weaker inhibitory effect on signaling mediated by one or more of GDF11, GDF8, activin A, BMP10, BMP6, GDF3, and BMP9 compared to a corresponding ActRIIB homomultimer in a cell-based assay. In other preferred instances, ALK7:ActRIIB heteromultimers have a stronger inhibitory effect on signaling mediated by one or more of activin AC, activin BC, activin C, and BMP5 compared to a corresponding ActRIIB homomultimer in a cell-based assay. Optionally, ALK7:ActRIIB heteromultimers may further inhibit signaling by one or more of BMP2, BMP2/7, BMP3, BMP4, BMP4/7, BMP7, BMP8a, BMP8b, GDF5, GDF6/BMP13, GDF7, GDF9b/BMP15, GDF15/MIC1, TGF- β 1, TGF- β 2, TGF- β 3, glial cell-derived neurotrophic factor (GDNF), neurturin, artemin, persephin, MIS, and Lefty in a cell-based assay.

[0065] As used herein, the term "ActRIIB" refers to a family of activin receptor type IIB (ActRIIB) proteins from any species and variants derived from such ActRIIB proteins by mutagenesis or other modification. Reference to ActRIIB herein is understood to be a reference to any one of the currently identified forms. Members of the ActRIIB family are generally transmembrane proteins, composed of a ligand-binding extracellular domain comprising a cysteine-rich region, a transmembrane domain, and a cytoplasmic domain with predicted serine/threonine kinase activity.

[0066] The term "ActRIIB polypeptide" includes polypeptides comprising any naturally occurring polypeptide of an ActRIIB family member as well as any variants thereof (including mutants, fragments, fusions, and peptidomimetic forms) that retain a useful activity. Examples of such variant ActRIIB polypeptides are provided throughout the present disclosure as well as in International Patent Application Publication Nos. WO 2006/012627, WO 2008/097541, and WO 2010/151426. Numbering of amino acids for all ActRIIB-related polypeptides described herein is based on the numbering of the human ActRIIB precursor protein sequence provided below (SEQ ID NO: 1), unless specifically designated otherwise.

[0067] The human ActRIIB precursor protein sequence is as follows:

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1  MTAPWVALAL LWGSLCAGSG RGEAETRECI YYNANWELER TNQSGLERCE
51 GEQDKRLHCY ASWRNSSGTI ELVKKGCWLD DFNCYDRQEC VATEENPQVY
101 FCCCEGNFCN ERFTHLPEAG GPEVTYEPPP TAPTLLTVLA YSLLPIGGLS
151 LIVLLAFWMY RHRKPPYGHV DIHEDPGPPP PSPLVGLKPL QLEIKARGR
201 FGCVWKAQLM NDFVAVKIFP LQDKQSWQSE REIFSTPGMK HENLLQFIAA
251 EKRGSNLEVE LWLITAFHDK GSLTDYLGKN IITWNECHV AETMSRGLSY
301 LHEDVPWCRG EGHKPSIAHR DFKSKNVLLK SDLTAVLADF GLAVRFEPGK
351 PPGDTHGQVG TRRYMAPEVL EGAINFQRDA FLRIDMYAMG LVLWELVSRC
401 KAADGPVDEY MLPFEEEIGQ HPSLEELQEV VVHKMRPTI KDHWLKHPGL
451 AQLCVTIEEC WDHDAEARLS AGCVEERVSL IRRSVNGTTS DCLVSLVTSV

501 TNVDLPPKES SI (SEQ ID NO: 1)

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[0068] The signal peptide is indicated with a single underline; the extracellular domain is indicated in bold font; and the potential, endogenous N-linked glycosylation sites are indicated with a double underline.

The processed (mature) extracellular ActRIIB polypeptide sequence is as follows:

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GRGEAETRECIYYNANWELERTNQSGLERCEGEQDKRLHCYASWRNSSGTIELVKKGCWLDD
FNCYDRQECVATEENPQVYFCCCEGNFCNERFTHLPEAGGPEVTYEPPTAPT (SEQ ID
NO: 2)

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[0069] In some instances, the protein may be produced with an "SGR..." sequence at the N-terminus. The C-terminal "tail" of the extracellular domain is indicated by a single underline. The sequence with the "tail" deleted (a $\Delta 15$ sequence) is as follows:

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GRGEAETRECIYYNANWELERTNQSGLERCEGEQDKRLHCYASWRNSSGTIELVKKGCWLDD
FNCYDRQECVATEENPQVYFCCCEGNFCNERFTHLPEA (SEQ ID NO: 3)

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[0070] A form of ActRIIB with an alanine at position 64 of SEQ ID NO: 1 (A64) is also reported in the literature. See, e.g., Hilden et al. (1994) Blood, 83(8): 2163-2170. Applicants have ascertained that an ActRIIB-Fc fusion protein comprising an extracellular domain of ActRIIB with the A64 substitution has a relatively low affinity for activin and GDF11. By contrast, the same ActRIIB-Fc fusion protein with an arginine at position 64 (R64) has an affinity for activin and GDF11 in the low nanomolar to high picomolar range. Therefore, sequences with an R64 are used as the "wild-type" reference sequence for human ActRIIB in this disclosure.

[0071] The form of ActRIIB with an alanine at position 64 is as follows:

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1  MTAPWVALAL LWGSLCAGSG RGEAETRECI YYNANWELER TNQSGLERCE
51 GEQDKRLHCY ASWANSSGTI ELVKKGCWLD DFNCYDRQEC VATEENPQVY
101 FCCCEGNFCN ERFTHLPEAG GPEVTYEPPP TAPTLLTVLA YSLLPIGGLS
151 LIVLLAFWMY RHRKPPYGHV DIHEDPGPPP PSPLVGLKPL QLEIKARGR
201 FGCVWKAQLM NDFVAVKIFP LQDKQSWQSE REIFSTPGMK HENLLQFIAA
251 EKRGSNLEVE LWLITAFHDK GSLTDYLGKN IITWNECHV AETMSRGLSY
301 LHEDVPWCRG EGHKPSIAHR DFKSKNVLLK SDLTAVLADF GLAVRFEPGK
351 PPGDTHGQVG TRRYMAPEVL EGAINFQRDA FLRIDMYAMG LVLWELVSRC
401 KAADGPVDEY MLPFEEEIGQ HPSLEELQEV VVHKMRPTI KDHWLKHPGL
451 AQLCVTIEEC WDHDAEARLS AGCVEERVSL IRRSVNGTTS DCLVSLVTSV

```

201 FGCVWKAQLM NDFVAVKIEP LQDKQSWQSE RELFSTPGMK HENLLQFIAA
 251 EKRGSNLEVE LWLITAFHDK GSLTDYLKGN IITWNELCHV AETMSRGLSY
 301 LHEDVPWCRG EGHKPSIAHR DFKSKNVLLK SDLTAVLADF GLAVRFEPGK
 351 PPGDTHGQVG TRRYMAPEVL EGAINFQRDA FLRIDMYAMG LVLWELVSRG
 401 KAADGPFVDEY MLPFEEEEIGQ HPSLEELQEV VVHKKMRPTI KDHWLKHPGL
 451 AQLCVTIEEC WDHDAEARLS AGCVEERVSL IRRSVNGTTS DCLVSLVTSV
 501 TNVDLPPKES SI (SEQ ID NO: 4)

[0072] The signal peptide is indicated by single underline and the extracellular domain is indicated by **bold font**.

[0073] The processed (mature) extracellular ActRIIB polypeptide sequence of the alternative A64 form is as follows:

GRGEAETRECIYYNANWELERTNQSGLERCEGEQDKRLHCYASWANSSGTIELVKKGCVLDD
 FNCYDRQECVATEENPQVYFCCCEGNFCNERFTHLPEAGGPEVTYEPPTAPT (SEQ ID
 NO: 5)

[0074] In some instances, the protein may be produced with an "SGR..." sequence at the N-terminus. The C-terminal "tail" of the extracellular domain is indicated by single underline. The sequence with the "tail" deleted (a $\Delta 15$ sequence) is as follows:

GRGEAETRECIYYNANWELERTNQSGLERCEGEQDKRLHCYASWANSSGTIELVKKGCVLDD
 FNCYDRQECVATEENPQVYFCCCEGNFCNERFTHLPEA (SEQ ID NO: 6)

[0075] A nucleic acid sequence encoding the human ActRIIB precursor protein is shown below (SEQ ID NO: 7), representing nucleotides 25-1560 of Genbank Reference Sequence NM_001106.3, which encode amino acids 1-513 of the ActRIIB precursor. The sequence as shown provides an arginine at position 64 and may be modified to provide an alanine instead. The signal sequence is underlined.

1 ATGACGGCGC CCTGGGTGGC CCTCGCCCTC CTCTGGGGAT CGCTGTGCGC
 51 CGGCTCTGGG CGTGGGGAGG CTGAGACACG GGAGTGCATC TACTACAACG
 101 CCAACTGGGA GCTGGAGCGC ACCAACCAGA GCGGCCTGGA GCGCTGCGAA
 151 GGCGAGCAGG ACAAGCGGCT GCACTGCTAC GCCTCCTGGC GCAACAGCTC
 201 TGGCACCATC GAGCTCGTGA AGAAGGGCTG CTGGCTAGAT GACTTCAACT
 251 GCTACGATAG GCAGGAGTGT GTGGCCACTG AGGAGAACCC CCAGGTGTAC
 301 TTCTGCTGCT GTGAAGGCAA CTTCTGCAAC GAACGCTTCA CTCATTTGCC
 351 AGAGGCTGGG GGCCCGGAAG TCACGTACGA GCCACCCCGG ACAGCCCCCA
 401 CCCTGCTCAC GGTGCTGGCC TACTCACTGC TGCCCATCGG GGGCCTTTCC
 451 CTCATCGTCC TGCTGGCCTT TTGGATGTAC CGGCATCGCA AGCCCCCCTA
 501 CGGTCATGTG GACATCCATG AGGACCCTGG GCCTCCACCA CCATCCCCTC
 551 TGGTGGGCCT GAAGCCACTG CAGCTGCTGG AGATCAAGGC TCGGGGGCGC
 601 TTTGGCTGTG TCTGGAAGGC CCAGCTCATG AATGACTTTG TAGCTGTCAA
 651 -----

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651 GATCTTCCCA CTCCAGGACA AGCAGTCGTG GCAGAGTGAA CGGGAGATCT
701 TCAGCACACC TGGCATGAAG CACGAGAACC TGCTACAGTT CATTGCTGCC
751 GAGAAGCGAG GCTCCAACCT CGAAGTAGAG CTGTGGCTCA TCACGGCCTT
801 CCATGACAAG GGCTCCCTCA CGGATTACCT CAAGGGGAAC ATCATCACAT
851 GGAACGAACT GTGTCATGTA GCAGAGACGA TGTCACGAGG CCTCTCATA
901 CTGCATGAGG ATGTGCCCTG GTGCCGTGGC GAGGGCCACA AGCCGTCTAT
951 TGCCCACAGG GACTTTAAAA GTAAGAATGT ATTGCTGAAG AGCGACCTCA
1001 CAGCCGTGCT GGCTGACTTT GGCTTGGCTG TTCGATTIGA GCCAGGGAAA
1051 CCTCCAGGGG ACACCCACGG ACAGGTAGGC ACGAGACGGT ACATGGCTCC
1101 TGAGGTGCTC GAGGGAGCCA TCAACTTCCA GAGAGATGCC TTCCTGCGCA
1151 TTGACATGTA TGCCATGGGG TTGGTGCTGT GGGAGCTTGT GTCTCGCTGC
1201 AAGGCTGCAG ACGGACCCGT GGATGAGTAC ATGCTGCCCT TTGAGGAAGA
1251 GATTGGCCAG CACCCTTCGT TGGAGGAGCT GCAGGAGGTG GTGGTGCACA
1301 AGAAGATGAG GCCCACCATT AAAGATCACT GGTTGAAACA CCCGGGCCTG
1351 GCCCAGCTTT GTGTGACCAT CGAGGAGTGC TGGGACCATG ATGCAGAGGC
1401 TCGCTTGTCG GCGGGCTGTG TGGAGGAGCG GGTGTCCCTG ATTCGGAGGT
1451 CGGTCAACGG CACTACCTCG GACTGTCTCG TTCCCTGGT GACCTCTGTC
1501 ACCAATGTGG ACCTGCCCCC TAAAGAGTCA AGCATC (SEQ ID NO: 7)

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[0076] A nucleic acid sequence encoding processed extracellular human ActRIIB polypeptide is shown below (SEQ ID NO: 8). The sequence as shown provides an arginine at position 64, and may be modified to provide an alanine instead.

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1 GGGCGTGGGG AGGCTGAGAC ACGGGAGTGC ATCTACTACA ACGCCAACTG
51 GGAGCTGGAG CGCACCAACC AGAGCGGCCT GGAGCGCTGC GAAGGCGAGC
101 AGGACAAGCG GCTGCACTGC TACGCCTCCT GGCGCAACAG CTCTGGCACC

151 ATCGAGCTCG TGAAGAAGGG CTGCTGGCTA GATGACTTCA ACTGCTACGA
201 TAGGCAGGAG TGTGTGGCCA CTGAGGAGAA CCCCAGGTG TACTTCTGCT
251 GCTGTGAAGG CAACTTCTGC AACGAACGCT TCACTCATTT GCCAGAGGCT
301 GGGGGCCCGG AAGTCACGTA CGAGCCACCC CCGACAGCCC CCACC
(SEQ ID NO: 8)

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[0077] An alignment of the amino acid sequences of human ActRIIB extracellular domain and human ActRIIA extracellular domain are illustrated in Figure 3. This alignment indicates amino acid residues within both receptors that are believed to directly contact ActRII ligands. For example, the composite ActRII structures indicated that the ActRIIB-ligand binding pocket is defined, in part, by residues Y31, N33, N35, L38 through T41, E47, E50, Q53 through K55, L57, H58, Y60, S62, K74, W78 through N83, Y85, R87, A92, and E94 through F101. At these positions, it is expected that conservative mutations will be tolerated.

[0078] In addition, ActRIIB is well-conserved among vertebrates, with large stretches of the extracellular domain completely conserved. For example, Figure 4 depicts a multi-sequence alignment of a human ActRIIB extracellular domain compared to various ActRIIB orthologs.

Many of the ligands that bind to ActRIIB are also highly conserved. Accordingly, from these alignments, it is possible to predict key amino acid positions within the ligand-binding domain that are important for normal ActRIIB-ligand binding activities as well as to predict amino acid positions that are likely to be tolerant of substitution without significantly altering normal ActRIIB-ligand binding activities. Therefore, an active, human ActRIIB variant polypeptide useful in accordance with the presently disclosed methods may include one or more amino acids at corresponding positions from the sequence of another vertebrate ActRIIB, or may include a residue that is similar to that in the human or other vertebrate sequences. Without meaning to be limiting, the following examples illustrate this approach to defining an active ActRIIB variant. L46 in the human extracellular domain (SEQ ID NO: 53) is a valine in *Xenopus* ActRIIB (SEQ ID NO: 55), and so this position may be altered, and optionally may be altered to another hydrophobic residue, such as V, I or F, or a nonpolar residue such as A. E52 in the human extracellular domain is a K in *Xenopus*, indicating that this site may be tolerant of a wide variety of changes, including polar residues, such as E, D, K, R, H, S, T, P, G, Y and probably A. T93 in the human extracellular domain is a K in *Xenopus*, indicating that a wide structural variation is tolerated at this position, with polar residues favored, such as S, K, R, E, D, H, G, P, G and Y. F108 in the human extracellular domain is a Y in *Xenopus*, and therefore Y or other hydrophobic group, such as I, V or L should be tolerated. E111 in the human extracellular domain is K in *Xenopus*, indicating that charged residues will be tolerated at this position, including D, R, K and H, as well as Q and N. R112 in the human extracellular domain is K in *Xenopus*, indicating that basic residues are tolerated at this position, including R and H. A at position 119 in the human extracellular domain is relatively poorly conserved, and appears as P in rodents and V in *Xenopus*, thus essentially any amino acid should be tolerated at this position.

[0079] Moreover, ActRII proteins have been characterized in the art in terms of structural and functional characteristics, particularly with respect to ligand binding [Attisano et al. (1992) Cell 68(1):97-108; Greenwald et al. (1999) Nature Structural Biology 6(1): 18-22; Allendorph et al. (2006) PNAS 103(20: 7643-7648; Thompson et al. (2003) The EMBO Journal 22(7): 1555-1566; as well as U.S. Patent Nos: 7,709,605, 7,612,041, and 7,842,663]. In addition to the teachings herein, these references provide amply guidance for how to generate ActRIIB variants that retain one or more normal activities (e.g., ligand-binding activity).

[0080] For example, a defining structural motif known as a three-finger toxin fold is important for ligand binding by type I and type II receptors and is formed by conserved cysteine residues located at varying positions within the extracellular domain of each monomeric receptor [Greenwald et al. (1999) Nat Struct Biol 6:18-22; and Hinck (2012) FEBS Lett 586:1860-1870]. Accordingly, the core ligand-binding domains of human ActRIIB, as demarcated by the outermost of these conserved cysteines, corresponds to positions 29-109 of SEQ ID NO: 1 (ActRIIB precursor). Thus, the structurally less-ordered amino acids flanking these cysteine-demarcated core sequences can be truncated by about 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, or 28 residues at the N-terminus and/or by about 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, or 25 residues at the C-terminus without necessarily altering ligand binding. Exemplary ActRIIB

extracellular domains for N-terminal and/or C-terminal truncation include SEQ ID NOs: 2, 3, 5, and 6.

[0081] Attisano *et al.* showed that a deletion of the proline knot at the C-terminus of the extracellular domain of ActRIIB reduced the affinity of the receptor for activin. An ActRIIB-Fc fusion protein containing amino acids 20-119 of present SEQ ID NO: 1, "ActRIIB(20-119)-Fc", has reduced binding to GDF11 and activin relative to an ActRIIB(20-134)-Fc, which includes the proline knot region and the complete juxtamembrane domain (see, e.g., U.S. Patent No. 7,842,663). However, an ActRIIB(20-129)-Fc protein retains similar, but somewhat reduced activity, relative to the wild-type, even though the proline knot region is disrupted.

[0082] Thus, ActRIIB extracellular domains that stop at amino acid 134, 133, 132, 131, 130 and 129 (with respect to SEQ ID NO: 1) are all expected to be active, but constructs stopping at 134 or 133 may be most active. Similarly, mutations at any of residues 129-134 (with respect to SEQ ID NO: 1) are not expected to alter ligand-binding affinity by large margins. In support of this, it is known in the art that mutations of P129 and P130 (with respect to SEQ ID NO: 1) do not substantially decrease ligand binding. Therefore, an ActRIIB polypeptide of the present disclosure may end as early as amino acid 109 (the final cysteine), however, forms ending at or between 109 and 119 (e.g., 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, or 119) are expected to have reduced ligand binding. Amino acid 119 (with respect to present SEQ ID NO: 1) is poorly conserved and so is readily altered or truncated. ActRIIB polypeptides ending at 128 (with respect to SEQ ID NO: 1) or later should retain ligand-binding activity. ActRIIB polypeptides ending at or between 119 and 127 (e.g., 119, 120, 121, 122, 123, 124, 125, 126, or 127), with respect to SEQ ID NO: 1, will have an intermediate binding ability. Any of these forms may be desirable to use, depending on the clinical or experimental setting.

[0083] At the N-terminus of ActRIIB, it is expected that a protein beginning at amino acid 29 or before (with respect to SEQ ID NO: 1) will retain ligand-binding activity. Amino acid 29 represents the initial cysteine. An alanine-to-asparagine mutation at position 24 (with respect to SEQ ID NO: 1) introduces an N-linked glycosylation sequence without substantially affecting ligand binding [U.S. Patent No. 7,842,663]. This confirms that mutations in the region between the signal cleavage peptide and the cysteine cross-linked region, corresponding to amino acids 20-29, are well tolerated. In particular, ActRIIB polypeptides beginning at position 20, 21, 22, 23, and 24 (with respect to SEQ ID NO: 1) should retain general ligand-binding activity, and ActRIIB polypeptides beginning at positions 25, 26, 27, 28, and 29 (with respect to SEQ ID NO: 1) are also expected to retain ligand-binding activity. It has been demonstrated, e.g., U.S. Patent No. 7,842,663, that, surprisingly, an ActRIIB construct beginning at 22, 23, 24, or 25 will have the most activity.

[0084] Taken together, a general formula for an active portion (e.g., ligand-binding portion) of ActRIIB comprises amino acids 29-109 of SEQ ID NO: 1. Therefore ActRIIB polypeptides may, for example, comprise, consist essentially of, or consist of an amino acid sequence that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identical to a portion of ActRIIB beginning at a residue corresponding

to any one of amino acids 20-29 (e.g., beginning at any one of amino acids 20, 21, 22, 23, 24, 25, 26, 27, 28, or 29) of SEQ ID NO: 1 and ending at a position corresponding to any one amino acids 109-134 (e.g., ending at any one of amino acids 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133, or 134) of SEQ ID NO: 1. Other examples include polypeptides that begin at a position from 20-29 (e.g., any one of positions 20, 21, 22, 23, 24, 25, 26, 27, 28, or 29) or 21-29 (e.g., any one of positions 21, 22, 23, 24, 25, 26, 27, 28, or 29) of SEQ ID NO: 1 and end at a position from 119-134 (e.g., any one of positions 119, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133, or 134), 119-133 (e.g., any one of positions 119, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, or 133), 129-134 (e.g., any one of positions 129, 130, 131, 132, 133, or 134), or 129-133 (e.g., any one of positions 129, 130, 131, 132, or 133) of SEQ ID NO: 1. Other examples include constructs that begin at a position from 20-24 (e.g., any one of positions 20, 21, 22, 23, or 24), 21-24 (e.g., any one of positions 21, 22, 23, or 24), or 22-25 (e.g., any one of positions 22, 23, or 25) of SEQ ID NO: 1 and end at a position from 109-134 (e.g., any one of positions 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133, or 134), 119-134 (e.g., any one of positions 119, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133, or 134) or 129-134 (e.g., any one of positions 129, 130, 131, 132, 133, or 134) of SEQ ID NO: 1. Variants within these ranges are also contemplated, particularly those having at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identity to the corresponding portion of SEQ ID NO: 1.

[0085] The variations described herein may be combined in various ways. In some instances, ActRIIB variants comprise no more than 1, 2, 5, 6, 7, 8, 9, 10 or 15 conservative amino acid changes in the ligand-binding pocket, and zero, one, or more non-conservative alterations at positions 40, 53, 55, 74, 79 and/or 82 in the ligand-binding pocket. Sites outside the binding pocket, at which variability may be particularly well tolerated, include the amino and carboxy termini of the extracellular domain (as noted above), and positions 42-46 and 65-73 (with respect to SEQ ID NO: 1). An asparagine-to-alanine alteration at position 65 (N65A) actually improves ligand binding in the A64 background, and is thus expected to have no detrimental effect on ligand binding in the R64 background [U.S. Patent No. 7,842,663]. This change probably eliminates glycosylation at N65 in the A64 background, thus demonstrating that a significant change in this region is likely to be tolerated. While an R64A change is poorly tolerated, R64K is well-tolerated, and thus another basic residue, such as H may be tolerated at position 64 [U.S. Patent No. 7,842,663]. Additionally, the results of the mutagenesis program described in the art indicate that there are amino acid positions in ActRIIB that are often beneficial to conserve. With respect to SEQ ID NO: 1, these include position 80 (acidic or hydrophobic amino acid), position 78 (hydrophobic, and particularly tryptophan), position 37 (acidic, and particularly aspartic or glutamic acid), position 56 (basic amino acid), position 60 (hydrophobic amino acid, particularly phenylalanine or tyrosine). Thus, the disclosure provides a framework of amino acids that may be conserved in ActRIIB polypeptides. Other positions that may be desirable to conserve are as follows: position 52 (acidic amino acid), position 55 (basic amino acid), position 81 (acidic), 98 (polar or charged, particularly E, D, R or K), all with respect to SEQ ID NO: 1.

[0086] In certain instances, the disclosure relates to heteromultimers that comprise at least one ActRIIB polypeptide, which includes fragments, functional variants, and modified forms thereof. Preferably, ActRIIB polypeptides for use in accordance with the disclosure are soluble (e.g., an extracellular domain of ActRIIB). In other preferred instances, ActRIIB polypeptides for use in accordance with the disclosure bind to one or more TGF-beta superfamily ligands. Therefore, in some instances, ActRIIB polypeptides for use in accordance with the disclosure inhibit (antagonize) activity (e.g., inhibition of Smad signaling) of one or more TGF-beta superfamily ligands. In some instances, heteromultimers of the disclosure comprise at least one ActRIIB polypeptide that comprises, consists essentially of, or consists of an amino acid sequence that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identical to a portion of ActRIIB beginning at a residue corresponding to amino acids 20-29 (e.g., beginning at any one of amino acids 20, 21, 22, 23, 24, 25, 26, 27, 28, or 29) of SEQ ID NO: 1 and ending at a position corresponding to amino acids 109-134 (e.g., ending at any one of amino acids 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133, or 134) of SEQ ID NO: 1. In certain preferred instances, heteromultimers of the disclosure comprise at least one ActRIIB polypeptide that comprises, consists, or consists essentially of an amino acid sequence that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identical amino acids 29-109 of SEQ ID NO: 1. In other preferred instances, heteromultimers of the disclosure comprise at least one ActRIIB polypeptide that comprises, consists, or consists essentially of an amino acid sequence that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identical amino acids 25-131 of SEQ ID NO: 1. In some instances, heteromultimers of the disclosure comprise at least one ActRIIB polypeptide that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 97%, 98%, 99%, or 100% identical to the amino acid sequence of any one of SEQ ID NOs: 1, 2, 3, 4, 5, 6, 71, 73, 77, and 78. In certain instances, heteromultimers of the disclosure comprise at least one ActRIIB polypeptide wherein the amino acid position corresponding to L79 of SEQ ID NO: 1 is not an acidic amino acid (*i.e.*, is not a naturally occurring D or E amino acid residue or artificial acidic amino acid).

[0087] In certain aspects, the present disclosure relates to protein complexes that comprise an ALK7 polypeptide. As used herein, the term "ALK7" refers to a family of activin receptor-like kinase-7 proteins from any species and variants derived from such ALK7 proteins by mutagenesis or other modification. Reference to ALK7 herein is understood to be a reference to any one of the currently identified forms. Members of the ALK7 family are generally transmembrane proteins, composed of a ligand-binding extracellular domain with a cysteine-rich region, a transmembrane domain, and a cytoplasmic domain with predicted serine/threonine kinase activity.

[0088] The term "ALK7 polypeptide" includes polypeptides comprising any naturally occurring polypeptide of an ALK7 family member as well as any variants thereof (including mutants, fragments, fusions, and peptidomimetic forms) that retain a useful activity. Numbering of amino

acids for all ALK7-related polypeptides described herein is based on the numbering of the human ALK7 precursor protein sequence below (SEQ ID NO: 9), unless specifically designated otherwise.

[0089] There are various naturally occurring isoforms of human ALK7. The sequence of canonical human ALK7 isoform 1 precursor protein (NCBI Ref Seq NP_660302.2) is as follows:

1 MTRALCSALR QALLLLAAAA **ELSPGLKVC** **LLCDSSNFTC** **QTEGACWASV**
MLTNGKEQVI
61 **KSCVSLPELN** **AQVFCHSSNN** **VTKTECCFTD** **FCNNITLHLP** **TASPNAPKLG**
PMELAIITV
121 **PVCLLSIAAM** **LTVWACQGRQ** **CSYRKKKRPN** **VEEPLSECNL** **VNAGKTLKDL**
IYDVTASGSG
181 **SGLPLLQRT** **IARTIVLQEI** **VGKGRFGEVW** **HGRWCGEDVA** **VKIFSSRDER**
SWFREAEIYQ
241 **TVMLRHENIL** **GFIAADNKDN** **GTWTQLWLVS** **EYHEQGSLYD** **YLNRNIVTVA**
GMIKLALSIA
301 **SGLAHLHMEI** **VGTOGKPAIA** **HRDIKSKNIL** **VKKCETCAIA** **DLGLAVKHDS**
ILNTIDIPQN
361 **PKVGTKRYMA** **PEMLDDTMNV** **NIFESFKRAD** **IYSVGLVYWE** **IARRCSVGGI**
VEEYQLPYD
421 **MVPSDPSIEE** **MRKVCDQKF** **RPSIPNQWQS** **CEALRVMGRI** **MRECWYANGA**
ARLTALRIKK
481 **TISQLCVKED** **CKA** (SEQ ID NO: 9)

[0090] The signal peptide is indicated by a single underline and the extracellular domain is indicated in bold font.

[0091] The processed extracellular ALK7 isoform 1 polypeptide sequence is as follows:

ELSPGLKVC**LLCDSSNFTC****QTEGACWASV****MLTNGKEQVI****KSCVSLPELNAQVFCHSSNNVT**
KTECCFTD**FCNNITLHLP****TASPNAPKLG****PME** (SEQ ID NO: 10)

[0092] A nucleic acid sequence encoding human ALK7 isoform 1 precursor protein is shown below (SEQ ID NO: 11), corresponding to nucleotides 244-1722 of Genbank Reference Sequence NM_145259.2. The signal sequence is underlined and the extracellular domain is indicated in bold font.

ATGACCCGGGCGCTCTGCTCAGCGCTCCGCCAGGCTCTCCTGCTGCTCGCAGCGGCCGCGGA
GCTCTCGCCAGGACTGAAGTGTGTATGTCTTTTGTGTGATTCTTCAAACCTTTACCTGCCAAA
CAGAAGGAGCATGTTGGGCATCAGTCATGCTAACCAATGGAAAAGAGCAGGTGATCAAATCC
TGTGTCTCCCTTCCAGAACTGAATGCTCAAGTCTTCTGTCATAGTTCCAACAATGTTACCAA
AACCGAATGCTGCTTCACAGATTTTTGCAACAACATAACACTGCACCTTCCAACAGCATCAC
CAAATGCCCCAAAACCTTGGACCCATGGAGCTGGCCATCATTATTACTGTGCCTGTTTGCCTC
CTGTCCATAGCTGCGATGCTGACAGTATGGGCATGCCAGGGTCGACAGTGCTCCTACAGGAA

GAAAAAGAGACCAAATGTGGAGGAACCACTCTCTGAGTGCAATCTGGTAAATGCTGGAAAAA
 CTCTGAAAGATCTGATTTATGATGTGACCGCCTCTGGATCTGGCTCTGGTCTACCTCTGTTG
 GTTCAAAGGACAATTGCAAGGACGATTGTGCTTCAGGAAATAGTAGGAAAAGGTAGATTTGG
 TGAGGTGTGGCATGGAAGATGGTGTGGGGAAGATGTGGCTGTGAAAATATTCTCCTCCAGAG
 ATGAAAGATCTTGGTTTCGTGAGGCAGAAATTTACCAGACGGTCATGCTGCGACATGAAAAC
 ATCCTTGGTTTTCAATTGCTGCTGACAACAAAGATAATGGAACCTGGACTCAACTTTGGCTGGT
 ATCTGAATATCATGAACAGGGCTCCTTATATGACTATTTGAATAGAAATATAGTGACCGTGG
 CTGGAATGATCAAGCTGGCGCTCTCAATTGCTAGTGGTCTGGCACACCTTCATATGGAGATT
 GTTGGTACACAAGGTAAACCTGCTATTGCTCATCGAGACATAAAATCAAAGAATATCTTAGT
 GAAAAAGTGTGAAACTTGTGCCATAGCGGACTTAGGGTTGGCTGTGAAGCATGATTCAATAC
 TGAACACTATCGACATACCTCAGAATCCTAAAGTGGGAACCAAGAGGTATATGGCTCCTGAA
 ATGCTTGATGATACAATGAATGTGAATATCTTTGAGTCCTTCAAACGAGCTGACATCTATTC
 TGTGGTCTGGTTTACTGGGAAATAGCCCGGAGGTGTTTCTGTCGGAGGAATTGTTGAGGAGT
 ACCAATTGCCTTATTATGACATGGTGCCTTCAGATCCCTCGATAGAGGAAATGAGAAAGGTT
 GTTTGTGACCAGAAGTTTCGACCAAGTATCCCAAACCAAGTGGCAAAGTTGTGAAGCACTCCG
 AGTCATGGGGAGAATAATGCGTGAGTGTTGGTATGCCAACGGAGCGGCCCCGCCTAACTGCTC
 TTCGTATTAAGAAGACTATATCTCAACTTTGTGTCAAAGAAGACTGCAAAGCC (SEQ ID
 NO: 11)

[0093] A nucleic acid sequence encoding the processed extracellular ALK7 polypeptide (isoform 1) is as follows:

GAGCTCTCGCCAGGACTGAAGTGTGTATGTCTTTTGTGTGATTCTTCAAACCTTACCTGCCA
 AACAGAAGGAGCATGTTGGGCATCAGTCATGCTAACCAATGGAAAAGAGCAGGTGATCAAAT
 CCTGTGTCTCCCTTCCAGAACTGAATGCTCAAGTCTTCTGTCATAGTTCCAACAATGTTACC
 AAAACCGAATGCTGCTTCACAGATTTTTTGCAACAACATAACACTGCACCTTCCAACAGCATC
 ACCAAATGCCCCAAACTTGGACCCATGGAG (SEQ ID NO: 12)

[0094] The amino acid sequence of an alternative isoform of human ALK7, isoform 2 (NCBI Ref Seq NP_001104501.1), is shown in its processed form as follows (SEQ ID NO: 19), where the extracellular domain is indicated in bold font.

1 **MLTNGKEQVI KSCVSLPELN AQVFCHSSNN VTKTECCFTD FCNNITLHLP**
TASPNAPKLG
 61 **PMEL**AIITV PVCLLSIAAM LTVWACQGRQ CSYRKKKRPN VEEPLSECNL
 VNAGKTLKDL
 121 IYDVTASGSG SGLPLLVRT IARTIVLQEI VGKGRFGEVW HGRWCGEDVA
 VKIFSSRDER
 181 SWFREAEIYQ TVMLRHENIL GFIAADNKDN GTWTQLWLVS EYHEQGSLYD
 YLNRNIVTVA
 241 GMIKLALSIA SGLAHLHMEI VGTQGKPAIA HRDIKSKNIL VKKCETCAIA
 DLGLAVKHDS
 301 ILNTIDIPQN PKVGTKRYMA PEMLDDTMNV NIFESFKRAD IYSVGLVYWE
 TARRCSVGGT

361 VEEYQLPYD MVPSDPSIEE MRKVCDQKF RPSIPNQWQS CEALRVMGRI
MRECWYANGA

421 ARLTALRIKK TISQLCVKED CKA (SEQ ID NO: 19)

[0095] The amino acid sequence of the extracellular ALK7 polypeptide (isoform 2) is as follows:

MLTNGKEQVIKSCVSLPELNAQVFCHSSNNVTKTECCFTDFCENNITLHLPTASPNAPK
LGPME (SEQ ID NO: 20).

[0096] A nucleic acid sequence encoding the processed ALK7 polypeptide (isoform 2) is shown below (SEQ ID NO: 21), corresponding to nucleotides 279-1607 of NCBI Reference Sequence NM_001111031.1. The extracellular domain is indicated in bold font.

ATGCTAACCAATGGAAAAGAGCAGGTGATCAAATCCTGTGTCTCCCTTCCAGAACTGAATGC
TCAAGTCTTCTGTCATAGTTCCAACAATGTTACCAAAACCGAATGCTGCTTCACAGATTTTT
GCAACAACATAACACTGCACCTTCCAACAGCATCACCAAATGCCCCAAACTTGGACCCATG
GAGCTGGCCATCATTATTACTGTGCCTGTTTGCCTCCTGTCCATAGCTGCGATGCTGACAGT
ATGGGCATGCCAGGGTCGACAGTGCTCCTACAGGAAGAAAAAGAGACCAAATGTGGAGGAAC
CACTCTCTGAGTGCAATCTGGTAAATGCTGGAAAACTCTGAAAGATCTGATTTATGATGTG
ACCGCCTCTGGATCTGGCTCTGGTCTACCTCTGTTGGTTCAAAGGACAATTGCAAGGACGAT
TGTGCTTCAGGAAATAGTAGGAAAAGGTAGATTTGGTGAGGTGTGGCATGGAAGATGGTGTG
GGGAAGATGTGGCTGTGAAAATATTCTCCTCCAGAGATGAAAGATCTTGGTTTCGTGAGGCA
GAAATTTACCAGACGGTCATGCTGCGACATGAAAACATCCTTGGTTTCATTGCTGCTGACAA
CAAAGATAATGGAACCTTGGACTCAACTTTGGCTGGTATCTGAATATCATGAACAGGGCTCCT
TATATGACIATTTGAATAGAAATATAGTGACCGTGGCTGGAATGATCAAGCTGGCGCTCTCA
ATTGCTAGTGGTCTGGCACACCTTCATATGGAGATTGTTGGTACACAAGGTAAACCTGCTAT
TGCTCATCGAGACATAAAATCAAAGAATATCTTAGTGAAAAAGTGTGAAACTTGTGCCATAG
CGGACTTAGGGTTGGCTGTGAAGCATGATTCAATACTGAACACTATCGACATACCTCAGAAT
CCTAAAGTGGGAACCAAGAGGTATATGGCTCCTGAAATGCTTGATGATACAATGAATGTGAA
TATCTTTGAGTCCTTCAAACGAGCTGACATCTATTCTGTTGGTCTGGTTTACTGGGAAATAG
CCCGGAGGTGTTTCACTCGGAGGAATTGTTGAGGAGTACCAATTGCCTTATTATGACATGGTG
CCTTCAGATCCCTCGATAGAGGAAATGAGAAAGGTTGTTTGTGACCAGAAGTTTCGACCAAG
TATCCCAAACCAAGTGGCAAAGTTGTGAAGCACTCCGAGTCATGGGGAGAATAATGCGTGAGT
GTTGGTATGCCAACGGAGCGGCCCGCCTAACTGCTCTTCGTATTAAAGAAGACTATATCTCAA
CTTTGTGTCAAAGAAGACTGCAAAGCC (SEQ ID NO: 21)

[0097] A nucleic acid sequence encoding the extracellular ALK7 polypeptide (isoform 2) is as follows (SEQ ID NO: 22):

ATGCTAACCAATGGAAAAGAGCAGGTGATCAAATCCTGTGTCTCCCTTCCAGAACTGAATGC
TCAAGTCTTCTGTCATAGTTCCAACAATGTTACCAAAACCGAATGCTGCTTCACAGATTTTT
GCAACAACATAACACTGCACCTTCCAACAGCATCACCAAATGCCCCAAACTTGGACCCATG
GAG (SEQ ID NO: 22)

[0098] The amino acid sequence of an alternative human ALK7 precursor protein, isoform 3 (NCBI Ref Seq NP_001104502.1), is shown as follows (SEQ ID NO: 38), where the signal peptide is indicated by a single underline.

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1  MTRALCSALR QALLLLAAAA ELSPGLKCVC LLCSSNFTC QTEGACWASV
MLINGKEQVI
61 KSCVSLPELN AQVFCHSSNN VTKTECCFTD FCNNITLHLP TGLPLLVRT
IARTIVLQEI
121 VGKGRFGEVW HGRWCGEDVA VKIFSSRDER SWFREAEIYQ TVMLRHENIL
GFIAADNKDN
181 GTWTQLWLVS EYHEQGSLYD YLNRNIVTVA GMIKLALSIA SGLAHLHMEI
VGTQGKPAIA
241 HRDIKSKNIL VKKCETCAIA DLGLAVKHDS ILNTIDIPQN PKVGTKRYMA
PEMLDDTMNV
301 NIFESFKRAD IYSVGLVYWE IARRCSVGGI VEEYQLPYD MVPSDPSIEE
MRKVVCQKF
361 RPSIPNQWQS CEALRVMGRI MRECWYANGA ARLTALRIK TISQLCVKED
CKA

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(SEQ ID NO: 38)

[0099] The amino acid sequence of the processed ALK7 polypeptide (isoform 3) is as follows (SEQ ID NO: 39). This isoform lacks a transmembrane domain and is therefore proposed to be soluble in its entirety (Roberts et al., 2003, Biol Reprod 68:1719-1726). N-terminal variants of SEQ ID NO: 39 are predicted as described below.

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1  ELSPGLKCVC LLCSSNFTC QTEGACWASV MLINGKEQVI KSCVSLPELN
AQVFCHSSNN
61 VTKTECCFTD FCNNITLHLP TGLPLLVRT IARTIVLQEI VGKGRFGEVW
HGRWCGEDVA
121 VKIFSSRDER SWFREAEIYQ TVMLRHENIL GFIAADNKDN GTWTQLWLVS
EYHEQGSLYD
181 YLNRNIVTVA GMIKLALSIA SGLAHLHMEI VGTQGKPAIA HRDIKSKNIL
VKKCETCAIA
241 DLGLAVKHDS ILNTIDIPQN PKVGTKRYMA PEMLDDTMNV NIFESFKRAD
IYSVGLVYWE
301 IARRCSVGGI VEEYQLPYD MVPSDPSIEE MRKVVCQKF RPSIPNQWQS
CEALRVMGRI
361 MRECWYANGA ARLTALRIK TISQLCVKED CKA (SEQ ID NO: 39)

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[0100] A nucleic acid sequence encoding the unprocessed ALK7 polypeptide precursor protein (isoform 3) is shown below (SEQ ID NO: 40), corresponding to nucleotides 244-1482 of NCBI Reference Sequence NM_001111032.1. The signal sequence is indicated by solid underline.

ATGACCCGGGCGCTCTGCTCAGCGCTCCGCCAGGCTCTCCTGCTGCTCGCAGCGGCCGCCGA
 GCTCTCGCCAGGACTGAAGTGTGTATGTCTTTTGTGTGATTCTTCAAACCTTTACCTGCCAAA
 CAGAAGGAGCATGTTGGGCATCAGTCATGCTAACCAATGGAAAAGAGCAGGTGATCAAATCC
 TGTGTCTCCCTTCCAGAACTGAATGCTCAAGTCTTCTGTCATAGTTCCAACAATGTTACCAA
 AACCGAATGCTGCTTCACAGATTTTTTGCAACAACATAAACTGCACCTTCCAACAGGTCTAC
 CTCTGTTGGTTCAAAGGACAATTGCAAGGACGATTGTGCTTCAGGAAATAGTAGGAAAAGGT
 AGATTTGGTGAGGTGTGGCATGGAAGATGGTGTGGGGAAGATGTGGCTGTGAAAATATTCTC
 CTCCAGAGATGAAAGATCTTGGTTTCGTGAGGCAGAAATTTACCAGACGGTCATGCTGCGAC
 ATGAAAACATCCTTGGTTTCATTGCTGCTGACAACAAAGATAATGGAACCTTGGACTCAACTT
 TGGCTGGTATCTGAATATCATGAACAGGGCTCCTTATATGACTATTTGAATAGAAATATAGT
 GACCGTGGCTGGAATGATCAAGCTGGCGCTCTCAATTGCTAGTGGTCTGGCACACCTTCATA
 TGGAGATTGTTGGTACACAAGGTAAACCTGCTATTGCTCATCGAGACATAAAATCAAAGAAT
 ATCTTAGTGAAAAAGTGTGAAACTTGTGCCATAGCGGACTTAGGGTTGGCTGTGAAGCATGA
 TTCAATACTGAACACTATCGACATACCTCAGAATCCTAAAGTGGGAACCAAGAGGTATATGG
 CTCCTGAAATGCTTGATGATACAATGAATGTGAATATCTTTGAGTCCTTCAAACGAGCTGAC
 ATCTATTCTGTTGGTCTGGTTTACTGGGAAATAGCCCGGAGGTGTTTCAGTCGGAGGAATTGT
 TGAGGAGTACCAATTGCCTTATTATGACATGGTGCCTTCAGATCCCTCGATAGAGGAAATGA
 GAAAGGTTGTTTGTGACCAGAAGTTTCGACCAAGTATCCCAAACCAAGTGGCAAAGTTGTGAA
 GCACTCCGAGTCATGGGGAGAATAATGCGTGAGTGTTGGTATGCCAACGGAGCGGCCCGCCT
 AACTGCTCTTCGTATTAAGAAGACTATATCTCAACTTTGTGTCAAAGAAGACTGCAAAGCC
 (SEQ ID NO: 40)

[0101] A nucleic acid sequence encoding the processed ALK7 polypeptide (isoform 3) is as follows (SEQ ID NO: 41):

GAGCTCTCGCCAGGACTGAAGTGTGTATGTCTTTTGTGTGATTCTTCAAACCTTTACCTGCCA
 AACAGAAGGAGCATGTTGGGCATCAGTCATGCTAACCAATGGAAAAGAGCAGGTGATCAAAT
 CCTGTGTCTCCCTTCCAGAACTGAATGCTCAAGTCTTCTGTCATAGTTCCAACAATGTTACC
 AAAACCGAATGCTGCTTCACAGATTTTTTGCAACAACATAAACTGCACCTTCCAACAGGTCT
 ACCTCTGTTGGTTCAAAGGACAATTGCAAGGACGATTGTGCTTCAGGAAATAGTAGGAAAAG
 GTAGATTTGGTGAGGTGTGGCATGGAAGATGGTGTGGGGAAGATGTGGCTGTGAAAATATTC
 TCCTCCAGAGATGAAAGATCTTGGTTTCGTGAGGCAGAAATTTACCAGACGGTCATGCTGCG
 ACATGAAAACATCCTTGGTTTCATTGCTGCTGACAACAAAGATAATGGAACCTTGGACTCAAC
 TTTGGCTGGTATCTGAATATCATGAACAGGGCTCCTTATATGACTATTTGAATAGAAATATA
 GTGACCGTGGCTGGAATGATCAAGCTGGCGCTCTCAATTGCTAGTGGTCTGGCACACCTTCA
 TATGGAGATTGTTGGTACACAAGGTAAACCTGCTATTGCTCATCGAGACATAAAATCAAAGA
 ATATCTTAGTGAAAAAGTGTGAAACTTGTGCCATAGCGGACTTAGGGTTGGCTGTGAAGCAT
 GATTCAATACTGAACACTATCGACATACCTCAGAATCCTAAAGTGGGAACCAAGAGGTATAT
 GGCTCCTGAAATGCTTGATGATACAATGAATGTGAATATCTTTGAGTCCTTCAAACGAGCTG
 ACATCTATTCTGTTGGTCTGGTTTACTGGGAAATAGCCCGGAGGTGTTTCAGTCGGAGGAATT
 GTTGAGGAGTACCAATTGCCTTATTATGACATGGTGCCTTCAGATCCCTCGATAGAGGAAAT
 GAGAAAGGTTGTTTGTGACCAGAAGTTTCGACCAAGTATCCCAAACCAAGTGGCAAAGTTGTG
 AAGCACTCCGAGTCATGGGGAGAATAATGCGTGAGTGTTGGTATGCCAACGGAGCGGCCCGC

CTAACTGCTCTTCGTATTAAGAAGACTATATCTCAACTTTGTGTCAAAGAAGACTGCAAAGC
C (SEQ ID NO: 308)

[0102] The amino acid sequence of an alternative human ALK7 precursor protein, isoform 4 (NCBI Ref Seq NP_001104503.1), is shown as follows (SEQ ID NO: 42), where the signal peptide is indicated by a single underline.

1 MTRALCSALR QALLLLAAAA ELSPGLKCVC LLCSSNFTC QTEGACWASV
MLTNGKEQVI
61 KSCVSLPELN AQVFCHSSNN VTKTECCFTD FCNNITLHLP TDNGTWTQLW
LVSEYHEQGS
121 LYDYLNRNIV TVAGMIKLAL SIASGLAHLH MEIVGTQGKP AIAHRDIKSK
NILVKKCETC
181 AIADLGLAVK HDSILNTIDI PQNPVGTKR YMAPEMLDDT MNVNIFESFK
RADIYSVGLV
241 YWEIARRCSV GGIVEEYQLP YYDMVPSDPS IEEMRKVVCD QKFRPSIPNQ
WQSCEALRVM
301 GRIMRECWYA NGAARLTALR IKKTISQLCV KEDCKA (SEQ ID NO: 42)

[0103] The amino acid sequence of the processed ALK7 polypeptide (isoform 4) is as follows (SEQ ID NO: 43). Like ALK7 isoform 3, isoform 4 lacks a transmembrane domain and is therefore proposed to be soluble in its entirety (Roberts et al., 2003, Biol Reprod 68:1719-1726). N-terminal variants of SEQ ID NO: 43 are predicted as described below.

1 ELSPGLKCVC LLCSSNFTC QTEGACWASV MLTNGKEQVI KSCVSLPELN
AQVFCHSSNN
61 VTKTECCFTD FCNNITLHLP TDNGTWTQLW LVSEYHEQGS LYDYLNRNIV
TVAGMIKLAL
121 SIASGLAHLH MEIVGTQGKP AIAHRDIKSK NILVKKCETC AIADLGLAVK
HDSILNTIDI
181 PQNPVGTKR YMAPEMLDDT MNVNIFESFK RADIYSVGLV YWEIARRCSV
GGIVEEYQLP
240 YYDMVPSDPS IEEMRKVVCD QKFRPSIPNQ WQSCEALRVM GRIMRECWYA
NGAARLTALR
301 IKKTISQLCV KEDCKA (SEQ ID NO: 43)

[0104] A nucleic acid sequence encoding the unprocessed ALK7 polypeptide precursor protein (isoform 4) is shown below (SEQ ID NO: 44), corresponding to nucleotides 244-1244 of NCBI Reference Sequence NM_001111033.1. The signal sequence is indicated by solid underline.

ATGACCCGGGCGCTCTGCTCAGCGCTCCGCCAGGCTCTCCTGCTGCTCGCAGCGGCCGCCGA
GCTCTCGCCAGGACTGAAGTGTGTATGTCTTTTGTGTGATTCTTCAAACCTTTACCTGCCAAA
CAGAAGGAGCATGTTGGGCATCAGTCATGCTAACCAATGGAAAAGAGCAGGTGATCAAATCC
TGTGTCTCCCTTCCAGAACTGAATGCTCAAGTCTTCTGTCATAGTTCCAACAATGTTACCAA
AACCGAATGCTGCTTCACAGATTTTGTGCAACAACATAACACTGCACCTTCCAACAGATAATG

GAACTTGGACTCAACTTTGGCTGGTATCTGAATATCATGAACAGGGCTCCTTATATGACTAT
 TTGAATAGAAATATAGTGACCGTGGCTGGAATGATCAAGCTGGCGCTCTCAATTGCTAGTGG
 TCTGGCACACCTTCATATGGAGATTGTTGGTACACAAGGTAAACCTGCTATTGCTCATCGAG
 ACATAAAATCAAAGAATATCTTAGTGAAAAAGTGTGAAACTTGTGCCATAGCGGACTTAGGG
 TTGGCTGTGAAGCATGATTCAATACTGAACACTATCGACATACCTCAGAATCCTAAAGTGGG
 AACCAAGAGGTATATGGCTCCTGAAATGCTTGATGATACAATGAATGTGAATATCTTTGAGT
 CCTTCAAACGAGCTGACATCTATTCTGTTGGTCTGGTTTACTGGGAAATAGCCCGGAGGTGT
 TCAGTCGGAGGAATTGTTGAGGAGTACCAATTGCCTTATTATGACATGGTGCCTTCAGATCC
 CTCGATAGAGGAAATGAGAAAGGTTGTTTGTGACCAGAAGTTTCGACCAAGTATCCCAAACC
 AGTGGCAAAGTTGTGAAGCACTCCGAGTCATGGGGAGAATAATGCGTGAGTGTTGGTATGCC
 AACGGAGCGGCCCCGCCTAACTGCTCTTCGTATTAAGAAGACTATATCTCAACTTTGTGTCAA
 AGAAGACTGCAAAGCCTAA (SEQ ID NO: 44)

[0105] A nucleic acid sequence encoding the processed ALK7 polypeptide (isoform 4) is as follows (SEQ ID NO: 45):

GAGCTCTCGCCAGGACTGAAGTGTGTATGTCTTTTGTGTGATTCTTCAAACCTTTACCTGCCA
 AACAGAAGGAGCATGTTGGGCATCAGTCATGCTAACCAATGGAAAAGAGCAGGTGATCAAAT
 CCTGTGTCTCCCTTCCAGAACTGAATGCTCAAGTCTTCTGTCATAGTTCCAACAATGTTACC
 AAAACCGAATGCTGCTTCACAGATTTTTTGCAACAACATAACACTGCACCTTCCAACAGATAA
 TGGAACCTTGGACTCAACTTTGGCTGGTATCTGAATATCATGAACAGGGCTCCTTATATGACT
 ATTTGAATAGAAATATAGTGACCGTGGCTGGAATGATCAAGCTGGCGCTCTCAATTGCTAGT
 GGTCTGGCACACCTTCATATGGAGATTGTTGGTACACAAGGTAAACCTGCTATTGCTCATCG
 AGACATAAAATCAAAGAATATCTTAGTGAAAAAGTGTGAAACTTGTGCCATAGCGGACTTAG
 GGTGGCTGTGAAGCATGATTCAATACTGAACACTATCGACATACCTCAGAATCCTAAAGTG
 GGAACCAAGAGGTATATGGCTCCTGAAATGCTTGATGATACAATGAATGTGAATATCTTTGA
 GTCCTTCAAACGAGCTGACATCTATTCTGTTGGTCTGGTTTACTGGGAAATAGCCCGGAGGT
 GTTCAGTCGGAGGAATTGTTGAGGAGTACCAATTGCCTTATTATGACATGGTGCCTTCAGAT
 CCCTCGATAGAGGAAATGAGAAAGGTTGTTTGTGACCAGAAGTTTCGACCAAGTATCCCAA
 CCAGTGGCAAAGTTGTGAAGCACTCCGAGTCATGGGGAGAATAATGCGTGAGTGTTGGTATG
 CCAACGGAGCGGCCCCGCCTAACTGCTCTTCGTATTAAGAAGACTATATCTCAACTTTGTGTC
 AAAGAAGACTGCAAAGCCTAA (SEQ ID NO: 45)

[0106] Based on the signal sequence of full-length ALK7 (isoform 1) in the rat (see NCBI Reference Sequence NP_620790.1) and on the high degree of sequence identity between human and rat ALK7, it is predicted that a processed form of human ALK7 isoform 1 is as follows (SEQ ID NO: 46).

1 LKCVCLLCDS SNFTCQTEGA CWASVMLTNG KEQVIKSCVS LPFLNAQVFC
 HSSNNVTKTE

61 CCFTDFCNNI TLHLPTASPN APKLG PME (SEQ ID NO: 46)

[0107] Active variants of processed ALK7 isoform 1 are predicted in which SEQ ID NO: 10 is

truncated by 1, 2, 3, 4, 5, 6, or 7 amino acids at the N-terminus and SEQ ID NO: 46 is truncated by 1 or 2 amino acids at the N-terminus. Consistent with SEQ ID NO: 46, it is further expected that leucine is the N-terminal amino acid in the processed forms of human ALK7 isoform 3 (SEQ ID NO: 39) and human ALK7 isoform 4 (SEQ ID NO: 43).

[0108] In certain instances, the disclosure relates to heteromultimers that comprise at least one ALK7 polypeptide, which includes fragments, functional variants, and modified forms thereof. Preferably, ALK7 polypeptides for use in accordance with the disclosure (e.g., heteromultimers comprising an ALK7 polypeptide and uses thereof) are soluble (e.g., an extracellular domain of ALK7). In other preferred instances, ALK7 polypeptides for use in accordance with the disclosure bind to one or more TGF-beta superfamily ligands. Therefore, in some preferred instances, ALK7 polypeptides for use in accordance with the disclosure inhibit (antagonize) activity (e.g., induction of Smad 2/3 and/or Smad 1/5/8 signaling) of one or more TGF-beta superfamily ligands. In some instances, heteromultimers of the disclosure comprise at least one ALK7 polypeptide that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 97%, 98%, or 99% identical to the amino acid sequence of SEQ ID NO: 9, 10, 19, 20, 38, 39, 42, 43, 46, 74, 75, 79, or 80. In some instances, heteromultimer of the disclosure consist or consist essentially of at least one ALK7 polypeptide that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 97%, 98%, or 99% identical to the amino acid sequence of SEQ ID NO: 9, 10, 19, 20, 38, 39, 42, 43, 46, 74, 75, 79, and 80.

[0109] ALK7 is well-conserved among vertebrates, with large stretches of the extracellular domain completely conserved. For example, Figure 7 depicts a multi-sequence alignment of a human ALK7 extracellular domain compared to various ALK7 orthologs. Accordingly, from these alignments, it is possible to predict key amino acid positions within the ligand-binding domain that are important for normal ALK7-ligand binding activities as well as to predict amino acid positions that are likely to be tolerant to substitution without significantly altering normal ALK7-ligand binding activities. Therefore, an active, human ALK7 variant polypeptide useful in accordance with the presently disclosed methods may include one or more amino acids at corresponding positions from the sequence of another vertebrate ALK7, or may include a residue that is similar to that in the human or other vertebrate sequences. Without meaning to be limiting, the following examples illustrate this approach to defining an active ALK7 variant. V61 in the human ALK7 extracellular domain (SEQ ID NO: 59) is isoleucine in *Callithrix jacchus* ALK7 (SEQ ID NO: 62), and so the position may be altered, and optionally may be altered to another hydrophobic residue such as L, I, or F, or a non-polar residue such as A. L32 in the human extracellular domain is R in *Tarsius syrichta* (SEQ ID NO: 63) ALK7, indicating that this site may be tolerant of a wide variety of changes, including polar residues, such as E, D, K, R, H, S, T, P, G, Y, and probably a non-polar residue such as A. K37 in the human extracellular domain is R in *Pan troglodytes* ALK7 (SEQ ID NO: 60), indicating that basic residues are tolerated at this position, including R, K, and H. P4 in the human extracellular domain is relatively poorly conserved, appearing as A in *Pan troglodytes* ALK7 thus indicating that a wide variety of amino acid should be tolerated at this position.

[0110] Moreover, ALK7 proteins have been characterized in the art in terms of structural and functional characteristics [e.g., Romano et al (2012) Journal of Molecular Modeling 18(8): 3617-3625]. For example, a defining structural motif known as a three-finger toxin fold is important for ligand binding by type I and type II receptors and is formed by conserved cysteine residues located at varying positions within the extracellular domain of each monomeric receptor [Greenwald et al. (1999) Nat Struct Biol 6:18-22; and Hinck (2012) FEBS Lett 586:1860-1870]. Accordingly, the core ligand-binding domains of human ALK7, as demarcated by the outermost of these conserved cysteines, corresponds to positions 28-92 of SEQ ID NO: 9. The structurally less-ordered amino acids flanking these cysteine-demarcated core sequences can be truncated by 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, or 27 residues at the N-terminus and by 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, or 21 residues at the C-terminus without necessarily altering ligand binding. Exemplary ALK7 extracellular domains for N-terminal and/or C-terminal truncation include SEQ ID NOs: 10, 20, 39, and 43.

[0111] Accordingly, a general formula for an active portion (e.g., a ligand-binding portion) of ALK7 comprises amino acids 28-92. Therefore ALK7 polypeptides may, for example, comprise, consists essentially of, or consists of an amino acid sequence that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identical to a portion of ALK7 beginning at a residue corresponding to any one of amino acids 20-28 (e.g., beginning at any one of amino acids 20, 21, 22, 23, 24, 25, 26, 27, or 28) of SEQ ID NO: 9 and ending at a position corresponding to any one amino acids 92-113 (e.g., ending at any one of amino acids 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, or 113) of SEQ ID NO: 9.

[0112] Other examples include constructs that begin at a position from 21-28 (e.g., any one of positions 21, 22, 23, 24, 25, 26, 27, or 28), 24-28 (e.g., any one of positions 24, 25, 26, 27, or 28), or 25-28 (e.g., any one of positions 25, 26, 27, or 28) of SEQ ID NO: 9 and end at a position from 93-112 (e.g., any one of positions 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, or 112), 93-110 (e.g., any one of positions 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, or 110), 93-100 (e.g., any one of positions 93, 94, 95, 96, 97, 98, 99, or 100), or 93-95 (e.g., any one of positions 93, 94, or 95) of SEQ ID NO: 9. Variants within these ranges are also contemplated, particularly those having at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identity to the corresponding portion of SEQ ID NO: 9.

[0113] The variations described herein may be combined in various ways. In some instances, ALK7 variants comprise no more than 1, 2, 5, 6, 7, 8, 9, 10 or 15 conservative amino acid changes in the ligand-binding pocket. Sites outside the binding pocket, at which variability may be particularly well tolerated, include the amino and carboxy termini of the extracellular domain (as noted above).

[0114] In certain aspects, the present disclosure relates to heteromultimers comprising one or more ALK7 receptor polypeptides (e.g., SEQ ID Nos: 9, 10, 19, 20, 38, 39, 42, 43, 46, 74, 76,

79, and 80) and one or more ActRIIB receptor polypeptides (e.g., SEQ ID NOs: 1, 2, 3, 4, 5, 6, 71, 73, 77, and 78), which are generally referred to herein as "ALK7:ActRIIB heteromultimer complexes" or "ALK7:ActRIIB heteromultimers". Preferably, ALK7:ActRIIB heteromultimers are soluble, e.g., a heteromultimer comprises a soluble portion (domain) of an ALK7 receptor and a soluble portion (domain) of an ActRIIB receptor. In general, the extracellular domains of ALK7 and ActRIIB correspond to soluble portion of these receptors. Therefore, in some instances, heteromultimers comprise an extracellular domain of an ALK7 receptor and an extracellular domain of an ActRIIB receptor. Example extracellular domains of ALK7 and ActRIIB receptors are disclosed herein and such sequences, as well as fragments, functional variants, and modified forms thereof, may be used in accordance with the disclosure (e.g., ALK7:ActRIIB heteromultimer compositions and uses thereof). In some instances, ALK7:ActRIIB heteromultimers comprise at least one ALK7 polypeptide that comprises, consists essentially of, or consists of a sequence that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94% 95%, 97%, 98%, 99%, or 100% identical to the amino acid sequence of SEQ ID NO: 9, 10, 19, 20, 38, 39, 42, 43, 46, 74, 76, 79, and 80. In some instances, ALK7:ActRIIB heteromultimers comprise at least one ALK7 polypeptide that comprises, consists essentially of, consists of a sequence that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94% 95%, 97%, 98%, 99%, or 100% identical to a portion of ALK7 beginning at a residue corresponding to any one of amino acids 21-28, 22-28, 23-28, 24-28, 25-28, 26-28, or 27-28 of SEQ ID NO: 9 and ending at a position from 93-112, 93, 110, 93-100, 93-95 of SEQ ID NO: 9. In some instances, ALK7:ActRIIB heteromultimers comprise at least one ALK7 polypeptide that comprises, consists essentially of, consists of a sequence that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94% 95%, 97%, 98%, 99%, or 100% identical to amino acids 28-92 of SEQ ID NO: 9. In some instances, ALK7-ActRIIB heteromultimers comprise at least one ActRIIB polypeptide that comprises, consists essentially of, consists of a sequence that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94% 95%, 97%, 98%, 99%, or 100% identical to the amino acid sequence of any one of SEQ ID NOs: 1, 2, 3, 4, 5, 6, 71, 73, 77, and 78. In some instances, ALK7:ActRIIB heteromultimers comprise at least one ActRIIB polypeptide that comprises, consists essentially of, consists of a sequence that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94% 95%, 97%, 98%, 99%, or 100% identical to a portion of ActRIIB beginning at a residue corresponding to any one of amino acids 20-29, 20-24, 21-24, 22-25, or 21-29 and end at a position from 109-134, 119-134, 119-133, 129-134, or 129-133 of SEQ ID NO: 1. In some instances, ALK7:ActRIIB heteromultimers comprise at least one ActRIIB polypeptide that comprises, consists essentially of, or consists of a sequence that is at least 70%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94% 95%, 97%, 98%, 99%, or 100% identical to amino acids 29-109 of SEQ ID NO: 1. In some instances, ALK7:ActRIIB heteromultimers comprise at least one ActRIIB polypeptide that comprises, consists essentially of, consists of a sequence that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94% 95%, 97%, 98%, 99%, or 100% identical to amino acids 25-125 of SEQ ID NO: 1. In certain preferred instances, ALK7:ActRIIB heteromultimers comprise at least one ActRIIB polypeptide wherein the position corresponding to L79 of SEQ ID NO: 1 is not an acidic amino acid (*i.e.*, not naturally occurring D or E amino acids or an artificial acidic acid residue). ALK7:ActRIIB heteromultimers include, e.g., heterodimers, heterotrimers,

heterotetramers and further higher order oligomeric structures. See, e.g., Figures 1, 2, and 8-10. In certain preferred instances, heteromultimers of the disclosure are ALK7:ActRIIB heterodimers.

[0115] In some instances, the present disclosure contemplates making functional variants by modifying the structure of an ALK7 polypeptide and/or an ActRIIB polypeptide. Variants can be produced by amino acid substitution, deletion, addition, or combinations thereof. For instance, it is reasonable to expect that an isolated replacement of a leucine with an isoleucine or valine, an aspartate with a glutamate, a threonine with a serine, or a similar replacement of an amino acid with a structurally related amino acid (e.g., conservative mutations) will not have a major effect on the biological activity of the resulting molecule. Conservative replacements are those that take place within a family of amino acids that are related in their side chains. Whether a change in the amino acid sequence of a polypeptide of the disclosure results in a functional homolog can be readily determined by assessing the ability of the variant polypeptide to produce a response in cells in a fashion similar to the wild-type polypeptide, or to bind to one or more TGF-beta superfamily ligands including, for example, BMP2, BMP2/7, BMP3, BMP4, BMP4/7, BMP5, BMP6, BMP7, BMP8a, BMP8b, BMP9, BMP10, GDF3, GDF5, GDF6/BMP13, GDF7, GDF8, GDF9b/BMP15, GDF11/BMP11, GDF15/MIC1, TGF- β 1, TGF- β 2, TGF- β 3, activin A, activin B, activin C, activin E, activin AB, activin AC, activin AE, activin BC, activin BE, nodal, glial cell-derived neurotrophic factor (GDNF), neurturin, artemin, persephin, MIS, and Lefty.

[0116] In some instances, the present disclosure contemplates making functional variants by modifying the structure of an ALK7 polypeptide and/or an ActRIIB polypeptide for such purposes as enhancing therapeutic efficacy or stability (e.g., shelf-life and resistance to proteolytic degradation *in vivo*).

[0117] In some instances, the present disclosure contemplates specific mutations of an ALK7 polypeptide and/or an ActRIIB polypeptide so as to alter the glycosylation of the polypeptide. Such mutations may be selected so as to introduce or eliminate one or more glycosylation sites, such as O-linked or N-linked glycosylation sites. Asparagine-linked glycosylation recognition sites generally comprise a tripeptide sequence, asparagine-X-threonine or asparagine-X-serine (where "X" is any amino acid) which is specifically recognized by appropriate cellular glycosylation enzymes. The alteration may also be made by the addition of, or substitution by, one or more serine or threonine residues to the sequence of the polypeptide (for O-linked glycosylation sites). A variety of amino acid substitutions or deletions at one or both of the first or third amino acid positions of a glycosylation recognition site (and/or amino acid deletion at the second position) results in non-glycosylation at the modified tripeptide sequence. Another means of increasing the number of carbohydrate moieties on a polypeptide is by chemical or enzymatic coupling of glycosides to the polypeptide. Depending on the coupling mode used, the sugar(s) may be attached to (a) arginine and histidine; (b) free carboxyl groups; (c) free sulfhydryl groups such as those of cysteine; (d) free hydroxyl groups such as those of serine, threonine, or hydroxyproline; (e) aromatic residues such as those of phenylalanine, tyrosine, or tryptophan; or (f) the amide group of glutamine. Removal of one or

more carbohydrate moieties present on a polypeptide may be accomplished chemically and/or enzymatically. Chemical deglycosylation may involve, for example, exposure of a polypeptide to the compound trifluoromethanesulfonic acid, or an equivalent compound. This treatment results in the cleavage of most or all sugars except the linking sugar (N-acetylglucosamine or N-acetylgalactosamine), while leaving the amino acid sequence intact. Enzymatic cleavage of carbohydrate moieties on polypeptides can be achieved by the use of a variety of endo- and exo-glycosidases as described by Thotakura et al. [Meth. Enzymol. (1987) 138:350]. The sequence of a polypeptide may be adjusted, as appropriate, depending on the type of expression system used, as mammalian, yeast, insect, and plant cells may all introduce differing glycosylation patterns that can be affected by the amino acid sequence of the peptide. In general, heteromeric complexes of the present disclosure for use in humans may be expressed in a mammalian cell line that provides proper glycosylation, such as HEK293 or CHO cell lines, although other mammalian expression cell lines are expected to be useful as well.

[0118] The present disclosure further contemplates a method of generating mutants, particularly sets of combinatorial mutants of an ALK7 and/or an ActRIIB polypeptide as well as truncation mutants. Pools of combinatorial mutants are especially useful for identifying functionally active (e.g., TGF-beta superfamily ligand binding) ALK7 and/or ActRIIB sequences. The purpose of screening such combinatorial libraries may be to generate, for example, polypeptides variants which have altered properties, such as altered pharmacokinetic or altered ligand binding. A variety of screening assays are provided below, and such assays may be used to evaluate variants. For example, ALK7:ActRIIB complex variants may be screened for ability to bind to one or more TGF-beta superfamily ligands, to prevent binding of a TGF-beta superfamily ligand to a TGF-beta superfamily receptor, and/or to interfere with signaling caused by an TGF-beta superfamily ligand.

[0119] The activity of a ALK7:ActRIIB heteromultimer may be tested, for example, in a cell-based or *in vivo* assay. For example, the effect of an ALK7:ActRIIB heteromultimer on the expression of genes or the activity of proteins involved in fat metabolism, kidney damage, kidney inflammation, and/or kidney fibrosis may be assessed. This may, as needed, be performed in the presence of one or more recombinant TGF-beta superfamily ligand proteins, and cells may be transfected so as to produce an ALK7:ActRIIB heteromultimer, and optionally, a TGF-beta superfamily ligand. Likewise, an ALK7:ActRIIB heteromultimer may be administered to a mouse or other animal, and one or more measurements, such as fat metabolism or kidney damage, inflammation, fibrosis and/or function may be assessed using art-recognized methods. Similarly, the activity of an ALK7:ActRIIB heteromultimer, or variants thereof, may be tested in, for example, adipocytes and/or glomerular cells for any effect on growth of these cells, for example, by the assays as described herein and those of common knowledge in the art. A SMAD-responsive reporter gene may be used in such cell lines to monitor effects on downstream signaling.

[0120] Combinatorial-derived variants can be generated which have increased selectivity or generally increased potency relative to a reference ALK7:ActRIIB heteromultimer. Such

variants, when expressed from recombinant DNA constructs, can be used in gene therapy protocols. Likewise, mutagenesis can give rise to variants which have intracellular half-lives dramatically different than the corresponding unmodified ALK7:ActRIIB heteromultimer. For example, the altered protein can be rendered either more stable or less stable to proteolytic degradation or other cellular processes which result in destruction, or otherwise inactivation, of an unmodified polypeptide. Such variants, and the genes which encode them, can be utilized to alter polypeptide complex levels by modulating the half-life of the polypeptide. For instance, a short half-life can give rise to more transient biological effects and, when part of an inducible expression system, can allow tighter control of recombinant polypeptide complex levels within the cell. In an Fc fusion protein, mutations may be made in the linker (if any) and/or the Fc portion to alter one or more activities of the ALK7:ActRIIB heteromultimer including, for example, immunogenicity, half-life, and solubility.

[0121] A combinatorial library may be produced by way of a degenerate library of genes encoding a library of polypeptides which each include at least a portion of potential ALK7 and/or ActRIIB sequences. For instance, a mixture of synthetic oligonucleotides can be enzymatically ligated into gene sequences such that the degenerate set of potential ALK7 and/or ActRIIB encoding nucleotide sequences are expressible as individual polypeptides, or alternatively, as a set of larger fusion proteins (e.g., for phage display).

[0122] There are many ways by which the library of potential homologs can be generated from a degenerate oligonucleotide sequence. Chemical synthesis of a degenerate gene sequence can be carried out in an automatic DNA synthesizer, and the synthetic genes can then be ligated into an appropriate vector for expression. The synthesis of degenerate oligonucleotides is well known in the art [Narang, SA (1983) *Tetrahedron* 39:3; Itakura et al. (1981) *Recombinant DNA, Proc. 3rd Cleveland Sympos. Macromolecules*, ed. AG Walton, Amsterdam: Elsevier pp273-289; Itakura et al. (1984) *Annu. Rev. Biochem.* 53:323; Itakura et al. (1984) *Science* 198:1056; and Ike et al. (1983) *Nucleic Acid Res.* 11:477]. Such techniques have been employed in the directed evolution of other proteins [Scott et al., (1990) *Science* 249:386-390; Roberts et al. (1992) *PNAS USA* 89:2429-2433; Devlin et al. (1990) *Science* 249:404-406; Cwirla et al., (1990) *PNAS USA* 87: 6378-6382; as well as U.S. Patent Nos: 5,223,409, 5,198,346, and 5,096,815].

[0123] Alternatively, other forms of mutagenesis can be utilized to generate a combinatorial library. For example, ALK7:ActRIIB heteromultimers can be generated and isolated from a library by screening using, for example, alanine scanning mutagenesis [Ruf et al. (1994) *Biochemistry* 33:1565-1572; Wang et al. (1994) *J. Biol. Chem.* 269:3095-3099; Balint et al. (1993) *Gene* 137:109-118; Grodberg et al. (1993) *Eur. J. Biochem.* 218:597-601; Nagashima et al. (1993) *J. Biol. Chem.* 268:2888-2892; Lowman et al. (1991) *Biochemistry* 30:10832-10838; and Cunningham et al. (1989) *Science* 244:1081-1085], by linker scanning mutagenesis [Gustin et al. (1993) *Virology* 193:653-660; and Brown et al. (1992) *Mol. Cell Biol.* 12:2644-2652; McKnight et al. (1982) *Science* 232:316], by saturation mutagenesis [Meyers et al., (1986) *Science* 232:613]; by PCR mutagenesis [Leung et al. (1989) *Method Cell Mol Biol* 1:11-19]; or by random mutagenesis, including chemical mutagenesis [Miller et al. (1992) *A Short*

Course in Bacterial Genetics, CSHL Press, Cold Spring Harbor, NY; and Greener et al. (1994) Strategies in Mol Biol 7:32-34]. Linker scanning mutagenesis, particularly in a combinatorial setting, is an attractive method for identifying truncated (bioactive) forms of ALK7 and/or ActRIIB polypeptides.

[0124] A wide range of techniques are known in the art for screening gene products of combinatorial libraries made by point mutations and truncations, and, for that matter, for screening cDNA libraries for gene products having a certain property. Such techniques will be generally adaptable for rapid screening of the gene libraries generated by the combinatorial mutagenesis of ALK7:ActRIIB heteromultimers. The most widely used techniques for screening large gene libraries typically comprise cloning the gene library into replicable expression vectors, transforming appropriate cells with the resulting library of vectors, and expressing the combinatorial genes under conditions in which detection of a desired activity facilitates relatively easy isolation of the vector encoding the gene whose product was detected. Preferred assays include TGF-beta superfamily ligand (e.g., BMP2, BMP2/7, BMP3, BMP4, BMP4/7, BMP5, BMP6, BMP7, BMP8a, BMP8b, BMP9, BMP10, GDF3, GDF5, GDF6/BMP13, GDF7, GDF8, GDF9b/BMP15, GDF11/BMP11, GDF15/MIC1, TGF- β 1, TGF- β 2, TGF- β 3, activin A, activin B, activin C, activin E, activin AB, activin AC, activin BC, activin AE, activin BE, nodal, glial cell-derived neurotrophic factor (GDNF), neurturin, artemin, persephin, MIS, and Lefty) binding assays and/or TGF-beta superfamily ligand-mediated cell signaling assays.

[0125] In certain instances, ALK7:ActRIIB heteromultimers may further comprise post-translational modifications in addition to any that are naturally present in the ALK7 and/or ActRIIB polypeptide. Such modifications include, but are not limited to, acetylation, carboxylation, glycosylation, phosphorylation, lipidation, and acylation. As a result, ALK7:ActRIIB heteromultimers may comprise non-amino acid elements, such as polyethylene glycols, lipids, polysaccharide or monosaccharide, and phosphates. Effects of such non-amino acid elements on the functionality of a heteromultimer complex may be tested as described herein for other heteromultimer variants. When a polypeptide of the disclosure is produced in cells by cleaving a nascent form of the polypeptide, post-translational processing may also be important for correct folding and/or function of the protein. Different cells (e.g., CHO, HeLa, MDCK, 293, WI38, NIH-3T3 or HEK293) have specific cellular machinery and characteristic mechanisms for such post-translational activities and may be chosen to ensure the correct modification and processing of the ALK7 and/or ActRIIB polypeptide as well as heteromultimers comprising the same.

[0126] In certain preferred instances, heteromultimers described herein comprise at least one ALK7 polypeptide associated, covalently or non-covalently, with at least one ActRIIB polypeptide. Preferably, polypeptides disclosed herein form heterodimeric complexes, although higher order heteromultimeric complexes are also included such as, but not limited to, heterotrimers, heterotetramers, and further oligomeric structures (see, e.g., Figure 1, 2, and 8-10). In some instances, ALK7 and/or ActRIIB polypeptides comprise at least one multimerization domain. As disclosed herein, the term "multimerization domain" refers to an amino acid or sequence of amino acids that promote covalent or non-covalent interaction

between at least a first polypeptide and at least a second polypeptide. Polypeptides disclosed herein may be joined covalently or non-covalently to a multimerization domain. Preferably, a multimerization domain promotes interaction between a first polypeptide (e.g., an ALK7 polypeptide) and a second polypeptide (e.g., an ActRIIB polypeptide) to promote heteromultimer formation (e.g., heterodimer formation), and optionally hinders or otherwise disfavors homomultimer formation (e.g., homodimer formation), thereby increasing the yield of desired heteromultimer (see, e.g., Figure 2).

[0127] Many methods known in the art can be used to generate ALK7:ActRIIB heteromultimers. For example, non-naturally occurring disulfide bonds may be constructed by replacing on a first polypeptide (e.g., an ALK7 polypeptide) a naturally occurring amino acid with a free thiol-containing residue, such as cysteine, such that the free thiol interacts with another free thiol-containing residue on a second polypeptide (e.g., an ActRIIB polypeptide) such that a disulfide bond is formed between the first and second polypeptides. Additional examples of interactions to promote heteromultimer formation include, but are not limited to, ionic interactions such as described in Kjaergaard et al., WO2007147901; electrostatic steering effects such as described in Kannan et al., U.S.8,592,562; coiled-coil interactions such as described in Christensen et al., U.S.20120302737; leucine zippers such as described in Pack & Plueckthun, (1992) *Biochemistry* 31: 1579-1584; and helix-turn-helix motifs such as described in Pack et al., (1993) *Bio/Technology* 11: 1271-1277. Linkage of the various segments may be obtained via, e.g., covalent binding such as by chemical crosslinking, peptide linkers, disulfide bridges, *etc.*, or affinity interactions such as by avidin-biotin or leucine zipper technology.

[0128] In certain aspects, a multimerization domain may comprise one component of an interaction pair. In some instances, the polypeptides disclosed herein may form protein complexes comprising a first polypeptide covalently or non-covalently associated with a second polypeptide, wherein the first polypeptide comprises the amino acid sequence of an ALK7 polypeptide and the amino acid sequence of a first member of an interaction pair; and the second polypeptide comprises the amino acid sequence of an ActRIIB polypeptide and the amino acid sequence of a second member of an interaction pair. The interaction pair may be any two polypeptide sequences that interact to form a complex, particularly a heterodimeric complex although operative instances may also employ an interaction pair that can form a homodimeric complex. One member of the interaction pair may be fused to an ALK7 or ActRIIB polypeptide as described herein, including for example, a polypeptide sequence comprising, consisting essentially of, or consisting of an amino acid sequence that is at least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identical to the sequence of any one of SEQ ID NOs: 2, 3, 5, 6, 10, 20, 39, 43, and 46. An interaction pair may be selected to confer an improved property/activity such as increased serum half-life, or to act as an adaptor on to which another moiety is attached to provide an improved property/activity. For example, a polyethylene glycol moiety may be attached to one or both components of an interaction pair to provide an improved property/activity such as improved serum half-life.

[0129] The first and second members of the interaction pair may be an asymmetric pair,

meaning that the members of the pair preferentially associate with each other rather than self-associate. Accordingly, first and second members of an asymmetric interaction pair may associate to form a heterodimeric complex (see, e.g., Figure 2). Alternatively, the interaction pair may be unguided, meaning that the members of the pair may associate with each other or self-associate without substantial preference and thus may have the same or different amino acid sequences. Accordingly, first and second members of an unguided interaction pair may associate to form a homodimer complex or a heterodimeric complex. Optionally, the first member of the interaction pair (e.g., an asymmetric pair or an unguided interaction pair) associates covalently with the second member of the interaction pair. Optionally, the first member of the interaction pair (e.g., an asymmetric pair or an unguided interaction pair) associates non-covalently with the second member of the interaction pair.

[0130] As specific examples, the present disclosure provides fusion proteins comprising ALK7 or ActRIIB fused to a polypeptide comprising a constant domain of an immunoglobulin, such as a CH1, CH2, or CH3 domain of an immunoglobulin or an Fc domain. Fc domains derived from human IgG1, IgG2, IgG3, and IgG4 are provided herein. Other mutations are known that decrease either CDC or ADCC activity, and collectively, any of these variants are included in the disclosure and may be used as advantageous components of a heteromultimeric complex of the disclosure. Optionally, the IgG1 Fc domain of SEQ ID NO: 31 has one or more mutations at residues such as Asp-265, Lys-322, and Asn-434 (numbered in accordance with the corresponding full-length IgG1). In certain cases, the mutant Fc domain having one or more of these mutations (e.g., Asp-265 mutation) has reduced ability of binding to the Fcγ receptor relative to a wildtype Fc domain. In other cases, the mutant Fc domain having one or more of these mutations (e.g., Asn-434 mutation) has increased ability of binding to the MHC class I-related Fc-receptor (FcRN) relative to a wildtype Fc domain.

[0131] An example of a native amino acid sequence that may be used for the Fc portion of human IgG1 (G1Fc) is shown below (SEQ ID NO: 31). Dotted underline indicates the hinge region, and solid underline indicates positions with naturally occurring variants. In part, the disclosure provides polypeptides comprising, consisting essentially of, or consisting of amino acid sequences with 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identity to SEQ ID NO: 31. Naturally occurring variants in G1Fc would include E134D and M136L according to the numbering system used in SEQ ID NO: 31 (see Uniprot P01857).

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1  THTCPPCPAP ELLGGPSVFL FPPKPKDTLM ISRTPEVTCV VVDVSHEDPE
51  VKFNWYVDGV EVHNAKTKPR EEQYNSTYRV VSVLTVLHQD WLNGKEYKCK
101 VSNKALPAPI EKTISKAKGQ PREPQVYTLP PSREEMTKNQ VSLTCLVKGF

151 YPSDIAVEWE SNGQPENNYK TTPPVLDSDG SFFLYSKLTV DKSRWQQGNV
201 FSCSVMEAL HNHYTQKSLS LSPGK          (SEQ ID NO: 31)

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[0132] An example of a native amino acid sequence that may be used for the Fc portion of human IgG2 (G2Fc) is shown below (SEQ ID NO: 32). Dotted underline indicates the hinge region and double underline indicates positions where there are data base conflicts in the

sequence (according to UniProt P01859). In part, the disclosure provides polypeptides comprising, consisting essential of, or consisting of amino acid sequences with 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identity to SEQ ID NO: 32.

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1  VECPPCPAPP VAGPSVFLFP PKPKDTLMIS RTPEVTCVVV DVSHEDPEVQ
51  FNWYVDGVEV HNAKTKPREE QFNSTFRVVS VLTVVHQDWL NGKEYKCKVS
101 NKGLPAPIEK TISKTKGQPR EPQVYTLPPS REEMTKNQVS LTCLVKGFYP
151 SDIAVEWESN GQPENNYKTT PPMLDSDGSF FLYSKLTVDK SRWQQGNVFS
201 CSVMHEALHN HYTQKSLSLS PGK (SEQ ID NO: 32)

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[0133] Two examples of amino acid sequences that may be used for the Fc portion of human IgG3 (G3Fc) are shown below. The hinge region in G3Fc can be up to four times as long as in other Fc chains and contains three identical 15-residue segments preceded by a similar 17-residue segment. The first G3Fc sequence shown below (SEQ ID NO: 33) contains a short hinge region consisting of a single 15-residue segment, whereas the second G3Fc sequence (SEQ ID NO: 34) contains a full-length hinge region. In each case, dotted underline indicates the hinge region, and solid underline indicates positions with naturally occurring variants according to UniProt P01859. In part, the disclosure provides polypeptides comprising, consisting essential of, or consisting of amino acid sequences with 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identity to SEQ ID NOs: 33 and 34.

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1  EPKSCDTPPP CPRCPAPELL GGPSVFLFPP KPKDTLMISR TPEVTCVVVD
51  VSHEDPEVQF KWYVDGVEVH NAKTKPREEQ YNSTFRVVSV LTVLHQDWLN
101 GKEYKCKVSN KALPAPIEKT ISKTKGQPRE PQVYTLPPSR EEMTKNQVSL
151 TCLVKGFYPS DIAVEWESSG QPENNYNTTP PMLDSDGSFF LYSKLTVDKS
201 RWQQGNIFSC SVMHEALHNR FTQKSLSLSP GK (SEQ ID NO: 33)

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1  ELKTPLGDTT HTCPRCPEPK SCDTPPPCPR CPEPKSCDTP PPCPRCPEPK
51  SCDTPPPCPR CPAPELLGGP SVFLFPPKPK DTLMISRTPE VTCVVVDVSH
101 EDPEVQFKWY VDGVEVHNAK TKPREEQYNS TFRVVSVLTV LHQDWLNGKE
151 YKCKVSNKAL PAPIEKTISK TKGQPREPQV YTLPPSREEM TKNQVSLTCL
201 VKGFYPSDIA VEWESSGQPE NNYNTTPPML DSDGSFFLYS KLTVDKSRWQ
251 QGNIFSCSVM HEALHNRFTQ KSLSLSPGK (SEQ ID NO:
34)

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[0134] Naturally occurring variants in G3Fc (for example, see Uniprot P01860) include E68Q, P76L, E79Q, Y81F, D97N, N100D, T124A, S169N, S169del, F221Y when converted to the numbering system used in SEQ ID NO: 33, and the present disclosure provides fusion proteins comprising G3Fc domains containing one or more of these variations. In addition, the human immunoglobulin IgG3 gene (*IGHG3*) shows a structural polymorphism characterized by different hinge lengths [see Uniprot P01859]. Specifically, variant WIS is lacking most of the V region and all of the CH1 region. It has an extra interchain disulfide bond at position 7 in addition to the 11 normally present in the hinge region. Variant ZUC lacks most of the V region,

all of the CH1 region, and part of the hinge. Variant OMM may represent an allelic form or another gamma chain subclass. The present disclosure provides additional fusion proteins comprising G3Fc domains containing one or more of these variants.

[0135] An example of a native amino acid sequence that may be used for the Fc portion of human IgG4 (G4Fc) is shown below (SEQ ID NO: 35). Dotted underline indicates the hinge region. In part, the disclosure provides polypeptides comprising, consisting essential of, or consisting of amino acid sequences with 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% identity to SEQ ID NO: 35.

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1  ESKYGPPCPS CPAPEFLGGP SVFLFPPKPK DTLMISRTP E VTCVVVDVSQ
51 EDPEVQFNWY VDGVEVHNAK TKPREEQFNS TYRVVSVLTV LHQDWLNGKE
101 YKCKVSNKGL PSSIEKTISK AKGQPREPQV YTLPPSQEEM TKNQVSLTCL
151 VKGFYPSDIA VEWESNGQPE NNYKTTTPVL DSDGSFFLYS RLTVDKSRWQ

201 EGNVFSCSVM HEALHNHYTQ KSLSLSLGK (SEQ ID NO: 35)
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[0136] A variety of engineered mutations in the Fc domain are presented herein with respect to the G1Fc sequence (SEQ ID NO: 31), and analogous mutations in G2Fc, G3Fc, and G4Fc can be derived from their alignment with G1Fc in Figure 5. Due to unequal hinge lengths, analogous Fc positions based on isotype alignment (Figure 5) possess different amino acid numbers in SEQ ID NOs: 31, 32, 33, 34, and 35. It can also be appreciated that a given amino acid position in an immunoglobulin sequence consisting of hinge, C_H2, and C_H3 regions (e.g., SEQ ID NOs: 31, 32, 33, 34, and 35) will be identified by a different number than the same position when numbering encompasses the entire IgG1 heavy-chain constant domain (consisting of the C_H1, hinge, C_H2, and C_H3 regions) as in the Uniprot database. For example, correspondence between selected C_H3 positions in a human G1Fc sequence (SEQ ID NO: 31), the human IgG1 heavy chain constant domain (Uniprot P01857), and the human IgG1 heavy chain is as follows.

Correspondence of C _H 3 Positions in Different Numbering Systems		
G1Fc (Numbering begins at first threonine in hinge region)	IgG1 heavy chain constant domain (Numbering begins at C _H 1)	IgG1 heavy chain (EU numbering scheme of Kabat et al., 1991*)
Y127	Y232	Y349
S132	S237	S354
E134	E239	E356
T144	T249	T366
L146	L251	L368
K170	K275	K392
D177	D282	D399
Y185	Y290	Y407

Correspondence of C _H 3 Positions in Different Numbering Systems		
G1Fc (Numbering begins at first threonine in hinge region)	IgG1 heavy chain constant domain (Numbering begins at C _H 1)	IgG1 heavy chain (EU numbering scheme of Kabat et al., 1991*)
K187	K292	K409
* Kabat et al. (eds) 1991; pp. 688-696 in Sequences of Proteins of Immunological Interest, 5th ed., Vol. 1, NIH, Bethesda, MD.		

[0137] A problem that arises in large-scale production of asymmetric immunoglobulin-based proteins from a single cell line is known as the "chain association issue". As confronted prominently in the production of bispecific antibodies, the chain association issue concerns the challenge of efficiently producing a desired multichain protein from among the multiple combinations that inherently result when different heavy chains and/or light chains are produced in a single cell line [Klein et al (2012) mAbs 4:653-663]. This problem is most acute when two different heavy chains and two different light chains are produced in the same cell, in which case there are a total of 16 possible chain combinations (although some of these are identical) when only one is typically desired. Nevertheless, the same principle accounts for diminished yield of a desired multichain fusion protein that incorporates only two different (asymmetric) heavy chains.

[0138] Various methods are known in the art that increase desired pairing of Fc-containing fusion polypeptide chains in a single cell line to produce a preferred asymmetric fusion protein at acceptable yields [Klein et al (2012) mAbs 4:653-663; and Spiess et al (2015) Molecular Immunology 67(2A): 95-106]. Methods to obtain desired pairing of Fc-containing chains include, but are not limited to, charge-based pairing (electrostatic steering), "knobs-into-holes" steric pairing, SEEDbody pairing, and leucine zipper-based pairing [Ridgway et al (1996) Protein Eng 9:617-621; Merchant et al (1998) Nat Biotech 16:677-681; Davis et al (2010) Protein Eng Des Sel 23:195-202; Gunasekaran et al (2010); 285:19637-19646; Wranik et al (2012) J Biol Chem 287:43331-43339; US5932448; WO 1993/011162; WO 2009/089004, and WO 2011/034605]. As described herein, these methods may be used to generate ALK7-Fc:ActRIIB-Fc heteromultimer complexes. See Figures 8-10.

[0139] For example, one means by which interaction between specific polypeptides may be promoted is by engineering protuberance-into-cavity (knob-into-holes) complementary regions such as described in Arathoon et al., U.S.7,183,076 and Carter et al., U.S.5,731,168. "Protuberances" are constructed by replacing small amino acid side chains from the interface of the first polypeptide (e.g., a first interaction pair) with larger side chains (e.g., tyrosine or tryptophan). Complementary "cavities" of identical or similar size to the protuberances are optionally created on the interface of the second polypeptide (e.g., a second interaction pair) by replacing large amino acid side chains with smaller ones (e.g., alanine or threonine). Where a suitably positioned and dimensioned protuberance or cavity exists at the interface of either the first or second polypeptide, it is only necessary to engineer a corresponding cavity or

protuberance, respectively, at the adjacent interface.

[0140] At neutral pH (7.0), aspartic acid and glutamic acid are negatively charged and lysine, arginine, and histidine are positively charged. These charged residues can be used to promote heterodimer formation and at the same time hinder homodimer formation. Attractive interactions take place between opposite charges and repulsive interactions occur between like charges. In part, protein complexes disclosed herein make use of the attractive interactions for promoting heteromultimer formation (e.g., heterodimer formation), and optionally repulsive interactions for hindering homodimer formation (e.g., homodimer formation) by carrying out site directed mutagenesis of charged interface residues.

[0141] For example, the IgG1 CH3 domain interface comprises four unique charge residue pairs involved in domain-domain interactions: Asp356-Lys439', Glu357-Lys370', Lys392-Asp399', and Asp399-Lys409' [residue numbering in the second chain is indicated by (')]. It should be noted that the numbering scheme used here to designate residues in the IgG1 CH3 domain conforms to the EU numbering scheme of Kabat. Due to the 2-fold symmetry present in the CH3-CH3 domain interactions, each unique interaction will be represented twice in the structure (e.g., Asp-399-Lys409' and Lys409-Asp399'). In the wild-type sequence, K409-D399' favors both heterodimer and homodimer formation. A single mutation switching the charge polarity (e.g., K409E; positive to negative charge) in the first chain leads to unfavorable interactions for the formation of the first chain homodimer. The unfavorable interactions arise due to the repulsive interactions occurring between the same charges (negative-negative; K409E-D399' and D399-K409E'). A similar mutation switching the charge polarity (D399K'; negative to positive) in the second chain leads to unfavorable interactions (K409'-D399K' and D399K-K409') for the second chain homodimer formation. But, at the same time, these two mutations (K409E and D399K') lead to favorable interactions (K409E-D399K' and D399-K409') for the heterodimer formation.

[0142] The electrostatic steering effect on heterodimer formation and homodimer discouragement can be further enhanced by mutation of additional charge residues which may or may not be paired with an oppositely charged residue in the second chain including, for example, Arg355 and Lys360. The table below lists possible charge change mutations that can be used, alone or in combination, to enhance ALK7:ActRIIB heteromultimer formation.

Examples of Pair-Wise Charged Residue Mutations to Enhance Heterodimer Formation			
Position in first chain	Mutation in first chain	Interacting position in second chain	Corresponding mutation in second chain
Lys409	Asp or Glu	Asp399'	Lys, Arg, or His
Lys392	Asp or Glu	Asp399'	Lys, Arg, or His
Lys439	Asp or Glu	Asp356'	Lys, Arg, or His
Lys370	Asp or Glu	Glu357'	Lys, Arg, or His
Asp399	Lys, Arg, or His	Lys409'	Asp or Glu

Examples of Pair-Wise Charged Residue Mutations to Enhance Heterodimer Formation			
Position in first chain	Mutation in first chain	Interacting position in second chain	Corresponding mutation in second chain
Asp399	Lys, Arg, or His	Lys392'	Asp or Glu
Asp356	Lys, Arg, or His	Lys439'	Asp or Glu
Glu357	Lys, Arg, or His	Lys370'	Asp or Glu

[0143] In some instances, one or more residues that make up the CH3-CH3 interface in a fusion protein of the instant application are replaced with a charged amino acid such that the interaction becomes electrostatically unfavorable. For example, a positive-charged amino acid in the interface (e.g., a lysine, arginine, or histidine) is replaced with a negatively charged amino acid (e.g., aspartic acid or glutamic acid). Alternatively, or in combination with the forgoing substitution, a negative-charged amino acid in the interface is replaced with a positive-charged amino acid. In certain instances, the amino acid is replaced with a non-naturally occurring amino acid having the desired charge characteristic. It should be noted that mutating negatively charged residues (Asp or Glu) to His will lead to increase in side chain volume, which may cause steric issues. Furthermore, His proton donor- and acceptor-form depends on the localized environment. These issues should be taken into consideration with the design strategy. Because the interface residues are highly conserved in human and mouse IgG subclasses, electrostatic steering effects disclosed herein can be applied to human and mouse IgG1, IgG2, IgG3, and IgG4. This strategy can also be extended to modifying uncharged residues to charged residues at the CH3 domain interface.

[0144] In part, the disclosure provides desired pairing of asymmetric Fc-containing polypeptide chains using Fc sequences engineered to be complementary on the basis of charge pairing (electrostatic steering). One of a pair of Fc sequences with electrostatic complementarity can be arbitrarily fused to the ALK7 or ActRIIB polypeptide of the construct, with or without an optional linker, to generate an ALK7:ActRIIB heteromultimer. This single chain can be coexpressed in a cell of choice along with the Fc sequence complementary to the first Fc to favor generation of the desired multichain construct (e.g., ALK7:ActRIIB heteromultimer). In this example based on electrostatic steering, SEQ ID NO: 23 [human G1Fc(E134K/D177K)] and SEQ ID NO: 24 [human G1Fc(K170D/K187D)] are examples of complementary Fc sequences in which the engineered amino acid substitutions are double underlined, and the TGF-beta superfamily type I or type II receptor polypeptide of the construct can be fused to either SEQ ID NO: 23 or SEQ ID NO: 24, but not both. Given the high degree of amino acid sequence identity between native hG1Fc, native hG2Fc, native hG3Fc, and native hG4Fc, it can be appreciated that amino acid substitutions at corresponding positions in hG2Fc, hG3Fc, or hG4Fc (see Figure 5) will generate complementary Fc pairs which may be used instead of

the complementary hG1Fc pair below (SEQ ID NOs: 23 and 24).

```

1  THTCPPCPAP ELLGGPSVFL FPPKPKDTLM ISRTPEVTCV VVDVSHEDPE
51 VKFNWYVDGV EVHNAKTKPR EEQYNSTYRV VSVLTVLHQD WLNGKEYKCK
101 VSNKALPAPI EKTISKAKGQ PREPQVYTLP PSRKEMTKNQ VSLTCLVKGF
151 YPSDIAVEWE SNGQPENNYK TTPPVLKSDG SFFLYSKLTV DKSRWQQGNV
201 FSCSVMHEAL HNHYTQKSLS LSPGK (SEQ ID NO: 23)

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1  THTCPPCPAP ELLGGPSVFL FPPKPKDTLM ISRTPEVTCV VVDVSHEDPE
51 VKFNWYVDGV EVHNAKTKPR EEQYNSTYRV VSVLTVLHQD WLNGKEYKCK

101 VSNKALPAPI EKTISKAKGQ PREPQVYTLP PSREEMTKNQ VSLTCLVKGF
151 YPSDIAVEWE SNGQPENNYD TTPPVLDSDG SFFLYSDLTV DKSRWQQGNV
201 FSCSVMHEAL HNHYTQKSLS LSPGK (SEQ ID NO: 24)

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[0145] In part, the disclosure provides desired pairing of asymmetric Fc-containing polypeptide chains using Fc sequences engineered for steric complementarity. In part, the disclosure provides knobs-into-holes pairing as an example of steric complementarity. One of a pair of Fc sequences with steric complementarity can be arbitrarily fused to the ALK7 or ActRIIB polypeptide of the construct, with or without an optional linker, to generate an ALK7:ActRIIB heteromultimer. This single chain can be co-expressed in a cell of choice along with the Fc sequence complementary to the first Fc to favor generation of the desired multi-chain construct. In this example based on knobs-into-holes pairing, SEQ ID NO: 25 [human G1Fc(T144Y)] and SEQ ID NO: 26 [human G1Fc(Y185T)] are examples of complementary Fc sequences in which the engineered amino acid substitutions are double underlined, and the ALK7 or ActRIIB polypeptide of the construct can be fused to either SEQ ID NO: 25 or SEQ ID NO: 26, but not both. Given the high degree of amino acid sequence identity between native hG1Fc, native hG2Fc, native hG3Fc, and native hG4Fc, it can be appreciated that amino acid substitutions at corresponding positions in hG2Fc, hG3Fc, or hG4Fc (see Figure 5) will generate complementary Fc pairs which may be used instead of the complementary hG1Fc pair below (SEQ ID NOs: 25 and 26).

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1  THTCPPCPAP ELLGGPSVFL FPPKPKDTLM ISRTPEVTCV VVDVSHEDPE
51 VKFNWYVDGV EVHNAKTKPR EEQYNSTYRV VSVLTVLHQD WLNGKEYKCK
101 VSNKALPAPI EKTISKAKGQ PREPQVYTLP PSREEMTKNQ VSLYCLVKGF
151 YPSDIAVEWE SNGQPENNYK TTPPVLDSDG SFFLYSKLTV DKSRWQQGNV
201 FSCSVMHEAL HNHYTQKSLS LSPGK (SEQ ID NO: 25)

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1  THTCPPCPAP ELLGGPSVFL FPPKPKDTLM ISRTPEVTCV VVDVSHEDPE
51 VKFNWYVDGV EVHNAKTKPR EEQYNSTYRV VSVLTVLHQD WLNGKEYKCK
101 VSNKALPAPI EKTISKAKGQ PREPQVYTLP PSREEMTKNQ VSLTCLVKGF
151 YPSDIAVEWE SNGQPENNYK TTPPVLDSDG SFFLTSKLTV DKSRWQQGNV
201 FSCSVMHEAL HNHYTQKSLS LSPGK (SEQ ID NO: 26)

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[0146] An example of Fc complementarity based on knobs-into-holes pairing combined with an engineered disulfide bond is disclosed in SEQ ID NO: 27 [hG1Fc(S132C/T144W)] and SEQ ID

NO: 28 [hG1Fc(Y127C/T144S/L146A/Y185V)]. The engineered amino acid substitutions in these sequences are double underlined, and the TGF-beta superfamily type I or type II polypeptide of the construct can be fused to either SEQ ID NO: 27 or SEQ ID NO: 28, but not both. Given the high degree of amino acid sequence identity between native hG1Fc, native hG2Fc, native hG3Fc, and native hG4Fc, it can be appreciated that amino acid substitutions at corresponding positions in hG2Fc, hG3Fc, or hG4Fc (see Figure 5) will generate complementary Fc pairs which may be used instead of the complementary hG1Fc pair below (SEQ ID NOs: 27 and 28).

```

1  THTCPPCPAP ELLGGPSVFL FPPKPKDTLM ISRTPEVTCV VVDVSHEDPE
51 VKFNWYVDGV EVHNAKTKPR EEQYNSTYRV VSVLTVLHQD WLNGKEYKCK
101 VSNKALPAPI EKTISKAKGQ PREPQVYTL PCREEMTKNQ VSLWCLVKGF
151 YPSDIAVEWE SNGQPENNYK TTPPVLDSDG SFFLYSKLTV DKSRWQQGNV
201 FSCSVMHEAL HNHYTQKSLS LSPGK (SEQ ID NO: 27)

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1  THTCPPCPAP ELLGGPSVFL FPPKPKDTLM ISRTPEVTCV VVDVSHEDPE
51 VKFNWYVDGV EVHNAKTKPR EEQYNSTYRV VSVLTVLHQD WLNGKEYKCK
101 VSNKALPAPI EKTISKAKGQ PREPQVCTLP PSREEMTKNQ VSLSCAVKGF
151 YPSDIAVEWE SNGQPENNYK TTPPVLDSDG SFFLYSKLTV DKSRWQQGNV
201 FSCSVMHEAL HNHYTQKSLS LSPGK (SEQ ID NO: 28)

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[0147] In part, the disclosure provides desired pairing of asymmetric Fc-containing polypeptide chains using Fc sequences engineered to generate interdigitating β -strand segments of human IgG and IgA C_H3 domains. Such methods include the use of strand-exchange engineered domain (SEED) C_H3 heterodimers allowing the formation of SEEDbody fusion proteins [Davis et al. (2010) Protein Eng Design Sel 23:195-202]. One of a pair of Fc sequences with SEEDbody complementarity can be arbitrarily fused to the ALK7 or ActRIIB of the construct, with or without an optional linker, to generate an ALK7 or ActRIIB fusion polypeptide. This single chain can be co-expressed in a cell of choice along with the Fc sequence complementary to the first Fc to favor generation of the desired multi-chain construct. In this example based on SEEDbody (Sb) pairing, SEQ ID NO: 29 [hG1Fc(Sb_{AG})] and SEQ ID NO: 30 [hG1Fc(Sb_{GA})] are examples of complementary IgG Fc sequences in which the engineered amino acid substitutions from IgA Fc are double underlined, and the ALK7 or ActRIIB polypeptide of the construct can be fused to either SEQ ID NO: 29 or SEQ ID NO: 30, but not both. Given the high degree of amino acid sequence identity between native hG1Fc, native hG2Fc, native hG3Fc, and native hG4Fc, it can be appreciated that amino acid substitutions at corresponding positions in hG1Fc, hG2Fc, hG3Fc, or hG4Fc (see Figure 5) will generate an Fc monomer which may be used in the complementary IgG-IgA pair below (SEQ ID NOs: 29 and 30).

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1  THTCPPCPAP ELLGGPSVFL FPPKPKDTLM ISRTPEVTCV VVDVSHEDPE
51 VKFNWYVDGV EVHNAKTKPR EEQYNSTYRV VSVLTVLHQD WLNGKEYKCK
101 VSNKALPAPI EKTISKAKGQ PFRPEVHLLP PSREEMTKNQ VSLTCLARGE
151 YPKDIAVEWE SNGQPENNYK TTPSRQEPSQ GTITFAVISK LTVDKSRWQQ
201 GNVFSCSVMH EALHNHYTQK TISLSPGK (SEQ ID NO: 29)

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1  THTCPPCPAP ELLGGPSVFL FPPKPKDTLM ISRTPEVTCV VVDVSHEDPE

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51 VKFNWYVDGV EVHNAKTKPR EEQYNSTYRV VSVLTVLHQD WLNGKEYKCK
101 VSNKALPAPI EKTISKAKGQ PREPQVYTLF PPSEELALNE LVTLTCLVKG
151 FYPSDIAVEW ESNGQELPRE KYLTWAPVLD SDGSFFLYSI LRVAAEDWKK
201 GDTFSCSVMH EALHNHYTQK SLDRSPGK (SEQ ID NO: 30)

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[0148] In part, the disclosure provides desired pairing of asymmetric Fc-containing polypeptide chains with a cleavable leucine zipper domain attached at the C-terminus of the Fc C_H3 domains. Attachment of a leucine zipper is sufficient to cause preferential assembly of heterodimeric antibody heavy chains [Wranik et al (2012) J Biol Chem 287:43331-43339]. As disclosed herein, one of a pair of Fc sequences attached to a leucine zipper-forming strand can be arbitrarily fused to the ALK7 or ActRIIB polypeptide of the construct, with or without an optional linker, to generate an ALK7 or ActRIIB fusion polypeptide. This single chain can be co-expressed in a cell of choice along with the Fc sequence attached to a complementary leucine zipper-forming strand to favor generation of the desired multi-chain construct. Proteolytic digestion of the construct with the bacterial endoprotease Lys-C post purification can release the leucine zipper domain, resulting in an Fc construct whose structure is identical to that of native Fc. In this example based on leucine zipper pairing, SEQ ID NO: 36 [hG1Fc-Ap1 (acidic)] and SEQ ID NO: 37 [hG1Fc-Bp1 (basic)] are examples of complementary IgG Fc sequences in which the engineered complimentary leucine zipper sequences are underlined, and the ALK7 or ActRIIB polypeptide of the construct can be fused to either SEQ ID NO: 36 or SEQ ID NO: 37, but not both. Given the high degree of amino acid sequence identity between native hG1Fc, native hG2Fc, native hG3Fc, and native hG4Fc, it can be appreciated that leucine zipper-forming sequences attached, with or without an optional linker, to hG1Fc, hG2Fc, hG3Fc, or hG4Fc (see Figure 5) will generate an Fc monomer which may be used in the complementary leucine zipper-forming pair below (SEQ ID NOs: 36 and 37).

```

1 THTCPPCPAP ELLGGPSVFL FPPKPKDTLM ISRTPEVTCV VVDVSHEDPE
51 VKFNWYVDGV EVHNAKTKPR EEQYNSTYRV VSVLTVLHQD WLNGKEYKCK
101 VSNKALPAPI EKTISKAKGQ PREPQVYTLF PSREEMTKNQ VSLTCLVKGF
151 YPSDIAVEWE SNGQPENNYK TTPPVLDSDG SFFLYSKLTV DKSRWQQGNV
201 FSCSVMHEAL HNHYTQKSLS LSPGKGSSAQ LEKELQALEK ENAOLEWELQ
251 ALEKELAQGA T (SEQ ID NO: 36)

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1 THTCPPCPAP ELLGGPSVFL FPPKPKDTLM ISRTPEVTCV VVDVSHEDPE
51 VKFNWYVDGV EVHNAKTKPR EEQYNSTYRV VSVLTVLHQD WLNGKEYKCK
101 VSNKALPAPI EKTISKAKGQ PREPQVYTLF PSREEMTKNQ VSLTCLVKGF
151 YPSDIAVEWE SNGQPENNYK TTPPVLDSDG SFFLYSKLTV DKSRWQQGNV
201 FSCSVMHEAL HNHYTQKSLS LSPGKGSSAQ LKKKLQALKK KNAQLKWKLO
251 ALKKKLAQGA T (SEQ ID NO: 37)

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[0149] As described above, various methods are known in the art that increase desired pairing of Fc-containing fusion polypeptide chains in a single cell line to produce a preferred asymmetric fusion protein at acceptable yields [Klein et al (2012) mAbs 4:653-663; and Spiess

et al (2015) *Molecular Immunology* 67(2A): 95-106]. In addition, ALK7:ActRIIB heteromultimers may be generated using a combination of heavy and light chain fusion proteins comprising either an ALK7 or ActRIIB polypeptide. For example, in some instances, an ALK7 polypeptide may be fused, with or without a linker domain, to an immunoglobulin heavy chain (IgG1, IgG2, IgG3, IgG4, IgM, IgA1, or IgA2) that comprises at least a portion of the C_H1 domain. Similarly, an ActRIIB polypeptide may be fused, with or without a linker domain, to an immunoglobulin light chain (kappa or lambda) that comprises at least a portion of the light chain constant domain (C_L). In alternative instances, an ActRIIB polypeptide may be fused, with or without a linker domain, to an immunoglobulin heavy chain (IgG1, IgG2, IgG3, IgG4, IgM, IgA1, or IgA2) that comprises at least a portion of the C_H1 domain, and an ALK7 polypeptide may be fused, with or without a linker domain, to an immunoglobulin light chain (kappa or lambda) that comprises at least a portion of the light chain constant domain (C_L). This design takes advantage of the natural ability of the heavy chains to heterodimerize with light chains. In particular, heterodimerization of a heavy and light chain occurs between the C_H1 with the C_L, which is generally stabilized by covalent linking of the two domains via a disulfide bridge. Constructs employing the full-length heavy chain, or at least a portion of the heavy chain comprising the hinge region, could give rise to antibody-like molecules comprising two "light chains" and two "heavy chains". See Figure 9. A potential advantage of this design is that it may more closely mimic the naturally occurring ALK7-ligand-ActRIIB complex and may display higher affinity for the ligand than comparable single heterodimers. In some instances, this design may be modified by incorporating various heavy chain truncations including, for example, truncations that comprise the C_H1 domain and some or all of the hinge domain (giving rise to F(ab')₂-like molecules) as well as truncations that only comprise the C_H1 domain or a fragment thereof (giving rise to Fab-like molecules). See Figure 9G. Various methods for designing such heteromultimer constructs are described in US 2009/0010879, Klein et al [(2012) *mAbs* 4:653-663], and Spiess et al [(2015) *Molecular Immunology* 67(2A): 95-106].

[0150] In some instances, it is desirable to generate antibody-like ALK7:ActRIIB heterodimers comprising at least one branch of the complex comprising an ALK7-C_L:ActRIIB-C_H1 heterodimer pair and at least a second branch comprising an ActRIIB-C_L:ALK7-C_H1 heterodimer pair. See, e.g., Figure 9B. Such heterodimer complexes can be generated, for example, using combinations of heavy chain and light chain asymmetrical pairing technologies [Spiess et al (2015) *Molecular Immunology* 67(2A): 95-106]. For example, in CrossMab technology, [Schaefer et al (2011). *Proc. Natl. Acad. Sci. U.S.A.* 108: 11187-11192] light chain mispairing is overcome using domain crossovers and heavy chains heterodimerized using knobs-into-holes [Merchant et al (1998) *Nat. Biotechnol.* 16: 677-681]. For the domain crossovers either the variable domains or the constant domains are swapped between light and heavy chains to create two asymmetric Fab arms that drive cognate light chain pairing while preserving the structural and functional integrity of the variable domain [Fenn et al (2013) *PLoS ONE* 8: e61953]. An alternative approach for overcoming light chain mispairing is designing heavy and light chains with orthogonal Fab inter-faces [Lewis (2014) *Nat. Biotechnol.* 32: 191-198]. This has been accomplished by computational modeling [Das et al (2008) *Annu. Rev. Biochem.* 77: 363-382] in combination with X-ray crystallography to identify mutations at

the V_H/V_L and C_H1/C_L interfaces. For the heterodimers generated using this methodology, it may be necessary to engineer mutations into both V_H/V_L and C_H1/C_L interfaces to minimize heavy/light chain mispairing. The designed orthogonal Fab interface may be used in conjunction with a heavy chain heterodimerization strategy to facilitate efficient IgG production in a single host cell. Electrostatic steering may also be used to generate orthogonal Fab interfaces to facilitate the construction of such heterodimers. Peptide linkers may be used to ensure cognate pairing of light and heavy chains in a format known as "LUZ-Y" [Wranik et al (2012) J. Biol. Chem. 287: 43331-43339], wherein heavy chain heterodimerization is accomplished using leucine zippers which may be subsequently removed by proteolysis in vitro.

[0151] Alternatively, ALK7:ActRIIB heteromultimers may comprise one or more single-chain ligand traps as described herein, optionally which may be covalently or non-covalently associated with one or more ALK7 or ActRIIB polypeptides as well as additional ALK7:ActRIIB single chain ligand traps [US 2011/0236309 and US2009/0010879]. See Figure 12. As described herein, single-chain ligand traps do not require fusion to any multimerization domain such as coiled-coil Fc domains to be multivalent. In general, single-chain ligand traps of the present disclosure comprise at least one ALK7 polypeptide domain and one ActRIIB polypeptide domain. The ALK7 and ActRIIB polypeptide domains, generally referred to herein as binding domains (BD), optionally may be joined by a linker region.

[0152] For example, in one aspect, the present disclosure provides heteromultimers comprising a polypeptide having the following structure:

$$(<BD1>-linker1)_k-[<BD2>-linker2-\{<BD3>-linker3\}_f]_n-(<BD4>)_m-(linker4-BD5)_d)_h$$

where: n and h are independently greater than or equal to one; d, f, m, and k are independently equal to or greater than zero; BD1, BD2, BD3, BD4, and BD5 are independently ALK7 or ActRIIB polypeptide domains, wherein at least one of BD1, BD2, BD3, and BD4 is an ALK7 polypeptide domain, and wherein at least one of BD1, BD2, BD3, and BD4 is an ActRIIB polypeptide domain, and linker1, linker2, linker3, and linker 4 are independently greater than or equal to zero. In some instance, ALK7:ActRIIB single-chain traps comprise at least two different ALK7 polypeptides. In some instances, ALK7:ActRIIB single-chain traps comprise at least two different ActRIIB polypeptides. In some instance, ALK7:ActRIIB single-chain traps comprise at least two different linkers. Depending on the values of selected for d, f, h, k, m, and n, the heteromultimer structure may comprise a large number of repeating units in various combinations or may be a relatively simple structure.

[0153] In another aspect, the present disclosure provides heteromultimers comprising a polypeptide having the following structure:

$$<BD1>-linker1-<BD2>$$

[0154] In yet another aspect, the present disclosure provides heteromultimers comprising a polypeptide having the following structure:

$$<BD1>-(linker2-<BD2>)_n$$

where n is greater than or equal one.

[0155] Another aspect of the disclosure provides heteromultimers comprising a polypeptide having the following structure:

$(\langle \text{BD1} \rangle\text{-linker1-}\langle \text{BD1} \rangle)_f\text{-linker2-}(\langle \text{BD2} \rangle\text{-linker3-}\langle \text{BD3} \rangle)_g$

wherein f and g are greater than or equal to one.

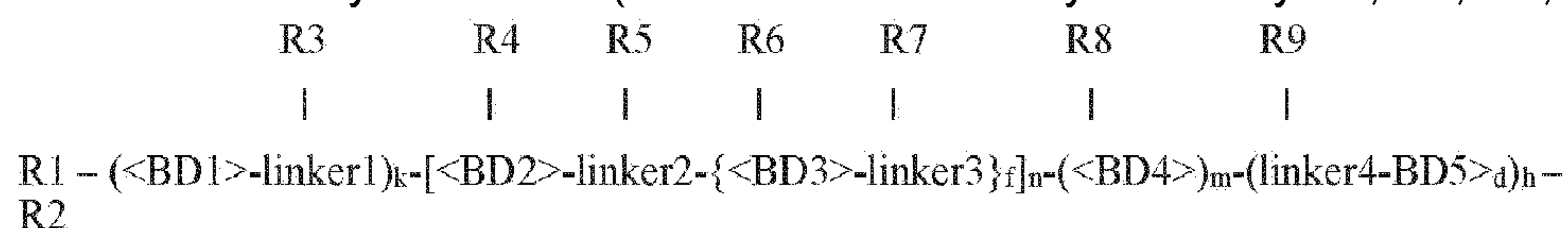
[0156] In an instance where BD2 and BD3 are the same, and f and g are the same number, this can result in a substantially mirror symmetric structure around linker 2, subject to differences in the linkers. In instances where BD2 is different from BD3 and/or where f and g are different numbers, different structures will be produced. It is within the capacity of one of ordinary skill in the art to select suitable binding domains, linkers, and repeat frequencies in light of the disclosure herein and knowledge in the art. Specific, non-limiting examples of such single-chain ligand traps in accordance with the present disclosure are represented schematically in Figure 11.

[0157] The linkers (1, 2, 3, and 4) may be the same or different. The linker region provides a segment that is distinct from the structured ligand-binding domains of ALK7 and ActRIIB and thus can be used for conjugation to accessory molecules (e.g., molecules useful in increasing stability such as PEGylation moieties) without having to chemically modify the binding domains. The linker may include an unstructured amino acid sequence that may be either the same as or derived from conservative modifications to the sequence of a natural unstructured region in the extracellular portion of the receptor for the ligand of interest or another receptor in the TGF- β superfamily. In other instances, such linkers may be entirely artificial in composition and origin but will contain amino acids selected to provide an unstructured flexible linker with a low likelihood of encountering electrostatic or steric hindrance complications when brought into close proximity to the ligand of interest. Linker length will be considered acceptable when it permits binding domains located on each of the N- and C-termini of the linker to bind their natural binding sites on their natural ligand such that, with both binding domains so bound, the ligand is bound with a higher affinity than it would be bound by binding of only one of the binding domains. In some instances, the number of amino acid residues in the linker of either natural or artificial origin is selected to be equal to or greater than the minimum required distance for simultaneous (bridged) binding to two binding sites on the ALK7 and/or ActRIIB ligand. For example, and without wishing to be limiting in any manner, the linker length may be between about 1- 10 amino acids, 10-20 amino acids, 18-80 amino acids, 25-60 amino acids, 35-45 amino acids, or any other suitable length.

[0158] Linkers may be designed to facilitate purification of the polypeptide. The exact purification scheme chosen will determine what modifications are needed, for example and without wishing to be limiting, additions of purification "tags" such as His tags is contemplated; in other examples, the linker may include regions to facilitate the addition of cargo or accessory molecules. When such additions affect the unstructured nature of the linker or introduce potential electrostatic or steric concerns, appropriate increases to the linker length will be made to ensure that the two binding domains are able to bind their respective sites on the ligand. In

light of the methods and teachings herein, such determinations could be made routinely by one skilled in the art.

[0159] In addition, the present design permits linkage of other cargo molecules (for example imaging agents like fluorescent molecules), toxins, etc. For example, and without wishing to be limiting in any manner, single-chain polypeptides can be modified to add one or more cargo and/or accessory molecules (referred to collectively herein by R1, R2, R3, R4, etc.):



[0160] Without limiting the generality of R substituents available, R1, R2, R3, R4, R5, R6, R7, R8, R9, may or may not be present; when present, they may be the same or different, and may independently be one or more of: a fusion protein for targeting, for example, but not limited to such as an antibody fragment (e.g. single chain Fv) and/or a single domain antibody (sdAb); a radiotherapy and/or imaging agent, for example, but not limited to a radionuclide (e.g. ^{123}I , ^{111}In , ^{18}F , ^{64}Cu , ^{68}Ga , ^{124}I , ^{131}I , ^{90}Y , ^{177}Lu , ^{57}Cu , ^{213}Bi , ^{211}At), a fluorescent dye (e.g. Alexa Fluor, Cy dye) and/or a fluorescent protein tag (e.g. GFP, DsRed); a cytotoxic agent for chemotherapy, for example, but not limited to doxorubicin, calicheamicin, a maytansinoid derivatives (e.g. DM1, DM4), a toxin (eg. truncated Pseudomonas endotoxin A, diphtheria toxin); a nanoparticle-based carrier, for example, but not limited to polyethylene glycol (PEG), a polymer-conjugated to drug, nanocarrier or imaging agent (e.g. of a polymer N-(2-hydroxypropyl) methacrylamide (HPMA), glutamic acid, PEG, dextran); a drug (for example, but not limited to doxorubicin, camptothecin, paclitaxel, palatinat); a nanocarrier, for example, but not limited to a nanoshell or liposome; an imaging agent, for example, but not limited to Supermagnetic Iron Oxide (SPIO); a dendrimer; and/or a solid support for use in ligand purification, concentration or sequestration (e.g. nanoparticles, inert resins, suitable silica supports).

[0161] In general, it will not be preferable to have cargo or accessory molecules in all possible positions, as this may cause steric or electrostatic complications. However, the effects of adding a cargo or accessory molecule to any given position or positions on the structure can be determined routinely in light of the disclosure herein by modeling the linker between the binding domains and carrying out molecular dynamics simulations to substantially minimize molecular mechanics energy and reduce steric and electrostatic incompatibility between the linker and the ALK7 and ActRIIB polypeptides as taught herein.

[0162] It may be preferable to add the cargo or accessory molecule to the linker portion of the agent, rather to the binding domain, to reduce the likelihood of interference in binding function. However, addition to the binding domain is possible and could be desirable in some instances and the effect of such an addition can be determined routinely in advance by modeling the binding agent and the linker with the proposed addition as described herein.

[0163] Conjugation methodologies may be performed using commercial kits that enable conjugation via common reactive groups such as primary amines, succinimidyl (NHS) esters and sulfhydryl-reactive groups. Some non-limiting examples are: Alexa Fluor 488 protein labeling kit (Molecular Probes, Invitrogen detection technologies) and PEGylation kits (Pierce Biotechnology Inc.).

[0164] In certain aspects, ALK7:ActRIIB single-chain traps may be covalently or non-covalently associated with one or more ALK7 or ActRIIB polypeptides as well as additional ALK7:ActRIIB single chain ligand traps to form higher order heteromultimers, which may be used in accordance with the methods described herein. See, e.g., Figure 12. For example, an ALK7:ActRIIB single chain ligand trap may further comprise a multimerization domain as described herein. In some instances, ALK7:ActRIIB single chain ligand traps comprise a constant domain of an Ig immunoglobulin. Such immunoglobulins constant domains may be selected to promote symmetrical or asymmetrical complexes comprising at least one single-chain ALK7:ActRIIB trap.

[0165] In certain aspects, an ALK7:ActRIIB single-chain trap, or combinations of such traps, may be used as ALK7:ActRIIB antagonists to treat or prevent an ALK7:ActRIIB disorder or disease as described herein (e.g., kidney disease and/or a metabolic disorder or condition).

[0166] It is understood that different elements of the fusion proteins (e.g., immunoglobulin Fc fusion proteins) may be arranged in any manner that is consistent with desired functionality. For example, an ALK7 and/or ActRIIB polypeptide domain may be placed C-terminal to a heterologous domain, or alternatively, a heterologous domain may be placed C-terminal to an ALK7 and/or ActRIIB polypeptide domain. The ALK7 and/or ActRIIB polypeptide domain and the heterologous domain need not be adjacent in a fusion protein, and additional domains or amino acid sequences may be included C- or N-terminal to either domain or between the domains.

[0167] For example, an ALK7 and/or ActRIIB receptor fusion protein may comprise an amino acid sequence as set forth in the formula A-B-C. The B portion corresponds to an ALK7 or ActRIIB polypeptide domain. The A and C portions may be independently zero, one, or more than one amino acid, and both the A and C portions when present are heterologous to B. The A and/or C portions may be attached to the B portion via a linker sequence. A linker may be rich in glycine (e.g., 2-10, 2-5, 2-4, 2-3 glycine residues) or glycine and proline residues and may, for example, contain a single sequence of threonine/serine and glycines or repeating sequences of threonine/serine and/or glycines, e.g., GGG (SEQ ID NO: 13), GGGG (SEQ ID NO: 14), TGGGG (SEQ ID NO: 15), SGGGG (SEQ ID NO: 16), TGGG (SEQ ID NO: 17), SGGG (SEQ ID NO: 18), or GGGGS (SEQ ID NO: 58) singlets, or repeats. In certain instances, an ALK7 and/or ActRIIB fusion protein comprises an amino acid sequence as set forth in the formula A-B-C, wherein A is a leader (signal) sequence, B consists of an ALK7 and/or ActRIIB polypeptide domain, and C is a polypeptide portion that enhances one or more of *in vivo* stability, *in vivo* half-life, uptake/administration, tissue localization or distribution, formation of protein complexes, and/or purification. In certain instances, an ALK7 and/or ActRIIB fusion

protein comprises an amino acid sequence as set forth in the formula A-B-C, wherein A is a TPA leader sequence, B is an ALK7 or ActRIIB receptor polypeptide domain, and C is an immunoglobulin Fc domain. Preferred fusion proteins comprise the amino acid sequence set forth in any one of SEQ ID NOs: 71, 73, 74, 76, 77, 78, 79 and 80.

[0168] In some instances, ALK7:ActRIIB heteromultimers further comprise one or more heterologous portions (domains) so as to confer a desired property. For example, some fusion domains are particularly useful for isolation of the fusion proteins by affinity chromatography. Well-known examples of such fusion domains include, but are not limited to, polyhistidine, Glu-Glu, glutathione S-transferase (GST), thioredoxin, protein A, protein G, an immunoglobulin heavy-chain constant region (Fc), maltose binding protein (MBP), or human serum albumin. For the purpose of affinity purification, relevant matrices for affinity chromatography, such as glutathione-, amylase-, and nickel- or cobalt- conjugated resins are used. Many of such matrices are available in "kit" form, such as the Pharmacia GST purification system and the QIAexpress™ system (Qiagen) useful with (His₆) fusion partners. As another example, a fusion domain may be selected so as to facilitate detection of the ligand trap polypeptides. Examples of such detection domains include the various fluorescent proteins (e.g., GFP) as well as "epitope tags," which are usually short peptide sequences for which a specific antibody is available. Well-known epitope tags for which specific monoclonal antibodies are readily available include FLAG, influenza virus haemagglutinin (HA), and c-myc tags. In some cases, the fusion domains have a protease cleavage site, such as for factor Xa or thrombin, which allows the relevant protease to partially digest the fusion proteins and thereby liberate the recombinant proteins therefrom. The liberated proteins can then be isolated from the fusion domain by subsequent chromatographic separation.

[0169] In certain instances, ALK7 and/or ActRIIB polypeptides may contain one or more modifications that are capable of stabilizing the polypeptides. For example, such modifications enhance the *in vitro* half-life of the polypeptides, enhance circulatory half-life of the polypeptides, and/or reduce proteolytic degradation of the polypeptides. Such stabilizing modifications include, but are not limited to, fusion proteins (including, for example, fusion proteins comprising an ALK7 and/or ActRIIB polypeptide domain and a stabilizer domain), modifications of a glycosylation site (including, for example, addition of a glycosylation site to a polypeptide of the disclosure), and modifications of carbohydrate moiety (including, for example, removal of carbohydrate moieties from a polypeptide of the disclosure). As used herein, the term "stabilizer domain" not only refers to a fusion domain (e.g., an immunoglobulin Fc domain) as in the case of fusion proteins, but also includes nonproteinaceous modifications such as a carbohydrate moiety, or nonproteinaceous moiety, such as polyethylene glycol.

[0170] In preferred instances, ALK7:ActRIIB heteromultimers to be used in accordance with the methods described herein are isolated complexes. As used herein, an isolated protein (or protein complex) or polypeptide (or polypeptide complex) is one which has been separated from a component of its natural environment. In some instances, a heteromultimer of the disclosure is purified to greater than 95%, 96%, 97%, 98%, or 99% purity as determined by, for example, electrophoretic (e.g., SDS-PAGE, isoelectric focusing (IEF), capillary electrophoresis)

or chromatographic (e.g., ion exchange or reverse phase HPLC). Methods for assessment of antibody purity are well known in the art [Flatman et al., (2007) J. Chromatogr. B 848:79-87].. In some instances, ALK7:ActRIIB heteromultimer preparations are substantially free of ALK7 and/or ActRIIB homomultimers. For example, in some instances, ALK7:ActRIIB heteromultimers preparations comprise less than about 10%, 9%, 8%, 7%, 6%, 5%, 4%, 3%, 2%, or less than about 1% ALK7 homomultimers. In some instances, ALK7:ActRIIB heteromultimer preparations comprise less than about 10%, 9%, 8%, 7%, 6%, 5%, 4%, 3%, 2%, or less than about 1% ActRIIB homomultimers. In some instances, ALK7:ActRIIB heteromultimer preparations comprise less than about 10%, 9%, 8%, 7%, 6%, 5%, 4%, 3%, 2%, or less than about 1% ALK7 homomultimers and less than about 10%, 9%, 8%, 7%, 6%, 5%, 4%, 3%, 2%, or less than about 1% ActRIIB homomultimers.

[0171] In certain instances, ALK7 and/or ActRIIB polypeptides, as well as heteromultimers comprising the same, can be produced by a variety of art-known techniques. For example, polypeptides can be synthesized using standard protein chemistry techniques such as those described in Bodansky, M. Principles of Peptide Synthesis, Springer Verlag, Berlin (1993) and Grant G. A. (ed.), Synthetic Peptides: A User's Guide, W. H. Freeman and Company, New York (1992). In addition, automated peptide synthesizers are commercially available (Advanced ChemTech Model 396; Milligen/Bioscience 9600). Alternatively, the polypeptides and complexes, including fragments or variants thereof, may be recombinantly produced using various expression systems [*E. coli*, Chinese Hamster Ovary (CHO) cells, COS cells, baculovirus] as is well known in the art. In a further instance, the modified or unmodified polypeptides may be produced by digestion of recombinantly produced full-length ALK7 and/or ActRIIB polypeptides by using, for example, a protease, e.g., trypsin, thermolysin, chymotrypsin, pepsin, or paired basic amino acid converting enzyme (PACE). Computer analysis (using commercially available software, e.g., MacVector, Omega, PCGene, Molecular Simulation, Inc.) can be used to identify proteolytic cleavage sites.

B. Nucleic Acids Encoding ALK7 and/or ActRIIB polypeptides

[0172] In certain instances, the present disclosure provides isolated and/or recombinant nucleic acids encoding ALK7 and/or ActRIIB receptors (including fragments, functional variants, and fusion proteins thereof) disclosed herein. For example, SEQ ID NO: 11 encodes a naturally occurring human ALK7 precursor polypeptide, while SEQ ID NO: 12 encodes a mature extracellular domain of ALK7. The subject nucleic acids may be single-stranded or double stranded. Such nucleic acids may be DNA or RNA molecules. These nucleic acids may be used, for example, in methods for making ALK7:ActRIIB heteromultimers as described herein.

[0173] As used herein, isolated nucleic acid(s) refers to a nucleic acid molecule that has been separated from a component of its natural environment. An isolated nucleic acid includes a nucleic acid molecule contained in cells that ordinarily contain the nucleic acid molecule, but the nucleic acid molecule is present extrachromosomally or at a chromosomal location that is different from its natural chromosomal location.

[0174] In certain instances, nucleic acids encoding ALK7 and/or ActRIIB polypeptides of the present disclosure are understood to include any one of SEQ ID NOs: 7, 8, 11, 12, 21, 22, 40, 41, 44, 45, 72, or 75, as well as variants thereof. Variant nucleotide sequences include sequences that differ by one or more nucleotide substitutions, additions, or deletions including allelic variants, and therefore, will include coding sequences that differ from the nucleotide sequence designated in any one of SEQ ID NOs: 7, 8, 11, 12, 21, 22, 40, 41, 44, 45, 72, or 75.

[0175] In certain instances, TGF β superfamily ALK7 and/or ActRIIB polypeptides of the present disclosure are encoded by isolated or recombinant nucleic acid sequences that comprise, consist essentially of, or consists of a sequence that is least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99% or 100% identical to SEQ ID NOs: 7, 8, 11, 12, 21, 22, 40, 41, 44, 45, 72, or 75. One of ordinary skill in the art will appreciate that nucleic acid sequences that comprise, consist essentially of, or consists of a sequence complementary to a sequence that is least 70%, 75%, 80%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99% or 100% identical to SEQ ID NOs: 7, 8, 11, 12, 21, 22, 40, 41, 44, 45, 72, or 75 also within the scope of the present disclosure. In further instances, the nucleic acid sequences of the disclosure can be isolated, recombinant, and/or fused with a heterologous nucleotide sequence or in a DNA library.

[0176] In other instances, nucleic acids of the present disclosure also include nucleotide sequences that hybridize under stringent conditions to the nucleotide sequence designated in SEQ ID NOs: 7, 8, 11, 12, 21, 22, 40, 41, 44, 45, 72, or 75, the complement sequence of SEQ ID NOs: 7, 8, 11, 12, 21, 22, 40, 41, 44, 45, 72, or 75, or fragments thereof. One of ordinary skill in the art will understand readily that appropriate stringency conditions which promote DNA hybridization can be varied. For example, one could perform the hybridization at 6.0 x sodium chloride/sodium citrate (SSC) at about 45 °C, followed by a wash of 2.0 x SSC at 50 °C. For example, the salt concentration in the wash step can be selected from a low stringency of about 2.0 x SSC at 50 °C to a high stringency of about 0.2 x SSC at 50 °C. In addition, the temperature in the wash step can be increased from low stringency conditions at room temperature, about 22 °C, to high stringency conditions at about 65 °C. Both temperature and salt may be varied, or temperature or salt concentration may be held constant while the other variable is changed. In one instance, the disclosure provides nucleic acids which hybridize under low stringency conditions of 6 x SSC at room temperature followed by a wash at 2 x SSC at room temperature.

[0177] Isolated nucleic acids which differ from the nucleic acids as set forth in SEQ ID NOs: 7, 8, 11, 12, 21, 22, 40, 41, 44, 45, 72, or 75 to degeneracy in the genetic code are also within the scope of the disclosure. For example, a number of amino acids are designated by more than one triplet. Codons that specify the same amino acid, or synonyms (for example, CAU and CAC are synonyms for histidine) may result in "silent" mutations which do not affect the amino acid sequence of the protein. However, it is expected that DNA sequence polymorphisms that do lead to changes in the amino acid sequences of the subject proteins will exist among mammalian cells. One skilled in the art will appreciate that these variations in one

or more nucleotides (up to about 3-5% of the nucleotides) of the nucleic acids encoding a particular protein may exist among individuals of a given species due to natural allelic variation. Any and all such nucleotide variations and resulting amino acid polymorphisms are within the scope of this disclosure.

[0178] In certain instances, the recombinant nucleic acids of the disclosure may be operably linked to one or more regulatory nucleotide sequences in an expression construct. Regulatory nucleotide sequences will generally be appropriate to the host cell used for expression. Numerous types of appropriate expression vectors and suitable regulatory sequences are known in the art for a variety of host cells. Typically, said one or more regulatory nucleotide sequences may include, but are not limited to, promoter sequences, leader or signal sequences, ribosomal binding sites, transcriptional start and termination sequences, translational start and termination sequences, and enhancer or activator sequences. Constitutive or inducible promoters as known in the art are contemplated by the disclosure. The promoters may be either naturally occurring promoters, or hybrid promoters that combine elements of more than one promoter. An expression construct may be present in a cell on an episome, such as a plasmid, or the expression construct may be inserted in a chromosome. In some instances, the expression vector contains a selectable marker gene to allow the selection of transformed host cells. Selectable marker genes are well known in the art and will vary with the host cell used.

[0179] In certain aspects, the subject nucleic acid is provided in an expression vector comprising a nucleotide sequence encoding an ALK7 and/or ActRIIB polypeptide and operably linked to at least one regulatory sequence. Regulatory sequences are art-recognized and are selected to direct expression of ALK7 and/or ActRIIB polypeptide. Accordingly, the term regulatory sequence includes promoters, enhancers, and other expression control elements. Exemplary regulatory sequences are described in Goeddel; Gene Expression Technology: Methods in Enzymology, Academic Press, San Diego, CA (1990). For instance, any of a wide variety of expression control sequences that control the expression of a DNA sequence when operatively linked to it may be used in these vectors to express DNA sequences encoding a ALK7 and/or ActRIIB polypeptides. Such useful expression control sequences, include, for example, the early and late promoters of SV40, *tet* promoter, adenovirus or cytomegalovirus immediate early promoter, RSV promoters, the lac system, the *trp* system, the TAC or TRC system, T7 promoter whose expression is directed by T7 RNA polymerase, the major operator and promoter regions of phage lambda, the control regions for fd coat protein, the promoter for 3-phosphoglycerate kinase or other glycolytic enzymes, the promoters of acid phosphatase, e.g., Pho5, the promoters of the yeast α -mating factors, the polyhedron promoter of the baculovirus system and other sequences known to control the expression of genes of prokaryotic or eukaryotic cells or their viruses, and various combinations thereof. It should be understood that the design of the expression vector may depend on such factors as the choice of the host cell to be transformed and/or the type of protein desired to be expressed. Moreover, the vector's copy number, the ability to control that copy number and the expression of any other protein encoded by the vector, such as antibiotic markers, should also be considered.

[0180] A recombinant nucleic acid of the present disclosure can be produced by ligating the cloned gene, or a portion thereof, into a vector suitable for expression in either prokaryotic cells, eukaryotic cells (yeast, avian, insect or mammalian), or both. Expression vehicles for production of a recombinant ALK7 and/or ActRIIB polypeptides include plasmids and other vectors. For instance, suitable vectors include plasmids of the following types: pBR322-derived plasmids, pEMBL-derived plasmids, pEX-derived plasmids, pBTac-derived plasmids and pUC-derived plasmids for expression in prokaryotic cells, such as *E. coli*.

[0181] Some mammalian expression vectors contain both prokaryotic sequences to facilitate the propagation of the vector in bacteria, and one or more eukaryotic transcription units that are expressed in eukaryotic cells. The pcDNA1/amp, pcDNA1/neo, pRc/CMV, pSV2gpt, pSV2neo, pSV2-dhfr, pTk2, pRSVneo, pMSG, pSVT7, pko-neo and pHyg derived vectors are examples of mammalian expression vectors suitable for transfection of eukaryotic cells. Some of these vectors are modified with sequences from bacterial plasmids, such as pBR322, to facilitate replication and drug resistance selection in both prokaryotic and eukaryotic cells. Alternatively, derivatives of viruses such as the bovine papilloma virus (BPV-1), or Epstein-Barr virus (pHEBo, pREP-derived and p205) can be used for transient expression of proteins in eukaryotic cells. Examples of other viral (including retroviral) expression systems can be found below in the description of gene therapy delivery systems. The various methods employed in the preparation of the plasmids and in transformation of host organisms are well known in the art. For other suitable expression systems for both prokaryotic and eukaryotic cells, as well as general recombinant procedures [Molecular Cloning A Laboratory Manual, 3rd Ed., ed. by Sambrook, Fritsch and Maniatis Cold Spring Harbor Laboratory Press, 2001]. In some instances, it may be desirable to express the recombinant polypeptides by the use of a baculovirus expression system. Examples of such baculovirus expression systems include pVL-derived vectors (such as pVL1392, pVL1393 and pVL941), pAcUW-derived vectors (such as pAcUW1), and pBlueBac-derived vectors (such as the β -gal containing pBlueBac III).

[0182] In a preferred instance, a vector will be designed for production of the subject ALK7 and/or ActRIIB polypeptides in CHO cells, such as a Pcmv-Script vector (Stratagene, La Jolla, Calif.), pcDNA4 vectors (Invitrogen, Carlsbad, Calif.) and pCI-neo vectors (Promega, Madison, Wisc.). As will be apparent, the subject gene constructs can be used to cause expression of the subject ALK7 and/or ActRIIB polypeptide in cells propagated in culture, e.g., to produce proteins, including fusion proteins or variant proteins, for purification.

[0183] This disclosure also pertains to a host cell transfected with a recombinant gene including a coding sequence for one or more of the subject ALK7 and/or ActRIIB polypeptides. The host cell may be any prokaryotic or eukaryotic cell. For example, an ALK7 and/or ActRIIB polypeptide may be expressed in bacterial cells such as *E. coli*, insect cells (e.g., using a baculovirus expression system), yeast, or mammalian cells [e.g. a Chinese hamster ovary (CHO) cell line]. Other suitable host cells are known to those skilled in the art.

[0184] Accordingly, the present disclosure further pertains to methods of producing the subject

ALK7 and/or ActRIIB polypeptides. For example, a host cell transfected with an expression vector encoding an ALK7 and/or ActRIIB polypeptide can be cultured under appropriate conditions to allow expression of the ALK7 and/or ActRIIB polypeptide to occur. The polypeptide may be secreted and isolated from a mixture of cells and medium containing the polypeptide. Alternatively, ALK7 and/or ActRIIB polypeptide may be isolated from a cytoplasmic or membrane fraction obtained from harvested and lysed cells. A cell culture includes host cells, media and other byproducts. Suitable media for cell culture are well known in the art. The subject polypeptides can be isolated from cell culture medium, host cells, or both, using techniques known in the art for purifying proteins, including ionexchange chromatography, gel filtration chromatography, ultrafiltration, electrophoresis, immunoaffinity purification with antibodies specific for particular epitopes of ALK7 and/or ActRIIB polypeptides and affinity purification with an agent that binds to a domain fused to ALK7 and/or ActRIIB polypeptide (e.g., a protein A column may be used to purify ALK7-Fc and/or ActRIIB-Fc fusion proteins). In some instances, the ALK7 and/or ActRIIB polypeptide is a fusion protein containing a domain which facilitates its purification.

[0185] In some instances, purification is achieved by a series of column chromatography steps, including, for example, three or more of the following, in any order: protein A chromatography, Q sepharose chromatography, phenylsepharose chromatography, size exclusion chromatography, and cation exchange chromatography. The purification could be completed with viral filtration and buffer exchange. An ALK7 and/or ActRIIB polypeptide, as well as fusion proteins and heteromeric complexes thereof, may be purified to a purity of >90%, >95%, >96%, >98%, or >99% as determined by size exclusion chromatography and >90%, >95%, >96%, >98%, or >99% as determined by SDS PAGE. The target level of purity should be one that is sufficient to achieve desirable results in mammalian systems, particularly non-human primates, rodents (mice), and humans.

[0186] In another instance, a fusion gene coding for a purification leader sequence, such as a poly-(His)/enterokinase cleavage site sequence at the N-terminus of the desired portion of the recombinant ALK7 and/or ActRIIB polypeptide, can allow purification of the expressed fusion protein by affinity chromatography using a Ni^{2+} metal resin. The purification leader sequence can then be subsequently removed by treatment with enterokinase to provide the purified ALK7 and/or ActRIIB polypeptide, as well as heteromultimers thereof [Hochuli et al. (1987) J. Chromatography 411:177; and Janknecht et al. (1991) PNAS USA 88:8972].

[0187] Techniques for making fusion genes are well known. Essentially, the joining of various DNA fragments coding for different polypeptide sequences is performed in accordance with conventional techniques, employing blunt-ended or stagger-ended termini for ligation, restriction enzyme digestion to provide for appropriate termini, filling-in of cohesive ends as appropriate, alkaline phosphatase treatment to avoid undesirable joining, and enzymatic ligation. In another instance, the fusion gene can be synthesized by conventional techniques including automated DNA synthesizers. Alternatively, PCR amplification of gene fragments can be carried out using anchor primers which give rise to complementary overhangs between two consecutive gene fragments which can subsequently be annealed to generate a chimeric gene

sequence. See, e.g., Current Protocols in Molecular Biology, eds. Ausubel et al., John Wiley & Sons: 1992.

C. Antibody Antagonists

[0188] In certain aspects, an ALK7:ActRIIB antagonist is an antibody (ALK7:ActRIIB antagonist antibody), or combination of antibodies. An ALK7:ActRIIB antagonist antibody, or combination of antibodies, may bind to, for example, one or more ALK7 ligands, ActRIIB ligands, ALK7:ActRIIB-binding ligands, an ALK7 receptor, an ActRIIB receptor, and/or a TGF-beta superfamily co-receptor (e.g., Crypto or Cryptic). As described herein, ALK7:ActRIIB antagonist antibodies may be used, alone or in combination with one or more supportive therapies or active agents, to treat a patient in need thereof (e.g., patients having kidney disease and/or a metabolic disorder or condition).

[0189] In certain aspects, an ALK7:ActRIIB antagonist antibody, or combination of antibodies, is an antibody that inhibits one or more of the ligands bound or likely bound by an ALK7:ActRIIB heteromultimer, such as activin B, GDF11, activin A, BMP10, BMP6, BMP5, GDF3, activin C, activin E, activin AC, activin BC, activin AE, nodal, or activin BE. Therefore, in some instances, an ALK7:ActRIIB antagonist antibody, or combination of antibodies, binds to at least one of such ligands. As an example, as used herein, an activin C antibody (or anti-activin C antibody) generally refers to an antibody that can bind to activin C with sufficient affinity such that the antibody is useful as a diagnostic and/or therapeutic agent in targeting activin C. In certain instances, the extent of binding of a activin C antibody to an unrelated, non-activin C protein is less than about 10%, 9%, 8%, 7%, 6%, 5%, 4%, 3%, 2%, or less than about 1% of the binding of the antibody to activin C as measured, for example, by a radioimmunoassay (RIA), Biacore, or other protein interaction or binding affinity assay. In certain instances, an activin C antibody binds to an epitope of activin C that is conserved among activin C from different species. In certain preferred instances, an anti-activin C antibody binds to human activin C. In some instances, an activin C antibody may inhibit activin C from binding to a type I and/or type II receptor (e.g., ActRIIB and/or ALK7) and thus inhibit activin C-mediated signaling (e.g., Smad signaling). In some instances, an activin C antibody may inhibit activin C from binding to a co-receptor and thus inhibit activin C-mediated signaling (e.g., Smad signaling). It should be noted that activin C shares some sequence homology to activin A, B and E and therefore antibodies that bind to activin C, in some instances, may also bind to and/or inhibit another activin. In some instances, the disclosure relates to a multispecific antibody (e.g., bi-specific antibody), and uses thereof, that binds to, for example, activin C and further binds to, for example, one or more additional TGF- β superfamily ligands that bind to ALK7:ActRIIB heteromultimer [e.g., activin (e.g., activin A, activin B, activin C, activin E, activin AB, activin AC, activin BC, activin AE, or activin BE), GDF11, GDF8, BMP10, BMP6, BMP5, nodal, and GDF3], one or more type I receptor and/or type II receptors (e.g., ActRIIB and/or ALK7), and/or one or more co-receptors. In some instances, a multispecific antibody that binds to activin C does not bind or does not substantially bind to BMP9 (e.g., binds to BMP9 with a K_D of greater than 1×10^{-7} M or has

relatively modest binding, e.g., about 1×10^{-8} M or about 1×10^{-9} M). In some instances, the disclosure relates to combinations of antibodies, and uses thereof, wherein the combination of antibodies comprises a combination of antibodies that bind to, for example, two or more TGF- β superfamily ligand that bind to ALK7:ActRIIB heteromultimer [e.g., activin (e.g., activin A, activin B, activin C, activin E, activin AB, activin AC, activin BC, activin AE, or activin BE), GDF11, GDF8, BMP10, BMP6, BMP5, nodal, and GDF] one or more type I receptor and/or type II receptors (e.g., ActRIIB and/or ALK7), and/or one or more co-receptors. In some instances, a combination of antibodies does not comprise a BMP9 antibody.

[0190] In certain aspects, an ALK7:ActRIIB antagonist antibody, or combination of antibodies, is an antibody that inhibits at least GDF8. Therefore, in some instances, an ALK7:ActRIIB antagonist antibody, or combination of antibodies, binds to at least GDF8. As used herein, a GDF8 antibody (or anti-GDF8 antibody) generally refers to an antibody that binds to GDF8 with sufficient affinity such that the antibody is useful as a diagnostic and/or therapeutic agent in targeting GDF8. In certain instances, the extent of binding of a GDF8 antibody to an unrelated, non- GDF8 protein is less than about 10%, 9%, 8%, 7%, 6%, 5%, 4%, 3%, 2%, or less than about 1% of the binding of the antibody to GDF8 as measured, for example, by a radioimmunoassay (RIA), Biacore, or other protein interaction or binding affinity assay. In certain instances, a GDF8 antibody binds to an epitope of GDF8 that is conserved among GDF8 from different species. In certain preferred instances, an anti-GDF8 antibody binds to human GDF8. In some instances, a GDF8 antibody may inhibit GDF8 from binding to a type I and/or type II receptor (e.g., ActRIIB and/or ALK7) and thus inhibit GDF8-mediated signaling (e.g., Smad signaling). In some instances, a GDF8 antibody may inhibit GDF8 from binding to a co-receptor and thus inhibit GDF8-mediated signaling (e.g., Smad signaling). It should be noted that GDF8 has high sequence homology to GDF11 and therefore antibodies that bind to GDF8, in some instances, may also bind to and/or inhibit GDF11. In some instances, the disclosure relates to a multispecific antibody (e.g., bi-specific antibody), and uses thereof, that binds to GDF8 and further binds to, for example, one or more additional TGF- β superfamily ligands [e.g., activin (e.g., activin A, activin B, activin C, activin E, activin AB, activin AC, activin BC, activin AE, activin BE), GDF11, BMP10, BMP6, BMP5, nodal, and GDF3], one or more type I receptor and/or type II receptors (e.g., ActRIIB and/or ALK7), and/or one or more co-receptors. In some instances, a multispecific antibody that binds to GDF8 does not bind or does not substantially bind to BMP9 (e.g., binds to BMP9 with a K_D of greater than 1×10^{-7} M or has relatively modest binding, e.g., about 1×10^{-8} M or about 1×10^{-9} M). In some instances, the disclosure relates to combinations of antibodies, and uses thereof, wherein the combination of antibodies comprises a GDF8 antibody and one or more additional antibodies that bind to, for example, one or more additional TGF- β superfamily ligand [e.g., activin (e.g., activin A, activin B, activin C, activin E, activin AB, activin AC, activin BC, activin AE, activin BE), GDF11, GDF3, BMP6, BMP10, nodal, and BMP5], one or more type I receptor and/or type II receptors (e.g., ActRIIB and/or ALK7), and/or one or more co-receptors. In some instances, a combination of antibodies that comprises a GDF8 antibody does not comprise a BMP9 antibody.

[0191] In certain aspects, an ALK7:ActRIIB antagonist antibody, or combination of antibodies, is an antibody that inhibits at least GDF11. Therefore, in some instances, an ALK7:ActRIIB antagonist antibody, or combination of antibodies, binds to at least GDF11. As used herein, a GDF11 antibody (or anti-GDF 11 antibody) generally refers to an antibody that binds to GDF11 with sufficient affinity such that the antibody is useful as a diagnostic and/or therapeutic agent in targeting GDF 11. In certain instances, the extent of binding of a GDF11 antibody to an unrelated, non-GDF11 protein is less than about 10%, 9%, 8%, 7%, 6%, 5%, 4%, 3%, 2%, or less than about 1% of the binding of the antibody to GDF11 as measured, for example, by a radioimmunoassay (RIA), Biacore, or other protein interaction or binding affinity assay. In certain instances, a GDF11 antibody binds to an epitope of GDF11 that is conserved among GDF11 from different species. In certain preferred instances, an anti-GDF11 antibody binds to human GDF11. In some instances, a GDF11 antibody may inhibit GDF11 from binding to a type I and/or type II receptor (e.g., ActRIIB and/or ALK7) and thus inhibit GDF11-mediated signaling (e.g., Smad signaling). In some instances, a GDF11 antibody may inhibit GDF11 from binding to a co-receptor and thus inhibit GDF11-mediated signaling (e.g., Smad signaling). It should be noted that GDF11 has high sequence homology to GDF8 and therefore antibodies that bind to GDF11, in some instances, may also bind to and/or inhibit GDF8. In some instances, the disclosure relates to a multispecific antibody (e.g., bi-specific antibody), and uses thereof, that binds to GDF11 and further binds to, for example, one or more additional TGF- β superfamily ligands [e.g., activin (e.g., activin A, activin B, activin C, activin E, activin AB, activin AC, activin BC, activin AE, activin BE), GDF11, BMP10, BMP6, BMP5, nodal, and GDF3], one or more type I receptor and/or type II receptors (e.g., ActRIIB and/or ALK7), and/or one or more co-receptors. In some instances, a multispecific antibody that binds to GDF11 does not bind or does not substantially bind to BMP9 (e.g., binds to BMP9 with a K_D of greater than 1×10^{-7} M or has relatively modest binding, e.g., about 1×10^{-8} M or about 1×10^{-9} M). In some instances, the disclosure relates to combinations of antibodies, and uses thereof, wherein the combination of antibodies comprises a GDF11 antibody and one or more additional antibodies that bind to, for example, one or more additional TGF- β superfamily ligand [e.g., activin (e.g., activin A, activin B, activin C, activin E, activin AB, activin AC, activin BC, activin AE, activin BE), GDF8, GDF3, BMP6, BMP10, nodal, and BMP5], one or more type I receptor and/or type II receptors (e.g., ActRIIB and/or ALK7), and/or one or more co-receptors. In some instances, a combination of antibodies that comprises a GDF11 antibody does not comprise a BMP9 antibody.

[0192] In certain aspects, an ALK7:ActRIIB antagonist antibody, or combination of antibodies, is an antibody that inhibits at least activin (activin A, activin B, activin C, activin E, activin AB, activin AC, activin AE, activin BC and/or activin BE). Therefore, in some instances, an ALK7:ActRIIB antagonist antibody, or combination of antibodies, binds to at least activin (activin A, activin B, activin C, activin E, activin AB, activin AC, activin AE, activin BC and/or activin BE). As used herein, an activin antibody (or anti-activin antibody) generally refers to an antibody that can bind to a form of activin with sufficient affinity such that the antibody is useful as a diagnostic and/or therapeutic agent in targeting that form of activin. In certain instances, the extent of binding of an activin antibody to an unrelated, non-activin protein is less than about 10%, 9%, 8%, 7%, 6%, 5%, 4%, 3%, 2%, or less than about 1% of the binding of the antibody

to activin as measured, for example, by a radioimmunoassay (RIA), Biacore, or other protein interaction or binding affinity assay. In certain instances, an activin antibody binds to an epitope of activin that is conserved among activin from different species. In certain preferred instances, an anti-activin antibody binds to human activin. In other preferred instances, a activin antibody may inhibit activin from binding to a type I and/or type II receptor (e.g., ActRIIB and/or ALK7) and thus inhibit activin-mediated signaling (e.g., Smad signaling). In some instances, an activin antibody binds to activin B. In some instances, an activin antibody binds to activin A. In some instances, an activin antibody binds to activin A and activin B. In some instances, an activin antibody binds to activin AB. In some instances, an activin antibody binds to activin C. In some instances, an activin antibody binds to activin E. In some instances, an activin antibody binds to activin A and activin C. In some instances, an activin antibody binds to activin AC. In some instances, an activin antibody binds to activin A and activin E. In some instances, an activin antibody binds to activin AE. In some instances, an activin antibody binds to activin B and activin C. In some instances, an activin antibody binds to activin BC. In some instances, an activin antibody binds to activin B and activin E. In some instances, an activin antibody binds to activin BE. In some instances, an activin antibody binds to activin A, activin B, and activin C. In some instances, an activin antibody binds to activin A, activin B, and activin E. Optionally, an activin antibody that binds to one or more of activin A, activin B, and activin C may further bind to activin E. In some instances, the disclosure relates to a multispecific antibody (e.g., bi-specific antibody), and uses thereof, that binds to activin and further binds to, for example, one or more additional TGF- β superfamily ligands [e.g., GDF11, GDF8, BMP10, BMP6, BMP5, nodal, and GDF3], one or more type I receptor and/or type II receptors (e.g., ActRIIB and/or ALK7), and/or one or more co-receptors. In some instances, a multispecific antibody that binds to activin does not bind or does not substantially bind to BMP9 (e.g., binds to BMP9 with a K_D of greater than 1×10^{-7} M or has relatively modest binding, e.g., about 1×10^{-6} M or about 1×10^{-9} M. In some instances, the disclosure relates to combinations of antibodies, and uses thereof, wherein the combination of antibodies comprises an activin antibody and one or more additional antibodies that bind to, for example, one or more additional TGF- β superfamily ligand [e.g., GDF11, GDF8 GDF3, BMP6, BMP10, nodal, and BMP5], one or more type I receptor and/or type II receptors (e.g., ActRIIB and/or ALK7), and/or one or more co-receptors. In some instances, a combination of antibodies that comprises an activin antibody does not comprise a BMP9 antibody.

[0193] In certain aspects, an ALK7:ActRIIB antagonist antibody, or combination of antibodies, is an antibody that inhibits at least BMP6. Therefore, in some instances, an ALK7:ActRIIB antagonist antibody, or combination of antibodies, binds to at least BMP6. As used herein, a BMP6 antibody (or anti-BMP6 antibody) generally refers to an antibody that can bind to BMP6 with sufficient affinity such that the antibody is useful as a diagnostic and/or therapeutic agent in targeting BMP6. In certain instances, the extent of binding of a BMP6 antibody to an unrelated, non-BMP6 protein is less than about 10%, 9%, 8%, 7%, 6%, 5%, 4%, 3%, 2%, or less than about 1% of the binding of the antibody to BMP6 as measured, for example, by a radioimmunoassay (RIA), Biacore, or other protein interaction or binding affinity assay. In certain instances, a BMP6 antibody binds to an epitope of BMP6 that is conserved among

BMP6 from different species. In certain preferred instances, an anti-BMP6 antibody binds to human BMP6. In some instances, a BMP6 antibody may inhibit BMP6 from binding to a type I and/or type II receptor (e.g., ActRIIB and/or ALK7) and thus inhibit BMP6-mediated signaling (e.g., Smad signaling). In some instances, a BMP6 antibody may inhibit BMP6 from binding to a co-receptor and thus inhibit BMP6-mediated signaling (e.g., Smad signaling). In some instances, the disclosure relates to a multispecific antibody (e.g., bi-specific antibody), and uses thereof, that binds to BMP6 and further binds to, for example, one or more additional TGF- β superfamily ligands [e.g., activin (e.g., activin A, activin B, activin C, activin E, activin AB, activin AC, activin BC, activin AE, activin BE), GDF8, BMP10, GDF11, BMP5, nodal, and GDF3], one or more type I receptor and/or type II receptors (e.g., ActRIIB and/or ALK7), and/or one or more co-receptors. In some instances, a multispecific antibody that binds to BMP6 does not bind or does not substantially bind to BMP9 (e.g., binds to BMP9 with a K_D of greater than 1×10^{-7} M or has relatively modest binding, e.g., about 1×10^{-8} M or about 1×10^{-9} M). In some instances, the disclosure relates to combinations of antibodies, and uses thereof, wherein the combination of antibodies comprises a BMP6 antibody and one or more additional antibodies that bind to, for example, one or more additional TGF- β superfamily ligand [e.g., activin (e.g., activin A, activin B, activin C, activin E, activin AB, activin AC, activin BC, activin AE, activin BE), GDF8 GDF3, GDF11, BMP10, nodal, and BMP5], one or more type I receptor and/or type II receptors (e.g., ActRIIB and/or ALK7), and/or one or more co-receptors. In some instances, a combination of antibodies that comprises a BMP6 antibody does not comprise a BMP9 antibody.

[0194] In certain aspects, an ALK7:ActRIIB antagonist antibody, or combination of antibodies, is an antibody that inhibits at least GDF3. Therefore, in some instances, an ALK7:ActRIIB antagonist antibody, or combination of antibodies, binds to at least GDF3. As used herein, a GDF3 antibody (or anti-GDF3 antibody) generally refers to an antibody that binds to GDF3 with sufficient affinity such that the antibody is useful as a diagnostic and/or therapeutic agent in targeting GDF3. In certain instances, the extent of binding of a GDF3 antibody to an unrelated, non-GDF3 protein is less than about 10%, 9%, 8%, 7%, 6%, 5%, 4%, 3%, 2%, or less than about 1% of the binding of the antibody to GDF3 as measured, for example, by a radioimmunoassay (RIA), Biacore, or other protein interaction or binding affinity assay. In certain instances, a GDF3 antibody binds to an epitope of GDF3 that is conserved among GDF3 from different species. In certain preferred instances, a GDF3 antibody binds to human GDF3. In some instances, a GDF3 antibody may inhibit GDF3 from binding to a type I and/or type II receptor (e.g., ActRIIB and/or ALK7) and thus inhibit GDF3-mediated signaling (e.g., Smad signaling). In some instances, a GDF3 antibody may inhibit GDF3 from binding to a co-receptor and thus inhibit GDF3-mediated signaling (e.g., Smad signaling). In some instances, the disclosure relates to a multispecific antibody (e.g., bi-specific antibody), and uses thereof, that binds to GDF3 and further binds to, for example, one or more additional TGF- β superfamily ligands [e.g., activin (e.g., activin A, activin B, activin C, activin E, activin AB, activin AC, activin BC, activin AE, activin BE), GDF11, BMP10, BMP6, BMP5, and nodal], one or more type I receptor and/or type II receptors (e.g., ActRIIB and/or ALK7), and/or one or more co-receptors. In some instances, a multispecific antibody that binds to GDF3 does not bind or

does not substantially bind to BMP9 (e.g., binds to BMP9 with a K_D of greater than 1×10^{-7} M or has relatively modest binding, e.g., about 1×10^{-8} M or about 1×10^{-9} M). In some instances, the disclosure relates to combinations of antibodies, and uses thereof, wherein the combination of antibodies comprises a GDF3 antibody and one or more additional antibodies that bind to, for example, one or more additional TGF- β superfamily ligand [e.g., activin (e.g., activin A, activin B, activin C, activin E, activin AB, activin AC, activin BC, activin AE, activin BE), GDF11, BMP10, BMP6, BMP5, and nodal, one or more type I receptor and/or type II receptors (e.g., ActRIIB and/or ALK7), and/or one or more co-receptors. In some instances, a combination of antibodies that comprises a GDF3 antibody does not comprise a BMP9 antibody.

[0195] In certain aspects, an ALK7:ActRIIB antagonist antibody, or combination of antibodies, is an antibody that inhibits at least BMP5. Therefore, in some instances, an ALK7:ActRIIB antagonist antibody, or combination of antibodies, binds to at least BMP5. As used herein, a BMP5 antibody (or anti-BMP5 antibody) generally refers to an antibody that binds to BMP5 with sufficient affinity such that the antibody is useful as a diagnostic and/or therapeutic agent in targeting BMP5. In certain instances, the extent of binding of a BMP5 antibody to an unrelated, non-BMP5 protein is less than about 10%, 9%, 8%, 7%, 6%, 5%, 4%, 3%, 2%, or less than about 1% of the binding of the antibody to BMP5 as measured, for example, by a radioimmunoassay (RIA), Biacore, or other protein interaction or binding affinity assay. In certain instances, a BMP5 antibody binds to an epitope of BMP5 that is conserved among BMP5 from different species. In certain preferred instances, an anti-BMP5 antibody binds to human BMP5. In some instances, a BMP5 antibody may inhibit BMP5 from binding to a type I and/or type II receptor (e.g., ActRIIB and/or ALK7) and thus inhibit BMP5-mediated signaling (e.g., Smad signaling). In some instances, a BMP5 antibody may inhibit BMP5 from binding to a co-receptor and thus inhibit BMP5-mediated signaling (e.g., Smad signaling). In some instances, the disclosure relates to a multispecific antibody (e.g., bi-specific antibody), and uses thereof, that binds to BMP5 and further binds to, for example, one or more additional TGF- β superfamily ligands [e.g., activin (e.g., activin A, activin B, activin C, activin E, activin AB, activin AC, activin BC, activin AE and activin BE), GDF8, BMP10, BMP6, GDF11, nodal, and GDF3], one or more type I receptor and/or type II receptors (e.g., ActRIIB and/or ALK7), and one or more co-receptors. In some instances, a multispecific antibody that binds to BMP5 does not bind or does not substantially bind to BMP9 (e.g., binds to BMP9 with a K_D of greater than 1×10^{-7} M or has relatively modest binding, e.g., about 1×10^{-8} M or about 1×10^{-9} M). In some instances, the disclosure relates to combinations of antibodies, and uses thereof, wherein the combination of antibodies comprises a BMP5 antibody and one or more additional antibodies that bind to, for example, one or more additional TGF- β superfamily ligand [e.g., activin (e.g., activin A, activin B, activin C, activin E, activin AB, activin AC, activin BC, activin AE, and activin BE), GDF8 GDF3, BMP6, BMP10, nodal, and GDF11], type I receptor, and/or type II receptors (e.g., ActRIIB and/or ALK7), and/or co-receptor. In some instances, a combination of antibodies that comprises a BMP5 antibody does not comprise a BMP9 antibody.

[0196] In certain aspects, an ALK7:ActRIIB antagonist antibody, or combination of antibodies, is an antibody that inhibits at least BMP10. Therefore, in some instances, an ALK7:ActRIIB antagonist antibody, or combination of antibodies, binds to at least BMP10. As used herein, a BMP10 antibody (or anti-BMP10 antibody) generally refers to an antibody that can bind to BMP10 with sufficient affinity such that the antibody is useful as a diagnostic and/or therapeutic agent in targeting BMP10. In certain instances, the extent of binding of a BMP10 antibody to an unrelated, non-BMP10 protein is less than about 10%, 9%, 8%, 7%, 6%, 5%, 4%, 3%, 2%, or less than about 1% of the binding of the antibody to BMP10 as measured, for example, by a radioimmunoassay (RIA), Biacore, or other protein interaction or binding affinity assay. In certain instances, a BMP10 antibody binds to an epitope of BMP10 that is conserved among BMP10 from different species. In certain preferred instances, an anti-BMP10 antibody binds to human BMP10. In some instances, a BMP10 antibody may inhibit BMP10 from binding to a type I and/or type II receptor (e.g., ActRIIB and/or ALK7) and thus inhibit BMP10-mediated signaling (e.g., Smad signaling). In some instances, a BMP10 antibody may inhibit BMP10 from binding to a co-receptor and thus inhibit BMP10-mediated signaling (e.g., Smad signaling). In some instances, the disclosure relates to a multispecific antibody (e.g., bi-specific antibody), and uses thereof, that binds to BMP10 and further binds to, for example, one or more additional TGF- β superfamily ligands [e.g., activin (e.g., activin A, activin B, activin C, activin E, activin AB, activin AC, activin BC, activin AE and activin BE), GDF8, GDF11, BMP6, BMP5, nodal, and GDF3], one or more type I receptor and/or type II receptors (e.g., ActRIIB and/or ALK7), and/or one or more co-receptors. In some instances, a multispecific antibody that binds to BMP10 does not bind or does not substantially bind to BMP9 (e.g., binds to BMP9 with a K_D of greater than 1×10^{-7} M or has relatively modest binding, e.g., about 1×10^{-8} M or about 1×10^{-9} M). In some instances, the disclosure relates to combinations of antibodies, and uses thereof, wherein the combination of antibodies comprises a BMP10 antibody and one or more additional antibodies that bind to, for example, one or more additional TGF- β superfamily ligand [e.g., activin (e.g., activin A, activin B, activin C, activin E, activin AB, activin AC, activin BC, activin AE and activin BE), GDF8 GDF3, BMP6, GDF11, nodal, and BMP5], one or more type I receptor and/or type II receptors (e.g., ActRIIB and/or ALK7), and/or one or more co-receptors. In some instances, a combination of antibodies that comprises a BMP10 antibody does not comprise a BMP9 antibody.

[0197] In certain aspects, an ALK7:ActRIIB antagonist antibody, or combination of antibodies, is an antibody that inhibits at least nodal. Therefore, in some instances, an ALK7:ActRIIB antagonist antibody, or combination of antibodies, binds to at least nodal. As used herein, a nodal antibody (or anti-nodal antibody) generally refers to an antibody that can bind to nodal with sufficient affinity such that the antibody is useful as a diagnostic and/or therapeutic agent in targeting nodal. In certain instances, the extent of binding of a nodal antibody to an unrelated, non-nodal protein is less than about 10%, 9%, 8%, 7%, 6%, 5%, 4%, 3%, 2%, or less than about 1% of the binding of the antibody to nodal as measured, for example, by a radioimmunoassay (RIA), Biacore, or other protein interaction or binding affinity assay. In certain instances, a nodal antibody binds to an epitope of nodal that is conserved among nodal from different species. In certain preferred instances, an anti-nodal antibody binds to human

nodal. In some instances, a nodal antibody may inhibit nodal from binding to a type I and/or type II receptor (e.g., ActRIIB and/or ALK7) and thus inhibit nodal-mediated signaling (e.g., Smad signaling). In some instances, a nodal antibody may inhibit nodal from binding to a co-receptor and thus inhibit nodal-mediated signaling (e.g., Smad signaling). In some instances, the disclosure relates to a multispecific antibody (e.g., bi-specific antibody), and uses thereof, that binds to nodal and further binds to, for example, one or more additional TGF- β superfamily ligands [e.g., activin (e.g., activin A, activin B, activin C, activin E, activin AB, activin AC, activin BC, activin AE and activin BE), GDF8, GDF11, BMP6, BMP5, BMP10, and GDF3], one or more type I receptor and/or type II receptors (e.g., ActRIIB and/or ALK7), and/or one or more co-receptors. In some instances, a multispecific antibody that binds to nodal does not bind or does not substantially bind to BMP9 (e.g., binds to BMP9 with a K_D of greater than 1×10^{-7} M or has relatively modest binding, e.g., about 1×10^{-8} M or about 1×10^{-9} M). In some instances, the disclosure relates to combinations of antibodies, and uses thereof, wherein the combination of antibodies comprises a nodal antibody and one or more additional antibodies that bind to, for example, one or more additional TGF- β superfamily ligand [e.g., activin (e.g., activin A, activin B, activin C, activin E, activin AB, activin AC, activin BC, activin AE and activin BE), GDF8 GDF3, BMP6, GDF11, BMP10, and BMP5], one or more type I receptor and/or type II receptors (e.g., ActRIIB and/or ALK7), and/or one or more co-receptors. In some instances, a combination of antibodies that comprises a nodal antibody does not comprise a BMP9 antibody.

[0198] With respect to antibodies that bind to and antagonize ligands that bind to ALK7:ActRIIB, [e.g., activin (e.g., activin A, activin B, activin C, activin E, activin AB, activin AC, activin BC, activin AE and activin BE), GDF8 GDF3, BMP6, GDF11, BMP10, and BMP5], it is contemplated that an antibody may be designed as a bispecific antibody comprising a first portion that binds to an epitope of such ligand, such that the first portion of the antibody competes for binding with a type I receptor and comprising a second portion that binds to an epitope of such ligand, such that the second portion of the antibody competes for binding with a type II receptor. In this manner, a bispecific antibody targeting a single ligand can be designed to mimic the dual type I-type II receptor binding blockade that may be conferred by an ALK7:ActRIIB heteromultimer. Similarly it is contemplated that the same effect could be achieved using a combination of two or more antibodies wherein at least a first antibody binds to an epitope of such ligand, such that the first antibody competes for binding with a type I receptor and at least a second antibody binds to an epitope of such ligand, such that the the second antibody competes for binding with a type II receptor.

[0199] In certain aspects, an ALK7:ActRIIB antagonist antibody, or combination of antibodies, is an antibody that inhibits at least ActRIIB. Therefore, in some instances, an ALK7:ActRIIB antagonist antibody, or combination of antibodies, binds to at least ActRIIB. As used herein, an ActRIIB antibody (anti-ActRIIB antibody) generally refers to an antibody that binds to ActRIIB with sufficient affinity such that the antibody is useful as a diagnostic and/or therapeutic agent in targeting ActRIIB. In certain instances, the extent of binding of an anti- ActRIIB antibody to an unrelated, non-ActRIIB protein is less than about 10%, 9%, 8%, 7%, 6%, 5%, 4%, 3%, 2%, or less than about 1% of the binding of the antibody to ActRIIB as measured, for example, by a

radioimmunoassay (RIA), Biacore, or other protein-protein interaction or binding affinity assay. In certain instances, an anti-ActRIIB antibody binds to an epitope of ActRIIB that is conserved among ActRIIB from different species. In certain preferred instances, an anti-ActRIIB antibody binds to human ActRIIB. In some instances, an anti-ActRIIB antibody may inhibit one or more TGF- β superfamily ligands [e.g., GDF8, activin (e.g., activin A, activin B, activin C, activin E, activin AB, activin AC, activin BC, activin AE and activin BE) GDF3, BMP6, BMP10, nodal and BMP9] from binding to ActRIIB and/or ALK7. In some instances, an anti-ActRIIB antibody is a multispecific antibody (e.g., bi-specific antibody) that binds to ActRIIB and one or more TGF- β superfamily ligands [e.g., GDF11, GDF8, activin (e.g., activin A, activin B, activin C, activin E, activin AB, activin AC) GDF3, BMP6, BMP10, nodal, and BMP9], type I receptor (e.g., ALK7), co-receptor, and/or an additional type II receptor. In some instances, the disclosure relates to combinations of antibodies, and uses thereof, wherein the combination of antibodies comprises an anti-ActRIIB antibody and one or more additional antibodies that bind to, for example, one or more TGF- β superfamily ligands [e.g., GDF11, GDF8, activin (e.g., activin A, activin B, activin C, activin E, activin AB, activin AC, activin BC, activin AE and activin BE) GDF3, BMP6, BMP10, nodal, and BMP9], co-receptors, type I receptors (e.g., ALK7), and/or additional type II receptors. It should be noted that ActRIIB has sequence similarity to ActRIIA and therefore antibodies that bind to ActRIIB, in some instances, may also bind to and/or inhibit ActRIIA.

[0200] In certain aspects, an ALK7:ActRIIB antagonist antibody, or combination of antibodies, is an antibody that inhibits at least ALK7. Therefore, in some instances, an ALK7:ActRIIB antagonist antibody, or combination of antibodies, binds to at least ALK7. As used herein, an ALK7 antibody (anti-ALK7 antibody) generally refers to an antibody that binds to ALK7 with sufficient affinity such that the antibody is useful as a diagnostic and/or therapeutic agent in targeting ALK7. In certain instances, the extent of binding of an anti-ALK7 antibody to an unrelated, non-ALK7 protein is less than about 10%, 9%, 8%, 7%, 6%, 5%, 4%, 3%, 2%, or less than about 1% of the binding of the antibody to ALK7 as measured, for example, by a radioimmunoassay (RIA), Biacore, or other protein-protein interaction or binding affinity assay. In certain instances, an anti-ALK7 antibody binds to an epitope of ALK7 that is conserved among ALK7 from different species. In certain preferred instances, an anti-ALK7 antibody binds to human ALK7. In some instances, an anti-ALK7 antibody may inhibit one or more TGF- β superfamily ligands [e.g., GDF11, GDF8, activin (e.g., activin A, activin B, activin C, activin E, activin AB, activin AC, activin BC, activin AE and activin BE) GDF3, BMP5, BMP6, and BMP10] from binding to a type I receptor (e.g., ALK7), type II receptor (e.g., ActRIIB), or co-receptor. In some instances, an anti-ALK7 antibody is a multispecific antibody (e.g., bi-specific antibody) that binds to ALK7 and one or more TGF- β superfamily ligands [e.g., activin (e.g., activin A, activin B, activin C, activin E, activin AB, activin AC, activin BC, activin AE and activin BE), GDF11, GDF8, BMP10, BMP6, BMP5, nodal, and GDF3, type II receptors (e.g., ActRIIB), co-receptors, and/or an additional type I receptor. In some instances, the disclosure relates to combinations of antibodies, and uses thereof, wherein the combination of antibodies comprises an anti-ALK7 antibody and one or more additional antibodies that bind to, for example, one or more TGF- β superfamily ligands [e.g., activin (e.g., activin A, activin B, activin C, activin E, activin AB, activin AC, activin BC, activin AE and activin BE), GDF11, GDF8, BMP10, BMP6, BMP5, nodal, and GDF3], co-receptors, an additional type I receptor, and/or type II receptors

(e.g., ActRIIB).

[0201] In certain aspects, an ALK7:ActRIIB antagonist antibody, or combination of antibodies, is an antibody that inhibits at least Cripto or Cryptic. Therefore, in some instances, an ALK7:ActRIIB antagonist antibody, or combination of antibodies, binds to at least Cripto or Cryptic. As used herein, an Cripto antibody (anti-Cripto antibody) generally refers to an antibody that binds to Cripto with sufficient affinity such that the antibody is useful as a diagnostic and/or therapeutic agent in targeting Cripto. In certain instances, the extent of binding of an anti-Cripto antibody to an unrelated, non-Cripto protein is less than about 10%, 9%, 8%, 7%, 6%, 5%, 4%, 3%, 2%, or less than about 1% of the binding of the antibody to Cripto as measured, for example, by a radioimmunoassay (RIA), Biacore, or other protein-protein interaction or binding affinity assay. In certain instances, an anti-Cripto antibody binds to an epitope of Cripto that is conserved among Cripto from different species. In certain preferred instances, an anti-Cripto antibody binds to human Cripto. As used herein, a Cryptic antibody (anti-Cryptic antibody) generally refers to an antibody that binds to Cryptic with sufficient affinity such that the antibody is useful as a diagnostic and/or therapeutic agent in targeting Cryptic. In certain instances, the extent of binding of an anti-Cripto antibody to an unrelated, non-Cryptic protein is less than about 10%, 9%, 8%, 7%, 6%, 5%, 4%, 3%, 2%, or less than about 1% of the binding of the antibody to Cryptic as measured, for example, by a radioimmunoassay (RIA), Biacore, or other protein-protein interaction or binding affinity assay. In certain instances, an anti- Cryptic antibody binds to an epitope of Cryptic that is conserved among Cryptic from different species. In certain preferred instances, an anti- Cryptic antibody binds to human Cryptic. In some instances, an anti-Cripto or Cryptic antibody may inhibit one or more TGF- β superfamily ligands [e.g., activin (e.g., activin A, activin B, activin C, activin E, activin AB, activin AC, activin BC, activin AE and activin BE), GDF11, GDF8, BMP10, BMP6, BMP5, nodal, and GDF3] from binding to Cripto or Cryptic, respectively, or to ActRIIB and/or ALK7. In some instances, an anti-Cripto or Cryptic antibody may inhibit nodal from binding to a type I and/or type II receptor. In some instances, an anti-Cripto or Cryptic antibody is a multispecific antibody (e.g., bi-specific antibody) that binds to Cripto or Cryptic and one or more TGF- β superfamily [e.g., activin (e.g., activin A, activin B, activin C, activin E, activin AB, activin AC, activin BC, activin AE and activin BE), GDF11, GDF8, BMP10, BMP6, BMP5, nodal, and GDF3], type I receptor (e.g., ALK7), additional co-receptor, and/or type II receptor. In some instances an antibody may bind to both Cripto and Cryptic. In some instances, the disclosure relates to combinations of antibodies, and uses thereof, wherein the combination of antibodies comprises an anti-Cripto or Cryptic antibody and one or more additional antibodies that bind to, for example, one or more TGF- β superfamily ligands [e.g., activin (e.g., activin A, activin B, activin C, activin E, activin AB, activin AC, activin BC, activin AE and activin BE), GDF11, GDF8, BMP10, BMP6, BMP5, nodal, and GDF3], additional co-receptors, type I receptors (e.g., ALK7), and/or type II receptors.

[0202] As described herein, there are a variety of methods for generating heteromultimeric complexes. Such methods may be used to generate heteromultimer complexes comprising an antibody-binding domain (e.g., a complex of V_L and V_H chains) and one or more polypeptides selected from an ALK7 polypeptide, an ActRIIB polypeptide, an ALK7:ActRIIB heteromer, or an

ALK7:ActRIIB single trap polypeptide. See Figure 10A, 10B and 12D. For example, in some instances, the disclosure provides protein complexes comprising a ligand-binding domain of an antibody that binds to an ALK7:ActRIIB-binding ligand [e.g., activin (e.g., activin A, activin B, activin C, activin E, activin AB, activin AC, activin BC, activin AE and activin BE), GDF11, GDF8, BMP10, BMP6, BMP5, nodal, and GDF3] which is covalently or non-covalently associated with an ALK7 polypeptide. In some instances, the disclosure provides protein complexes comprising a ligand-binding domain of an antibody that binds to an ALK7:ActRIIB-binding ligand [e.g., activin (e.g., activin A, activin B, activin C, activin E, activin AB, activin AC, activin BC, activin AE and activin BE), GDF11, GDF8, BMP10, BMP6, BMP5, nodal, and GDF3] which is covalently or non-covalently associated with an ActRIIB polypeptide. In some instances, the disclosure provides protein complexes comprising a ligand-binding domain of an antibody that binds to an ALK7:ActRIIB-binding ligand [e.g., activin (e.g., activin A, activin B, activin C, activin E, activin AB, activin AC, activin BC, activin AE and activin BE), GDF11, GDF8, BMP10, BMP6, BMP5, nodal, and GDF3] which is covalently or non-covalently associated with an ALK7:ActRIIB single-chain ligand trap. In some instances, the disclosure provides protein complexes comprising a ligand-binding domain of an antibody that binds to an ALK7:ActRIIB-binding ligand [e.g., activin (e.g., activin A, activin B, activin C, activin E, activin AB, activin AC, activin BC, activin AE and activin BE), GDF11, GDF8, BMP10, BMP6, BMP5, nodal, and GDF3] which is covalently or non-covalently associated with ALK7:ActRIIB heteromultimer.

[0203] The term antibody is used herein in the broadest sense and encompasses various antibody structures, including but not limited to monoclonal antibodies, polyclonal antibodies, multispecific antibodies (e.g., bispecific antibodies), and antibody fragments so long as they exhibit the desired antigen-binding activity. An antibody fragment refers to a molecule other than an intact antibody that comprises a portion of an intact antibody that binds the antigen to which the intact antibody binds. Examples of antibody fragments include, but are not limited to, Fv, Fab, Fab', Fab'-SH, F(ab')₂; diabodies; linear antibodies; single-chain antibody molecules (e.g., scFv); and multispecific antibodies formed from antibody fragments [see, e.g., Hudson et al. (2003) Nat. Med. 9:129-134; Plückthun, in The Pharmacology of Monoclonal Antibodies, vol. 113, Rosenberg and Moore eds., (Springer-Verlag, New York), pp. 269-315 (1994); WO 93/16185; and U.S. Pat. Nos. 5,571,894; 5,587,458; and 5,869,046]. Diabodies are antibody fragments with two antigen-binding sites that may be bivalent or bispecific [see, e.g., EP 404,097; WO 1993/01161; Hudson et al. (2003) Nat. Med. 9:129-134 (2003); and Hollinger et al. (1993) Proc. Natl. Acad. Sci. USA 90: 6444-6448]. Triabodies and tetrabodies are also described in Hudson et al. (2003) Nat. Med. 9:129-134. Single-domain antibodies are antibody fragments comprising all or a portion of the heavy-chain variable domain or all or a portion of the light-chain variable domain of an antibody. In certain instances, a single-domain antibody is a human single-domain antibody [see, e.g., U.S. Pat. No. 6,248,516]. Antibodies disclosed herein may be polyclonal antibodies or monoclonal antibodies. In certain instances, the antibodies of the present disclosure comprise a label attached thereto and able to be detected (e.g., the label can be a radioisotope, fluorescent compound, enzyme, or enzyme co-factor). In certain preferred instances, the antibodies of the present disclosure are isolated antibodies. In certain preferred instances, the antibodies of the present disclosure are recombinant antibodies.

[0204] The antibodies herein may be of any class. The class of an antibody refers to the type of constant domain or constant region possessed by its heavy chain. There are five major classes of antibodies: IgA, IgD, IgE, IgG, and IgM, and several of these may be further divided into subclasses (isotypes), for example, IgG₁, IgG₂, IgG₃, IgG₄, IgA₁, and IgA₂. The heavy chain constant domains that correspond to the different classes of immunoglobulins are called alpha, delta, epsilon, gamma, and mu.

[0205] In general, an antibody for use in the methods disclosed herein specifically binds to its target antigen, preferably with high binding affinity. Affinity may be expressed as a K_D value and reflects the intrinsic binding affinity (*e.g.*, with minimized avidity effects). Typically, binding affinity is measured *in vitro*, whether in a cell-free or cell-associated setting. Any of a number of assays known in the art, including those disclosed herein, can be used to obtain binding affinity measurements including, for example, Biacore, radiolabeled antigen-binding assay (RIA), and ELISA. In some instances, antibodies of the present disclosure bind to their target antigens (*e.g.* ALK7, ActRIIB, activin, GDF11, GDF8, BMP10, BMP6, GDF3, nodal, and/or BMP5) with at least a K_D of 1×10^{-7} or stronger, 1×10^{-8} or stronger, 1×10^{-9} or stronger, 1×10^{-10} or stronger, 1×10^{-11} or stronger, 1×10^{-12} or stronger, 1×10^{-13} or stronger, or 1×10^{-14} or stronger.

[0206] In certain instances, K_D is measured by RIA performed with the Fab version of an antibody of interest and its target antigen as described by the following assay. Solution binding affinity of Fabs for the antigen is measured by equilibrating Fab with a minimal concentration of radiolabeled antigen (*e.g.*, ^{125}I -labeled) in the presence of a titration series of unlabeled antigen, then capturing bound antigen with an anti-Fab antibody-coated plate [see, *e.g.*, Chen et al. (1999) J. Mol. Biol. 293:865-881]. To establish conditions for the assay, multi-well plates (*e.g.*, MICROTITER® from Thermo Scientific) are coated (*e.g.*, overnight) with a capturing anti-Fab antibody (*e.g.*, from Cappel Labs) and subsequently blocked with bovine serum albumin, preferably at room temperature (approximately 23°C). In a non-adsorbent plate, radiolabeled antigen are mixed with serial dilutions of a Fab of interest [*e.g.*, consistent with assessment of the anti-VEGF antibody, Fab-12, in Presta et al., (1997) Cancer Res. 57:4593-4599]. The Fab of interest is then incubated, preferably overnight but the incubation may continue for a longer period (*e.g.*, about 65 hours) to ensure that equilibrium is reached. Thereafter, the mixtures are transferred to the capture plate for incubation, preferably at room temperature for about one hour. The solution is then removed and the plate is washed times several times, preferably with polysorbate 20 and PBS mixture. When the plates have dried, scintillant (*e.g.*, MICROSCINT® from Packard) is added, and the plates are counted on a gamma counter (*e.g.*, TOPCOUNT® from Packard).

[0207] According to another instance, K_D is measured using surface plasmon resonance assays using, for example a BIACORE® 2000 or a BIACORE® 3000 (BIAcore, Inc., Piscataway, N.J.) with immobilized antigen CM5 chips at about 10 response units (RU). Briefly, carboxymethylated dextran biosensor chips (CM5, BIACORE, Inc.) are activated with N-ethyl-N'-(3-dimethylaminopropyl)-carbodiimide hydrochloride (EDC) and N-hydroxysuccinimide

(NHS) according to the supplier's instructions. For example, an antigen can be diluted with 10 mM sodium acetate, pH 4.8, to 5 µg/ml (about 0.2 µM) before injection at a flow rate of 5 µl/minute to achieve approximately 10 response units (RU) of coupled protein. Following the injection of antigen, 1 M ethanolamine is injected to block unreacted groups. For kinetics measurements, two-fold serial dilutions of Fab (0.78 nM to 500 nM) are injected in PBS with 0.05% polysorbate 20 (TWEEN-20®) surfactant (PBST) at a flow rate of approximately 25 µl/min. Association rates (k_{on}) and dissociation rates (k_{off}) are calculated using, for example, a simple one-to-one Langmuir binding model (BIAcore® Evaluation Software version 3.2) by simultaneously fitting the association and dissociation sensorgrams. The equilibrium dissociation constant (K_D) is calculated as the ratio k_{off} / k_{on} [see, e.g., Chen et al., (1999) J. Mol. Biol. 293:865-881]. If the on-rate exceeds, for example, $10^6 \text{ M}^{-1} \text{ s}^{-1}$ by the surface plasmon resonance assay above, then the on-rate can be determined by using a fluorescent quenching technique that measures the increase or decrease in fluorescence emission intensity (e.g., excitation=295 nm; emission=340 nm, 16 nm bandpass) of a 20 nM anti-antigen antibody (Fab form) in PBS in the presence of increasing concentrations of antigen as measured in a spectrometer, such as a stop-flow equipped spectrophotometer (Aviv Instruments) or a 8000-series SLM-AMINCO® spectrophotometer (ThermoSpectronic) with a stirred cuvette.

[0208] Antibody fragments can be made by various techniques, including but not limited to proteolytic digestion of an intact antibody as well as production by recombinant host cells (e.g., E. coli or phage), as described herein. The nucleic acid and amino acid sequences of human ActRIIB, activin (activin A, activin B, activin C, and activin E), GDF11, GDF8, BMP10, BMP6, GDF3, nodal, and/or BMP5 are known in the art. In addition, numerous methods for generating antibodies are well known in the art, some of which are described herein. Therefore antibody antagonists for use in accordance with this disclosure may be routinely made by the skilled person in the art based on the knowledge in the art and teachings provided herein.

[0209] In certain instances, an antibody provided herein is a chimeric antibody. A chimeric antibody refers to an antibody in which a portion of the heavy and/or light chain is derived from a particular source or species, while the remainder of the heavy and/or light chain is derived from a different source or species. Certain chimeric antibodies are described, for example, in U.S. Pat. No. 4,816,567; and Morrison et al., (1984) Proc. Natl. Acad. Sci. USA, 81:6851-6855. In some instances, a chimeric antibody comprises a non-human variable region (e.g., a variable region derived from a mouse, rat, hamster, rabbit, or non-human primate, such as a monkey) and a human constant region. In some instances, a chimeric antibody is a "class switched" antibody in which the class or subclass has been changed from that of the parent antibody. In general, chimeric antibodies include antigen-binding fragments thereof.

[0210] In certain instances, a chimeric antibody provided herein is a humanized antibody. A humanized antibody refers to a chimeric antibody comprising amino acid residues from non-human hypervariable regions (HVRs) and amino acid residues from human framework regions (FRs). In certain instances, a humanized antibody will comprise substantially all of at least one, and typically two, variable domains, in which all or substantially all of the HVRs (e.g., CDRs)

correspond to those of a non-human antibody, and all or substantially all of the FRs correspond to those of a human antibody. A humanized antibody optionally may comprise at least a portion of an antibody constant region derived from a human antibody. A "humanized form" of an antibody, e.g., a non-human antibody, refers to an antibody that has undergone humanization. Humanized antibodies and methods of making them are reviewed, for example, in Almagro and Fransson (2008) *Front. Biosci.* 13:1619-1633 and are further described, for example, in Riechmann et al., (1988) *Nature* 332:323-329; Queen et al. (1989) *Proc. Nat'l Acad. Sci. USA* 86:10029-10033; U.S. Pat. Nos. 5,821,337; 7,527,791; 6,982,321; and 7,087,409; Kashmiri et al., (2005) *Methods* 36:25-34 [describing SDR (a-CDR) grafting]; Padlan, *Mol. Immunol.* (1991) 28:489-498 (describing "resurfacing"); Dall'Acqua et al. (2005) *Methods* 36:43-60 (describing "FR shuffling"); Osbourn et al. (2005) *Methods* 36:61-68; and Klimka et al. *Br. J. Cancer* (2000) 83:252-260 (describing the "guided selection" approach to FR shuffling). Human framework regions that may be used for humanization include but are not limited to: framework regions selected using the "best-fit" method [see, e.g., Sims et al. (1993) *J. Immunol.* 151:2296]; framework regions derived from the consensus sequence of human antibodies of a particular subgroup of light or heavy chain variable regions [see, e.g., Carter et al. (1992) *Proc. Natl. Acad. Sci. USA*, 89:4285; and Presta et al. (1993) *J. Immunol.*, 151:2623]; human mature (somatically mutated) framework regions or human germline framework regions [see, e.g., Almagro and Fransson (2008) *Front. Biosci.* 13:1619-1633]; and framework regions derived from screening FR libraries [see, e.g., Baca et al., (1997) *J. Biol. Chem.* 272:10678-10684; and Rosok et al., (1996) *J. Biol. Chem.* 271:22611-22618].

[0211] In certain instances, an antibody provided herein is a human antibody. Human antibodies can be produced using various techniques known in the art. Human antibodies are described generally in van Dijk and van de Winkel (2008) *Curr. Opin. Pharmacol.* 5: 368-74 (2001) and Lonberg, *Curr. Opin. Immunol.* 20:450-459. For example, human antibodies may be prepared by administering an immunogen (e.g., a GDF11 polypeptide, an activin B polypeptide, an ActRIIA polypeptide, or an ActRIIB polypeptide) to a transgenic animal that has been modified to produce intact human antibodies or intact antibodies with human variable regions in response to antigenic challenge. Such animals typically contain all or a portion of the human immunoglobulin loci, which replace the endogenous immunoglobulin loci, or which are present extrachromosomally or integrated randomly into the animal's chromosomes. In such transgenic animals, the endogenous immunoglobulin loci have generally been inactivated. For a review of methods for obtaining human antibodies from transgenic animals see, for example, Lonberg (2005) *Nat. Biotech.* 23:1117-1125; U.S. Pat. Nos. 6,075,181 and 6,150,584 (describing XENOMOUSE™ technology); U.S. Pat. No. 5,770,429 (describing HuMab® technology); U.S. Pat. No. 7,041,870 (describing K-M MOUSE® technology); and U.S. Patent Application Publication No. 2007/0061900 (describing VelociMouse® technology). Human variable regions from intact antibodies generated by such animals may be further modified, for example, by combining with a different human constant region.

[0212] Human antibodies provided herein can also be made by hybridoma-based methods. Human myeloma and mouse-human heteromyeloma cell lines for the production of human monoclonal antibodies have been described [see, e.g., Kozbor *J. Immunol.*, (1984) 133: 3001;

Brodeur et al. (1987) *Monoclonal Antibody Production Techniques and Applications*, pp. 51-63, Marcel Dekker, Inc., New York; and Boemer et al. (1991) *J. Immunol.*, 147: 86]. Human antibodies generated via human B-cell hybridoma technology are also described in Li et al., (2006) *Proc. Natl. Acad. Sci. USA*, 103:3557-3562. Additional methods include those described, for example, in U.S. Pat. No. 7,189,826 (describing production of monoclonal human IgM antibodies from hybridoma cell lines) and Ni, Xiandai Mianyixue (2006) 26(4):265-268 (2006) (describing human-human hybridomas). Human hybridoma technology (Trioma technology) is also described in Vollmers and Brandlein (2005) *Histol. Histopathol.*, 20(3):927-937 (2005) and Vollmers and Brandlein (2005) *Methods Find Exp. Clin. Pharmacol.*, 27(3):185-91. Human antibodies provided herein may also be generated by isolating Fv clone variable-domain sequences selected from human-derived phage display libraries. Such variable-domain sequences may then be combined with a desired human constant domain. Techniques for selecting human antibodies from antibody libraries are known in the art and described herein.

[0213] For example, antibodies of the present disclosure may be isolated by screening combinatorial libraries for antibodies with the desired activity or activities. A variety of methods are known in the art for generating phage display libraries and screening such libraries for antibodies possessing the desired binding characteristics. Such methods are reviewed, for example, in Hoogenboom et al. (2001) in *Methods in Molecular Biology* 178:1-37, O'Brien et al., ed., Human Press, Totowa, N.J. and further described, for example, in the McCafferty et al. (1991) *Nature* 348:552-554; Clackson et al., (1991) *Nature* 352: 624-628; Marks et al. (1992) *J. Mol. Biol.* 222:581-597; Marks and Bradbury (2003) in *Methods in Molecular Biology* 248:161-175, Lo, ed., Human Press, Totowa, N.J.; Sidhu et al. (2004) *J. Mol. Biol.* 338(2):299-310; Lcc et al. (2004) *J. Mol. Biol.* 340(5):1073-1093; Fellouse (2004) *Proc. Natl. Acad. Sci. USA* 101(34):12467-12472; and Lee et al. (2004) *J. Immunol. Methods* 284(1-2): 119-132.

[0214] In certain phage display methods, repertoires of VH and VL genes are separately cloned by polymerase chain reaction (PCR) and recombined randomly in phage libraries, which can then be screened for antigen-binding phage as described in Winter et al. (1994) *Ann. Rev. Immunol.*, 12: 433-455. Phage typically display antibody fragments, either as single-chain Fv (scFv) fragments or as Fab fragments. Libraries from immunized sources provide high-affinity antibodies to the immunogen (*e.g.*, ALK7, ActRIIB, activin, GDF11, GDF8, BMP10, BMP6, GDF3, and/or BMP5) without the requirement of constructing hybridomas. Alternatively, the naive repertoire can be cloned (*e.g.*, from human) to provide a single source of antibodies to a wide range of non-self and also self-antigens without any immunization as described by Griffiths et al. (1993) *EMBO J.*, 12: 725-734. Finally, naive libraries can also be made synthetically by cloning unrearranged V-gene segments from stem cells, and using PCR primers containing random sequence to encode the highly variable CDR3 regions and to accomplish rearrangement *in vitro*, as described by Hoogenboom and Winter (1992) *J. Mol. Biol.*, 227: 381-388. Patent publications describing human antibody phage libraries include, for example: U.S. Pat. No. 5,750,373, and U.S. Patent Publication Nos. 2005/0079574, 2005/0119455, 2005/0266000, 2007/0117126, 2007/0160598, 2007/0237764, 2007/0292936, and 2009/0002360.

[0215] In certain instances, an antibody provided herein is a multispecific antibody, for example, a bispecific antibody. Multispecific antibodies (typically monoclonal antibodies) that have binding specificities for at least two different epitopes (e.g., two, three, four, five, or six or more) on one or more (e.g., two, three, four, five, six or more) antigens.

[0216] Techniques for making multispecific antibodies include, but are not limited to, recombinant co-expression of two immunoglobulin heavy-chain/light-chain pairs having different specificities [see, e.g., Milstein and Cuello (1983) *Nature* 305: 537; International patent publication no. WO 93/08829; and Traunecker et al. (1991) *EMBO J.* 10: 3655, and U.S. Pat. No. 5,731,168 ("knob-in-hole" engineering)]. Multispecific antibodies may also be made by engineering electrostatic steering effects for making antibody Fc-heterodimeric molecules (see, e.g., WO 2009/089004A1); cross-linking two or more antibodies or fragments [see, e.g., U.S. Pat. No. 4,676,980; and Brennan et al. (1985) *Science*, 229: 81]; using leucine zippers to produce bispecific antibodies [see, e.g., Kostelny et al. (1992) *J. Immunol.*, 148(5):1547-1553]; using "diabody" technology for making bispecific antibody fragments [see, e.g., Hollinger et al. (1993) *Proc. Natl. Acad. Sci. USA*, 90:6444-6448]; using single-chain Fv (sFv) dimers [see, e.g., Gruber et al. (1994) *J. Immunol.*, 152:5368]; and preparing trispecific antibodies (see, e.g., Tutt et al. (1991) *J. Immunol.* 147: 60. Multispecific antibodies can be prepared as full-length antibodies or antibody fragments. Engineered antibodies with three or more functional antigen-binding sites, including "Octopus antibodies," are also included herein [see, e.g., US 2006/0025576A1].

[0217] In certain instances, an antibody disclosed herein is a monoclonal antibody. Monoclonal antibody refers to an antibody obtained from a population of substantially homogeneous antibodies, *i.e.*, the individual antibodies comprising the population are identical and/or bind the same epitope, except for possible variant antibodies, e.g., containing naturally occurring mutations or arising during production of a monoclonal antibody preparation, such variants generally being present in minor amounts. In contrast to polyclonal antibody preparations, which typically include different antibodies directed against different epitopes, each monoclonal antibody of a monoclonal antibody preparation is directed against a single epitope on an antigen. Thus, the modifier "monoclonal" indicates the character of the antibody as being obtained from a substantially homogeneous population of antibodies, and is not to be construed as requiring production of the antibody by any particular method. For example, the monoclonal antibodies to be used in accordance with the present methods may be made by a variety of techniques, including but not limited to the hybridoma method, recombinant DNA methods, phage-display methods, and methods utilizing transgenic animals containing all or part of the human immunoglobulin loci, such methods and other exemplary methods for making monoclonal antibodies being described herein.

[0218] For example, by using immunogens derived from activin, anti-protein/anti-peptide antisera or monoclonal antibodies can be made by standard protocols [see, e.g., *Antibodies: A Laboratory Manual* ed. by Harlow and Lane (1988) Cold Spring Harbor Press: 1988]. A mammal, such as a mouse, hamster, or rabbit, can be immunized with an immunogenic form

of the activin polypeptide, an antigenic fragment which is capable of eliciting an antibody response, or a fusion protein. Techniques for conferring immunogenicity on a protein or peptide include conjugation to carriers or other techniques well known in the art. An immunogenic portion of a activin polypeptide can be administered in the presence of adjuvant. The progress of immunization can be monitored by detection of antibody titers in plasma or serum. Standard ELISA or other immunoassays can be used with the immunogen as antigen to assess the levels of antibody production and/or level of binding affinity.

[0219] Following immunization of an animal with an antigenic preparation of activin, antisera can be obtained and, if desired, polyclonal antibodies can be isolated from the serum. To produce monoclonal antibodies, antibody-producing cells (lymphocytes) can be harvested from an immunized animal and fused by standard somatic cell fusion procedures with immortalizing cells such as myeloma cells to yield hybridoma cells. Such techniques are well known in the art, and include, for example, the hybridoma technique [see, e.g., Kohler and Milstein (1975) *Nature*, 256: 495-497], the human B cell hybridoma technique [see, e.g., Kozbar et al. (1983) *Immunology Today*, 4:72], and the EBV-hybridoma technique to produce human monoclonal antibodies [Cole et al. (1985) *Monoclonal Antibodies and Cancer Therapy*, Alan R. Liss, Inc. pp. 77-96]. Hybridoma cells can be screened immunochemically for production of antibodies specifically reactive with a activin polypeptide, and monoclonal antibodies isolated from a culture comprising such hybridoma cells.

[0220] In certain instances, one or more amino acid modifications may be introduced into the Fc region of an antibody provided herein thereby generating an Fc region variant. The Fc region variant may comprise a human Fc region sequence (e.g., a human IgG1, IgG2, IgG3 or IgG4 Fc region) comprising an amino acid modification (e.g., a substitution, deletion, and/or addition) at one or more amino acid positions.

[0221] For example, the present disclosure contemplates an antibody variant that possesses some but not all effector functions, which make it a desirable candidate for applications in which the half-life of the antibody *in vivo* is important yet certain effector functions [e.g., complement-dependent cytotoxicity (CDC) and antibody-dependent cellular cytotoxicity (ADCC)] are unnecessary or deleterious. *In vitro* and/or *in vivo* cytotoxicity assays can be conducted to confirm the reduction/depletion of CDC and/or ADCC activities. For example, Fc receptor (FcR) binding assays can be conducted to ensure that the antibody lacks FcγR binding (hence likely lacking ADCC activity), but retains FcRn binding ability. The primary cells for mediating ADCC, NK cells, express FcγRIII only, whereas monocytes express FcγRI, FcγRII and FcγRIII. FcR expression on hematopoietic cells is summarized in, for example, Ravetch and Kinet (1991) *Annu. Rev. Immunol.* 9:457-492. Non-limiting examples of *in vitro* assays to assess ADCC activity of a molecule of interest are described in U.S. Pat. No. 5,500,362; Hellstrom, I. et al. (1986) *Proc. Natl. Acad. Sci. USA* 83:7059-7063; Hellstrom, I et al. (1985) *Proc. Natl. Acad. Sci. USA* 82:1499-1502; U.S. Pat. No. 5,821,337; Bruggemann, M. et al. (1987) *J. Exp. Med.* 166:1351-1361. Alternatively, non-radioactive assays methods may be employed (e.g., ACTI™, non-radioactive cytotoxicity assay for flow cytometry; CellTechnology, Inc. Mountain View, Calif.; and CytoTox 96® non-radioactive cytotoxicity assay, Promega,

Madison, Wis.). Useful effector cells for such assays include peripheral blood mononuclear cells (PBMC) and natural killer (NK) cells. Alternatively, or additionally, ADCC activity of the molecule of interest may be assessed *in vivo*, for example, in an animal model such as that disclosed in Clynes et al. (1998) Proc. Natl. Acad. Sci. USA 95:652-656. C1q binding assays may also be carried out to confirm that the antibody is unable to bind C1q and hence lacks CDC activity [see, e.g., C1q and C3c binding ELISA in WO 2006/029879 and WO 2005/100402]. To assess complement activation, a CDC assay may be performed [see, e.g., Gazzano-Santoro et al. (1996) J. Immunol. Methods 202:163; Cragg, M. S. et al. (2003) Blood 101:1045-1052; and Cragg, M. S. and M. J. Glennie (2004) Blood 103:2738-2743]. FcRn binding and *in vivo* clearance/half-life determinations can also be performed using methods known in the art [see, e.g., Petkova, S. B. et al. (2006) Intl. Immunol. 18(12):1759-1769]. Antibodies of the present disclosure with reduced effector function include those with substitution of one or more of Fc region residues 238, 265, 269, 270, 297, 327 and 329 (U.S. Pat. No. 6,737,056). Such Fc mutants include Fc mutants with substitutions at two or more of amino acid positions 265, 269, 270, 297 and 327, including the so-called "DANA" Fc mutant with substitution of residues 265 and 297 to alanine (U.S. Pat. No. 7,332,581).

[0222] In certain instances, it may be desirable to create cysteine engineered antibodies, e.g., "thioMAbs," in which one or more residues of an antibody are substituted with cysteine residues. In particular instances, the substituted residues occur at accessible sites of the antibody. By substituting those residues with cysteine, reactive thiol groups are thereby positioned at accessible sites of the antibody and may be used to conjugate the antibody to other moieties, such as drug moieties or linker-drug moieties, to create an immunoconjugate, as described further herein. In certain instances, any one or more of the following residues may be substituted with cysteine: V205 (Kabat numbering) of the light chain; A118 (EU numbering) of the heavy chain; and S400 (EU numbering) of the heavy chain Fc region. Cysteine engineered antibodies may be generated as described, for example, in U.S. Pat. No. 7,521,541.

[0223] In addition, the techniques used to screen antibodies in order to identify a desirable antibody may influence the properties of the antibody obtained. For example, if an antibody is to be used for binding an antigen in solution, it may be desirable to test solution binding. A variety of different techniques are available for testing interactions between antibodies and antigens to identify particularly desirable antibodies. Such techniques include ELISAs, surface plasmon resonance binding assays (e.g., the Biacore binding assay, Biacore AB, Uppsala, Sweden), sandwich assays (e.g., the paramagnetic bead system of IGEN International, Inc., Gaithersburg, Maryland), western blots, immunoprecipitation assays, and immunohistochemistry.

[0224] In certain instances, amino acid sequence variants of the antibodies and/or the binding polypeptides provided herein are contemplated. For example, it may be desirable to improve the binding affinity and/or other biological properties of the antibody and/or binding polypeptide. Amino acid sequence variants of an antibody and/or binding polypeptides may be prepared by introducing appropriate modifications into the nucleotide sequence encoding the

antibody and/or binding polypeptide, or by peptide synthesis. Such modifications include, for example, deletions from, and/or insertions into and/or substitutions of residues within the amino acid sequences of the antibody and/or binding polypeptide. Any combination of deletion, insertion, and substitution can be made to arrive at the final construct, provided that the final construct possesses the desired characteristics, e.g., target-binding (e.g., and activin such as activin E and/or activin C binding).

[0225] Alterations (e.g., substitutions) may be made in HVRs, for example, to improve antibody affinity. Such alterations may be made in HVR "hotspots," i.e., residues encoded by codons that undergo mutation at high frequency during the somatic maturation process [see, e.g., Chowdhury (2008) *Methods Mol. Biol.* 207:179-196 (2008)], and/or SDRs (a-CDRs), with the resulting variant VH or VL being tested for binding affinity. Affinity maturation by constructing and reselecting from secondary libraries has been described in the art [see, e.g., Hoogenboom et al., in *Methods in Molecular Biology* 178:1-37, O'Brien et al., ed., Human Press, Totowa, N.J., (2001)]. In some instances of affinity maturation, diversity is introduced into the variable genes chosen for maturation by any of a variety of methods (e.g., error-prone PCR, chain shuffling, or oligonucleotide-directed mutagenesis). A secondary library is then created. The library is then screened to identify any antibody variants with the desired affinity. Another method to introduce diversity involves HVR-directed approaches, in which several HVR residues (e.g., 4-6 residues at a time) are randomized. HVR residues involved in antigen binding may be specifically identified, e.g., using alanine scanning mutagenesis or modeling. CDR-H3 and CDR-L3 in particular are often targeted.

[0226] In certain instances, substitutions, insertions, or deletions may occur within one or more HVRs so long as such alterations do not substantially reduce the ability of the antibody to bind to the antigen. For example, conservative alterations (e.g., conservative substitutions as provided herein) that do not substantially reduce binding affinity may be made in HVRs. Such alterations may be outside of HVR "hotspots" or SDRs. In certain instances of the variant VH and VL sequences provided above, each HVR either is unaltered, or contains no more than one, two or three amino acid substitutions.

[0227] A useful method for identification of residues or regions of the antibody and/or the binding polypeptide that may be targeted for mutagenesis is called "alanine scanning mutagenesis" as described by Cunningham and Wells (1989) *Science*, 244:1081-1085. In this method, a residue or group of target residues (e.g., charged residues such as Arg, Asp, His, Lys, and Glu) are identified and replaced by a neutral or negatively charged amino acid (e.g., alanine or polyalanine) to determine whether the interaction of the antibody-antigen is affected. Further substitutions may be introduced at the amino acid locations demonstrating functional sensitivity to the initial substitutions. Alternatively, or additionally, a crystal structure of an antigen-antibody complex is determined to identify contact points between the antibody and antigen. Such contact residues and neighboring residues may be targeted or eliminated as candidates for substitution. Variants may be screened to determine whether they contain the desired properties.

[0228] Amino acid sequence insertions include amino- and/or carboxyl-terminal fusions ranging in length from one residue to polypeptides containing a hundred or more residues, as well as intrasequence insertions of single or multiple amino acid residues. Examples of terminal insertions include an antibody with an N-terminal methionyl residue. Other insertional variants of the antibody molecule include the fusion of the N- or C-terminus of the antibody to an enzyme (e.g., for ADEPT) or a polypeptide which increases the serum half-life of the antibody.

[0229] In certain instances, an antibody and/or binding polypeptide provided herein may be further modified to contain additional nonproteinaceous moieties that are known in the art and readily available. The moieties suitable for derivatization of the antibody and/or binding polypeptide include but are not limited to water soluble polymers. Non-limiting examples of water soluble polymers include, but are not limited to, polyethylene glycol (PEG), copolymers of ethylene glycol/propylene glycol, carboxymethylcellulose, dextran, polyvinyl alcohol, polyvinyl pyrrolidone, poly-1,3-dioxolane, poly-1,3,6-trioxane, ethylene/maleic anhydride copolymer, polyaminoacids (either homopolymers or random copolymers), and dextran or poly(n-vinyl pyrrolidone)polyethylene glycol, propylene glycol homopolymers, polypropylene oxide/ethylene oxide co-polymers, polyoxyethylated polyols (e.g., glycerol), polyvinyl alcohol, and mixtures thereof. Polyethylene glycol propionaldehyde may have advantages in manufacturing due to its stability in water. The polymer may be of any molecular weight, and may be branched or unbranched. The number of polymers attached to the antibody and/or binding polypeptide may vary, and if more than one polymer are attached, they can be the same or different molecules. In general, the number and/or type of polymers used for derivatization can be determined based on considerations including, but not limited to, the particular properties or functions of the antibody and/or binding polypeptide to be improved, whether the antibody derivative and/or binding polypeptide derivative will be used in a therapy under defined conditions.

D. Small Molecule Antagonists

[0230] In other aspects, an ALK7:ActRIIB antagonist is a small molecule (ALK7:ActRIIB small molecule antagonist), or combination of small molecule antagonists. An ALK7:ActRIIB small molecule antagonist, or combination of small molecule antagonists, may inhibit, for example, one or more ALK7:ActRIIB-binding ligands, a type I receptor (e.g., ALK7), a type II receptor (e.g., ActRIIB), and/or co-receptor (e.g., Cripto or Cryptic). In some instances, ALK7:ActRIIB small molecule antagonist, or combination of small molecule antagonists, inhibits signaling mediated by one or more ALK7:ActRIIB-binding ligands, for example, as determined in a cell-based assay such as those described herein. As described herein, ALK7:ActRIIB small molecule antagonists may be used, alone or in combination with one or more supportive therapies or active agents, to treat a patient in need thereof (e.g., patients having kidney disease and/or a metabolic disorder).

[0231] In some instances, an ALK7:ActRIIB small molecule antagonist, or combination of small molecule antagonists, inhibits at least GDF11. In some instances, an ALK7:ActRIIB small

molecule antagonist, or combination of small molecule antagonists, inhibits at least GDF8. In some instances, an ALK7:ActRIIB small molecule antagonist, or combination of small molecule antagonists, inhibits at least activin (activin A, activin B, activin C, activin E, activin AB, activin AC, activin BC, activin AE and/or activin BE). In some instances, an ALK7:ActRIIB small molecule antagonist, or combination of small molecule antagonists, inhibits at least GDF11, GDF8, and activin. In some instances, an ALK7:ActRIIB small molecule antagonist, or combination of small molecule antagonists, inhibits at least ALK7. In some instances, an ALK7:ActRIIB small molecule antagonist, or combination of small molecule antagonists, inhibits at least ActRIIB. In some instances, an ALK7:ActRIIB small molecule antagonist, or combination of small molecule antagonists, inhibits at least Cripto or Cryptic. In some instances, an ALK7:ActRIIB small molecule antagonist, or combination of small molecule antagonists, inhibits at least BMP6. In some instances, an ALK7:ActRIIB small molecule antagonist, or combination of small molecule antagonists, inhibits at least GDF3. In some instances, an ALK7:ActRIIB small molecule antagonist, or combination of small molecule antagonists, inhibits at least BMP5. In some instances, an ALK7:ActRIIB small molecule antagonist, or combination of small molecule antagonists, inhibits at least BMP10. In some instances, an ALK7:ActRIIB small molecule antagonist, or combination of small molecule antagonists, inhibits at least nodal. In some instances, an ALK7:ActRIIB small molecule antagonist, or combination of small molecule antagonists, as disclosed herein does not inhibit or does not substantially inhibit BMP9.

[0232] ALK7:ActRIIB small molecule antagonists can be direct or indirect inhibitors. For example, an indirect small molecule antagonist, or combination of small molecule antagonists, may inhibit the expression (*e.g.*, transcription, translation, cellular secretion, or combinations thereof) of at least one or more TGF- β superfamily ligands [*e.g.*, activin (*e.g.*, activin A, activin B, activin C, activin E, activin AB, activin AC, activin B, activin BC, activin AE, or Activin BE), GDF11, BMP10, BMP9, BMP6, BMP5, GDF3, activin C, activin E, Activin AC, GDF8, BMP10, BMP6, BMP5, nodal, and GDF3, type I receptor (*e.g.*, ALK7), type II receptors (*e.g.*, ActRIIB), co-receptor (*e.g.*, Cripto or Cryptic), and/or one or more downstream signaling components (*e.g.*, Smads). Alternatively, a direct small molecule antagonist, or combination of small molecule antagonists, may directly bind to and inhibit, for example, one or more TGF- β superfamily ligands [*e.g.*, activin (*e.g.*, activin A, activin B, activin C, activin E, activin AB, activin AC, activin B, activin BC, activin AE, or Activin BE), GDF11, BMP10, BMP9, BMP6, BMP5, GDF3, activin C, activin E, activin AC, GDF8, BMP10. BMP6, BMP5, nodal, and GDF3, type I receptors (*e.g.*, ALK7), type II receptors (*e.g.*, ActRIIB), co-receptors (*e.g.*, Cripto or Cryptic), and/or downstream signaling components (*e.g.*, Smads). Combinations of one or more indirect and one or more direct ALK7:ActRIIB small molecule antagonists may be used in accordance with the methods disclosed herein.

[0233] Binding small-molecule antagonists of the present disclosure may be identified and chemically synthesized using known methodology (see, *e.g.*, PCT Publication Nos. WO 00/00823 and WO 00/39585). In general, small molecule antagonists of the disclosure are usually less than about 2000 daltons in size, alternatively less than about 1500, 750, 500, 250 or 200 daltons in size, wherein such organic small molecules that are capable of binding,

preferably specifically, to a polypeptide as described herein. These small molecule antagonists may be identified without undue experimentation using well-known techniques. In this regard, it is noted that techniques for screening organic small-molecule libraries for molecules that are capable of binding to a polypeptide target are well known in the art (see, e.g., international patent publication Nos. WO00/00823 and WO00/39585).

[0234] Binding organic small molecules of the present disclosure may be, for example, aldehydes, ketones, oximes, hydrazones, semicarbazones, carbazides, primary amines, secondary amines, tertiary amines, N-substituted hydrazines, hydrazides, alcohols, ethers, thiols, thioethers, disulfides, carboxylic acids, esters, amides, ureas, carbamates, carbonates, ketals, thioketals, acetals, thioacetals, aryl halides, aryl sulfonates, alkyl halides, alkyl sulfonates, aromatic compounds, heterocyclic compounds, anilines, alkenes, alkynes, diols, amino alcohols, oxazolidines, oxazolines, thiazolidines, thiazolines, enamines, sulfonamides, epoxides, aziridines, isocyanates, sulfonyl chlorides, diazo compounds, and acid chlorides.

E. Polynucleotide Antagonists

[0235] In other aspects, an ALK7:ActRIIB antagonist is a polynucleotide (ALK7:ActRIIB polynucleotide antagonist), or combination of polynucleotides. An ALK7:ActRIIB polynucleotide antagonist, or combination of polynucleotide antagonists, may inhibit, for example, one or more ALK7:ActRIIB-binding ligands, type I receptors (e.g., ALK7), type II receptors (e.g., ActRIIB), co-receptor (e.g., Cripto or Cryptic), and/or downstream signaling component (e.g., Smads). In some instances, ALK7:ActRIIB polynucleotide antagonist, or combination of polynucleotide antagonists, inhibits signaling mediated by one or more ALK7:ActRIIB-binding ligands, for example, as determined in a cell-based assay such as those described herein. As described herein, ALK7:ActRIIB polynucleotide antagonists may be used, alone or in combination with one or more supportive therapies or active agents, to treat a patient in need thereof (e.g., patients having kidney disease and/or a metabolic disorder).

[0236] In some instances, an ALK7:ActRIIB polynucleotide antagonists, or combination of polynucleotide antagonists, inhibits at least GDF11. In some instances, an ALK7:ActRIIB polynucleotide antagonist, or combination of polynucleotide antagonists, inhibits at least GDF8. In some instances, an ALK7:ActRIIB polynucleotide antagonist, or combination of polynucleotide antagonists, inhibits at least activin (activin A, activin B, activin C, activin E, activin AB, activin AC, activin AE, activin BC and/or activin BE). In some instances, an ALK7:ActRIIB polynucleotide antagonist, or combination of polynucleotide antagonists, inhibits at least GDF11, GDF8, and activin. In some instances, an ALK7:ActRIIB polynucleotide antagonist, or combination of polynucleotide antagonists, inhibits at least ALK7. In some instances, an ALK7:ActRIIB polynucleotide antagonist, or combination of polynucleotide antagonists, inhibits at least ActRIIB. In some instances, an ALK7:ActRIIB polynucleotide antagonist, or combination of polynucleotide antagonists, inhibits at least Cripto or Cryptic. In some instances, an ALK7:ActRIIB polynucleotide antagonist, or combination of polynucleotide antagonists, inhibits at least ActRIIB. In some instances, an ALK7:ActRIIB polynucleotide

antagonist, or combination of polynucleotide antagonists, inhibits at least BMP6. In some instances, an ALK7:ActRIIB polynucleotide antagonist, or combination of polynucleotide antagonists, inhibits at least GDF3. In some instances, an ALK7:ActRIIB polynucleotide antagonist, or combination of polynucleotide antagonists, inhibits at least BMP10. In some instances, an ALK7:ActRIIB polynucleotide antagonist, or combination of polynucleotide antagonists, inhibits at least BMP5. In some instances, an ALK7:ActRIIB polynucleotide antagonist, or combination of polynucleotide antagonist, inhibits at least nodal. In some instances, an ALK7:ActRIIB polynucleotide antagonist, or combination of polynucleotide antagonists, as disclosed herein does not inhibit or does not substantially inhibit BMP9.

[0237] In some instances, the polynucleotide antagonists of the disclosure may be an antisense nucleic acid, an RNAi molecule [e.g., small interfering RNA (siRNA), small-hairpin RNA (shRNA), microRNA (miRNA)], an aptamer and/or a ribozyme. The nucleic acid and amino acid sequences of human GDF11, GDF8, activin (activin A, activin B, activin C, and activin E), BMP6, GDF3, BMP5, ALK7, ActRIIB, Cripto, Cryptic, Nodal, and BMP10 are known in the art. In addition, many different methods of generating polynucleotide antagonists are well known in the art. Therefore polynucleotide antagonists for use in accordance with this disclosure may be routinely made by the skilled person in the art based on the knowledge in the art and teachings provided herein.

[0238] Antisense technology can be used to control gene expression through antisense DNA or RNA, or through triple-helix formation. Antisense techniques are discussed, for example, in Okano (1991) *J. Neurochem.* 56:560; Oligodeoxynucleotides as Antisense Inhibitors of Gene Expression, CRC Press, Boca Raton, Fla. (1988). Triple-helix formation is discussed in, for instance, Cooney et al. (1988) *Science* 241:456; and Dervan et al., (1991) *Science* 251:1300. The methods are based on binding of a polynucleotide to a complementary DNA or RNA. In some instances, the antisense nucleic acids comprise a single-stranded RNA or DNA sequence that is complementary to at least a portion of an RNA transcript of a gene disclosed herein. However, absolute complementarity, although preferred, is not required.

[0239] A sequence "complementary to at least a portion of an RNA," referred to herein, means a sequence having sufficient complementarity to be able to hybridize with the RNA, forming a stable duplex; in the case of double-stranded antisense nucleic acids of a gene disclosed herein, a single strand of the duplex DNA may thus be tested, or triplex formation may be assayed. The ability to hybridize will depend on both the degree of complementarity and the length of the antisense nucleic acid. Generally, the larger the hybridizing nucleic acid, the more base mismatches with an RNA it may contain and still form a stable duplex (or triplex as the case may be). One skilled in the art can ascertain a tolerable degree of mismatch by use of standard procedures to determine the melting point of the hybridized complex.

[0240] Polynucleotides that are complementary to the 5' end of the message, for example, the 5'-untranslated sequence up to and including the AUG initiation codon, should work most efficiently at inhibiting translation. However, sequences complementary to the 3'-untranslated sequences of mRNAs have been shown to be effective at inhibiting translation of mRNAs as

well [see, e.g., Wagner, R., (1994) *Nature* 372:333-335]. Thus, oligonucleotides complementary to either the 5'- or 3'-non-translated, non-coding regions of a gene of the disclosure, could be used in an antisense approach to inhibit translation of an endogenous mRNA. Polynucleotides complementary to the 5'-untranslated region of the mRNA should include the complement of the AUG start codon. Antisense polynucleotides complementary to mRNA coding regions are less efficient inhibitors of translation but could be used in accordance with the methods of the present disclosure. Whether designed to hybridize to the 5'-, 3'- or coding region of an mRNA of the disclosure, antisense nucleic acids should be at least six nucleotides in length, and are preferably oligonucleotides ranging from 6 to about 50 nucleotides in length. In specific aspects the oligonucleotide is at least 10 nucleotides, at least 17 nucleotides, at least 25 nucleotides or at least 50 nucleotides.

[0241] In one instance, the antisense nucleic acid of the present disclosure is produced intracellularly by transcription from an exogenous sequence. For example, a vector or a portion thereof is transcribed, producing an antisense nucleic acid (RNA) of a gene of the disclosure. Such a vector would contain a sequence encoding the desired antisense nucleic acid. Such a vector can remain episomal or become chromosomally integrated, as long as it can be transcribed to produce the desired antisense RNA. Such vectors can be constructed by recombinant DNA technology methods standard in the art. Vectors can be plasmid, viral, or others known in the art, used for replication and expression in vertebrate cells. Expression of the sequence encoding desired genes of the instant disclosure, or fragments thereof, can be by any promoter known in the art to act in vertebrate, preferably human cells. Such promoters can be inducible or constitutive. Such promoters include, but are not limited to, the SV40 early promoter region [see, e.g., Benoist and Chambon (1981) *Nature* 290:304-310], the promoter contained in the 3' long-terminal repeat of Rous sarcoma virus [see, e.g., Yamamoto et al. (1980) *Cell* 22:787-797], the herpes thymidine promoter [see, e.g., Wagner et al. (1981) *Proc. Natl. Acad. Sci. U.S.A.* 78:1441-1445], and the regulatory sequences of the metallothionein gene [see, e.g., Brinster, et al. (1982) *Nature* 296:39-42].

[0242] In some instances, the polynucleotide antagonists are interfering RNA (RNAi) molecules that target the expression of one or more of: GDF11, GDF8, activin (activin A, activin B, activin C, and activin E), BMP6, GDF3, BMP5, ALK7, ActRIIB, Cripto, Cryptic, nodal, and BMP 10. RNAi refers to the expression of an RNA which interferes with the expression of the targeted mRNA. Specifically, RNAi silences a targeted gene via interacting with the specific mRNA through a siRNA (small interfering RNA). The ds RNA complex is then targeted for degradation by the cell. An siRNA molecule is a double-stranded RNA duplex of 10 to 50 nucleotides in length, which interferes with the expression of a target gene which is sufficiently complementary (e.g. at least 80% identity to the gene). In some instances, the siRNA molecule comprises a nucleotide sequence that is at least 85, 90, 95, 96, 97, 98, 99, or 100% identical to the nucleotide sequence of the target gene.

[0243] Additional RNAi molecules include short-hairpin RNA (shRNA); also short-interfering hairpin and microRNA (miRNA). The shRNA molecule contains sense and antisense sequences from a target gene connected by a loop. The shRNA is transported from the

nucleus into the cytoplasm, and it is degraded along with the mRNA. Pol III or U6 promoters can be used to express RNAs for RNAi. Paddison et al. [Genes & Dev. (2002) 16:948-958, 2002] have used small RNA molecules folded into hairpins as a means to affect RNAi. Accordingly, such short-hairpin RNA (shRNA) molecules are also advantageously used in the methods described herein. The length of the stem and loop of functional shRNAs varies; stem lengths can range anywhere from about 25 to about 30 nt, and loop size can range between 4 to about 25 nt without affecting silencing activity. While not wishing to be bound by any particular theory, it is believed that these shRNAs resemble the double-stranded RNA (dsRNA) products of the DICER RNase and, in any event, have the same capacity for inhibiting expression of a specific gene. The shRNA can be expressed from a lentiviral vector. An miRNA is a single-stranded RNA of about 10 to 70 nucleotides in length that are initially transcribed as pre-miRNA characterized by a "stem-loop" structure, which are subsequently processed into mature miRNA after further processing through the RISC.

[0244] Molecules that mediate RNAi, including without limitation siRNA, can be produced *in vitro* by chemical synthesis (Hohjoh, FEBS Lett 521:195-199, 2002), hydrolysis of dsRNA (Yang et al., Proc Natl Acad Sci USA 99:9942-9947, 2002), by *in vitro* transcription with T7 RNA polymerase (Donzeet et al., Nucleic Acids Res 30:e46, 2002; Yu et al., Proc Natl Acad Sci USA 99:6047-6052, 2002), and by hydrolysis of double-stranded RNA using a nuclease such as *E. coli* RNase III (Yang et al., Proc Natl Acad Sci USA 99:9942-9947, 2002).

[0245] According to another aspect, the disclosure provides polynucleotide antagonists including but not limited to, a decoy DNA, a double-stranded DNA, a single-stranded DNA, a complexed DNA, an encapsulated DNA, a viral DNA, a plasmid DNA, a naked RNA, an encapsulated RNA, a viral RNA, a double-stranded RNA, a molecule capable of generating RNA interference, or combinations thereof.

[0246] In some instances, the polynucleotide antagonists of the disclosure are aptamers. Aptamers are nucleic acid molecules, including double-stranded DNA and single-stranded RNA molecules, which bind to and form tertiary structures that specifically bind to a target molecule. The generation and therapeutic use of aptamers are well established in the art (see, e.g., U.S. Pat. No. 5,475,096). Additional information on aptamers can be found in U.S. Patent Application Publication No. 20060148748. Nucleic acid aptamers are selected using methods known in the art, for example via the Systematic Evolution of Ligands by Exponential Enrichment (SELEX) process. SELEX is a method for the *in vitro* evolution of nucleic acid molecules with highly specific binding to target molecules as described in, e.g., U.S. Pat. Nos. 5,475,096; 5,580,737; 5,567,588; 5,707,796; 5,763,177; 6,011,577; and 6,699,843. Another screening method to identify aptamers is described in U.S. Pat. No. 5,270,163. The SELEX process is based on the capacity of nucleic acids for forming a variety of two- and three-dimensional structures, as well as the chemical versatility available within the nucleotide monomers to act as ligands (form specific binding pairs) with virtually any chemical compound, whether monomeric or polymeric, including other nucleic acid molecules and polypeptides. Molecules of any size or composition can serve as targets. The SELEX method involves selection from a mixture of candidate oligonucleotides and stepwise iterations of binding,

partitioning and amplification, using the same general selection scheme, to achieve desired binding affinity and selectivity. Starting from a mixture of nucleic acids, which can comprise a segment of randomized sequence, the SELEX method includes steps of contacting the mixture with the target under conditions favorable for binding; partitioning unbound nucleic acids from those nucleic acids which have bound specifically to target molecules; dissociating the nucleic acid-target complexes; amplifying the nucleic acids dissociated from the nucleic acid-target complexes to yield a ligand enriched mixture of nucleic acids. The steps of binding, partitioning, dissociating and amplifying are repeated through as many cycles as desired to yield nucleic acid ligands which bind with high affinity and specificity to the target molecule.

[0247] Typically, such binding molecules are separately administered to the animal [see, e.g., O'Connor (1991) J. Neurochem. 56:560], but such binding molecules can also be expressed *in vivo* from polynucleotides taken up by a host cell and expressed *in vivo* [see, e.g., Oligodeoxynucleotides as Antisense Inhibitors of Gene Expression, CRC Press, Boca Raton, Fla. (1988)].

F. Follistatin and FLRG Antagonists

[0248] It is known that members of the follistatin and FLRG group of proteins antagonize ligands that signal through the ALK7:ActRIIB pathway. Accordingly, in other aspects, an ALK7:ActRIIB antagonist is a follistatin or FLRG polypeptide, which may be used alone or in combination with one or more additional supportive therapies and/or active agents as disclosed herein to achieve a desired effect (e.g., treat patients having kidney disease and/or a metabolic disorder).

[0249] The term "follistatin polypeptide" includes polypeptides comprising any naturally occurring polypeptide of follistatin as well as any variants thereof (including mutants, fragments, fusions, and peptidomimetic forms) that retain a useful activity, and further includes any functional monomer or multimer of follistatin. In certain preferred instances, follistatin polypeptides of the disclosure bind to and/or inhibit activin and/or GDF8 activity. Variants of follistatin polypeptides that retain activin binding properties can be identified based on previous studies involving follistatin and activin interactions. For example, WO2008/030367 discloses specific follistatin domains ("FSDs") that are shown to be important for activin binding. As shown below in SEQ ID NOs: 90-94, the follistatin N-terminal domain ("FSND" SEQ ID NO: 92), FSD2 (SEQ ID NO: 94), and to a lesser extent FSD1 (SEQ ID NO: 93) represent exemplary domains within follistatin that are important for activin binding. In addition, methods for making and testing libraries of polypeptides are described above in the context of ActRII polypeptides, and such methods also pertain to making and testing variants of follistatin. Follistatin polypeptides include polypeptides derived from the sequence of any known follistatin having a sequence at least about 80% identical to the sequence of a follistatin polypeptide, and optionally at least 85%, 90%, 95%, 96%, 97%, 98%, 99% or greater identity. Examples of follistatin polypeptides include the mature follistatin polypeptide or shorter isoforms or other variants of the human follistatin precursor polypeptide (SEQ ID NO: 90) as described, for

example, in WO2005/025601.

[0250] The human follistatin precursor polypeptide isoform FST344 is as follows:

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1  MVRARHQPGG LCLLLLLLCQ FMEDRSAQAG NCWLRQAKNG RCQVLYKTEL
51 SKEECCSTGR LSTSWTEEDV NDNTLFKWMI FNGGAPNCIP CKETCENVDC
101 GPGKKCRMNK KNKPRVCAP DCSNITWKGP VCGLDGKTYR NECALLKARC
151 KEQPELEVQY QGRCKKTCRD VFCPGSSTCV VDQTNNAYCV TCNRICPEPA
201 SSEQYLCGND GVTYSSACHL RKATCLLGRS IGLAYEGKCI KAKSCEDIQC
251 TGGKKCLWDF KVGRGRCSLC DELCPDSKSD EPVCASDNAT YASECAMKEA
301 ACSSGVLLEV KHSGSCNSIS EDTEEEEEDE DQDYSFPISS ILEW

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(SEQ ID NO: 90; NCBI Reference No. NP_037541.1)

[0251] The signal peptide is underlined; also underlined above are the last 27 residues which represent the C-terminal extension distinguishing this follistatin isoform from the shorter follistatin isoform FST317 shown below.

[0252] The human follistatin precursor polypeptide isoform FST317 is as follows:

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1  MVRARHQPGG LCLLLLLLCQ FMEDRSAQAG NCWLRQAKNG
RCQVLYKTEL
51 SKEECCSTGR LSTSWTEEDV NDNTLFKWMI FNGGAPNCIP CKETCENVDC
101 GPGKKCRMNK KNKPRVCAP DCSNITWKGP VCGLDGKTYR
NECALLKARC
151 KEQPELEVQY QGRCKKTCRD VFCPGSSTCV VDQTNNAYCV TCNRICPEPA
201 SSEQYLCGND GVTYSSACHL RKATCLLGRS IGLAYEGKCI KAKSCEDIQC
251 TGGKKCLWDF KVGRGRCSLC DELCPDSKSD EPVCASDNAT
YASECAMKEA
301 ACSSGVLLEV KHSGSCN (SEQ ID NO: 91; NCBI Reference No. NP_006341.1)

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The signal peptide is underlined.

[0253] The follistatin N-terminal domain (FSND) sequence is as follows:

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GNCWLRQAKNGRCQVLYKTELSKEECCSTGRLSTSWTEEDVNDN
TLFKWMIFNGGAPNCIPCK (SEQ ID NO: 92; FSND)

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[0254] The FSD1 and FSD2 sequences are as follows:

ETCENVDCGPGKKCRMNKKNKPRCV (SEQ ID NO: 93; FSD1)

KTCRDVFCPGSSTCVVDQTNNAYCVT (SEQ ID NO: 94; FSD2)

[0255] In other aspects, an ALK7:ActRIIB antagonist is a follistatin-like related gene (FLRG), also known as follistatin-related protein 3 (FSTL3). The term "FLRG polypeptide" includes

polypeptides comprising any naturally occurring polypeptide of FLRG as well as any variants thereof (including mutants, fragments, fusions, and peptidomimetic forms) that retain a useful activity. In certain instances, FLRG polypeptides of the disclosure bind to and/or inhibit activin activity, particularly activin A. Variants of FLRG polypeptides that retain activin binding properties can be identified using routine methods to assay FLRG and activin interactions (see, e.g., US 6,537,966). In addition, methods for making and testing libraries of polypeptides are described above in the context of ActRII and ALK7 polypeptides and such methods also pertain to making and testing variants of FLRG. FLRG polypeptides include polypeptides derived from the sequence of any known FLRG having a sequence at least about 80% identical to the sequence of an FLRG polypeptide, and optionally at least 85%, 90%, 95%, 97%, 99% or greater identity.

[0256] The human FLRG precursor (follistatin-related protein 3 precursor) polypeptide is as follows:

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1   MRPGAPGPLW PLPWGALAWA VGFVSSMGSG NPAPGGVCWL QQGQEATCSL
51  VLQTDVTRAE CCASGNIDTA WSNLTHPGNK INLLGFLGLV HCLPCKDSCD
101 GVECGPGKAC RMLGGRPRCE CAPDCSGLPA RLQVCGSDGA TYRDECELRA
151 ARCRGHPDLS VMYRGRCRKS CEHVVCPRPQ SCVVDQTGSA HCVVCRAAPC
201 PVPSSPGQEL CGNNNVTYIS SCHMRQATCF LGRSIGVRHA GSCAGTPEEP
251 PGGESAEEDD NFV (SEQ ID NO: 95; NCBI Reference No. NP_005851.1)

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The signal peptide is underlined.

[0257] In certain instances, functional variants or modified forms of the follistatin polypeptides and FLRG polypeptides include fusion proteins having at least a portion of the follistatin polypeptide or FLRG polypeptide and one or more fusion domains, such as, for example, domains that facilitate isolation, detection, stabilization or multimerization of the polypeptide. Suitable fusion domains are discussed in detail above with reference to the ActRII polypeptides. In some instance, an antagonist agent of the disclosure is a fusion protein comprising an activin-binding portion of a follistatin polypeptide fused to an Fc domain. In another instance, an antagonist agent of the disclosure is a fusion protein comprising an activin binding portion of an FLRG polypeptide fused to an Fc domain.

G. Lefty A and B

[0258] The Lefty A and B proteins are known to regulate Nodal and other proteins that signal through the ALK7:ActRIIB pathway. Accordingly, in other aspects, an ALK7:ActRIIB antagonist is a Lefty A or Lefty B polypeptide, which may be used alone or in combination with one or more additional supportive therapies and/or active agents as disclosed herein to achieve a desired effect (e.g., treat kidney disease and/or a metabolic condition or disorder).

[0259] The term "Lefty A polypeptide" includes polypeptides comprising any naturally occurring

polypeptide of Lefty A as well as any variants thereof (including mutants, fragments, fusions, and peptidomimetic forms) that retain a useful activity, and further includes any functional monomer or multimer of Lefty A. In certain preferred instances, Lefty A polypeptides of the disclosure binds to and/or inhibit nodal activity. In addition, methods for making and testing libraries of polypeptides are described above in the context of ActRII and ALK7 polypeptides, and such methods also pertain to making and testing variants of Lefty A. Lefty A polypeptides include polypeptides derived from the sequence of any known Lefty A having a sequence at least about 80% identical to the sequence of a Lefty A polypeptide, and optionally at least 85%, 90%, 95%, 96%, 97%, 98%, 99% or greater identity. Examples of Lefty A polypeptides include the mature Lefty A polypeptide or shorter isoforms or other variants of the human Lefty A precursor polypeptide (SEQ ID NO: 96).

[0260] The human Lefty A precursor polypeptide is as follows:

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1  MWPLWLCWAL  WVLPLAGPGA  ALTEEQLLGS  LLRQLQLSEV  PVLDRADMEK  LVIPAHVRAQ
61  YVLLRRSHG  DSRGKRFSQ  SFREVAGRFL  ASEASTHLIV  FGMEQRLPPN  SELVQAVLRL
121 FQEPVPKAAL  HRHGRLSPRS  AQARVIVEWL  RVRDDGSNRT  SLIDSRLVSV  HESGWKAQDV
181 TEAVNFWQQL  SRPRQPLLLQ  VSVQREHLGP  LASGAHKLVR  FASQGAPAGL  GEPQLELHTL
241 DLRDYGAQGD  CDPEAPMTEG  TRCCRQEMYI  DLQGMKWAKN  WVLEPPGFLA  YECVGTCCQP
301 PEALAFNWP  LGPRQCIASE  TASLPMIVSI  KEGGRTRPQV  VSLPNMRVQK  CSCASDGALV
361 PRRLQP

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(SEQ ID NO: 96; GenBank Id: AAD48145.1)

The signal peptide is underlined.

[0261] The term "Lefty B polypeptide" includes polypeptides comprising any naturally occurring polypeptide of Lefty B as well as any variants thereof (including mutants, fragments, fusions, and peptidomimetic forms) that retain a useful activity, and further includes any functional monomer or multimer of Lefty B. In certain preferred instances, Lefty B polypeptides of the disclosure inhibit nodal activity. In addition, methods for making and testing libraries of polypeptides are described above in the context of ActRII and ALK7 polypeptides, and such methods also pertain to making and testing variants of Lefty B. Lefty B polypeptides include polypeptides derived from the sequence of any known Lefty B having a sequence at least about 80% identical to the sequence of a Lefty B polypeptide, and optionally at least 85%, 90%, 95%, 96%, 97%, 98%, 99% or greater identity. Examples of Lefty B polypeptides include the mature Lefty B polypeptide or shorter isoforms or other variants of the human Lefty B precursor polypeptide (SEQ ID NO: 97).

[0262] The human Lefty B precursor polypeptide is as follows:

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1  MQPLWLCWAL  WVLPLASPGA  ALTGEQLLGS  LLRQLQLKEV  PTLDRADMEE  LVIPTHVRAQ
61  YVALLQRSHG  DSRGKRFSQ  SFREVAGRFL  ALEASTHLIV  FGMEQRLPPN  SELVQAVLRL
121 FQEPVPKAAL  HRHGRLSPRS  ARARVIVEWL  RVRDDGSNRT  SLIDSRLVSV  HESGWKAQDV
181 TEAVNFWQQL  SRPRQPLLLQ  VSVQREHLGP  LASGAHKLVR  FASQGAPAGL  GEPQLELHTL
241 DLGDYGAQGD  CDPEAPMTEG  TRCCRQEMYI  DLQGMKWAEN  WVLEPPGFLA  YECVGTCTQP
301 PEALAFKWP  LGPRQCIASE  TDSLPMIVSI  KEGGRTRPQV  VSLPNMRVQK  CSCASDGALV
361 PRRLQP

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(SEQ ID NO: 97; GenBank Id: AAD48144.1)

The signal peptide is underlined.

[0263] In certain instances, functional variants or modified forms of the Lefty A polypeptides and Lefty B polypeptides include fusion proteins having at least a portion of the Lefty A polypeptide or Lefty B polypeptide and one or more fusion domains, such as, for example, domains that facilitate isolation, detection, stabilization or multimerization of the polypeptide.

Suitable fusion domains are discussed in detail above with reference to the ActRII and ALK7 polypeptides. In some instance, an antagonist agent of the disclosure is a fusion protein comprising a nodal-binding portion of a Lefty A and/or Lefty B polypeptide fused to an Fc domain.

H. DAN-related Proteins

[0264] Members of the DAN family of proteins are known to regulate ligands that signal through the ALK7:ActRIIB pathway. Accordingly, in other aspects, an ALK7:ActRIIB antagonist is a DAN-related protein (e.g., Cerberus and Coco), which may be used alone or in combination with one or more additional supportive therapies and/or active agents as disclosed herein to achieve a desired effect (e.g., treat patients having kidney disease and/or a metabolic disorder).

[0265] The term "Cerberus polypeptide" includes polypeptides comprising any naturally occurring polypeptide of Cerberus as well as any variants thereof (including mutants, fragments, fusions, and peptidomimetic forms) that retain a useful activity, and further includes any functional monomer or multimer of Cerberus. In certain preferred instances, Cerberus polypeptides of the disclosure bind to and/or inhibit nodal activity. In addition, methods for making and testing libraries of polypeptides are described above in the context of ActRII and ALK7 polypeptides, and such methods also pertain to making and testing variants of Cerberus. Cerberus polypeptides include polypeptides derived from the sequence of any known Cerberus having a sequence at least about 80% identical to the sequence of a Cerberus polypeptide, and optionally at least 85%, 90%, 95%, 96%, 97%, 98%, 99% or greater identity. Examples of Cerberus polypeptides include the mature Cerberus polypeptide or shorter isoforms or other variants of the human Cerberus precursor polypeptide (SEQ ID NO: 98).

[0266] The human Cerberus precursor polypeptide is as follows:

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1  MHLLLFQLLV LLPLGKTTRH QDGRQNQSSL SPVLLPRNQR ELPTGNHEEA EEKPDLEFVAV
61 PHLVATSPAG EGQRQREKML SRFGREWKKP EREMHPSRDS DSEPFPPGTQ SLIQPIDGMK
121 MEKSPLREEA KKFVHHFMFR KTPASQGVIL PIKSHEVHWE TCRTVPFSQT ITHGCEKVV
181 VQNNLCFGKC GSVHFPGAAQ HSHTSCSHCL PAKFTTMHLP LNCTELSSVI KVVMLVEECQ
241 CKVKTEHEDG HILHAGSQDS FIPGVSA

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(SEQ ID NO: 98; NCBI Reference: NP_005445.1)

The signal peptide is underlined.

[0267] The term "Coco polypeptide" includes polypeptides comprising any naturally occurring polypeptide of Coco as well as any variants thereof (including mutants, fragments, fusions, and peptidomimetic forms) that retain a useful activity, and further includes any functional monomer or multimer of Coco. In certain preferred instances, Coco polypeptides of the disclosure bind to and/or inhibit nodal activity. In addition, methods for making and testing libraries of polypeptides are described above in the context of ActRII and ALK7 polypeptides, and such methods also pertain to making and testing variants of Coco. Coco polypeptides include polypeptides derived from the sequence of any known Coco having a sequence at least about 80% identical to the sequence of a Coco polypeptide, and optionally at least 85%, 90%, 95%,

96%, 97%, 98%, 99% or greater identity. Examples of Coco polypeptides include the mature Coco polypeptide or shorter isoforms or other variants of the human Coco precursor polypeptide (SEQ ID NO: 99).

[0268] The human Coco precursor polypeptide is as follows:

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1  MLLGQLSTLL CLLSGALPTG SGRPEPQSPR PQSWAAANQT WALGPGALPP LVPASALGSW
61 KAFLGLQKAR QLGMGRLOQG QDEVAAVTLP LNPQEVIGGM CKAVPFVQVF SRPGCSAIRL
121 RNHLCFGHCS SLYIPGSDPT PLVLCNSCMP ARKRWAPVVL WCLIGSSASR RRVKISTMLI
181 EGCHCSPKA
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(SEQ ID NO: 99; GenBank Id:)

The signal peptide is underlined.

[0269] In certain instances, functional variants or modified forms of the Cerberus polypeptides and Coco polypeptides include fusion proteins having at least a portion of the Cerberus polypeptide and/or Coco polypeptide and one or more fusion domains, such as, for example, domains that facilitate isolation, detection, stabilization or multimerization of the polypeptide. Suitable fusion domains are discussed in detail above with reference to the ActRII and ALK7 polypeptides. In some instance, an antagonist agent of the disclosure is a fusion protein comprising a nodal-binding portion of a Cerberus and/or Coco polypeptide fused to an Fc domain.

3. Screening Assays

[0270] In certain instances, ALK7:ActRIIB receptor heteromultimers (e.g., ALK7:ActRIIB heterodimers) may be used to generate and/or screen for ALK7:ActRIIB inhibitors, particularly inhibitors that interfere with ALK7-ligand and/or ALK7-Type II receptor (e.g., ActRIIB) interaction (e.g., anti-ALK7 antibodies).

[0271] As discussed herein, TGF-beta superfamily ligand signals are mediated by complexes of Type I and Type II kinase receptors, which phosphorylate and activate downstream Smad proteins upon ligand stimulation [see, e.g., Massague (2000) Nat. Rev. Mol. Cell. Biol. 1: 169-178]. While essential for signaling, Type I receptors generally have very weak affinity for TGF-beta superfamily ligands. Instead, Type II receptors generally bind to ligands with high affinity. This ligand binding promotes stable complex formation between Type I and II receptors, resulting in phosphorylation of type I receptors by Type II receptors and thus activation of Smad proteins. In view of the weaker affinity, it is generally difficult to observe ligand binding activity of Type I receptors in isolation.

[0272] Indeed, the examples herein demonstrate that an ActRIIB homodimer binds to many different ligands, many with high affinity. In contrast, an ALK7 homodimer did not display affinity for any of the ligands examined. As ligands do not detectably bind to ALK7, it is difficult to screen for/identify agents that can inhibit ALK7 activity. However, as demonstrated by the examples herein, the ligand-binding activity of ALK7 becomes measureable when paired with a

type II receptor. Thus, ALK7:ActRIIB heteromultimers (e.g., heterodimers) are a useful tool for identifying ALK7 inhibitors using various screening assays such as described herein as well as those known in the art. Therefore, in some instances, the present disclosure relate to the use of ALK7:Type II receptor heteromultimers (e.g., ALK7:ActRIIB heteromultimers) to identify (screen for) ALK7 inhibitors.

[0273] For example, ALK7:Type II receptor heteromultimers (e.g., ALK7:ActRIIB heteromultimers) may be particularly useful for generating/identifying antibodies that bind to ALK7, particularly antibodies that bind to and inhibit ALK7. While ALK7 polypeptides, including ALK7 homodimers as described herein, may be used to generate/identify antibodies that bind to ALK7, simple binding is not sufficient to demonstrate that a given ALK7 antibody can inhibit an ALK7 activity (e.g., interfere with ALK7-ligand or ALK7-Type II receptor interactions). As demonstrated herein, ALK7 polypeptides do not display ligand-binding activity in the absence of a Type II receptor, making it difficult to identify antibodies that can inhibit ALK7. ALK7:Type II receptor heteromultimers (e.g., ALK7:ActRIIB heteromultimers) solve this problem by providing a functional read out for ALK7 activity. Moreover, without wishing to be bound to any particular mechanisms of action, association with a Type II receptor (e.g., ActRIIB) may improve the ability to generate antibodies that inhibit ALK7 activity. For example, association with a Type II receptor may help to stabilize ALK7 in such a way as to optimize the processing and presentation of important ALK7 epitopes that mediate ligand-binding activities and thus improve the development of ALK7 inhibitory antibodies. Therefore, in some instances, the present disclosure relates to the use of ALK7:Type II heteromultimers (e.g., ALK7:ActRIIB heteromultimers) to generate antibodies that bind to and inhibit ALK7. Methods for generating and screening for antibodies are well known in the art and described herein, and ALK7-Type II heteromultimers (e.g., ALK7:ActRIIB heteromultimers) may be used in accordance with one or more of these methods to generate/identify antibodies that bind to and inhibit ALK7 activity.

[0274] In certain instances, ALK7:Type II receptor heterodimers (e.g., ALK7:ActRIIB heteromultimers such as heterodimers) may be used to identify activin C inhibitors, particularly inhibitors that bind to activin C and interfere with activin C-Type I/II receptor interaction.

[0275] Surprisingly, the data presented herein demonstrates that ALK7:ActRIIB heterodimers bind to activin C. Insight into this novel interaction provides an opportunity to develop/identify activin C inhibitors. In addition, given the structural similarity between activin C and activin E, it is expected that activin E also binds to ALK7:ActRIIB, and thus this novel interaction may be used to identify activin E antagonists as well. Heterodimeric ligands, such as activin AC, AE, BC and BE are also included in the reference to activin C or E, respectively in this section of the disclosure. Agents that affect both activin C and E are also contemplated. Various types of activin C or E antagonists are expected to be useful in accordance with the methods described herein including, for example, small molecules, antibodies, and inhibitor nucleic acids, particularly those that disrupt activin C (or E)-ALK7:ActRIIB interaction. An agent (e.g., an antibody or small molecule) that is specifically reactive with activin C or E and which either binds to activin C or E so as to compete with its binding to ALK7 and/or ActRIIB or otherwise inhibits activin C or E-mediated signaling may be used as an antagonist of activin C or E.

Likewise, an agent that is specifically reactive with ALK7 and/or ActRIIB and which disrupts activin C or E binding may be used as an antagonist. In regard to antibodies, immunogens can be derived from an activin C or E polypeptide, ALK7 polypeptide, or ActRIIB polypeptide and used to generate antibodies using standard methods known in the art. See, e.g., *Antibodies: A Laboratory Manual* ed. by Harlow and Lane, Cold Spring Harbor Press, 1988. Using various screening assays known in the art such as those described herein, ALK7:Type II receptor heterodimers (e.g., ALK7:ActRIIB heteromultimers such as heterodimers) may be used to identify activin C or E inhibitors.

[0276] In certain aspects, the present disclosure relates to the use of ALK7:ActRIIB heteromultimer complexes to identify compounds (agents) which are agonists or antagonists of TGF β superfamily receptors. Compounds identified through this screening can be tested to assess their ability to modulate tissue growth, such as bone, cartilage, muscle, fat, and/or neurons, growth *in vivo* or *in vitro*. These compounds can be tested, for example, in animal models.

[0277] There are numerous approaches to screening for therapeutic agents for modulating tissue growth by targeting TGF β superfamily ligand signaling (e.g., SMAD signaling). In certain instances, high-throughput screening of compounds can be carried out to identify agents that perturb TGF β superfamily receptor-mediated effects on a selected cell line. In certain instances, the assay is carried out to screen and identify compounds that specifically inhibit or reduce binding of an ALK7:ActRIIB heteromultimer to a binding partner (e.g., activin, GDF11, GDF8, BMP6, GDF3, BMP5, nodal, and BMP10). Alternatively, the assay can be used to identify compounds that enhance binding of an ALK7:ActRIIB heteromultimer to a ligand. In a further instance, the compounds can be identified by their ability to interact with an ALK7:ActRIIB heteromultimer.

[0278] In some instances, the present disclosure relates to the use of an ALK7:ActRIIB heteromultimer and activin C or E polypeptides to identify compounds which are agonists or antagonists of the activin C (or E)-ALK7:ActRIIB signaling pathway. Compounds identified through this screening assay can be tested to assess their ability to modulate activin C or E signaling activity *in vitro*. Optionally, these compounds can further be tested in animal models to assess their ability to modulate tissue growth *in vivo*. There are numerous approaches to screening for therapeutic agents for modulating tissue growth by targeting activin C or E and ALK7:ActRIIB heteromultimers. In certain instances, high-throughput screening of compounds can be carried out to identify agents that perturb activin C or E or ALK7:ActRIIB-mediated cell signaling. In certain instances, the assay is carried out to screen and identify compounds that specifically inhibit or reduce binding of an ALK7:ActRIIB heteromultimer to activin C or E. Alternatively, the assay can be used to identify compounds that enhance binding of an ALK7:ActRIIB heteromultimer to activin C or E. In a further instance, the compounds can be identified by their ability to interact with activin C or E or an ALK7:ActRIIB heteromultimer.

[0279] A variety of assay formats will suffice and, in light of the present disclosure, those not expressly described herein will nevertheless be comprehended by one of ordinary skill in the

art. As described herein, the test compounds (agents) of the disclosure may be created by any combinatorial chemical method. Alternatively, the subject compounds may be naturally occurring biomolecules synthesized *in vivo* or *in vitro*. Compounds (agents) to be tested for their ability to act as modulators of tissue growth can be produced, for example, by bacteria, yeast, plants or other organisms (e.g., natural products), produced chemically (e.g., small molecules, including peptidomimetics), or produced recombinantly. Test compounds contemplated by the present disclosure include non-peptidyl organic molecules, peptides, polypeptides, peptidomimetics, sugars, hormones, and nucleic acid molecules. In certain instances, the test agent is a small organic molecule having a molecular weight of less than about 2,000 Daltons.

[0280] The test compounds of the disclosure can be provided as single, discrete entities, or provided in libraries of greater complexity, such as made by combinatorial chemistry. These libraries can comprise, for example, alcohols, alkyl halides, amines, amides, esters, aldehydes, ethers and other classes of organic compounds. Presentation of test compounds to the test system can be in either an isolated form or as mixtures of compounds, especially in initial screening steps. Optionally, the compounds may be optionally derivatized with other compounds and have derivatizing groups that facilitate isolation of the compounds. Nonlimiting examples of derivatizing groups include biotin, fluorescein, digoxigenin, green fluorescent protein, isotopes, polyhistidine, magnetic beads, glutathione S-transferase (GST), photoactivatable crosslinkers or any combinations thereof.

[0281] In many drug-screening programs which test libraries of compounds and natural extracts, high-throughput assays are desirable in order to maximize the number of compounds surveyed in a given period of time. Assays which are performed in cell-free systems, such as may be derived with purified or semi-purified proteins, are often preferred as "primary" screens in that they can be generated to permit rapid development and relatively easy detection of an alteration in a molecular target which is mediated by a test compound. Moreover, the effects of cellular toxicity or bioavailability of the test compound can be generally ignored in the *in vitro* system, the assay instead being focused primarily on the effect of the drug on the molecular target as may be manifest in an alteration of binding affinity between an ALK7:ActRIIB heteromultimer complex and a binding partner (e.g., activin C or E).

[0282] Merely to illustrate, in an exemplary screening assay of the present disclosure, the compound of interest is contacted with an isolated and purified ALK7:ActRIIB heteromultimer which is ordinarily capable of binding to activin C, as appropriate for the intention of the assay. To the mixture of the compound and ALK7:ActRIIB heteromultimer complex is then added to a composition containing activin C or E. Detection and quantification of ALK7:ActRIIB heteromultimer-activin C or E complexes provides a means for determining the compound's efficacy at inhibiting (or potentiating) complex formation between the ALK7:ActRIIB heteromultimer and activin C or E. The efficacy of the compound can be assessed by generating dose-response curves from data obtained using various concentrations of the test compound. Moreover, a control assay can also be performed to provide a baseline for comparison. For example, in a control assay, isolated and purified activin C or E is added to a

composition containing the ALK7:ActRIIB heteromultimer, and the formation of ALK7:ActRIIB heteromultimer-activin C or E is quantitated in the absence of the test compound. It will be understood that, in general, the order in which the reactants may be admixed can be varied, and can be admixed simultaneously. Moreover, in place of purified proteins, cellular extracts and lysates may be used to render a suitable cell-free assay system.

[0283] Binding of a ALK7:ActRIIB heteromultimer complex to another protein (e.g., activin C or E) may be detected by a variety of techniques. For instance, modulation of the formation of complexes can be quantitated using, for example, detectably labeled proteins such as radiolabeled (e.g., ^{32}P , ^{35}S , ^{14}C or ^3H), fluorescently labeled (e.g., FITC), or enzymatically labeled ALK7:ActRIIB heteromeric complex and/or a binding partner (e.g., activin C or E), by immunoassay, or by chromatographic detection.

[0284] In certain instances, the present disclosure contemplates the use of fluorescence polarization assays and fluorescence resonance energy transfer (FRET) assays in measuring, either directly or indirectly, the degree of interaction between an ALK7:ActRIIB heteromultimer and a binding protein (e.g., activin C or E). Further, other modes of detection, such as those based on optical waveguides (PCT Publication WO 96/26432 and U.S. Pat. No. 5,677,196), surface plasmon resonance (SPR), surface charge sensors, and surface force sensors, are compatible with many instances of the disclosure.

[0285] Moreover, the present disclosure contemplates the use of an interaction trap assay, also known as the "two-hybrid assay," for identifying agents that disrupt or potentiate interaction between an ALK7:ActRIIB heteromultimer and a binding partner (e.g., activin C or E). See, e.g., U.S. Pat. No. 5,283,317; Zervos et al. (1993) Cell 72:223-232; Madura et al. (1993) J Biol Chem 268:12046-12054; Bartel et al. (1993) Biotechniques 14:920-924; and Iwabuchi et al. (1993) Oncogene 8:1693-1696). In a specific instance, the present disclosure contemplates the use of reverse two-hybrid systems to identify compounds (e.g., small molecules or peptides) that dissociate interactions between an ALK7:ActRIIB heteromultimer and a binding protein (e.g., activin C or E) [Vidal and Legrain, (1999) Nucleic Acids Res 27:919-29; Vidal and Legrain, (1999) Trends Biotechnol 17:374-81; and U.S. Pat. Nos. 5,525,490; 5,955,280; and 5,965,368].

[0286] In certain instances, the subject compounds are identified by their ability to interact with an ALK7:ActRIIB heteromultimer or activin C or E of the disclosure. The interaction between the compound and an ALK7:ActRIIB heteromultimer or activin C or E may be covalent or non-covalent. For example, such interaction can be identified at the protein level using *in vitro* biochemical methods, including photo-crosslinking, radiolabeled ligand binding, and affinity chromatography [Jakoby WB et al. (1974) Methods in Enzymology 46:1]. In certain cases, the compounds may be screened in a mechanism-based assay, such as an assay to detect compounds which bind to an ALK7:ActRIIB heteromultimer or activin C or E. This may include a solid-phase or fluid-phase binding event. Alternatively, the gene encoding an ALK7:ActRIIB heteromultimer or activin C or E can be transfected with a reporter system (e.g., β -galactosidase, luciferase, or green fluorescent protein) into a cell and screened against the

library preferably by high-throughput screening or with individual members of the library. Other mechanism-based binding assays may be used; for example, binding assays which detect changes in free energy. Binding assays can be performed with the target fixed to a well, bead or chip or captured by an immobilized antibody or resolved by capillary electrophoresis. The bound compounds may be detected usually using colorimetric endpoints or fluorescence or surface plasmon resonance.

4. Exemplary Therapeutic Uses

[0287] In certain instances, an ALK7:ActRIIB antagonist, or combinations of such antagonists, of the present disclosure can be used to treat or prevent a disease or condition that is associated with abnormal activity of an ALK7:ActRIIB-binding ligand. These diseases, disorders, or conditions are generally referred to herein as "ALK7:ActRIIB-associated conditions" or "ALK7:ActRIIB-associated disorders." In certain instances, the present disclosure provides methods of treating or preventing an ALK7:ActRIIB-associated condition in an individual by administering to an individual in need thereof a therapeutically effective amount of an ALK7:ActRIIB antagonist (e.g., an ALK7:ActRIIB heteromultimer such as an ALK7:ActRIIB heterodimer), or combinations of such antagonists, as described herein. The terms "subject," an "individual," or a "patient" are interchangeable throughout the specification. Any of the ALK7:ActRIIB antagonists of the disclosure can potentially be employed individually or in combination for therapeutic uses disclosed herein. These methods are particularly aimed at therapeutic and prophylactic treatments of mammals including, for example, rodents, primates, and humans.

[0288] As used herein, a therapeutic that "prevents" a disorder or condition refers to a compound that, in a statistical sample, reduces the occurrence of the disorder or condition in the treated sample relative to an untreated control sample, or delays the onset or reduces the severity of one or more symptoms of the disorder or condition relative to the untreated control sample. The term "treating" as used herein includes amelioration or elimination of the condition once it has been established. In either case, prevention or treatment may be discerned in the diagnosis provided by a physician or other health care provider and the intended result of administration of the therapeutic agent.

[0289] In general, treatment or prevention of a disease or condition as described in the present disclosure is achieved by administering an ALK7:ActRIIB antagonist, or combinations of such antagonists, of the present disclosure in an "effective amount". An effective amount of an agent refers to an amount effective, at dosages and for periods of time necessary, to achieve the desired therapeutic or prophylactic result. A "therapeutically effective amount" of an agent of the present disclosure may vary according to factors such as the disease state, age, sex, and weight of the individual, and the ability of the agent to elicit a desired response in the individual. A "prophylactically effective amount" refers to an amount effective, at dosages and for periods of time necessary, to achieve the desired prophylactic result.

[0290] The kidneys maintain many features of the blood, including volume, pH balance, electrolyte concentrations, and blood pressure, as well as bearing responsibility for toxin and waste filtration. These functions depend upon the intricate structure of the kidney nephrons, constant flow of blood through the various capillaries of the kidney, and the regulation of the kidney by signals from the rest of the body, including endocrine hormones. Problems with kidney function manifest by direct mechanisms (e.g. genetic defects, infection, or toxin exposure) and by indirect mechanisms progressively proceeding from long term stressors like hypertrophy and hyperfiltration (themselves often a result of more direct insults to kidney function). Due to the central role of the kidney in blood maintenance and waste secretion, kidney-associated disease manifestations are many and varied; they can be reviewed in Harrison's Principles of Internal Medicine, 18th edition, McGraw Hill, N.Y., Part 13, Chp 277-289.

[0291] As described herein, an ALK7:ActRIIB antagonist had various beneficial effects in a kidney disease model. In particular, treatment with an ALK7:ActRIIB heteromultimer reduced kidney tissue damage, inflammation, and fibrosis in subjects having unilateral ureteral obstruction. These data indicate that ALK7:ActRIIB antagonist may be used to treat or prevent kidney disease, particularly treating or preventing various complications (manifestations) of kidney disease including, for example, kidney tissue damage, inflammation, and/or fibrosis.

[0292] Therefore, methods of this disclosure can be applied to various kidney-associated diseases or conditions. As used herein, "kidney-associated disease or condition" can refer to any disease, disorder, or condition that affects the kidneys or the renal system. Examples of kidney-associated diseases or conditions include, but are not limited to, chronic kidney diseases (or failure), acute kidney diseases (or failure), primary kidney diseases, non-diabetic kidney diseases, glomerulonephritis, interstitial nephritis, diabetic kidney diseases, diabetic nephropathy, glomerulosclerosis, rapid progressive glomerulonephritis, renal fibrosis, Alport syndrome, IDDM nephritis, mesangial proliferative glomerulonephritis, membranoproliferative glomerulonephritis, crescentic glomerulonephritis, renal interstitial fibrosis, focal segmental glomerulosclerosis, membranous nephropathy, minimal change disease, pauci-immune rapid progressive glomerulonephritis, IgA nephropathy, polycystic kidney disease, Dent's disease, nephrocytosis, Heymann nephritis, autosomal dominant (adult) polycystic kidney disease, autosomal recessive (childhood) polycystic kidney disease, acute kidney injury, nephrotic syndrome, renal ischemia, podocyte diseases or disorders, proteinuria, glomerular diseases, membranous glomerulonephritis, focal segmental glomerulonephritis, pre-eclampsia, eclampsia, kidney lesions, collagen vascular diseases, benign orthostatic (postural) proteinuria, IgM nephropathy, membranous nephropathy, sarcoidosis, diabetes mellitus, kidney damage due to drugs, Fabry's disease, aminoaciduria, Fanconi syndrome, hypertensive nephrosclerosis, interstitial nephritis, Sickle cell disease, hemoglobinuria, myoglobinuria, Wegener's Granulomatosis, Glycogen Storage Disease Type 1, chronic kidney disease, chronic renal failure, low Glomerular Filtration Rate (GFR), nephroangiosclerosis, lupus nephritis, ANCA-positive pauci-immune crescentic glomerulonephritis, chronic allograft nephropathy, nephrotoxicity, renal toxicity, kidney necrosis, kidney damage, glomerular and tubular injury, kidney dysfunction, nephritic syndrome, acute renal failure, chronic renal failure,

proximal tubal dysfunction, acute kidney transplant rejection, chronic kidney transplant rejection, non-IgA mesangioproliferative glomerulonephritis, postinfectious glomerulonephritis, vasculitides with renal involvement of any kind, any hereditary renal disease, any interstitial nephritis, renal transplant failure, kidney cancer, kidney disease associated with other conditions (e.g., hypertension, diabetes, and autoimmune disease), Dent's disease, nephrocytosis, Heymann nephritis, a primary kidney disease, a collapsing glomerulopathy, a dense deposit disease, a cryoglobulinemia-associated glomerulonephritis, an Henoch-Schonlein disease, a postinfectious glomerulonephritis, a bacterial endocarditis, a microscopic polyangitis, a Churg-Strauss syndrome, an anti-GBM-antibody mediated glomerulonephritis, amyloidosis, a monoclonal immunoglobulin deposition disease, a fibrillary glomerulonephritis, an immunotactoid glomerulopathy, ischemic tubular injury, a medication-induced tubulo-interstitial nephritis, a toxic tubulo-interstitial nephritis, an infectious tubulo-interstitial nephritis, a bacterial pyelonephritis, a viral infectious tubulo-interstitial nephritis which results from a polyomavirus infection or an HIV infection, a metabolic-induced tubulo-interstitial disease, a mixed connective disease, a cast nephropathy, a crystal nephropathy which may results from urate or oxalate or drug-induced crystal deposition, an acute cellular tubulo-interstitial allograft rejection, a tumoral infiltrative disease which results from a lymphoma or a post-transplant lymphoproliferative disease, an obstructive disease of the kidney, vascular disease, a thrombotic microangiopathy, a nephroangiosclerosis, an atheroembolic disease, a mixed connective tissue disease, a polyarteritis nodosa, a calcineurin-inhibitor induced-vascular disease, an acute cellular vascular allograft rejection, an acute humoral allograft rejection, early renal function decline (ERFD), end stage renal disease (ESRD), renal vein thrombosis, acute tubular necrosis, acute interstitial nephritis, established chronic kidney disease, renal artery stenosis, ischemic nephropathy, uremia, drug and toxin-induced chronic tubulointerstitial nephritis, reflux nephropathy, kidney stones, Goodpasture's syndrome, normocytic normochromic anemia, renal anemia, diabetic chronic kidney disease, IgG4-related disease, von Hippel-Lindau syndrome, tuberous sclerosis, nephronophthisis, medullary cystic kidney disease, renal cell carcinoma, adenocarcinoma, nephroblastoma, lymphoma, leukemia, hyposialylation disorder, chronic cyclosporine nephropathy, renal reperfusion injury, renal dysplasia, azotemia, bilateral arterial occlusion, acute uric acid nephropathy, hypovolemia, acute bilateral obstructive uropathy, hypercalcemic nephropathy, hemolytic uremic syndrome, acute urinary retention, malignant nephrosclerosis, postpartum glomerulosclerosis, scleroderma, non-Goodpasture's anti-GBM disease, microscopic polyarteritis nodosa, allergic granulomatosis, acute radiation nephritis, post-streptococcal glomerulonephritis, Waldenstrom's macroglobulinemia, analgesic nephropathy, arteriovenous fistula, arteriovenous graft, dialysis, ectopic kidney, medullary sponge kidney, renal osteodystrophy, solitary kidney, hydronephrosis, microalbuminuria, uremia, haematuria, hyperlipidemia, hypoalbuminaemia, lipiduria, acidosis, hyperkalemia, and edema.

[0293] In some instances, an ALK7:ActRIIB antagonist, or combinations of such antagonists, of the present disclosure (e.g., ALK7:ActRIIB heteromultimers such as an ALK7:ActRIIB heterodimer) may be used to treat or prevent chronic kidney disease, optionally in combination with one or more supportive therapies for treating chronic kidney disease. In some instances, an ALK7:ActRIIB antagonist, or combinations of such antagonists, of the present disclosure

(e.g., ALK7:ActRIIB heteromultimers such as an ALK7:ActRIIB heterodimer) may be used to treat or prevent one or more complications (symptoms or manifestations) of chronic kidney disease (e.g., tissue damage, inflammation, and/or fibrosis), optionally in combination with one or more supportive therapies for treating chronic kidney disease. In some instances, an ALK7:ActRIIB antagonist, or combinations of such antagonists, of the present disclosure (e.g., ALK7:ActRIIB heteromultimers such as an ALK7:ActRIIB heterodimer) may be used to treat or prevent end-stage kidney failure, optionally in combination with one or more supportive therapies for treating end-stage kidney disease. Chronic kidney disease (CKD), also known as chronic renal disease, is a progressive loss in renal function over a period of months or years. The symptoms of worsening kidney function may include feeling generally unwell and experiencing a reduced appetite. Often, chronic kidney disease is diagnosed as a result of screening of people known to be at risk of kidney problems, such as those with high blood pressure or diabetes and those with a blood relative with CKD. This disease may also be identified when it leads to one of its recognized complications, such as cardiovascular disease, anemia, or pericarditis. Recent professional guidelines classify the severity of CKD in five stages, with stage 1 being the mildest and usually causing few symptoms and stage 5 being a severe illness with poor life expectancy if untreated. Stage 5 CKD is often called end-stage kidney disease, end-stage renal disease, or end-stage kidney failure, and is largely synonymous with the now outdated terms chronic renal failure or chronic kidney failure; and usually means the patient requires renal replacement therapy, which may involve a form of dialysis, but ideally constitutes a kidney transplant. CKD is initially without specific symptoms and is generally only detected as an increase in serum creatinine or protein in the urine. As the kidney function decreases, various symptoms may manifest as described below. Blood pressure may be increased due to fluid overload and production of vasoactive hormones created by the kidney via the renin-angiotensin system, increasing one's risk of developing hypertension and/or suffering from congestive heart failure. Urea may accumulate, leading to azotemia and ultimately uremia (symptoms ranging from lethargy to pericarditis and encephalopathy). Due to its high systemic circulation, urea is excreted in eccrine sweat at high concentrations and crystallizes on skin as the sweat evaporates ("uremic frost"). Potassium may accumulate in the blood (hyperkalemia with a range of symptoms including malaise and potentially fatal cardiac arrhythmias). Hyperkalemia usually does not develop until the glomerular filtration rate falls to less than 20-25 ml/min/1.73 m², at which point the kidneys have decreased ability to excrete potassium. Hyperkalemia in CKD can be exacerbated by acidemia (which leads to extracellular shift of potassium) and from lack of insulin. Erythropoietin synthesis may be decreased causing anemia. Fluid volume overload symptoms may occur, ranging from mild edema to life-threatening pulmonary edema. Hyperphosphatemia, due to reduced phosphate excretion, may occur generally following the decrease in glomerular filtration. Hyperphosphatemia is associated with increased cardiovascular risk, being a direct stimulus to vascular calcification. Hypocalcemia may manifest, which is generally caused by stimulation of fibroblast growth factor-23. Osteocytes are responsible for the increased production of FGF23, which is a potent inhibitor of the enzyme 1-alpha-hydroxylase (responsible for the conversion of 25-hydroxycholecalciferol into 1,25 dihydroxyvitamin D₃). Later, this progresses to secondary hyperparathyroidism, renal osteodystrophy, and vascular calcification that further impairs cardiac function. Metabolic

acidosis (due to accumulation of sulfates, phosphates, uric acid etc.) may occur and cause altered enzyme activity by excess acid acting on enzymes; and also increased excitability of cardiac and neuronal membranes by the promotion of hyperkalemia due to excess acid (acidemia). Acidosis is also due to decreased capacity to generate enough ammonia from the cells of the proximal tubule. Iron deficiency anemia, which increases in prevalence as kidney function decreases, is especially prevalent in those requiring haemodialysis. It is multifactorial in cause, but includes increased inflammation, reduction in erythropoietin, and hyperuricemia leading to bone marrow suppression. People with CKD suffer from accelerated atherosclerosis and are more likely to develop cardiovascular disease than the general population. Patients afflicted with CKD and cardiovascular disease tend to have significantly worse prognoses than those suffering only from the latter.

[0294] In another instance, an ALK7:ActRIIB antagonist (e.g., an ALK7:ActRIIB heterodimer), or combinations of such antagonists, may be used in patients with chronic kidney disease mineral bone disorder (CKD-MBD), a broad syndrome of interrelated skeletal, cardiovascular, and mineral-metabolic disorders arising from kidney disease. CKD-MBD encompasses various skeletal pathologies often referred to as renal osteodystrophy (ROD), which is a preferred instance for treatment with, an ALK7:ActRIIB antagonist (e.g., an ALK7:ActRIIB heterodimer), or combinations of such antagonists. Depending on the relative contribution of different pathogenic factors, ROD is manifested as diverse pathologic patterns of bone remodeling (Hruska et al., 2008, Chronic kidney disease mineral bone disorder (CKD-MBD); in Rosen et al. (ed) Primer on the Metabolic Bone Diseases and Disorders of Mineral Metabolism, 7th ed. American Society for Bone and Mineral Research, Washington D.C., pp 343-349). At one end of the spectrum is ROD with uremic osteodystrophy and low bone turnover, characterized by a low number of active remodeling sites, profoundly suppressed bone formation, and low bone resorption. At the other extreme is ROD with hyperparathyroidism, high bone turnover, and osteitis fibrosa. Given that an ALK7:ActRIIB antagonist (e.g., an ALK7:ActRIIB heterodimer), or combinations of such antagonists, may exert both anabolic and antiresorptive effects, these agents may be useful in patients across the ROD pathology spectrum.

[0295] In other instances, an ALK7:ActRIIB antagonist (e.g., an ALK7:ActRIIB heterodimer), or combinations of such antagonists, can be used for regulating body fat content in an animal and for treating or preventing conditions related thereto, and particularly, health-compromising conditions related thereto. According to the present disclosure, to regulate (control) body weight can refer to reducing or increasing body weight, reducing or increasing the rate of weight gain, or increasing or reducing the rate of weight loss, and also includes actively maintaining, or not significantly changing body weight (e.g., against external or internal influences which may otherwise increase or decrease body weight). One instance of the present disclosure relates to regulating body weight by administering to an animal (e.g., a human) in need thereof an ALK7:ActRIIB antagonist (e.g., an ALK7:ActRIIB heterodimer), or combinations of such antagonists. For example, in some instances, an ALK7:ActRIIB antagonist (e.g., an ALK7:ActRIIB heterodimer), or combinations of such antagonists, may be used to treat or prevent a disorder or condition selected from obesity (e.g., abdominal obesity); overweight; insulin resistance; metabolic syndrome and other metabolic diseases or conditions;

a lipid disorder such as, low HDL levels, high LDL levels, hyperlipidemia, hypertriglyceridemia or dyslipidemia; lipoprotein aberrations; decreased triglycerides; inflammation (e.g., liver inflammation and/or inflammation of adipose tissue), fatty liver disease; non-alcoholic fatty liver disease; hyperglycemia; impaired glucose tolerance (IGT); hyperinsulinemia; high cholesterol (e.g., high LDL levels and hypercholesterolemia); cardiovascular disease such as, heart disease including coronary heart disease, congestive heart failure, stroke, peripheral vascular disease, atherosclerosis; arteriosclerosis, and hypertension; Syndrome X; vascular restenosis; neuropathy; retinopathy; neurodegenerative disease; endothelial dysfunction, respiratory dysfunction; pancreatitis; polycystic ovarian syndrome; elevated uric acid levels; haemochromatosis (iron overload); acanthosis nigricans (dark patches on the skin); or cancer (e.g., ovarian, breast, endometrial, and colon cancer); or a another disorders/conditions associated with one or more of the above diseases or conditions. In some instances, the disease or condition treated using an ALK7:ActRIIB antagonist (e.g., an ALK7:ActRIIB heterodimer), or combinations of such antagonists, is associated with overweight (e.g., BMI of $\geq 25 \text{ kg/m}^2$), or with too much body fat.

[0296] In one instance, the disclosure provides a method of reducing body weight comprising administering to a subject desiring to reduce body weight, or in need thereof, an effective amount of an ALK7:ActRIIB antagonist (e.g., an ALK7:ActRIIB heterodimer), or combinations of such antagonists. In some instances, the subject is overweight (e.g., pre-obese). In some instances, the subject has a body mass index (BMI) of 25 kg/m^2 or greater. In further instances, the subject has a BMI of 25 kg/m^2 to 29.9 kg/m^2 , 30 kg/m^2 to 39.9 kg/m^2 , 25 kg/m^2 to 39.9 kg/m^2 , or 25 kg/m^2 to 50 kg/m^2 . In some instances, the subject is obese. In some instances, the subject has a BMI of 30 kg/m^2 or greater (e.g., 30 to 39.9 kg/m^2 or 30 kg/m^2 to 50 kg/m^2). In some instances, the subject is morbidly obese. In some instances, the subject has a BMI of 40 kg/m^2 or greater. In further instances, the subject has a BMI of 40 kg/m^2 to 45 kg/m^2 , or 40 kg/m^2 to 50 kg/m^2 . In some instances, the subject has central obesity (e.g., excess adiposity in the abdominal region, including belly fat and/or visceral fat). In some instances, the subject has a waist/hip circumference ratio (WHR) of 0.85 or greater. In some instances, the subject has peripheral obesity (e.g., excess adiposity on the hips). In some instances, the subject has type 2 diabetes mellitus. The ALK7:ActRIIB antagonist, or combination of antagonists, may administered alone or as a combination therapy other type of supportive therapy. For example, in some instances, the supportive therapy is diet and/or exercise.

[0297] In one instance, the disclosure provides a method of reducing weight gain comprising administering to a subject desiring to reduce weight gain, or in need thereof, an effective amount of an ALK7:ActRIIB antagonist (e.g., an ALK7:ActRIIB heterodimer), or combination of such antagonists. In some instances, the subject is overweight (e.g., pre-obese). In some instances, the subject has a BMI of 25 kg/m^2 or greater. In further instances, the subject has a BMI of 25 kg/m^2 to 29.9 kg/m^2 , 30 kg/m^2 to 39.9 kg/m^2 , 25 kg/m^2 to 39.9 kg/m^2 , or 25 kg/m^2 to

50 kg/m². In some instances, the subject is obese. In some instances, the subject has a BMI of 30 kg/m² or greater (e.g., 30 to 39.9 kg/m² or 30 kg/m² to 50 kg/m²). In some instances, the subject is morbidly obese. In some instances, the subject has a BMI of 40 kg/m² or greater. In further instances, the subject has a BMI of 40 kg/m² to 45 kg/m², or 40 kg/m² to 50 kg/m². In some instances, the subject has type 2 diabetes mellitus.

[0298] Also provided is a method of treating or preventing a disease or condition associated with excess body weight, comprising administering to a subject in need of treatment or prevention, an effective amount of an ALK7:ActRIIB antagonist (e.g., an ALK7:ActRIIB heterodimer), or combination of such antagonists. In one instance, the treated or prevented disease or condition is obesity. In one instance, the treated or prevented disease or condition is insulin resistance. In one instance, the treated or prevented disease or condition is a member selected from the group consisting of: dyslipidemia, hyperlipidemia (total cholesterol level >240 mg/dL), hypercholesterolemia (e.g., total cholesterol level of >200 mg/dL, >220 mg/dL, >240 mg/dL, >250 mg/dL, or >275 mg/dL), low HDL serum level (e.g., <40mg/dL, <45 mg/dL, or <50 mg/dL), high LDL serum level (e.g., ≥ 100 mg/dL, ≥ 130 mg/dL, ≥ 160 mg/dL, or ≥ 190 mg/dL), and hypertriglyceridemia (e.g., a fasting TG level of ≥ 150 mg/dL, ≥ 175 mg/dL, ≥ 200 mg/dL, ≥ 300 mg/dL, ≥ 400 mg/dL, or ≥ 499 mg/dL). In certain instances, the ALK7:ActRIIB antagonists treatment is an adjunct to diet and/or exercise.

[0299] In another instance the disclosure provides a method of reducing body weight in a subject who is overweight. The method includes administering to an overweight subject an effective amount of an ALK7:ActRIIB antagonist (e.g., an ALK7:ActRIIB heterodimer), or combination of such antagonists. In some instances, the subject has a body mass index (BMI) of 25 kg/m² or greater. In further instances, the subject has a BMI of 25 kg/m² to 29.9 kg/m², 30 kg/m² to 39.9 kg/m², 25 kg/m² to 39.9 kg/m², or 25 kg/m² to 50 kg/m². or 27 to 40 kg/m². In some instances, the subject is obese. In some instances, the subject has a BMI of 30 kg/m² or greater (e.g., 30 to 39.9 kg/m² or 30 kg/m² to 50 kg/m²). The ALK7-binding protein is administered alone or as a combination therapy. In some instances, the ALK7:ActRIIB antagonist treatment is an adjunct to diet and/or exercise.

[0300] In one instance the disclosure provides a method of reducing body weight in an obese subject. The method includes administering to the subject an effective amount of an ALK7:ActRIIB antagonist (e.g., an ALK7:ActRIIB heterodimer), or combination of such antagonists. In some instances, the subject has a BMI of 30 kg/m² or greater (e.g., 30 to 39.9 kg/m² or 30 kg/m² to 50 kg/m²). In some instances, the subject has a BMI of 40 kg/m² or greater. In some instances, the subject has central obesity (e.g., excess adiposity in the abdominal region, including belly fat and/or visceral fat). In some instances, the subject has a waist/hip circumference ratio (WHR) of 0.85 or greater. In some instances, the subject has peripheral obesity (e.g., excess adiposity on the hips). In some instances, the ALK7:ActRIIB antagonist treatment is an adjunct to diet and/or exercise.

[0301] In another instance, the disclosure provides a method of treating and/or ameliorating obesity or a disease or condition associated with obesity, comprising administering to an obese subject, an effective amount of an ALK7:ActRIIB antagonist (e.g., an ALK7:ActRIIB heterodimer), or combination of such antagonists. In some instances, the subject has a BMI of 30 kg/m² or greater. In further instances, the subject has a BMI of 30 to 39.9 kg/m² or 30 kg/m² to 50 kg/m². In some instances, the subject is morbidly obese. In some instances, the subject has a body BMI of 40 kg/m² or greater. In further instances, the subject has a BMI of 40 kg/m² to 45 kg/m², or 40 kg/m² to 50 kg/m². In some instances, the subject has type 2 diabetes mellitus. In some instances, the subject has a BMI of 30 kg/m² or greater (e.g., 30 to 39.9 kg/m²). In some instances, the subject has a BMI of at least 40 kg/m². In some instances, the subject has central obesity (e.g., excess adiposity in the abdominal region, including belly fat and/or visceral fat). In some instances, the subject has a waist/hip circumference ratio (WHR) of 0.85 or greater. In some instances, the subject has peripheral obesity (e.g., excess adiposity on the hips). In some instances, the ALK7:ActRIIB antagonist treatment is an adjunct to diet and/or exercise.

[0302] Also provided is a method of treating or preventing a disease or condition associated with obesity, comprising administering to a subject in need of treatment or prevention, an effective amount of an ALK7:ActRIIB antagonist (e.g., an ALK7:ActRIIB heterodimer), or combination of such antagonists. In one instance, the treated or prevented disease or condition is a member selected from the group consisting of: dyslipidemia, hyperlipidemia (total cholesterol level >240 mg/dL), hypercholesterolemia (e.g., total cholesterol level of >200 mg/dL, >220 mg/dL, >240 mg/dL, >250 mg/dL, or >275 mg/dL), low HDL serum level (e.g., <40mg/dL, <45 mg/dL, or <50 mg/dL), high LDL serum level (e.g., ≥ 100 mg/dL, ≥ 130 mg/dL, ≥ 160 mg/dL, or ≥ 190 mg/dL), and hypertriglyceridemia (e.g., a fasting TG level of ≥ 150 mg/dL, ≥ 175 mg/dL, ≥ 200 mg/dL, ≥ 300 mg/dL, ≥ 400 mg/dL, or ≥ 499 mg/dL). In one instance, the treated or prevented disease or condition is cardiovascular disease. In an additional instance, the treated or prevented disease or condition is hypertension (high blood pressure), myocardial infarction, peripheral artery disease, vasoregulation dysfunction, arteriosclerosis congestive heart failure, atherosclerosis, coronary heart disease, or microvascular disease. In one instance, the treated or prevented disease or condition is liver disease. In one instance, the treated or prevented liver disease or condition is NAFLD. In one instance, the liver disease is fatty liver. In one instance, the liver disease is NASH. In another instance, the treated or prevented disease or condition is a member selected from the group: steatohepatitis, steatosis, fibrosis, and/or cirrhosis. In certain instances, the ALK7:ActRIIB antagonist treatment is an adjunct to diet and/or exercise.

[0303] In another instance, the disclosure provides a method of treating, ameliorating, and/or preventing type 2 diabetes mellitus or a disease or condition associated with diabetes comprising administering to a subject having type 2 diabetes mellitus, or at risk of developing type 2 diabetes, an effective amount of an ALK7:ActRIIB antagonist (e.g., an ALK7:ActRIIB heterodimer), or combination of such antagonists. In some instances, the subject has a body

mass index BMI of 30 kg/m² or greater (e.g., 30 to 39.9 kg/m²). In some instances, the subject has a BMI of at least 40 kg/m². In some instances, the subject has central obesity (e.g., excess adiposity in the abdominal region, including belly fat and/or visceral fat). In some instances, the subject has a WHR of 0.85 or greater. In some instances, the subject has peripheral obesity (e.g., excess adiposity on the hips). In some instances, the ALK7:ActRIIB antagonist treatment is an adjunct to diet and/or exercise.

[0304] Also provided is a method of treating, ameliorating or preventing a disease or condition associated with diabetes, comprising administering to a subject having diabetes, an effective amount of an ALK7:ActRIIB antagonist (e.g., an ALK7:ActRIIB heterodimer), or combination of such antagonists. In one instance, the treated or prevented disease or condition is a member selected from the group consisting of: dyslipidemia, hyperlipidemia (total cholesterol level >240 mg/dL), hypercholesterolemia (e.g., total cholesterol level of >200 mg/dL, >220 mg/dL, >240 mg/dL, >250 mg/dL, or >275 mg/dL), low HDL serum level (e.g., <40mg/dL, <45 mg/dL, or <50 mg/dL), high LDL serum level (e.g., ≥ 100 mg/dL, ≥ 130 mg/dL, ≥ 160 mg/dL, or ≥ 190 mg/dL), and hypertriglyceridemia (e.g., a fasting TG level of ≥ 150 mg/dL, ≥ 175 mg/dL, ≥ 200 mg/dL, ≥ 300 mg/dL, ≥ 400 mg/dL, or ≥ 499 mg/dL). In one instance, the treated or prevented disease or condition is cardiovascular disease. In an additional instance, the treated or prevented disease or condition is hypertension (high blood pressure), myocardial infarction, peripheral artery disease, vasoregulation dysfunction, or arteriosclerosis. In one instance, the treated or prevented disease or condition is liver disease. In another instance, the treated or prevented disease or condition is a member selected from the group: fatty liver disease, steatohepatitis, steatosis, and/or cirrhosis. In one instance, the treated or prevented disease or condition is a member selected from the group consisting of: cataracts, obstructive sleep apnea, phlebitis, gout, osteoarthritis, gallbladder disease, and high cholesterol. In certain instances, the ALK7:ActRIIB antagonist treatment is an adjunct to diet and/or exercise.

[0305] The disclosure also provides a method for improving the blood-lipid profile in a subject, comprising administering to a subject in need of such treatment an effective amount of an ALK7:ActRIIB antagonist (e.g., an ALK7:ActRIIB heterodimer), or combination of such antagonists. In some instances, the disclosure provides a method for reducing levels of LDL cholesterol or increasing levels of HDL-cholesterol. In one instance, the subject has dyslipidemia. In another instance, the subject has elevated serum lipids (e.g., cholesterol (hypercholesterolemia) and/or triglycerides (e.g., hypertriglyceridemia). In one instance the subject has an LDL-C ≥ 100 mg/dL, ≥ 130 mg/dL, or ≥ 160 mg/dL). In one instance the subject has a TG ≥ 150 mg/dL, ≥ 160 mg/dL, ≥ 170 mg/dL). In one instance, the subject has elevated plasma insulin levels (hyperinsulinemia; e.g., fasting insulin level of >20 ug/ml can exceed 100). In some instances, the subject has type II diabetes.

[0306] According to one instance, the disclosure provides a method of treating or preventing a metabolic disease or disorder or a condition associated with a metabolic disease or disorder, comprising administering an ALK7:ActRIIB antagonist (e.g., an ALK7:ActRIIB heterodimer), or combination of such antagonists, to a subject in need thereof. In one instance, the treated metabolic disease, disorder, or condition is hyperglycemia (e.g., > 130 mg/dL in the fasting

state or following glucose administration during an oral glucose tolerance test). In one instance, the treated metabolic disease, disorder, or condition is a lipid metabolism disease, disorder, or condition. In one instance, the treated metabolic disease, disorder, or condition is dislipidemia. In a further instance, the lipid metabolism disease, disorder, or condition is a member selected from: low HDL levels, high LDL levels, high triglyceride levels, hyperlipidemia, and a lipoprotein aberration. In one instance, the subject has a total cholesterol level of >200 mg/dL, >220 mg/dL, >240 mg/dL, >250 mg/dL, or >275 mg/dL. In one instance, the subject has a HDL serum level of <40mg/dL, <45 mg/dL, or <50 mg/dL). In one instance, the subject has a LDL serum level $\geq$ 100 mg/dL, $\geq$ 130 mg/dL, $\geq$ 160 mg/dL, or $\geq$ 190 mg/dL. In one instance, the subject has fasting TG level of $\geq$ 150 mg/dL, $\geq$ 175 mg/dL, $\geq$ 200 mg/dL, $\geq$ 300 mg/dL, $\geq$ 400 mg/dL, or $\geq$ 499 mg/dL. In one instance, the treated metabolic disease, disorder, or condition is a glucose metabolism disease, disorder, or condition. In a further instance, the glucose metabolism disease, disorder, or condition is a member selected from: glucose intolerance, insulin resistance, impaired glucose tolerance (IGT), impaired fasting glucose (IFG). In one instance, the treated metabolic disease, disorder, or condition is a member selected from the group consisting of: high uric acid levels, NAFLD, fatty liver, NASH, and polycystic ovarian syndrome. In one instance, the treated subject has hyperinsulinemia. In one instance, the treated subject is obese (e.g., the subject has abdominal obesity). In another instance, the treated subject has type II diabetes.

[0307] Metabolic syndrome is a condition involving a set of disorders that enhances the risk of heart disease. The major components of metabolic syndrome are excess weight, the cardiovascular parameters (high blood pressure, dyslipidemia, high levels of triglycerides and/or low levels of HDL in the blood), atherosclerosis, diabetes, and/or insulin resistance. A subject having several of these components, *i.e.* metabolic syndrome, is highly prone to heart disease, though each component is a risk factor. The disclosure also provides a method for treating or preventing 1, 2, 3, or more of the above components of metabolic syndrome, comprising administering to a subject in need of treatment an effective amount of an ALK7:ActRIIB antagonist (e.g., an ALK7:ActRIIB heterodimer), or combination of such antagonists.

[0308] Additionally provided is a method of treating, preventing or ameliorating a cardiovascular disease or condition, comprising administering an ALK7:ActRIIB antagonist (e.g., an ALK7:ActRIIB heterodimer), or combination of such antagonists, to a subject in need thereof. In one instance, the treated, prevented, or ameliorated cardiovascular disease or condition is atherosclerosis. In one instance, the treated, prevented, or ameliorated cardiovascular disease or condition is hypertension (e.g., blood pressure >130/80 mmHg or >140/90 mmHg, in a resting state. In one instance, the cardiovascular disease is atherosclerosis (coronary heart disease disease).

[0309] In one instance, the disclosure provides a method for treating and/or ameliorating an inflammatory liver disease or condition that comprises administering an ALK7:ActRIIB antagonist (e.g., an ALK7:ActRIIB heterodimer), or combination of such antagonists, to a subject in need thereof. In one instance, the disease or condition is NAFLD. In a further

instance, the disease or condition is fatty liver. In a further instance, the disease or condition is steatosis (e.g., nonalcoholic steatohepatitis (NASH)). In a further instance, the disease or condition is alcoholic fatty liver disease.

[0310] This disclosure also provides a method of improving glycemic control, comprising administering to a subject in need of treatment an effective amount of an ALK7:ActRIIB antagonist (e.g., an ALK7:ActRIIB heterodimer). In one instance, the subject is administered has a fasting blood sugar level of >130, >135, >140, >145, or >150 mg/dL. In one instance, the subject is administered has a postprandial blood sugar level of >180, >185, >190, >195, or >200 mg/dL 2 hours after eating. In certain instances, the ALK7:ActRIIB antagonist treatment is an adjunct to diet and/or exercise. The administration can also reduce body weight or treat obesity. In certain instances, the subject has type 2 diabetes mellitus. In certain instances, the subject has a BMI of 27 to 40 kg/m². In certain instances, the subject has a BMI of 30 to 39.9 kg/m². In certain instances, the subject has a BMI of at least 40. In certain instances, the subject is overweight. In certain instances, the subject is obese. An improvement in glycemic control can be assessed using techniques known in the art such as a mixed-meal test.

[0311] The disclosure also provides compositions and methods for treating, preventing or ameliorating hyperglycemia or a condition associated with hyperglycemia in a subject comprising administering to a subject in need of such treatment an effective amount of an ALK7:ActRIIB antagonist (e.g., an ALK7:ActRIIB heterodimer). In one instance, the subject is administered has a fasting blood sugar level of >130, >135, >140, >145, or >150 mg/dL. In one instance, the subject is administered has a postprandial blood sugar level of >180, >185, >190, >195, or >200 mg/dL 2 hours after eating. In one instance, the result of the treatment, prevention or amelioration is a member selected from the group consisting of: a decrease in serum levels of glucose, a decrease in serum levels of triglycerides, a decrease in serum levels of insulin, and/or a decrease in serum levels of non-esterified fatty acids, as compared to serum levels in the subject prior to treatment. In one instance, the result of the treatment, prevention or amelioration is an increase in body temperature of about 0.4°C to 1°C as compared to body temperature of the subject prior to treatment. In some instances, the ALK7:ActRIIB treatment also reduces body weight of the subject.

[0312] In another instance, the disclosure provides a method of decreasing plasma insulin levels in a subject, comprising administering an effective amount of an ALK7:ActRIIB antagonist (e.g., an ALK7:ActRIIB heterodimer), to a subject in need of such treatment. In one instance, the subject has a fasting blood sugar level of >130, >135, >140, >145, or >150 mg/dL. In one instance, the subject has a postprandial blood sugar level of >180, >185, >190, >195, or >200 mg/dL 2 hours after eating. In one instance, the subject is overweight. In one instance, the subject is obese. In another instance, the subject has type 2 diabetes.

[0313] The disclosure also provides compositions and methods for treating, preventing or ameliorating hyperglycemia or a condition associated with hyperglycemia in a subject comprising administering to a subject in need of such treatment an effective amount of an ALK7:ActRIIB antagonist (e.g., an ALK7:ActRIIB heterodimer). In one instance, the subject has

a fasting blood sugar level of >130, >135, >140, >145, or >150 mg/dL. In one instance, the subject has a postprandial blood sugar level of >180, >185, >190, >195, or >200 mg/dL 2 hours after eating. In one instance, the result of the treatment, prevention or amelioration is a member selected from the group consisting of: a decrease in serum levels of glucose, a decrease in serum levels of triglycerides, a decrease in serum levels of insulin, and/or a decrease in serum levels of non-esterified fatty acids, as compared to serum levels in the subject prior to treatment. In one instance, the result of the treatment, prevention or amelioration is an increase in body temperature of about 0.4°C to 1°C as compared to body temperature of the subject prior to treatment. In some instances, the ALK7:ActRIIB antagonist treatment also reduces body weight of the subject.

[0314] In another instance, the disclosure provides a method of decreasing plasma insulin levels in a subject, comprising administering an effective amount of an ALK7:ActRIIB antagonist (e.g., an ALK7:ActRIIB heterodimer), or combination of such antagonists, to a subject in need of such treatment. In one instance, the subject has a fasting blood sugar level of >130, >135, >140, >145, or >150 mg/dL. In one instance, the subject has a postprandial blood sugar level of >180, >185, >190, >195, or >200 mg/dL 2 hours after eating. In one instance, the subject is overweight. In one instance, the subject is obese. In another instance, the subject has type 2 diabetes.

[0315] In another instance, the disclosure provides a method of treating, preventing, or ameliorating liver disease in a subject, comprising administering an effective amount of an ALK7:ActRIIB antagonist (e.g., an ALK7:ActRIIB heterodimer), or combination of such antagonists, to a subject having a liver disease. In one instance, the subject has inflammation of the liver. In one instance, the subject has NAFLD. In one instance the subject has fatty liver. In another instance, the subject has NASH. In one instance the subject has fatty liver. In another instance, the subject has alcoholic fatty liver disease. In one instance, the treated, prevented or ameliorated liver disease is fibrosis, scarring, cirrhosis, or liver failure. In another instance, the treated, prevented or ameliorated liver disease is liver cancer. In one instance, the subject is overweight. In another instance, the subject is obese. In another instance, the subject has type 2 diabetes.

[0316] In one instance, the disclosure provides a method of for increasing lipolysis in a cell (e.g., white or brown adipose cells or tissue) comprising administering effective amount of an ALK7:ActRIIB antagonist (e.g., an ALK7:ActRIIB heterodimer), or combination of such antagonists. In some instances the cell is contacted *in vitro*. In some instances the cell is contacted *in vivo*. In one instance, the method is carried out *in vivo*, for example, in a mammalian subject (e.g., an animal model). In a further instance, the subject is a human. In some instances, the method leads to increased glycerol production. In further instances, the method leads to increased glycerol and/or free fatty acid in an adipocyte culture. In some instances, the method leads to decreased triglyceride (TG) content in the cell or tissue. In some instances, the method leads to a decreased plasma TG level in a subject.

[0317] In another instance, the disclosure provides a method of increasing adrenergic

receptor- β (ADRB) signaling in a cell or tissue (e.g., white or brown adipose cells or tissue). The method comprises contacting a cell or tissue with an ALK7:ActRIIB antagonist (e.g., an ALK7:ActRIIB heterodimer), or combination of such antagonists, in an amount sufficient to increase ADRB signaling. In some instances the cell or tissue is contacted *in vitro*. In some instances the cell or tissue is contacted *in vivo*. In one instance, the method is carried out *in vivo*, for example, in a mammalian subject (e.g., an animal model). In a further instance, the subject is a human. In some instances, the method leads to increased glycerol production. In further instances, the method leads to increased glycerol and/or free fatty acid in an adipocyte culture. In some instances, the method leads to decreased TG content in the cell or tissue. In some instances, the method leads to a decreased plasma TG level in a subject. In some instances, the method leads to an increased ADRB signaling in an adipocyte or adipose tissue during nutrient overload.

[0318] In another instance, the disclosure provides a method of decreasing peroxisome proliferator-activated receptor-gamma (PPAR gamma) signaling in a cell or tissue (e.g., white and/or brown adipose cell or tissue). The method includes contacting a cell or tissue with an ALK7:ActRIIB antagonist (e.g., an ALK7:ActRIIB heterodimer), or combination of such antagonists, in an amount effective to decrease PPAR gamma activity. In some instances the cells or tissue is contacted *in vitro*. In some instances the differentiated cells or tissue is contacted *in vivo*. In one instance, the method is carried out *in vivo*, for example, in a mammalian subject (e.g., an animal model). In a further instance, the subject is a human. In some instances, the method leads to increased glycerol production. In further instances, the method leads to increased glycerol and/or free fatty acid in an adipocyte culture. In some instances, the method leads to decreased TG content in the cells or tissue. In some instances, the method leads to a decreased plasma TG level in a subject.

[0319] In another instance, the disclosure provides a method of decreasing insulin resistance in a cell or tissue (e.g., white and/or brown adipose cell or tissue). The method includes contacting a cell or tissue with an ALK7:ActRIIB antagonist (e.g., an ALK7:ActRIIB heterodimer), or combination of such antagonists, in an amount effective to reduce insulin resistance. In some instances the cell or tissue is contacted *in vitro*. In some instances the cell or tissue is contacted *in vivo*. In one instance, the method is carried out *in vivo*, for example, in a mammalian subject (e.g., an animal model). In a further instance, the subject is a human.

[0320] In another instance, the disclosure provides a method of increasing the metabolic rate of a cell or tissue (e.g., white and/or brown adipose cell or tissue). The method includes contacting cell or tissue with an ALK7:ActRIIB antagonist (e.g., an ALK7:ActRIIB heterodimer), or combination of such antagonists, in an amount effective to increase metabolism of the cell or tissue. In some instances the cell or tissue is contacted *in vitro*. In some instances the cell or tissue is contacted *in vivo*. In one instance, the method is carried out *in vivo*, for example, in a mammalian subject (e.g., an animal model). In a further instance, the subject is a human.

[0321] The disclosure provides methods that comprise administering a therapeutically effective amount of an ALK7:ActRIIB antagonist (e.g., an ALK7:ActRIIB heterodimer), or combination of

such antagonists, alone or in combination with one or more additional therapies (e.g., one or more additional therapeutic agents and/or supportive) to a subject having, or at risk for developing, an ALK7-mediated disease and/or condition such as, obesity (e.g., abdominal obesity); overweight; insulin resistance; metabolic syndrome and other metabolic diseases or conditions; a lipid disorder such as, low HDL levels, high LDL levels, hyperlipidemia, hypertriglyceridemia or dyslipidemia; lipoprotein aberrations; decreased triglycerides; fatty liver disease; non-alcoholic fatty liver disease; hyperglycemia; impaired glucose tolerance (IGT); hyperinsulinemia; high cholesterol (e.g., high LDL levels and/or hypercholesterolemia); cardiovascular disease such as, heart disease including coronary heart disease, congestive heart failure, atherosclerosis; arteriosclerosis, and/or hypertension; Syndrome X; vascular restenosis; neuropathy; and/or other disorders/conditions associated with one or more of the above diseases or conditions, and/or with overweight (e.g., BMI of ≥ 25 kg/m²), or with too much body fat.

[0322] In additional instances, the disclosure provides methods of treating and/or ameliorating cancer or a condition associated with cancer, that comprises administering an ALK7:ActRIIB antagonist (e.g., an ALK7:ActRIIB heterodimer), or combination of such antagonists. In some instances, the subject has a cancer selected from the group consisting of melanoma, breast, colon, and endometrial, pancreatic, gastric, and uterine cancer. In some instances, the subject has myeloma (e.g., multiple myeloma, plasmacytoma, localized myeloma, and extramedullary myeloma). In some instances, the ALK7:ActRIIB antagonist is administered to treat or prevent lymphatic metastasis, bloodstream metastasis, tumor growth, or tumor invasion.

[0323] Fibrosis generally refers to an excessive deposition of both collagen fibers and extracellular matrix combined with a relative decrease of cell number in an organ or tissue. While this process is an important feature of natural wound healing following injury, fibrosis can lead to pathological damage in various tissue and organs including, for example, the lungs, kidneys, liver, bone, muscle, and skin. The role TGF-beta in fibrosis has been extensively study. However, other TGF-beta superfamily ligands have also been implicated in fibrosis including, for example, activins (e.g., activin A and activin B) and GDF8 [Hedger et al (2013) Cytokine and Growth Factor Reviews 24:285-295; Hardy et al. (2015) 93: 567-574; and Cantini et al. (2008) J Sex Med 5:1607-1622]. Therefore, in some instances, an ALK7:ActRIIB antagonist (e.g., an ALK7:ActRIIB heterodimer), or combinations of such antagonists, of the present disclosure can be used to treat fibrosis, particularly fibrosis-associated disorders and conditions. For example, an ALK7:ActRIIB antagonist (e.g., an ALK7:ActRIIB heterodimer), or combinations of such antagonists, may be used to treat or prevent one or more of: pulmonary fibrosis, hypersensitivity pneumonitis, idiopathic fibrosis, tuberculosis, pneumonia, cystic fibrosis, asthma, chronic obstructive pulmonary disease (COPD), emphysema, renal (kidney) fibrosis, renal (kidney) failure, chronic renal (kidney) disease, bone fibrosis, myelofibrosis, rheumatoid arthritis, systemic lupus erythematosus, scleroderma, sarcoidosis, granulomatosis with polyangiitis, Peyronie's disease, liver fibrosis, Wilson's disease, glycogen storage diseases (particularly types III, IV, IX, and X), iron-overload, Gaucher disease, Zellweger syndrome, nonalcoholic and alcoholic steatohepatitis, biliary cirrhosis, sclerosing cholangitis, Budd-Chiari syndrome, surgery-associated fibrosis, Crohn's disease, Duputren's contracture, mediastinal

fibrosis, nephrogenic fibrosis, retroperitoneal fibrosis, atrial fibrosis, endomyocardial fibrosis, pancreatic fibrosis.

[0324] In part, the present disclosure relate to the surprising discovery that ALK7:ActRIIB heteromultimers can bind to activin C. Therefore, ALK7:ActRIIB heteromultimers represent a new class of activin C inhibitors that can be used to treat or prevent activin C-related disorders or conditions. In some instances, ALK7:ActRIIB heteromultimers may be used to inhibit activin C activity in a patient in need thereof. Overexpression of activin C has been implicated in disease and disorders associated with liver, testis, and prostate, particular with cancer in such tissues. See, e.g., Gold et al. Am J Pathol (2009) 174(1): 184-195.. In some instances, ALK7:ActRIIB heteromultimers may be used to increase male fertility, increase sperm production, increase seminiferous tubule volume, decrease liver inflammation, treat liver (hepatic) cancer, treat testicular cancer, treat prostate cancer, decrease prostate inflammation, and/or treat prostate hypertrophy.

[0325] In some instances, ALK7:ActRIIB-associated conditions include neuromuscular disorders (e.g., muscular dystrophy and muscle atrophy), congestive obstructive pulmonary disease (and muscle wasting associated with COPD), muscle wasting syndrome, sarcopenia, cachexia, adipose tissue disorders (e.g., obesity), type 2 diabetes (NIDDM, adult-onset diabetes), and bone degenerative disease (e.g., osteoporosis). Other exemplary ALK7:ActRIIB-associated conditions include musculodegenerative and neuromuscular disorders, tissue repair (e.g., wound healing), neurodegenerative diseases (e.g., amyotrophic lateral sclerosis), and immunologic disorders (e.g., disorders related to abnormal proliferation or function of lymphocytes).

[0326] In certain instances, an ALK7:ActRIIB antagonist (e.g., an ALK7:ActRIIB heterodimer), or combinations of such antagonists, of the disclosure may be used as part of a treatment for a muscular dystrophy. The term "muscular dystrophy" refers to a group of degenerative muscle diseases characterized by gradual weakening and deterioration of skeletal muscles and sometimes the heart and respiratory muscles. Muscular dystrophies are genetic disorders characterized by progressive muscle wasting and weakness that begin with microscopic changes in the muscle. As muscles degenerate over time, the person's muscle strength declines. Exemplary muscular dystrophies that can be treated with a regimen including the subject TGF-beta superfamily heteromultimer complexes include: Duchenne muscular dystrophy (DMD), Becker muscular dystrophy (BMD), Emery-Dreifuss muscular dystrophy (EDMD), limb-girdle muscular dystrophy (LGMD), facioscapulohumeral muscular dystrophy (FSH or FSHD) (also known as Landouzy-Dejerine), myotonic dystrophy (MMD; also known as Steinert's Disease), oculopharyngeal muscular dystrophy (OPMD), distal muscular dystrophy (DD), congenital muscular dystrophy (CMD).

[0327] Duchenne muscular dystrophy (DMD) was first described by the French neurologist Guillaumc Benjamin Amand Duchenne in the 1860s. Becker muscular dystrophy (BMD) is named after the German doctor Peter Emil Becker, who first described this variant of DMD in the 1950s. DMD is one of the most frequent inherited diseases in males, affecting one in 3,500

boys. DMD occurs when the dystrophin gene, located on the short arm of the X chromosome, is defective. Since males only carry one copy of the X chromosome, they only have one copy of the dystrophin gene. Without the dystrophin protein, muscle is easily damaged during cycles of contraction and relaxation. While early in the disease muscle compensates by regeneration, later on muscle progenitor cells cannot keep up with the ongoing damage and healthy muscle is replaced by non-functional fibro-fatty tissue.

[0328] BMD results from different mutations in the dystrophin gene. BMD patients have some dystrophin, but it is either of insufficient quantity or poor quality. The presence of some dystrophin protects the muscles of patients with BMD from degenerating as severely or as quickly as those of patients with DMD.

[0329] Studies in animals indicate that inhibition of the GDF8 signaling pathway may effectively treat various aspects of disease in DMD and BMD patients (Bogdanovich et al., 2002, Nature 420:418-421; Pistilli et al., 2011, Am J Pathol 178:1287-1297). Thus, ALK7:ActRIIB antagonists of the disclosure may act as GDF8 inhibitors (antagonists), and constitute an alternative means of blocking signaling by GDF8 and/or related TGF β superfamily ligands *in vivo* in DMD and BMD patients.

[0330] Similarly, ALK7:ActRIIB antagonists of the disclosure may provide an effective means to increase muscle mass in other disease conditions that are in need of muscle growth. For example, amyotrophic lateral sclerosis (ALS), also called Lou Gehrig's disease or motor neuron disease, is a chronic, progressive, and incurable CNS disorder that attacks motor neurons, which are components of the central nervous system required for initiation of skeletal muscle contraction. In ALS, motor neurons deteriorate and eventually die, and though a person's brain normally remains fully functioning and alert, initiation of muscle contraction is blocked at the spinal level. Individuals who develop ALS are typically between 40 and 70 years old, and the first motor neurons to degenerate are those innervating the arms or legs. Patients with ALS may have trouble walking, may drop things, fall, slur their speech, and laugh or cry uncontrollably. As the disease progresses, muscles in the limbs begin to atrophy from disuse. Muscle weakness becomes debilitating, and patients eventually require a wheel chair or become confined to bed. Most ALS patients die from respiratory failure or from complications of ventilator assistance like pneumonia 3-5 years from disease onset.

[0331] Promotion of increased muscle mass by ALK7:ActRIIB antagonists might also benefit those suffering from muscle wasting diseases. Gonzalez-Cadavid *et al.* (supra) reported that GDF8 expression correlates inversely with fat-free mass in humans and that increased expression of the GDF8 gene is associated with weight loss in men with AIDS wasting syndrome. By inhibiting the function of GDF8 in AIDS patients, at least certain symptoms of AIDS may be alleviated, if not completely eliminated, thus significantly improving quality of life in AIDS patients.

[0332] Since loss of GDF8 function is also associated with fat loss without diminution of nutrient intake (Zimmers et al., supra; McPherron and Lee, supra), the subject ALK7:ActRIIB

antagonists may further be used as a therapeutic agent for slowing or preventing the development of obesity and type 2 diabetes.

[0333] Cancer anorexia-cachexia syndrome is among the most debilitating and life-threatening aspects of cancer. This syndrome is a common feature of many types of cancer - present in approximately 80% of cancer patients at death - and is responsible not only for a poor quality of life and poor response to chemotherapy but also a shorter survival time than is found in patients with comparable tumors but without weight loss. Cachexia is typically suspected in patients with cancer if an involuntary weight loss of greater than five percent of premorbid weight occurs within a six-month period. Associated with anorexia, wasting of fat and muscle tissue, and psychological distress, cachexia arises from a complex interaction between the cancer and the host. Cancer cachexia affects cytokine production, release of lipid-mobilizing and proteolysis-inducing factors, and alterations in intermediary metabolism. Although anorexia is common, a decreased food intake alone is unable to account for the changes in body composition seen in cancer patients, and increasing nutrient intake is unable to reverse the wasting syndrome. Currently, there is no treatment to control or reverse the cachexic process. Since systemic overexpression of GDF8 in adult mice was found to induce profound muscle and fat loss analogous to that seen in human cachexia syndromes (Zimmers et al., supra), the subject ALK7:ActRIIB antagonists may be beneficially used to prevent, treat, or alleviate the symptoms of the cachexia syndrome, where muscle growth is desired. An example of a heteromeric complex useful for preventing, treating, or alleviating muscle loss as described above is an ALK7:ActRIIB heterodimer.

[0334] In certain instances, an ALK7:ActRIIB antagonist (e.g., an ALK7:ActRIIB heterodimer), or combinations of such antagonists, of the present disclosure may be used in methods of inducing bone and/or cartilage formation, preventing bone loss, increasing bone mineralization, preventing the demineralization of bone, and/or increasing bone density. ALK7:ActRIIB antagonists may be useful in patients who are diagnosed with subclinical low bone density, as a protective measure against the development of osteoporosis.

[0335] In some instances, an ALK7:ActRIIB antagonist (e.g., an ALK7:ActRIIB heterodimer), or combinations of such antagonists, of the present disclosure may find medical utility in the healing of bone fractures and cartilage defects in humans and other animals. The subject methods and compositions may also have prophylactic use in closed as well as open fracture reduction and also in the improved fixation of artificial joints. De novo bone formation induced by an osteogenic agent is useful for repair of craniofacial defects that are congenital, trauma-induced, or caused by oncologic resection, and is also useful in cosmetic plastic surgery. Further, methods and compositions of the disclosure may be used in the treatment of periodontal disease and in other tooth repair processes. In certain cases, an ALK7:ActRIIB antagonist (e.g., an ALK7:ActRIIB heterodimer), or combinations of such antagonists, may provide an environment to attract bone-forming cells, stimulate growth of bone-forming cells, or induce differentiation of progenitors of bone-forming cells. An ALK7:ActRIIB antagonist (e.g., an ALK7:ActRIIB heterodimer), or combinations of such antagonists, of the disclosure may also be useful in the treatment of osteoporosis. Further, ALK7:ActRIIB antagonists may be used in

repair of cartilage defects and prevention/reversal of osteoarthritis. Examples of heteromeric complexes useful for inducing bone formation, preventing bone loss, increasing bone mineralization, preventing the demineralization of bone, and/or increasing bone density as described herein are ALK7:ActRIIB heterodimers.

[0336] Rosen et al. (ed) Primer on the Metabolic Bone Diseases and Disorders of Mineral Metabolism, 7th ed. American Society for Bone and Mineral Research, Washington D.C. provides an extensive discussion of bone disorders that may be subject to treatment with an ALK7:ActRIIB antagonist, or with combinations of such antagonists. A partial listing is provided herein. Methods and compositions of the disclosure can be applied to conditions characterized by or causing bone loss, such as osteoporosis (including secondary osteoporosis), hyperparathyroidism, chronic kidney disease mineral bone disorder, sex hormone deprivation or ablation (e.g. androgen and/or estrogen), glucocorticoid treatment, rheumatoid arthritis, severe burns, hyperparathyroidism, hypercalcemia, hypocalcemia, hypophosphatemia, osteomalacia (including tumor-induced osteomalacia), hyperphosphatemia, vitamin D deficiency, hyperparathyroidism (including familial hyperparathyroidism) and pseudohypoparathyroidism, tumor metastases to bone, bone loss as a consequence of a tumor or chemotherapy, tumors of the bone and bone marrow (e.g., multiple myeloma), ischemic bone disorders, periodontal disease and oral bone loss, Cushing's disease, Paget's disease, thyrotoxicosis, chronic diarrheal state or malabsorption, renal tubular acidosis, or anorexia nervosa. Methods and compositions of the disclosure may also be applied to conditions characterized by a failure of bone formation or healing, including non-union fractures, fractures that are otherwise slow to heal, fetal and neonatal bone dysplasias (e.g., hypocalcemia, hypercalcemia, calcium receptor defects and vitamin D deficiency), osteonecrosis (including osteonecrosis of the jaw) and osteogenesis imperfecta. Additionally, the anabolic effects will cause such antagonists to diminish bone pain associated with bone damage or erosion. As a consequence of the anti-resorptive effects, such antagonists may be useful to treat disorders of abnormal bone formation, such as osteoblastic tumor metastases (e.g., associated with primary prostate or breast cancer), osteogenic osteosarcoma, osteopetrosis, progressive diaphyseal dysplasia, endosteal hyperostosis, osteopoikilosis, and melorheostosis. Other disorders that may be treated include fibrous dysplasia and chondrodysplasias.

[0337] In another specific instance, the disclosure provides a therapeutic method and composition for repairing fractures and other conditions related to cartilage and/or bone defects or periodontal diseases. The disclosure further provides therapeutic methods and compositions for wound healing and tissue repair. The types of wounds include, but are not limited to, burns, incisions and ulcers. See, e.g., PCT Publication No. WO 84/01106. Such compositions comprise a therapeutically effective amount of at least one of the ALK7:ActRIIB antagonists of the disclosure in admixture with a pharmaceutically acceptable vehicle, carrier, or matrix.

[0338] In some instances, an ALK7:ActRIIB antagonist (e.g., an ALK7:ActRIIB heterodimer), or combinations of such antagonists, of the disclosure can be applied to conditions causing bone

loss such as osteoporosis, hyperparathyroidism, Cushing's disease, thyrotoxicosis, chronic diarrheal state or malabsorption, renal tubular acidosis, or anorexia nervosa. It is commonly appreciated that being female, having a low body weight, and leading a sedentary lifestyle are risk factors for osteoporosis (loss of bone mineral density, leading to fracture risk). However, osteoporosis can also result from the long-term use of certain medications. Osteoporosis resulting from drugs or another medical condition is known as secondary osteoporosis. In Cushing's disease, the excess amount of cortisol produced by the body results in osteoporosis and fractures. The most common medications associated with secondary osteoporosis are the corticosteroids, a class of drugs that act like cortisol, a hormone produced naturally by the adrenal glands. Although adequate levels of thyroid hormones are needed for the development of the skeleton, excess thyroid hormone can decrease bone mass over time. Antacids that contain aluminum can lead to bone loss when taken in high doses by people with kidney problems, particularly those undergoing dialysis. Other medications that can cause secondary osteoporosis include phenytoin (Dilantin) and barbiturates that are used to prevent seizures; methotrexate (Rheumatrex, Immunex, Folex PFS), a drug for some forms of arthritis, cancer, and immune disorders; cyclosporine (Sandimmune, Neoral), a drug used to treat some autoimmune diseases and to suppress the immune system in organ transplant patients; luteinizing hormone-releasing hormone agonists (Lupron, Zoladex), used to treat prostate cancer and endometriosis; heparin (Calciparine, Liquaemin), an anticlotting medication; and cholestyramine (Questran) and colestipol (Colestid), used to treat high cholesterol. Bone loss resulting from cancer therapy is widely recognized and termed cancer therapy-induced bone loss (CTIBL). Bone metastases can create cavities in the bone that may be corrected by treatment with An ALK7:ActRIIB antagonist (e.g., an ALK7:ActRIIB heterodimer). Bone loss can also be caused by gum disease, a chronic infection in which bacteria located in gum recesses produce toxins and harmful enzymes.

[0339] In a further instance, the present disclosure provides methods and therapeutic agents for treating diseases or disorders associated with abnormal or unwanted bone growth. For example, patients with the congenital disorder fibrodysplasia ossificans progressiva (FOP) are afflicted by progressive ectopic bone growth in soft tissues spontaneously or in response to tissue trauma, with a major impact on quality of life. Additionally, abnormal bone growth can occur after hip replacement surgery and thus ruin the surgical outcome. This is a more common example of pathological bone growth and a situation in which the subject methods and compositions may be therapeutically useful. The same methods and compositions may also be useful for treating other forms of abnormal bone growth (e.g., pathological growth of bone following trauma, burns or spinal cord injury), and for treating or preventing the undesirable conditions associated with the abnormal bone growth seen in connection with metastatic prostate cancer or osteosarcoma.

[0340] In certain instances, an ALK7:ActRIIB antagonist (e.g., an ALK7:ActRIIB heterodimer), or combinations of such antagonists, of the disclosure may be used to promote bone formation in patients with cancer. Patients having certain tumors (e.g. prostate, breast, multiple myeloma or any tumor causing hyperparathyroidism) are at high risk for bone loss due to tumor-induced bone loss, bone metastases, and therapeutic agents. Such patients may be treated with a

TGF-beta superfamily heteromultimer complex, or a combination of complexes, even in the absence of evidence of bone loss or bone metastases. Patients may also be monitored for evidence of bone loss or bone metastases, and may be treated with an ALK7:ActRIIB antagonist in the event that indicators suggest an increased risk. Generally, DEXA scans are employed to assess changes in bone density, while indicators of bone remodeling may be used to assess the likelihood of bone metastases. Serum markers may be monitored. Bone specific alkaline phosphatase (BSAP) is an enzyme that is present in osteoblasts. Blood levels of BSAP are increased in patients with bone metastasis and other conditions that result in increased bone remodeling. Osteocalcin and procollagen peptides are also associated with bone formation and bone metastases. Increases in BSAP have been detected in patients with bone metastasis caused by prostate cancer, and to a lesser degree, in bone metastases from breast cancer. BMP7 levels are high in prostate cancer that has metastasized to bone, but not in bone metastases due to bladder, skin, liver, or lung cancer. Type I carboxy-terminal telopeptide (ICTP) is a crosslink found in collagen that is formed during the resorption of bone. Since bone is constantly being broken down and reformed, ICTP will be found throughout the body. However, at the site of bone metastasis, the level will be significantly higher than in an area of normal bone. ICTP has been found in high levels in bone metastasis due to prostate, lung, and breast cancer. Another collagen crosslink, Type I N-terminal telopeptide (NTx), is produced along with ICTP during bone turnover. The amount of NTx is increased in bone metastasis caused by many different types of cancer including lung, prostate, and breast cancer. Also, the levels of NTx increase with the progression of the bone metastasis. Therefore, this marker can be used to both detect metastasis as well as measure the extent of the disease. Other markers of resorption include pyridinoline and deoxypyridinoline. Any increase in resorption markers or markers of bone metastases indicate the need for therapy with an ALK7:ActRIIB antagonist in a patient.

[0341] An ALK7:ActRIIB antagonist (e.g., an ALK7:ActRIIB heterodimer), or combinations of such antagonists, of the disclosure may be conjointly administered with other bone-active pharmaceutical agents. Conjoint administration may be accomplished by administration of a single co-formulation, by simultaneous administration, or by administration at separate times. ALK7:ActRIIB antagonists may be particularly advantageous if administered with other bone-active agents. A patient may benefit from conjointly receiving an ALK7:ActRIIB antagonist complex and taking calcium supplements, vitamin D, appropriate exercise and/or, in some cases, other medication. Examples of other medications include, bisphosphonates (alendronate, ibandronate and risedronate), calcitonin, estrogens, parathyroid hormone and raloxifene. The bisphosphonates (alendronate, ibandronate and risedronate), calcitonin, estrogens and raloxifene affect the bone remodeling cycle and are classified as anti-resorptive medications. Bone remodeling consists of two distinct stages: bone resorption and bone formation. Anti-resorptive medications slow or stop the bone-resorbing portion of the bone-remodeling cycle but do not slow the bone-forming portion of the cycle. As a result, new formation continues at a greater rate than bone resorption, and bone density may increase over time. Teriparatide, a form of parathyroid hormone, increases the rate of bone formation in the bone remodeling cycle. Alendronate is approved for both the prevention (5 mg per day or 35 mg once a week) and treatment (10 mg per day or 70 mg once a week) of postmenopausal

osteoporosis. Alendronate reduces bone loss, increases bone density and reduces the risk of spine, wrist and hip fractures. Alendronate also is approved for treatment of glucocorticoid-induced osteoporosis in men and women as a result of long-term use of these medications (i.e., prednisone and cortisone) and for the treatment of osteoporosis in men. Alendronate plus vitamin D is approved for the treatment of osteoporosis in postmenopausal women (70 mg once a week plus vitamin D), and for treatment to improve bone mass in men with osteoporosis. Ibandronate is approved for the prevention and treatment of postmenopausal osteoporosis. Taken as a once-a-month pill (150 mg), ibandronate should be taken on the same day each month. Ibandronate reduces bone loss, increases bone density and reduces the risk of spine fractures. Risedronate is approved for the prevention and treatment of postmenopausal osteoporosis. Taken daily (5 mg dose) or weekly (35 mg dose or 35 mg dose with calcium), risedronate slows bone loss, increases bone density and reduces the risk of spine and non-spine fractures. Risedronate also is approved for use by men and women to prevent and/or treat glucocorticoid-induced osteoporosis that results from long-term use of these medications (i.e., prednisone or cortisone). Calcitonin is a naturally occurring hormone involved in calcium regulation and bone metabolism. In women who are more than 5 years beyond menopause, calcitonin slows bone loss, increases spinal bone density, and may relieve the pain associated with bone fractures. Calcitonin reduces the risk of spinal fractures. Calcitonin is available as an injection (50-100 IU daily) or nasal spray (200 IU daily).

[0342] A patient may also benefit from conjointly receiving an ALK7:ActRIIB antagonist, or combinations of such antagonists, and additional bone-active medications. Estrogen therapy (ET)/hormone therapy (HT) is approved for the prevention of osteoporosis. ET has been shown to reduce bone loss, increase bone density in both the spine and hip, and reduce the risk of hip and spinal fractures in postmenopausal women. ET is administered most commonly in the form of a pill or skin patch that delivers a low dose of approximately 0.3 mg daily or a standard dose of approximately 0.625 mg daily and is effective even when started after age 70. When estrogen is taken alone, it can increase a woman's risk of developing cancer of the uterine lining (endometrial cancer). To eliminate this risk, healthcare providers prescribe the hormone progestin in combination with estrogen (hormone replacement therapy or HT) for those women who have an intact uterus. ET/HT relieves menopause symptoms and has been shown to have a beneficial effect on bone health. Side effects may include vaginal bleeding, breast tenderness, mood disturbances and gallbladder disease. Raloxifene, 60 mg a day, is approved for the prevention and treatment of postmenopausal osteoporosis. It is from a class of drugs called Selective Estrogen Receptor Modulators (SERMs) that have been developed to provide the beneficial effects of estrogens without their potential disadvantages. Raloxifene increases bone mass and reduces the risk of spine fractures. Data are not yet available to demonstrate that raloxifene can reduce the risk of hip and other non-spine fractures. Teriparatide, a form of parathyroid hormone, is approved for the treatment of osteoporosis in postmenopausal women and men who are at high risk for a fracture. This medication stimulates new bone formation and significantly increases bone mineral density. In postmenopausal women, fracture reduction was noted in the spine, hip, foot, ribs and wrist. In men, fracture reduction was noted in the spine, but there were insufficient data to evaluate fracture reduction at other sites. Teriparatide is self-administered as a daily injection for up to

24 months.

[0343] As used herein, "in combination with", "combinations of", or "conjoint administration" refers to any form of administration such that additional therapies (e.g., second, third, fourth, etc.) are still effective in the body (e.g., multiple compounds are simultaneously effective in the patient, which may include synergistic effects of those compounds). Effectiveness may not correlate to measurable concentration of the agent in blood, serum, or plasma. For example, the different therapeutic compounds can be administered either in the same formulation or in separate formulations, either concomitantly or sequentially, and on different schedules. Thus, an individual who receives such treatment can benefit from a combined effect of different therapies. One or more ALK7:ActRIIB antagonists of the disclosure can be administered concurrently with, prior to, or subsequent to, one or more other additional agents or supportive therapies. In general, each therapeutic agent will be administered at a dose and/or on a time schedule determined for that particular agent. The particular combination to employ in a regimen will take into account compatibility of the antagonist of the present disclosure with the therapy and/or the desired.

5. Pharmaceutical Compositions

[0344] In certain aspects, ALK7:ActRIIB antagonists (e.g., ALK7:ActRIIB heteromultimers), or combinations of such antagonists, of the present disclosure can be administered alone or as a component of a pharmaceutical formulation (also referred to as a therapeutic composition or pharmaceutical composition). A pharmaceutical formation refers to a preparation which is in such form as to permit the biological activity of an active ingredient (e.g., an agent of the present disclosure) contained therein to be effective and which contains no additional components which are unacceptably toxic to a subject to which the formulation would be administered. The subject compounds may be formulated for administration in any convenient way for use in human or veterinary medicine. For example, one or more agents of the present disclosure may be formulated with a pharmaceutically acceptable carrier. A pharmaceutically acceptable carrier refers to an ingredient in a pharmaceutical formulation, other than an active ingredient, which is generally nontoxic to a subject. A pharmaceutically acceptable carrier includes, but is not limited to, a buffer, excipient, stabilizer, and/or preservative. In general, pharmaceutical formulations for use in the present disclosure are in a pyrogen-free, physiologically-acceptable form when administered to a subject. Therapeutically useful agents other than those described herein, which may optionally be included in the formulation as described above, may be administered in combination with the subject agents in the methods of the present disclosure.

[0345] In certain instances, compositions will be administered parenterally [e.g., by intravenous (I.V.) injection, intraarterial injection, intraosseous injection, intramuscular injection, intrathecal injection, subcutaneous injection, or intradermal injection]. Pharmaceutical compositions suitable for parenteral administration may comprise one or more agents of the disclosure in combination with one or more pharmaceutically acceptable sterile isotonic aqueous or

nonaqueous solutions, dispersions, suspensions or emulsions, or sterile powders which may be reconstituted into sterile injectable solutions or dispersions just prior to use. Injectable solutions or dispersions may contain antioxidants, buffers, bacteriostats, suspending agents, thickening agents, or solutes which render the formulation isotonic with the blood of the intended recipient. Examples of suitable aqueous and nonaqueous carriers which may be employed in the pharmaceutical formulations of the present disclosure include water, ethanol, polyols (e.g., glycerol, propylene glycol, polyethylene glycol, *etc.*), vegetable oils (e.g., olive oil), injectable organic esters (e.g., ethyl oleate), and suitable mixtures thereof. Proper fluidity can be maintained, for example, by the use of coating materials (e.g., lecithin), by the maintenance of the required particle size in the case of dispersions, and by the use of surfactants.

[0346] In some instances, a therapeutic method of the present disclosure includes administering the pharmaceutical composition systemically, or locally, from an implant or device. Further, the pharmaceutical composition may be encapsulated or injected in a form for delivery to a target tissue site (e.g., bone marrow or muscle). In certain instances, compositions of the present disclosure may include a matrix capable of delivering one or more of the agents of the present disclosure to a target tissue site (e.g., bone marrow or muscle), providing a structure for the developing tissue and optimally capable of being resorbed into the body. For example, the matrix may provide slow release of one or more agents of the present disclosure. Such matrices may be formed of materials presently in use for other implanted medical applications.

[0347] In some instances, pharmaceutical compositions will be administered to the eye including, e.g., by topical administration, intraocular (e.g., intravitreal) injection, or by implant or device. An intravitreal injection can be injected, for example, through the pars plana, 3 mm to 4 mm posterior to the limbus. Pharmaceutical compositions for administration to the eye may be formulated in a variety of ways including, for example, eye drops, ophthalmic solutions, ophthalmic suspensions, ophthalmic emulsions, intravitreal injections, sub-Tenon injections, ophthalmic biodegradable implant, and non-biodegradable ophthalmic inserts or depots.

[0348] The choice of matrix material may be based on one or more of: biocompatibility, biodegradability, mechanical properties, cosmetic appearance, and interface properties. The particular application of the subject compositions will define the appropriate formulation. Potential matrices for the compositions may be biodegradable and chemically defined calcium sulfate, tricalciumphosphate, hydroxyapatite, polylactic acid, and polyanhydrides. Other potential materials are biodegradable and biologically well-defined including, for example, bone or dermal collagen. Further matrices are comprised of pure proteins or extracellular matrix components. Other potential matrices are non-biodegradable and chemically defined including, for example, sintered hydroxyapatite, bioglass, aluminates, or other ceramics. Matrices may be comprised of combinations of any of the above mentioned types of material including, for example, polylactic acid and hydroxyapatite or collagen and tricalciumphosphate. The bioceramics may be altered in composition (e.g., calcium-aluminate-phosphate) and processing to alter one or more of pore size, particle size, particle shape, and biodegradability.

[0349] In certain instances, pharmaceutical compositions of present disclosure can be administered topically. "Topical application" or "topically" means contact of the pharmaceutical composition with body surfaces including, for example, the skin, wound sites, and mucous membranes. The topical pharmaceutical compositions can have various application forms and typically comprises a drug-containing layer, which is adapted to be placed near to or in direct contact with the tissue upon topically administering the composition. Pharmaceutical compositions suitable for topical administration may comprise one or more one or more TGF β superfamily type I and/or type II receptor polypeptide complexes of the disclosure in combination formulated as a liquid, a gel, a cream, a lotion, an ointment, a foam, a paste, a putty, a semi-solid, or a solid. Compositions in the liquid, gel, cream, lotion, ointment, foam, paste, or putty form can be applied by spreading, spraying, smearing, dabbing or rolling the composition on the target tissue. The compositions also may be impregnated into sterile dressings, transdermal patches, plasters, and bandages. Compositions of the putty, semi-solid or solid forms may be deformable. They may be elastic or non-elastic (e.g., flexible or rigid). In certain aspects, the composition forms part of a composite and can include fibers, particulates, or multiple layers with the same or different compositions.

[0350] Topical compositions in the liquid form may include pharmaceutically acceptable solutions, emulsions, microemulsions, and suspensions. In addition to the active ingredient(s), the liquid dosage form may contain an inert diluent commonly used in the art including, for example, water or other solvent, a solubilizing agent and/or emulsifier [e.g., ethyl alcohol, isopropyl alcohol, ethyl carbonate, ethyl acetate, benzyl alcohol, benzyl benzoate, propylene glycol, or 1,3-butylene glycol, an oil (e.g., cottonseed, groundnut, corn, germ, olive, castor, and sesame oil), glycerol, tetrahydrofuryl alcohol, a polyethylene glycol, a fatty acid ester of sorbitan, and mixtures thereof].

[0351] Topical gel, cream, lotion, ointment, semi-solid or solid compositions may include one or more thickening agents, such as a polysaccharide, synthetic polymer or protein-based polymer. In one instance of the disclosure, the gelling agent herein is one that is suitably nontoxic and gives the desired viscosity. The thickening agents may include polymers, copolymers, and monomers of: vinylpyrrolidones, methacrylamides, acrylamides N-vinylimidazoles, carboxy vinyls, vinyl esters, vinyl ethers, silicones, polyethylenoxides, polyethyleneglycols, vinylalcohols, sodium acrylates, acrylates, maleic acids, NN-dimethylacrylamides, diacetone acrylamides, acrylamides, acryloyl morpholine, pluronic, collagens, polyacrylamides, polyacrylates, polyvinyl alcohols, polyvinylenes, polyvinyl silicates, polyacrylates substituted with a sugar (e.g., sucrose, glucose, glucosamines, galactose, trehalose, mannose, or lactose), acylamidopropane sulfonic acids, tetramethoxyorthosilicates, methyltrimethoxyorthosilicates, tetraalkoxyorthosilicates, trialkoxyorthosilicates, glycols, propylene glycol, glycerine, polysaccharides, alginates, dextrans, cyclodextrin, celluloses, modified celluloses, oxidized celluloses, chitosans, chitins, guar, carrageenans, hyaluronic acids, inulin, starches, modified starches, agarose, methylcelluloses, plant gums, hylaronans, hydrogels, gelatins, glycosaminoglycans, carboxymethyl celluloses, hydroxyethyl celluloses, hydroxy propyl methyl celluloses, pectins, low-methoxy pectins, cross-linked dextrans, starch-acrylonitrile graft copolymers, starch sodium polyacrylate, hydroxyethyl methacrylates, hydroxyl

ethyl acrylates, polyvinylene, polyethylvinylethers, polymethyl methacrylates, polystyrenes, polyurethanes, polyalkanoates, polylactic acids, polylactates, poly(3-hydroxybutyrate), sulfonated hydrogels, AMPS (2-acrylamido-2-methyl-1-propanesulfonic acid), SEM (sulfoethylmethacrylate), SPM (sulfopropyl methacrylate), SPA (sulfopropyl acrylate), N,N-dimethyl-N-methacryloxyethyl-N-(3-sulfopropyl)ammonium betaine, methacrylic acid amidopropyl-dimethyl ammonium sulfobetaine, SPI (itaconic acid-bis(1-propyl sulfonizacid-3) ester di-potassium salt), itaconic acids, AMBC (3-acrylamido-3-methylbutanoic acid), beta-carboxyethyl acrylate (acrylic acid dimers), and maleic anhydride-methylvinyl ether polymers, derivatives thereof, salts thereof, acids thereof, and combinations thereof. In certain instances, pharmaceutical compositions of present disclosure can be administered orally, for example, in the form of capsules, cachets, pills, tablets, lozenges (using a flavored basis such as sucrose and acacia or tragacanth), powders, granules, a solution or a suspension in an aqueous or non-aqueous liquid, an oil-in-water or water-in-oil liquid emulsion, or an elixir or syrup, or pastille (using an inert base, such as gelatin and glycerin, or sucrose and acacia), and/or a mouth wash, each containing a predetermined amount of a compound of the present disclosure and optionally one or more other active ingredients. A compound of the present disclosure and optionally one or more other active ingredients may also be administered as a bolus, electuary, or paste.

[0352] In solid dosage forms for oral administration (e.g., capsules, tablets, pills, dragees, powders, and granules), one or more compounds of the present disclosure may be mixed with one or more pharmaceutically acceptable carriers including, for example, sodium citrate, dicalcium phosphate, a filler or extender (e.g., a starch, lactose, sucrose, glucose, mannitol, and silicic acid), a binder (e.g. carboxymethylcellulose, an alginate, gelatin, polyvinyl pyrrolidone, sucrose, and acacia), a humectant (e.g., glycerol), a disintegrating agent (e.g., agar-agar, calcium carbonate, potato or tapioca starch, alginic acid, a silicate, and sodium carbonate), a solution retarding agent (e.g. paraffin), an absorption accelerator (e.g. a quaternary ammonium compound), a wetting agent (e.g., cetyl alcohol and glycerol monostearate), an absorbent (e.g., kaolin and bentonite clay), a lubricant (e.g., a talc, calcium stearate, magnesium stearate, solid polyethylene glycols, sodium lauryl sulfate), a coloring agent, and mixtures thereof. In the case of capsules, tablets, and pills, the pharmaceutical formulation (composition) may also comprise a buffering agent. Solid compositions of a similar type may also be employed as fillers in soft and hard-filled gelatin capsules using one or more excipients including, e.g., lactose or a milk sugar as well as a high molecular-weight polyethylene glycol.

[0353] Liquid dosage forms for oral administration of the pharmaceutical composition may include pharmaceutically acceptable emulsions, microemulsions, solutions, suspensions, syrups, and elixirs. In addition to the active ingredient(s), the liquid dosage form may contain an inert diluent commonly used in the art including, for example, water or other solvent, a solubilizing agent and/or emulsifier [e.g., ethyl alcohol, isopropyl alcohol, ethyl carbonate, ethyl acetate, benzyl alcohol, benzyl benzoate, propylene glycol, or 1,3-butylene glycol, an oil (e.g., cottonseed, groundnut, corn, germ, olive, castor, and sesame oil), glycerol, tetrahydrofuryl alcohol, a polyethylene glycol, a fatty acid ester of sorbitan, and mixtures thereof]. Besides

inert diluents, the oral formulation can also include an adjuvant including, for example, a wetting agent, an emulsifying and suspending agent, a sweetening agent, a flavoring agent, a coloring agent, a perfuming agent, a preservative agent, and combinations thereof.

[0354] Suspensions, in addition to the active compounds, may contain suspending agents including, for example, an ethoxylated isostearyl alcohol, polyoxyethylene sorbitol, a sorbitan ester, microcrystalline cellulose, aluminum metahydroxide, bentonite, agar-agar, tragacanth, and combinations thereof.

[0355] Prevention of the action and/or growth of microorganisms may be ensured by the inclusion of various antibacterial and antifungal agents including, for example, paraben, chlorobutanol, and phenol sorbic acid.

[0356] In certain instances, it may be desirable to include an isotonic agent including, for example, a sugar or sodium chloride into the compositions. In addition, prolonged absorption of an injectable pharmaceutical form may be brought about by the inclusion of an agent that delay absorption including, for example, aluminum monostearate and gelatin.

[0357] It is understood that the dosage regimen will be determined by the attending physician considering various factors which modify the action of the one or more of the agents of the present disclosure. In the case of ALK7:ActRIIB antagonists that promote red blood cell formation, various factors may include, but are not limited to, the patient's red blood cell count, hemoglobin level, the desired target red blood cell count, the patient's age, the patient's sex, the patient's diet, the severity of any disease that may be contributing to a depressed red blood cell level, the time of administration, and other clinical factors. The addition of other known active agents to the final composition may also affect the dosage. Progress can be monitored by periodic assessment of one or more of red blood cell levels, hemoglobin levels, reticulocyte levels, and other indicators of the hematopoietic process.

[0358] In certain instances, the present disclosure also provides gene therapy for the *in vivo* production of one or more of the agents of the present disclosure. Such therapy would achieve its therapeutic effect by introduction of the agent sequences into cells or tissues having one or more of the disorders as listed above. Delivery of the agent sequences can be achieved, for example, by using a recombinant expression vector such as a chimeric virus or a colloidal dispersion system. Preferred therapeutic delivery of one or more of agent sequences of the disclosure is the use of targeted liposomes.

[0359] Various viral vectors which can be utilized for gene therapy as taught herein include adenovirus, herpes virus, vaccinia, or an RNA virus (e.g., a retrovirus). The retroviral vector may be a derivative of a murine or avian retrovirus. Examples of retroviral vectors in which a single foreign gene can be inserted include, but are not limited to: Moloney murine leukemia virus (MoMuLV), Harvey murine sarcoma virus (HaMuSV), murine mammary tumor virus (MuMTV), and Rous Sarcoma Virus (RSV). A number of additional retroviral vectors can incorporate multiple genes. All of these vectors can transfer or incorporate a gene for a

selectable marker so that transduced cells can be identified and generated. Retroviral vectors can be made target-specific by attaching, for example, a sugar, a glycolipid, or a protein. Preferred targeting is accomplished by using an antibody. Those of skill in the art will recognize that specific polynucleotide sequences can be inserted into the retroviral genome or attached to a viral envelope to allow target specific delivery of the retroviral vector containing one or more of the agents of the present disclosure.

[0360] Alternatively, tissue culture cells can be directly transfected with plasmids encoding the retroviral structural genes (gag, pol, and env), by conventional calcium phosphate transfection. These cells are then transfected with the vector plasmid containing the genes of interest. The resulting cells release the retroviral vector into the culture medium.

[0361] Another targeted delivery system for one or more of the agents of the present disclosure is a colloidal dispersion system. Colloidal dispersion systems include, for example, macromolecule complexes, nanocapsules, microspheres, beads, and lipid-based systems including oil-in-water emulsions, micelles, mixed micelles, and liposomes. In certain instances, the preferred colloidal system of this disclosure is a liposome. Liposomes are artificial membrane vesicles which are useful as delivery vehicles *in vitro* and *in vivo*. RNA, DNA, and intact virions can be encapsulated within the aqueous interior and be delivered to cells in a biologically active form [Fraley, et al. (1981) Trends Biochem. Sci., 6:77]. Methods for efficient gene transfer using a liposome vehicle are known in the art [Mannino, et al. (1988) Biotechniques, 6:682, 1988].

[0362] The composition of the liposome is usually a combination of phospholipids, which may include a steroid (e.g. cholesterol). The physical characteristics of liposomes depend on pH, ionic strength, and the presence of divalent cations. Other phospholipids or other lipids may also be used including, for example a phosphatidyl compound (e.g., phosphatidylglycerol, phosphatidylcholine, phosphatidylserine, phosphatidylethanolamine, a sphingolipid, a cerebroside, and a ganglioside), egg phosphatidylcholine, dipalmitoylphosphatidylcholine, and distearoylphosphatidylcholine. The targeting of liposomes is also possible based on, for example, organ-specificity, cell-specificity, and organelle-specificity and is known in the art.

[0363] While specific instances of the subject matter have been discussed, the above specification is illustrative and not restrictive. Many variations will become apparent to those skilled in the art upon review of this specification and the claims below. The full scope of the disclosure should be determined by reference to the claims, along with their full scope of equivalents, and the specification, along with such variations.

EXEMPLIFICATION

[0364] The disclosure now being generally described, it will be more readily understood by reference to the following examples, which are included merely for purposes of illustration of certain instances of the present disclosure, and are not intended to limit the disclosure.

Example 1. Generation of an ActRIIB-Fc:ALK7-Fc heterodimer

[0365] Applicants constructed a soluble ActRIIB-Fc:ALK7-Fc heteromeric complex comprising the extracellular domains of human ActRIIB and human ALK7, which are each fused to an Fc domain with a linker positioned between the extracellular domain and the Fc domain. The individual constructs are referred to as ActRIIB-Fc and ALK7-Fc, respectively.

[0366] A methodology for promoting formation of ActRIIB-Fc:ALK7-Fc heteromeric complexes, as opposed to the ActRIIB-Fc or ALK7-Fc homodimeric complexes, is to introduce alterations in the amino acid sequence of the Fc domains to guide the formation of asymmetric heteromeric complexes. Many different approaches to making asymmetric interaction pairs using Fc domains are described in this disclosure.

[0367] In one approach, illustrated in the ActRIIB-Fc and ALK7-Fc polypeptide sequences disclosed below, respectively, one Fc domain is altered to introduce cationic amino acids at the interaction face, while the other Fc domain is altered to introduce anionic amino acids at the interaction face. The ActRIIB-Fc fusion polypeptide and ALK7-Fc fusion polypeptide each employ the tissue plasminogen activator (TPA) leader:

MDAMKRGLCCVLLLCGAVFVSP (SEQ ID NO: 70).

[0368] The ActRIIB-Fc polypeptide sequence (SEQ ID NO: 71) is shown below:

```

1      MDAMKRGLCC VLLLCGAVFV SPGASGRGEA ETRECIYYNA NWELERTNQS
51     GLERCEGEQD KRLHCYASWR NSSGTIELVK KGCWLDDFNC YDRQECVATE
101    ENPQVYFCCC EGNFCNERFT HLPEAGGPEV TYEPPPTAPT GGGTHTCPPC
151    PAPELLGGPS VFLFPPKPKD TLMISRTPEV TCVVVDVSHE DPEVKFNWYV
201    DGVEVHNAKT KPREEQYNST YRVVSVLTVL HQDWLNGKEY KCKVSNKALP
251    APIEKTISKA KGQPREPQVY TLPPSRKEMT KNQVSLTCLV KGFYPSDIAV
301    EWESNGQPEN NYKTTTPVLK SDGSFFLYSK LTVDKSRWQQ GNVFSCSVMH
351    EALHNHYTQK SLSLSPGK (SEQ ID NO: 71)

```

[0369] The leader (signal) sequence and linker are underlined. To promote formation of the ActRIIB-Fc:ALK7-Fc heterodimer rather than either of the possible homodimeric complexes, two amino acid substitutions (replacing acidic amino acids with lysine) can be introduced into the Fc domain of the ActRIIB fusion protein as indicated by double underline above. The amino acid sequence of SEQ ID NO: 71 may optionally be provided with lysine (K) removed from the C-terminus.

[0370] This ActRIIB-Fc fusion protein is encoded by the following nucleic acid sequence (SEQ ID NO: 72):

```

1      ATGGATGCAA TGAAGAGAGG GCTCTGCTGT GTGCTGCTGC TGTGTGGAGC
51     AGTCTTCGTT TCGCCCGGCG CCTCTGGGCG TGGGGAGGCT GAGACACGGG
101    AGTGCATCTA CTACAACGCC AACTGGGAGC TGGAGCGCAC CAACCAGAGC
151    GGCCTGGAGC GCTGCGAAGG CGAGCAGGAC AAGCGGCTGC ACTGCTACGC
201    CTCCTGGCGC AACAGCTCTG GCACCATCGA GCTCGTGAAG AAGGGCTGCT
251    GGCTAGATGA CTTCAACTGC TACGATAGGC AGGAGTGTGT GGCCACTGAG
301    GAGAACCCCC AGGTGTACTT CTGCTGCTGT GAAGGCAACT TCTGCAACGA

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351 GCGCTTCACT CATTTGCCAG AGGCTGGGGG CCCGGAAGTC ACGTACGAGC
401 CACCCCCGAC AGCCCCCACC GGTGGTGGAA CTCACACATG CCCACCGTGC
451 CCAGCACCTG AACTCCTGGG GGGACCGTCA GTCTTCCTCT TCCCCC AAA
501 ACCCAAGGAC ACCCTCATGA TCTCCCGGAC CCCTGAGGTC ACATGCGTGG
551 TGGTGGACGT GAGCCACGAA GACCCTGAGG TCAAGTTCAA CTGGTACGTG
601 GACGGCGTGG AGGTGCATAA TGCCAAGACA AAGCCGCGGG AGGAGCAGTA
651 CAACAGCACG TACCGTGTGG TCAGCGTCCT CACCGTCCTG CACCAGGACT
701 GGCTGAATGG CAAGGAGTAC AAGTGCAAGG TCTCCAACAA AGCCCTCCCA
751 GCCCCCATCG AGAAAACCAT CTCCAAAGCC AAAGGGCAGC CCCGAGAACC
801 ACAGGTGTAC ACCCTGCCCC CATCCCGGAA GGAGATGACC AAGAACCAGG
851 TCAGCCTGAC CTGCCTGGTC AAAGGCTTCT ATCCCAGCGA CATCGCCGTG
901 GAGTGGGAGA GCAATGGGCA GCCGGAGAAC AACTACAAGA CCACGCCTCC
951 CGTGCTGAAG TCCGACGGCT CCTTCTTCT CTATAGCAAG CTCACCGTGG
1001 ACAAGAGCAG GTGGCAGCAG GGAACGTCT TCTCATGCTC CGTGATGCAT
1051 GAGGCTCTGC ACAACCACTA CACGCAGAAG AGCCTCTCCC TGTCTCCGGG
1101 TAAA (SEQ ID NO: 72)

```

[0371] The mature ActRIIB-Fc fusion polypeptide (SEQ ID NO: 73) is as follows, and may optionally be provided with lysine removed from the C-terminus.

```

1 GRGEAETREC IYYNANWELE RTNQSGLERC EGEQDKRLHC YASWRNSSGT
51 IELVKKGCWL DDFNCYDRQE CVATEENPOV YFCCCEGNFC NERFTHLPEA
101 GGPEVTIYEP PTAPTGGGTH TCPPCPAPEL LGGPSVFLFP FKPKDTLMIS
151 RTPEVTCVVV DVSHEDPEVK FNWYVDGVEV HNAKTKPREE QYNSTYRVVS
201 VLTVLHQDWL NGKEYKCKVS NKALPAPIEK TISKAKGQPR EPQVYTLPPS
251 RKEMTKNQVS LTCLVKGFYP SDIAVEWESN QPENNYKTT FPVLKSDGSF
301 FLYSKLTVDK SRWQQGNVFS CSVMHEALHN HTQKSLSLS FGK
(SEQ ID NO: 73)

```

[0372] The complementary form of ALK7-Fc fusion protein (SEQ ID NO: 74) is as follows:

```

1 MDAMKRG LCC VLLLCGAVFV SPGAGLKVC LLCDSNFTC QTEGACWASV
51 MLTNGKEQVI KSCVSLPELN AQVFCHSSNN VTKTECCFTD FCNNITLHLP
101 TASP NAPKL G PMETGGGTHT CPPCPAPELL GGPSVFLFPP KPKDTLMISR
151 TPEVTCVVVD VSHEDPEVKE NWYVDGVEVH NAKTKPREEQ YNSTYRVVSV

201 LTVLHQDWLN GKEYKCKVSN KALPAPIEKT ISKAKGQPRE PQVYTLPPSR
251 EEMTKNQVSL TCLVKGFYPS DIAVEWESNG QPENNYDTTP PVLDS DGSFF
301 LYSDLTVDKS RWQQGNVFSC SVMHEALHNH YTQKSLSLSP G
(SEQ ID NO: 74)

```

[0373] The signal sequence and linker sequence are underlined. To promote formation of the ActRIIB-Fc:ALK7-Fc heterodimer rather than either of the possible homodimeric complexes, two amino acid substitutions (replacing lysines with aspartic acids) can be introduced into the Fc domain of the fusion protein as indicated by double underline above. The amino acid sequence of SEQ ID NO: 74 may optionally be provided with a lysine added at the C-terminus.

[0374] This ALK7-Fc fusion protein is encoded by the following nucleic acid (SEQ ID NO: 75):

```

1 ATGGATGCAA TGAAGAGAGG GCTCTGCTGT GTGCTGCTGC TGTGTGGAGC
51 AGTCTTCGTT TCGCCCGGCG CCGGACTGAA GTGTGTATGT CTTTGTGTG
101 ATTCTTCAAA CTTTACCTGC CAAACAGAAG GAGCATGTTG GGCATCAGTC
151 ATGCTAACCA ATGGAAAAGA GCAGGTGATC AAATCCTGTG TCTCCCTTCC
201 AGAACTGAAT GCTCAAGTCT TCTGTCATAG TTCCAACAAT GTTACCAAAA
251 CCGAATGCTG CTTACAGAT TTTTGCAACA ACATAAACT GCACCTTCCA
301 ACAGCATCAC CAAATGCCCC AAAACTTGGA CCCATGGAGA CCGGTGGTGG
351 AACTCACACA TGCCACCGT GCCCAGCACC TGAACCTCTG GGGGGACCGT
401 CAGTCTTCCT CTTCCCCCA AAACCAAGG ACACCCTCAT GATCTCCCGG

```

```

451  ACCCCTGAGG TCACATGCGT GGTGGTGGAC GTGAGCCACG AAGACCCTGA
501  GGTCAAGTTC AACTGGTACG TGGACGGCGT GGAGGTGCAT AATGCCAAGA
551  CAAAGCCGCG GGAGGAGCAG TACAACAGCA CGTACCGTGT GGTCAGCGTC
601  CTCACCGTCC TGCACCAGGA CTGGCTGAAT GGCAAGGAGT ACAAGTGCAA
651  GGTCTCCAAC AAAGCCCTCC CAGCCCCCAT CGAGAAAACC ATCTCCAAAG
701  CCAAAGGGCA GCCCCGAGAA CCACAGGTGT ACACCCTGCC CCCATCCCGG
751  GAGGAGATGA CCAAGAACCA GGTGAGCCTG ACCTGCCTGG TCAAAGGCTT
801  CTATCCCAGC GACATCGCCG TGGAGTGGGA GAGCAATGGG CAGCCGGAGA
851  ACAACTACGA CACCACGCCT CCCGTGCTGG ACTCCGACGG CTCCTTCTTC
901  CTCTATAGCG ACCTCACCGT GGACAAGAGC AGGTGGCAGC AGGGGAACGT
951  CTTCTCATGC TCCGTGATGC ATGAGGCTCT GCACAACCAC TACACGCAGA
1001 AGAGCCTCTC CCTGTCTCCG GGT          (SEQ ID NO: 75)

```

[0375] The mature ALK7-Fc fusion protein sequence (SEQ ID NO: 76) is expected to be as follows and may optionally be provided with a lysine added at the C-terminus.

```

1    GLKCVCLLCD SSNFTCQTEG ACWASVMLTN GKEQVIKSCV SLPELNAQVF
51   CHSSNNVTKT ECCFTDFCNN ITLHLPTASP NAPKLGP MET GGGTHTCPPC

101  PAPELLGGPS VFLFPPKPKD TLMISRTPEV TCVVVDVSHE DPEVKFNWYV
151  DGVEVHNAKT KPREEQYNST YRVVSVLTVL HQDWLNGKEY KCKVSNKALP
201  APIEKTISKA KGQPREPQVY TLPPSREEMT KNQVSLTCLV KGFYPSDIAV
251  EWESNGQPEN NYDTTPPVLD SDGSFFLYSD LTVDKSRWQQ GNVFSCSVMH
301  EALHNHYTQK SLSLSPG          (SEQ ID NO: 76)

```

[0376] The ActRIIB-Fc and ALK7-Fc fusion proteins of SEQ ID NO: 71 and SEQ ID NO: 74, respectively, may be co-expressed and purified from a CHO cell line to give rise to a heteromeric complex comprising ActRIIB-Fc:ALK7-Fc.

[0377] In another approach to promote the formation of heteromultimer complexes using asymmetric Fc fusion proteins, the Fc domains are altered to introduce complementary hydrophobic interactions and an additional intermolecular disulfide bond as illustrated in the ActRIIB-Fc and ALK7-Fc polypeptide sequences of disclosed below.

[0378] The ActRIIB-Fc polypeptide sequence (SEQ ID NO: 77) is shown below:

```

1    MDAMKRGLCC VLLLCGAVFV SPGASGRGEA ETRECIYYNA NWELERTNQS
51   GLERCEGEQD KRLHCYASWR NSSGTIELVK KGCWLDDFNC YDRQECVATE
101  ENPQVYFCCC EGNFCNERFT HLPEAGGPEV TYEPPPTAPT GGGTHTCPPC
151  PAPELLGGPS VFLFPPKPKD TLMISRTPEV TCVVVDVSHE DPEVKFNWYV
201  DGVEVHNAKT KPREEQYNST YRVVSVLTVL HQDWLNGKEY KCKVSNKALP
251  APIEKTISKA KGQPREPQVY TLPPCREEMT KNQVSLWCLV KGFYPSDIAV
301  EWESNGQPEN NYKITTPPVLD SDGSFFLYSK LTVDKSRWQQ GNVFSCSVMH
351  EALHNHYTQK SLSLSPGK          (SEQ ID NO: 77)

```

[0379] The leader sequence and linker are underlined. To promote formation of the ActRIIB-Fc:ALK7-Fc heterodimer rather than either of the possible homodimeric complexes, two amino acid substitutions (replacing a serine with a cysteine and a threonine with a tryptophan) can be introduced into the Fc domain of the fusion protein as indicated by double underline above. The amino acid sequence of SEQ ID NO: 77 may optionally be provided with lysine removed from the C-terminus.

[0380] The mature ActRIIB-Fc fusion polypeptide (SEQ ID NO: 78) is as follows and may optionally be provided with lysine removed from the C-terminus.

```

1  GRGEAETREC IYNNANWELE RTNQSGLERC EGEQDKRLHC YASWRNSSGT
51  IELVKKG CWL DDFNCYDRQE CVATEENPQV YFCCCEGNFC NERFTHLPEA
101 GGPEVTYEPP PTAPTGGGTH TCPPCPAPEL LGGPSVFLFP PKPKDTLMIS
151 RTPEVTCVVV DVSHEDPEVK FNWYVDGVEV HNAKTKPREE QYNSTYRVVS

201 VLTVLHQDWL NGKEYKCKVS NKALPAPIEK TISKAKGQPR EPQVYTLPPC
251 REEMTKNQVS LWCLVKGFYP SDIAVEWESN GQPENNYKTT PPVLDSGDGSF
301 FLYSKLTVDK SRWQQGNVFS CSVMHEALHN HYTQKSLSLS PGK
      (SEQ ID NO: 78)

```

[0381] The complementary form of ALK7-Fc fusion polypeptide (SEQ ID NO: 79) is as follows:

```

1  MDAMKRGLCC VLLLCGAVFV SPGAGLKVCV LLCDSNFTC QTEGACWASV
51  MLTNGKEQVI KSCVSLPELN AQVFCHSSNN VTKTECCFTD FCNNITLHLP
101 TASNAPKLG PMETGGGTHT CPPCPAPEL LGGPSVFLFP PKPKDTLMISR
151 TPEVTCVVVD VSHEDPEVKF NWYVDGVEVH NAKTKPREEQ YNSTYRVVSV
201 LTVLHQDWLN GKEYKCKVSN KALPAPIEKT LSKAKGQPRE PQVCTLPFSR
251 EEMTKNQVSL SCAVKGFYPS DIAVEWESNG QPENNYKTTP PVLDSGDGSFF
301 LYSKLTVDKS RWQQGNVFSC SVMHEALHNH YTQKSLSLS SP GK
      (SEQ ID NO: 79)

```

[0382] The leader sequence and linker sequence are underlined. To guide heterodimer formation with the ActRIIB-Fc fusion polypeptide of SEQ ID NOs 76 and 78 above, four amino acid substitutions can be introduced into the Fc domain of the ALK7 fusion polypeptide as indicated by double underline above. The amino acid sequence of SEQ ID NO: 79 may optionally be provided with the lysine removed from the C-terminus.

[0383] The mature ALK7-Fc fusion protein sequence (SEQ ID NO: 80) is expected to be as follows and may optionally be provided with the lysine removed from the C-terminus.

```

1  GLKCVCLLCD SSNFTCQTEG ACWASVMLTN GKEQVIKSCV SLPELNAQVF
51  CHSSNNVTKT ECCFTDFCNN ITLHLPTASP NAPKLGP MET GGGTHTCP PC
101 PAPELLGGPS VFLFPPKPKD TLMISR TPEV TCVVVDVSHE DPEVKFNWYV
151 DGVEVHNAKT KPREEQYNST YRVVSVLTVL HQDWLNGKEY KCKVSNKALP
201 APIEKTISKA KGQPREPQVC TLPPSREEMT KNQVSLSCAV KGFYPSDIAV
251 EWESNGQPEN NYKTTPPVLD SDGSFFLVSK LTVDKSRWQQ GNVFSCSVMH
301 EALHNHYTQK SLSLSPGK      (SEQ ID NO: 80)

```

[0384] The ActRIIB-Fc and ALK7-Fc proteins of SEQ ID NO: 77 and SEQ ID NO: 79, respectively, may be co-expressed and purified from a CHO cell line, to give rise to a heteromeric complex comprising ActRIIB-Fc:ALK7-Fc.

[0385] Purification of various ActRIIB-Fc:ALK7-Fc complexes could be achieved by a series of column chromatography steps, including, for example, three or more of the following, in any order: protein A chromatography, Q sepharose chromatography, phenylsepharose chromatography, size exclusion chromatography, and cation exchange chromatography. The purification could be completed with viral filtration and buffer exchange.

Example 2. Ligand binding profile of ActRIIB-Fc:ALK7-Fc heterodimer compared to

ActRIIB-Fc homodimer and ALK7-Fc homodimer

[0386] A Biacore™-based binding assay was used to compare ligand binding selectivity of the ActRIIB-Fc:ALK7-Fc heterodimeric complex described above with that of ActRIIB-Fc and ALK7-Fc homodimeric complexes. The ActRIIB-Fc:ALK7-Fc heterodimer, ActRIIB-Fc homodimer, and ALK7-Fc homodimer were independently captured onto the system using an anti-Fc antibody. Ligands were injected and allowed to flow over the captured receptor protein. Results are summarized in the table below, in which ligand off-rates (k_d) most indicative of effective ligand traps are denoted by gray shading.

Ligand binding profile of ActRIIB-Fc:ALK7-Fc heterodimer compared to ActRIIB-Fc homodimer and ALK7-Fc homodimer									
Ligand	ActRIIB-Fc homodimer			ALK7-Fc homodimer			ActRIIB-Fc:ALK7-Fc heterodimer		
	k_a (1/Ms)	k_d (1/s)	K_D (pM)	k_a (1/Ms)	k_d (1/s)	K_D (pM)	k_a (1/Ms)	k_d (1/s)	K_D (pM)
activin A	1.3×10^7	1.4×10^{-4}	11	No binding			4.4×10^7	1.9×10^{-3}	43
activin B	1.5×10^7	1.6×10^{-4}	8	No binding			1.2×10^7	2.0×10^{-4}	17
activin C	No binding			No binding			3.5×10^5	2.4×10^{-3}	6900
activin AC	2.0×10^7	3.1×10^{-3}	160	No binding			2.6×10^6	5.7×10^{-4}	220
BMP5	2.6×10^7	7.5×10^{-2}	2900	No binding			1.5×10^5	8.5×10^{-3}	57000
BMP6	2.4×10^7	3.9×10^{-3}	160	No binding			1.2×10^6	6.3×10^{-3}	5300

BMP9	1.2 x10 ⁸	1.2 x10 ⁻³	10	No binding	Transient*		>1400
BMP10	5.9 x10 ⁶	1.5 x10 ⁻⁴	25	No binding	1.5 x10 ⁷	2.8 x10 ⁻³	190
GDF3	1.4 x10 ⁶	2.2 x10 ⁻³	1500	No binding	2.3 x10 ⁶	1.0 x10 ⁻²	4500
GDF8	3.5 x10 ⁶	2.4 x10 ⁻⁴	69	No binding	3.7 x10 ⁶	1.0 x10 ⁻³	270
GDF11	9.6 x10 ⁷	1.5 x10 ⁻⁴	2	No binding	9.5 x10 ⁷	7.5 x 10 ⁻⁴	8
* Indeterminate due to transient nature of interaction							
--- Not tested							

[0387] These comparative binding data demonstrate that the ActRIIB-Fc:ALK7-Fc heterodimer has an altered binding profile/selectivity relative to either the ActRIIB-Fc homodimer or ALK7-Fc homodimer. Interestingly, four of the five ligands with the strongest binding to ActRIIB-Fc homodimer (activin A, BMP10, GDF8, and GDF11) exhibit reduced binding to the ActRIIB-Fc:ALK7-Fc heterodimer, the exception being activin B which retains tight binding to the heterodimer. Similarly, three of the four ligands with intermediate binding to ActRIIB-Fc homodimer (GDF3, BMP6, and particularly BMP9) exhibit reduced binding to the ActRIIB-Fc:ALK7-Fc heterodimer, whereas binding to activin AC is increased to become the second

strongest ligand interaction with the heterodimer overall. Finally, activin C and BMP5 unexpectedly bind the ActRIIB-Fc:ALK7 heterodimer with intermediate strength despite no binding (activin C) or weak binding (BMP5) to ActRIIB-Fc homodimer. The net result is that the ActRIIB-Fc:ALK7-Fc heterodimer possesses a ligand-binding profile distinctly different from that of either ActRIIB-Fc homodimer or ALK7-Fc homodimer, which binds none of the foregoing ligands. See Figure 6.

[0388] These results therefore demonstrate that the ActRIIB-Fc:ALK7-Fc heterodimer is a more selective antagonist of activin B and activin AC compared to ActRIIB-Fc homodimer. Moreover, ActRIIB-Fc:ALK7-Fc heterodimer exhibits the unusual property of robust binding to activin C. Accordingly, an ActRIIB-Fc:ALK7-Fc heterodimer will be more useful than an ActRIIB-Fc homodimer in certain applications where such selective antagonism is advantageous. Examples include therapeutic applications where it is desirable to retain antagonism of activin B or activin AC but decrease antagonism of one or more of activin A, GDF3, GDF8, GDF11, BMP9, or BMP10. Also included are therapeutic, diagnostic, or analytic applications in which it is desirable to antagonize activin C or, based on the similarity between activin C and activin E, activin E.

Example 3. ALK7:ActRIIB heteromultimer treatment suppresses kidney fibrosis and inflammation and reduces kidney injury.

[0389] The effects of the ALK7-Fc:ActRIIB-Fc heterodimer described in Example 2 on kidney disease was assessed in a mouse unilateral ureteral obstruction model. See, e.g., Klahr and Morrissey (2002) *Am J Physiol Renal Physiol* 283: F861-F875.

[0390] Twenty-four C57BL/6 male mice 12 weeks of age underwent left unilateral ureteral ligation twice at the level of the lower pole of kidney. After 3 days, eight mice were euthanized and kidneys from individual animals were harvested to assess kidney injury. The remaining mice were randomized into two groups: i) eight mice were injected subcutaneously with the ALK7-Fc:ActRIIB-Fc heterodimer at a dose of 10mg/kg at day 3, day 7, day 10, and day 14 after surgery and a ii) eight mice were injected subcutaneously with vehicle control, phosphate buffered saline (PBS), at day 3, day 7, day 10, and day 14 after surgery. Both groups were sacrificed at day 17 in accordance with the relevant Animal Care Guidelines. Half kidneys from individual animals were collected for histology analysis (H&E, and Masson's Trichrome stain), from both the UUO kidney and contralateral kidney, and 1/4 kidneys were used for RNA extraction (RNeasy Midi Kit, Qiagen, IL).

[0391] Gene expression analysis on UUO kidney samples was performed to assess levels of various genes. QRT-PCR was performed on a CFX Connect™ Real-time PCR detection system (Bio-Rad, CA) to evaluate the expression of various fibrotic genes (Colla1, Col3a1, Fibronectin, PAI-1, CTGF, and α -SMA), inflammatory genes (Tnfa, and MCP1), cytokines (TGF β 1, TGF β 2, TGF β 3, and activin A), kidney injury genes (NGAL), Hypoxia-inducible factor 1-alpha (HIF1a), and activin A receptor (ActRIIA). See Figure 13. Treatment of mice with

ALK7-Fc:ActRIIB-Fc heterodimer significantly suppressed the expression of fibrotic and inflammatory genes, inhibited the upregulation of TGF β 1/2/3, activin A, and ActRIIa, and reduced kidney injury. Histology data confirmed that ALK7-Fc:ActRIIB-Fc heterodimer treatment significantly inhibited kidney fibrosis and reduced kidney injury in the UUO model.

[0392] Together, these data demonstrate that ALK7:ActRIIB heteromultimer treatment suppresses kidney fibrosis and inflammation and reduces kidney injury. Moreover, these data indicate that other ALK7:ActRIIB antagonists may be useful in the treatment or preventing of kidney disease including, for example, antagonists of ALK7 and/or ActRIIB-binding ligands (e.g., ligand antibodies and other ligand traps such as follistatin, Cerberus and Lefty), antagonists of ALK7 and/or ActRIIB receptors, antagonists of ALK7 and/or ActRIIB downstream signaling mediators (e.g., Smads), and antagonists of TGF β superfamily co-receptors (e.g., antagonists of Crypto or Cryptic).

Example 4. ALK7:ActRIIB heteromultimer increases lipolysis in adipocytes.

[0393] Lipolysis is the hydrolysis of triglycerides within the cell into glycerol and free fatty acids. The glycerol and free fatty acids are then released into the bloodstream or culture media. While lipolysis occurs in essentially all cells, it is most abundant in white and brown adipocytes. ALK7 signaling is thought to suppress lipolysis and to consequently lead to fat accumulation in adipocytes and adipose tissue. Accordingly, the effects of the ALK7-Fc:ActRIIB-Fc heterodimer described in Example 2 on lipolysis in adipocytes was assessed.

[0394] Specifically, 3T3-L1 cells (supplied by ATCC; ATCC® CL-173™) were grown in Dulbecco's Modified Eagle Medium (ATCC; ATCC® 30-2002™) containing 10% Bovine Serum (Life Technologies; 16170-060) until reaching confluency. To induce differentiation, at 2 days post-confluency medium was replaced by fresh Dulbecco's Modified Eagle Medium (ATCC; ATCC® 30-2002™) containing 10% fetal Bovine serum (Life Technologies; 10082147), dexamethasone (Sigma, D8893), IBMX (Sigma, 17018) and insulin (Sigma, 10516) for 2 weeks. Accumulation of lipid droplets on the cells, as determined by microscopy, was used to confirm a complete differentiation into mature adipocyte cells. Adipocytes were treated overnight with vehicle (PBS), activin B (50 ng/ml) or co-treated with activin B (50 ng/ml) and ALK7-Fc:ActRIIB-Fc heterodimer (5 μ g/ml). Cells were washed two times with PBS and incubated with lipolysis assay buffer (supplied by Abcam; ab185433). Lipolysis assay buffer was collected after 3 hours and glycerol levels were measured according to manufacturer's instruction (Abcam; ab185433). It was determined that the ALK7-Fc:ActRIIB-Fc heterodimer significantly increased lipolysis activity by 44.36% in this cell-based assay.

[0395] Accordingly, these data demonstrate that ALK7-Fc:ActRIIB-Fc heterodimer can be used to antagonize ALK7-mediated suppression of lipolysis and thereby increase fatty acid breakdown in adipocytes. Moreover, these data indicate that ALK7-Fc:ActRIIB-Fc heterodimers as well as other ALK7:ActRIIB antagonists, such as those disclosed herein, may be used to treat a variety of disorder or conditions associated with low lipolysis activity and/or excessive

fatty acid accumulation in cells, particularly adipocytes, including for example, obesity, diabetes, insulin resistance; metabolic syndrome, fatty liver disease and other metabolic diseases or conditions, particularly those associated with excess fat levels.

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Patentkrav

1. Opløselig rekombinant heteromultimer, der omfatter et ALK7-polypeptid og et ActRIIB-polypeptid, hvor ALK7-polypeptidet omfatter en aminosyresekvens, som er mindst 85 % identisk med aminosyrerne 28-92 ifølge SEQ ID NO: 9, og hvor ActRIIB-polypeptidet omfatter en aminosyresekvens, som er mindst 85 % identisk med aminosyrerne 29-109 ifølge SEQ ID NO: 1, hvor ALK7-polypeptidet er et fusionsprotein, der yderligere omfatter et heterologt domæne, hvor ActRIIB-polypeptidet er et fusionsprotein, der yderligere omfatter et heterologt domæne, og hvor heteromultimeren binder til én eller flere af activin A, activin B og GDF11.

2. Heteromultimer ifølge krav 1, hvor ALK7-polypeptidet omfatter en aminosyresekvens, som er mindst 90 %, 91 %, 92 %, 93 %, 94 %, 95 %, 96 %, 97 %, 98 %, 99 % eller 100 % identisk med et polypeptid, der:

- a. begynder ved en hvilken som helst af aminosyrerne 21, 22, 23, 24, 25, 26, 27 eller 28 ifølge SEQ ID NO: 9 og
- b. ender ved en hvilken som helst af aminosyrerne 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112 eller 113 ifølge SEQ ID NO: 9.

3. Heteromultimer ifølge krav 1 eller 2, hvor ActRIIB-polypeptidet omfatter en aminosyresekvens, som er mindst 90 %, 91 %, 92 %, 93 %, 94 %, 95 %, 96 %, 97 %, 98 %, 99 % eller 100 % identisk med et polypeptid, der:

- a. begynder ved en hvilken som helst af aminosyrerne 20, 21, 22, 23, 24, 25, 26, 27, 28 eller 29 ifølge SEQ ID NO: 1 og
- b. ender ved en hvilken som helst af aminosyrerne 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133 eller 134 ifølge SEQ ID NO: 1.

4. Heteromultimer ifølge et hvilket som helst af kravene 1-3, hvor det heterologe domæne omfatter et Fc-immunglobulindomæne.

- 5.** Heteromultimer ifølge krav 4, hvor Fc-immunglobulindomænet omfatter én eller flere aminosyremodifikationer, der fremmer heterodimerdannelse, og/eller som inhiberer homodimerdannelse.
- 6.** Heteromultimer ifølge krav 4 eller 5, hvor det heterologe domæne omfatter et Fc-immunglobulindomæne fra et IgG-immunglobulin.
- 7.** Heteromultimer ifølge et hvilket som helst af kravene 1-6, hvor fusionsproteinet yderligere omfatter et linker-domæne, der er positioneret mellem ALK7-domænet og det heterologe domæne.
- 8.** Heteromultimer ifølge et hvilket som helst af kravene 1-7, hvor ALK7-polypeptidet omfatter én eller flere modificerede aminosyrerester, der er valgt fra gruppen bestående af: en glycosyleret aminosyre, en PEGyleret aminosyre, en farnesyleret aminosyre, en acetyleret aminosyre, en biotinyleret aminosyre, en aminosyre, som er konjugeret til en lipiddel, og en aminosyre, som er konjugeret til et organisk derivatiseringsmiddel.
- 9.** Heteromultimer ifølge et hvilket som helst af kravene 1-8, hvor heteromultimeren binder til activin A, activin B, activin C, activin E, activin AB, activin AC, activin AE, activin BC, activin BE, GDF8, GDF11, nodal, BMP5, BMP6, GDF3 og/eller BMP10.
- 10.** Heteromultimer ifølge et hvilket som helst af kravene 1-9, hvor heteromultimeren inhiberer activin A-, activin B-, activin C-, activin E-, activin AB-, activin AC-, activin AE-, activin BC-, activin BE-, GDF8-, GDF11-, nodal-, BMP5-, BMP6-, GDF3- og/eller BMP10-signaler i et cellebaseret assay.
- 11.** Heteromultimer ifølge et hvilket som helst af kravene 1-10, hvor heteromultimeren er en ALK7:ActRIIB-heterodimer.

12. Heteromultimer ifølge et hvilket som helst af kravene 1-11, hvor heteromultimeren binder til activin B.

13. Farmaceutisk præparat, der omfatter heteromultimeren ifølge et hvilket som helst af kravene 1-12.

14. Farmaceutisk præparat ifølge krav 13, hvor det farmaceutiske præparat i det væsentlige er pyrogenfrit og/eller endvidere omfatter et yderligere aktivt middel.

15. Farmaceutisk præparat ifølge krav 13 eller krav 14, hvor det farmaceutiske præparat omfatter mindre end ca. 10 %, 9 %, 8 %, 7 %, 6 %, 5 %, 4 %, 3 %, 2 % eller mindre end ca. 1 % ALK7-homomultimerer og/eller mindre end ca. 10 %, 9 %, 8 %, 7 %, 6 %, 5 %, 4 %, 3 %, 2 % eller mindre end ca. 1 % ActRIIB-homomultimerer.

DRAWINGS

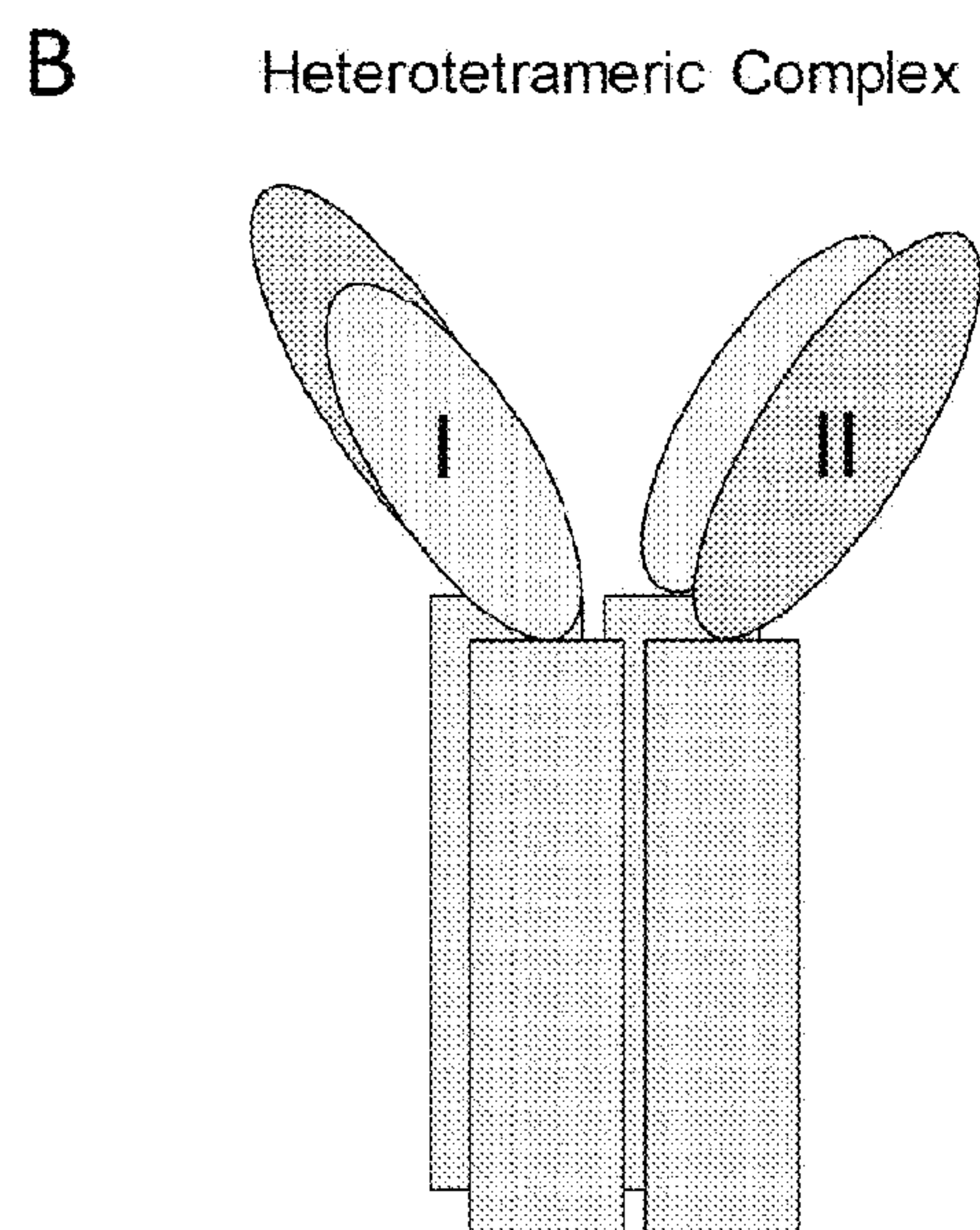
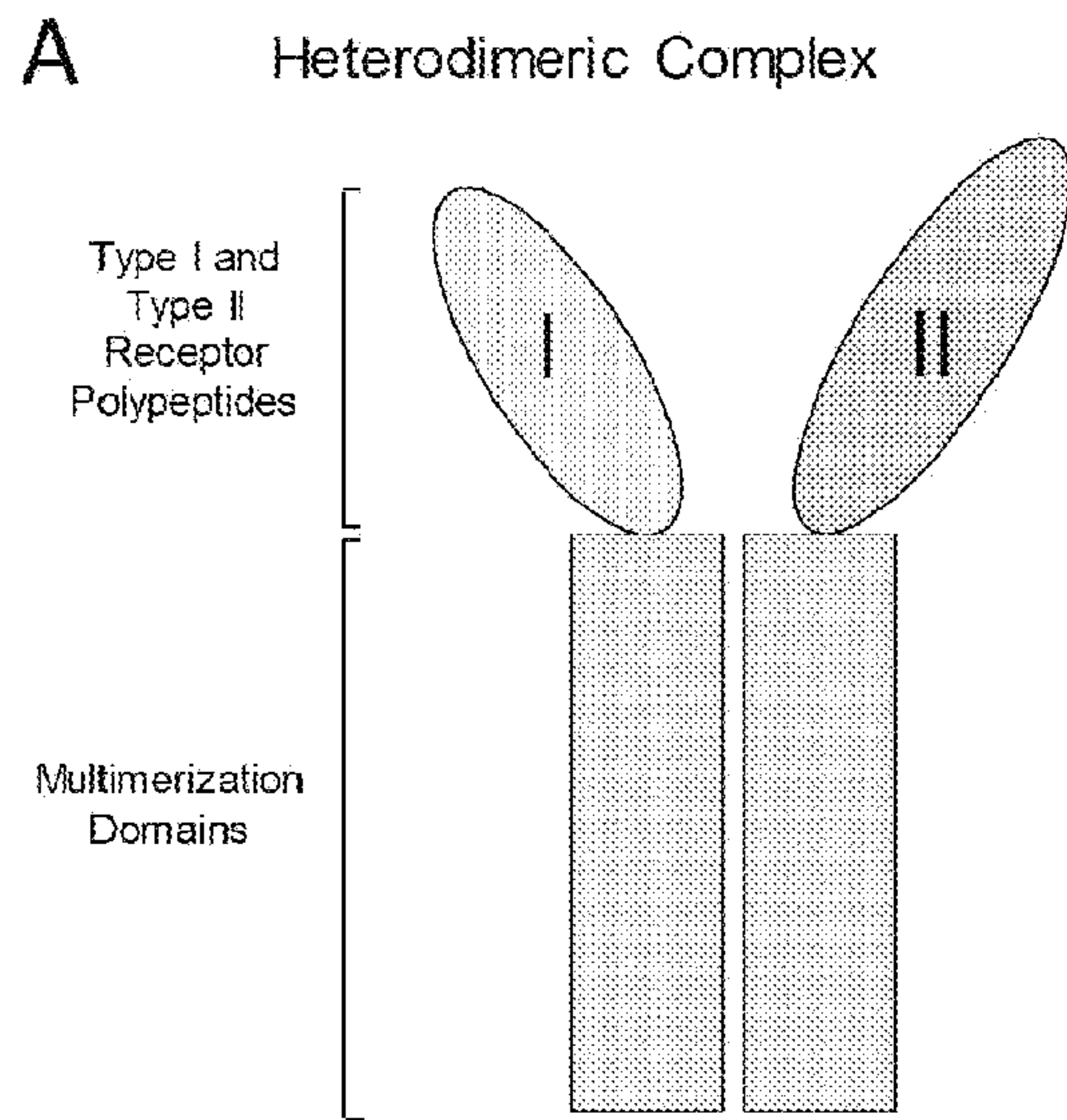


FIGURE 1

Schematic Heteromeric Protein Complex

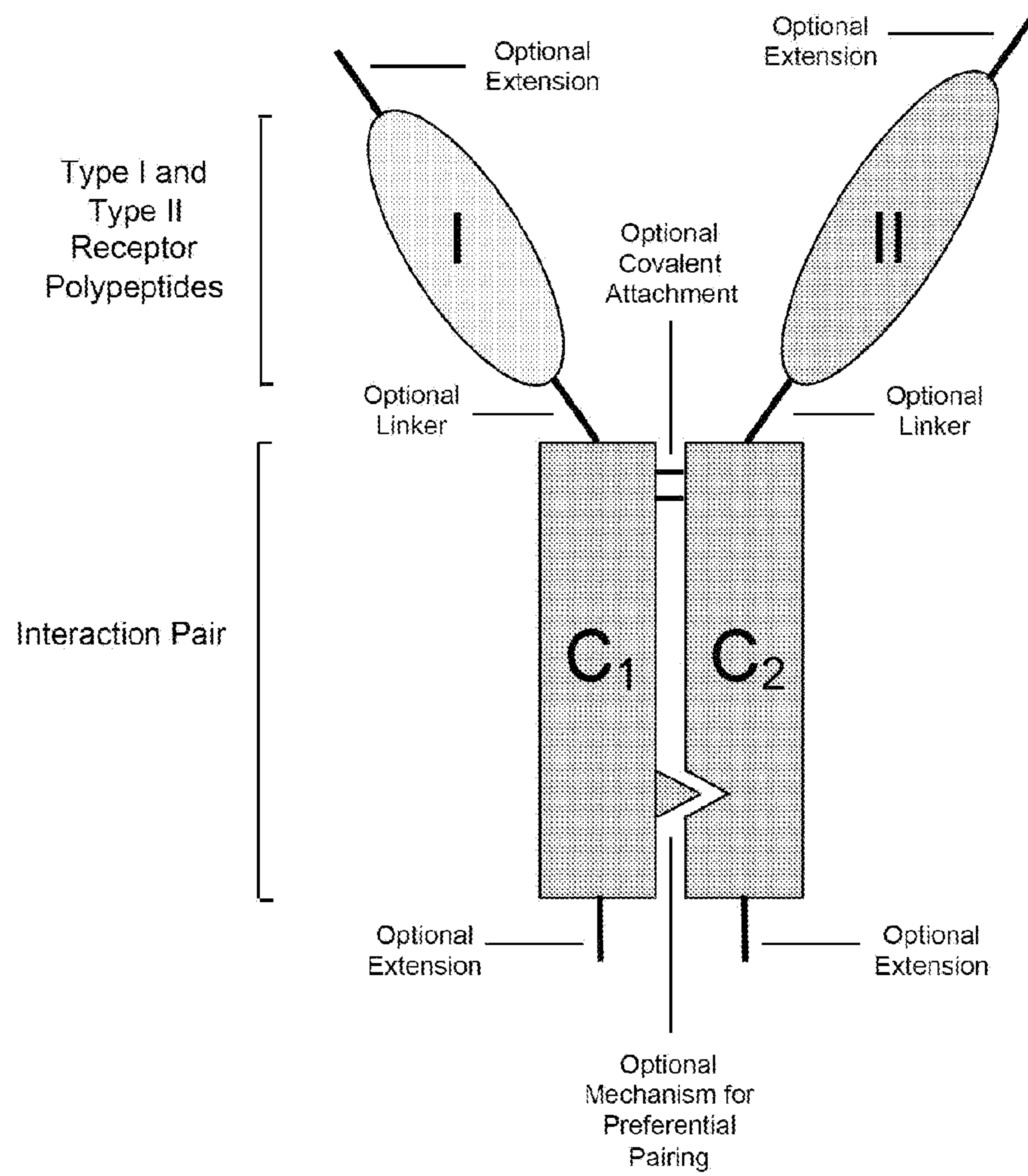


FIGURE 2

ActRIIa ILGRSETQEC IIRKAMWEKD RINQTSVEPC YGDKDFEERC FATHWNISGS
ActRIIb GRGEAETREC IYENAMWELE RTNQSGIERC EGEQDKRLHC YASWRNSSGT

IEINRQGCWL DDINCYRFD CVERKDSFEV YFCCEGNMC NEKFSYFFEM
IELVERGCWL DDFNCYERQE CVATEENPQV YFCCEGNFC NERFTHLPEA

EVTQPTSNPV TPKPP
GGPEVTYEPP PTAPT

FIGURE 3

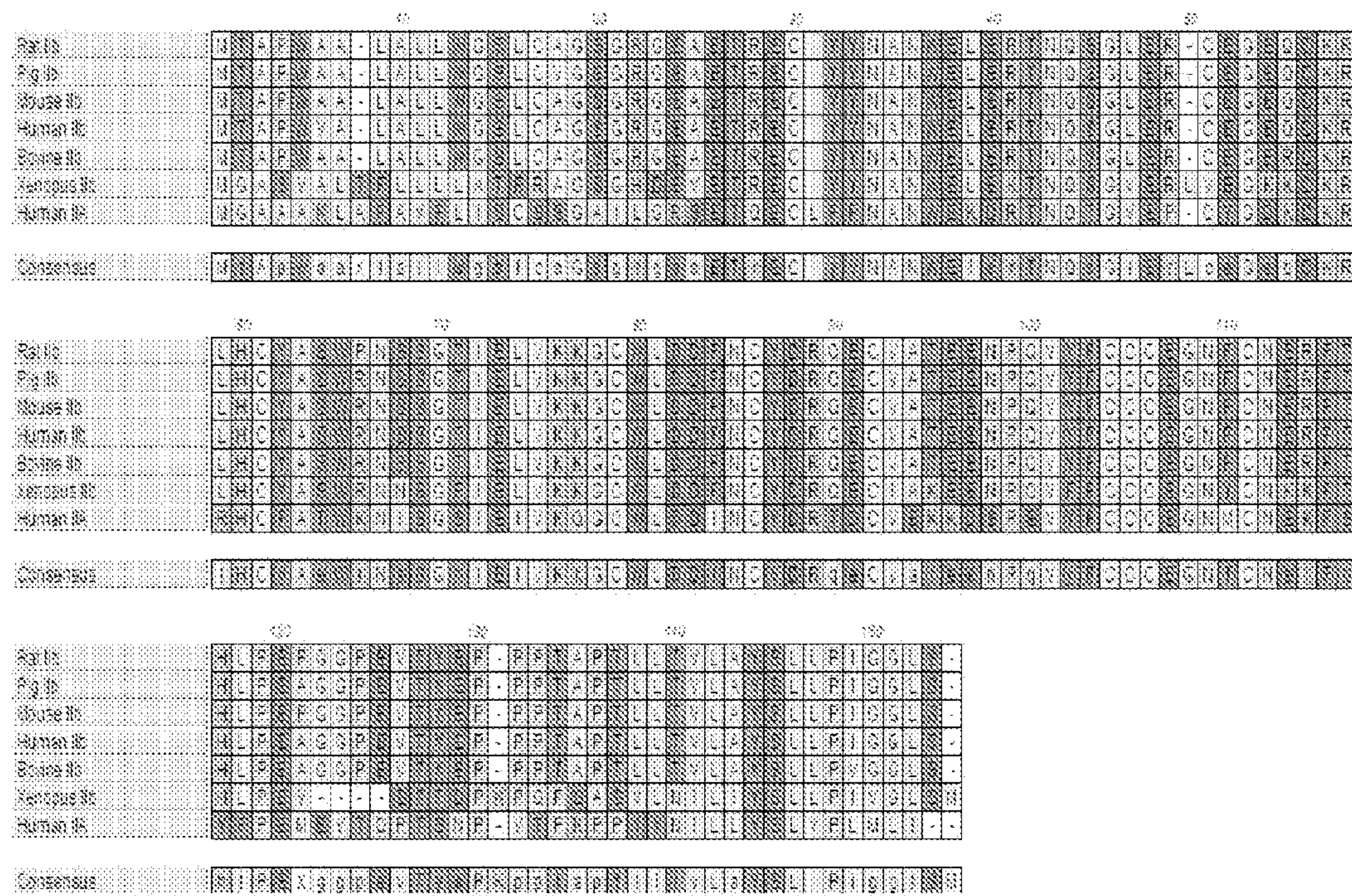


FIGURE 4

IgG1 -----THTCPPCPAPELLGGPSVFLFPPKPKDTLMISRTPEVTCVVVDVSHEDPEVKF 53

IgG4 ---ESKYGPPCPSCPAPEFLGGPSVFLFPPKPKDTLMISRTPEVTCVVVDVSQEDPEVQF 57

IgG2 -----VECPFCPAPPVAG-PSVFLFPPKPKDTLMISRTPEVTCVVVDVSHEDPEVQF 51

IgG3 EPKSCDTPPPCPRCPAPELLGGPSVFLFPPKPKDTLMISRTPEVTCVVVDVSHEDPEVQF 60

[illegible]

IgG1 NWYVDGVEVHNAKTKPREEQYNSTYRVVSVLTVLHQDWLNGKEYKCKVSNKALPAPIEKT 113

IgG4 NWYVDGVEVHNAKTKPREEQFNSTYRVVSVLTVLHQDWLNGKEYKCKVSNKGLPSSIEKT 117

IgG2 NWYVDGVEVHNAKTKPREEQFNSTFRVVSVLTVVHQDWLNGKEYKCKVSNKGLPAPIEKT 111

IgG3 KWTVDGVEVHNAKTKPREEQYNSTFRVVSVLTVLHQDWLNGKEYKCKVSNKALPAPIEKT 120

~~~~~

IgG1 ISKAKGQPREPQVYTLPPSREEMTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYK<sup>173</sup>TFP

IgG4 ISKAKGQPREPQVYTLPPSQEEMTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYK<sup>177</sup>TFP

IgG2 ISKTKGQPREPQVYTLPPSREEMTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYK<sup>171</sup>TFP

IgG3 ISKTKGQPREPQVYTLPPSREEMTKNQVSLTCLVKGFYPSDIAVEWESSGQPENNYNT<sup>180</sup>TFP

[illegible]

IgG1 PVLDSDGSFFLYSKLTVDKSRWQQGNVFSCSVMHEALHNHYTQKSLSLSPGK 225

IgG4 PVLDSDGSFFLYSRLTVDKSRWQEGNVFSCSVMHEALHNHYTQKSLSLGLK 229

IgG2 PMLDSDGSFFLYSKLTVDKSRWQQGNVFSCSVMHEALHNHYTQKSLSLSPGK 223

IgG3 PMLDSDGSFFLYSKLTVDKSRWQQGNIFSCSVMHEALHNRETQKSLSLSPGK 232

\*\*\*\*\*

FIGURE 5

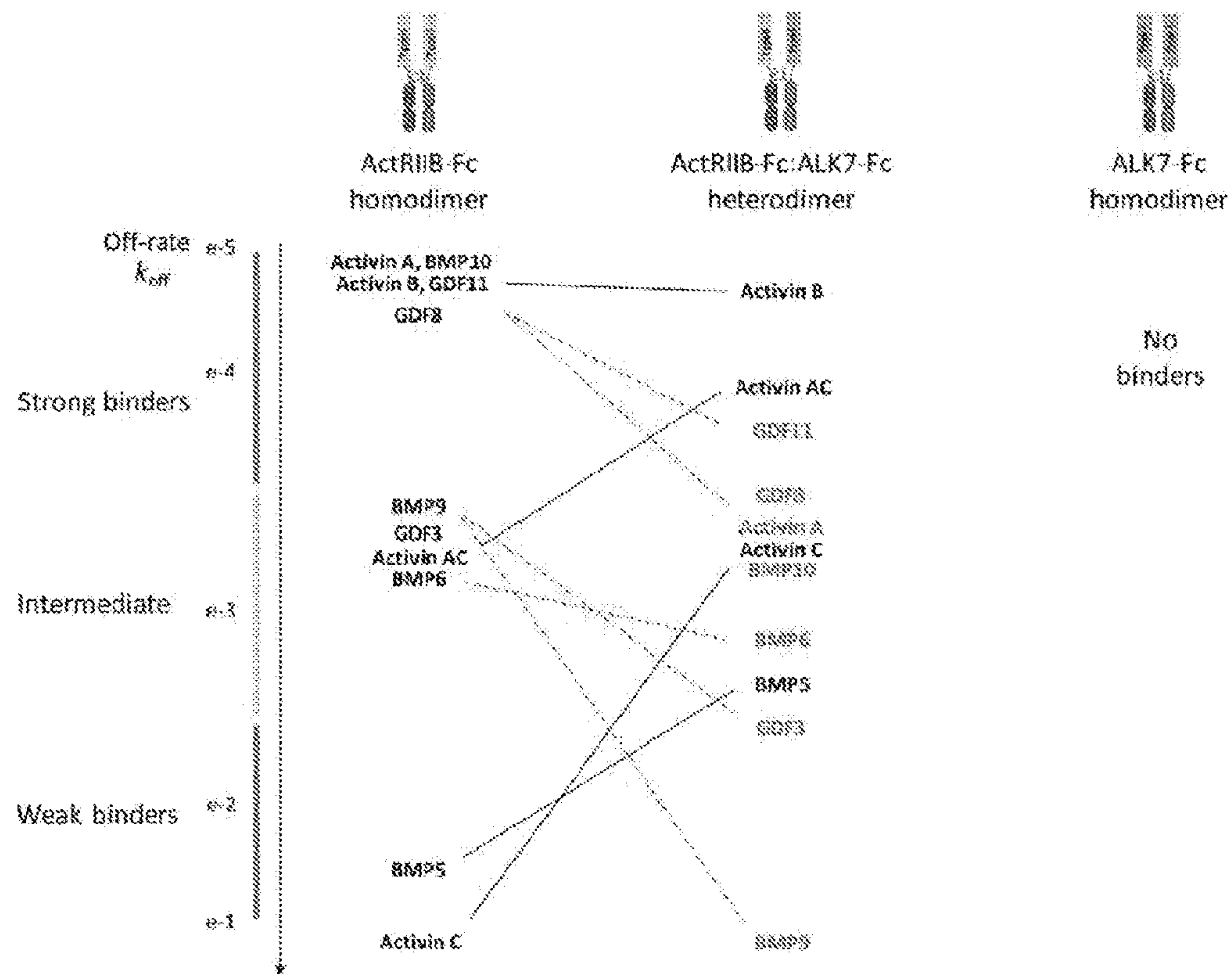


Figure 6

```

      . . . . . 10 . . . . . 20 . . . . . 30 . . . . . 40 . . . . . 50
Human  ELSPLGLKVC LLCDSSNFTC QTEGACWASV MLTNGREQVI KSCVSLPELN
Chimp  ELSAGLKCVC LLCDSSNFTC QTEGACWASV MLTNGREQVI KSCVSLPELN
Tarsier ELSAGLKCVC LLCDSSNFTC QTEGACWASV MRTNGREQVI KSCVSLPELN
Marmoset ELSAGLKCVC LLCDSSNFTC QTEGACWASV MLTNGREQVI KSCVSLPELN
Hamster ELTAGLKCVC LLCDSSNFTC QTEGACWASV MLTNGREQVI KSCVSLPELN
Squirrel ELSAGLKCVC LLCDSSNFTC QTEGACWASV MLTNGREQVI KSCVSLPELN

      . . . . . 60 . . . . . 70 . . . . . 80 . . . . . 90 . . .
Human  AQVFCHSSNN VTKTECCFTD FCNNITLHLP TASPNA PKLG PME
Chimp  AQVFCHSSNN VTKTECCFTD FCNNITLHLP TASPNA PKLG PME
Tarsier AQVFCHSSNN VTKTECCFTD FCNNITLHLP TASPNA PKLG PME
Marmoset AQVFCHSSNN ITKTECCFTD FCNNITLHLP TASPNA PKLG PME
Hamster AQVFCHSSNN VTKTECCFTD FCNNITLHLP TVSPSAPRLG PTE
Squirrel AQVFCHSSNN VTKTECCFTD FCNNITLHLP TVSPNAPRLG PME

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FIGURE 7

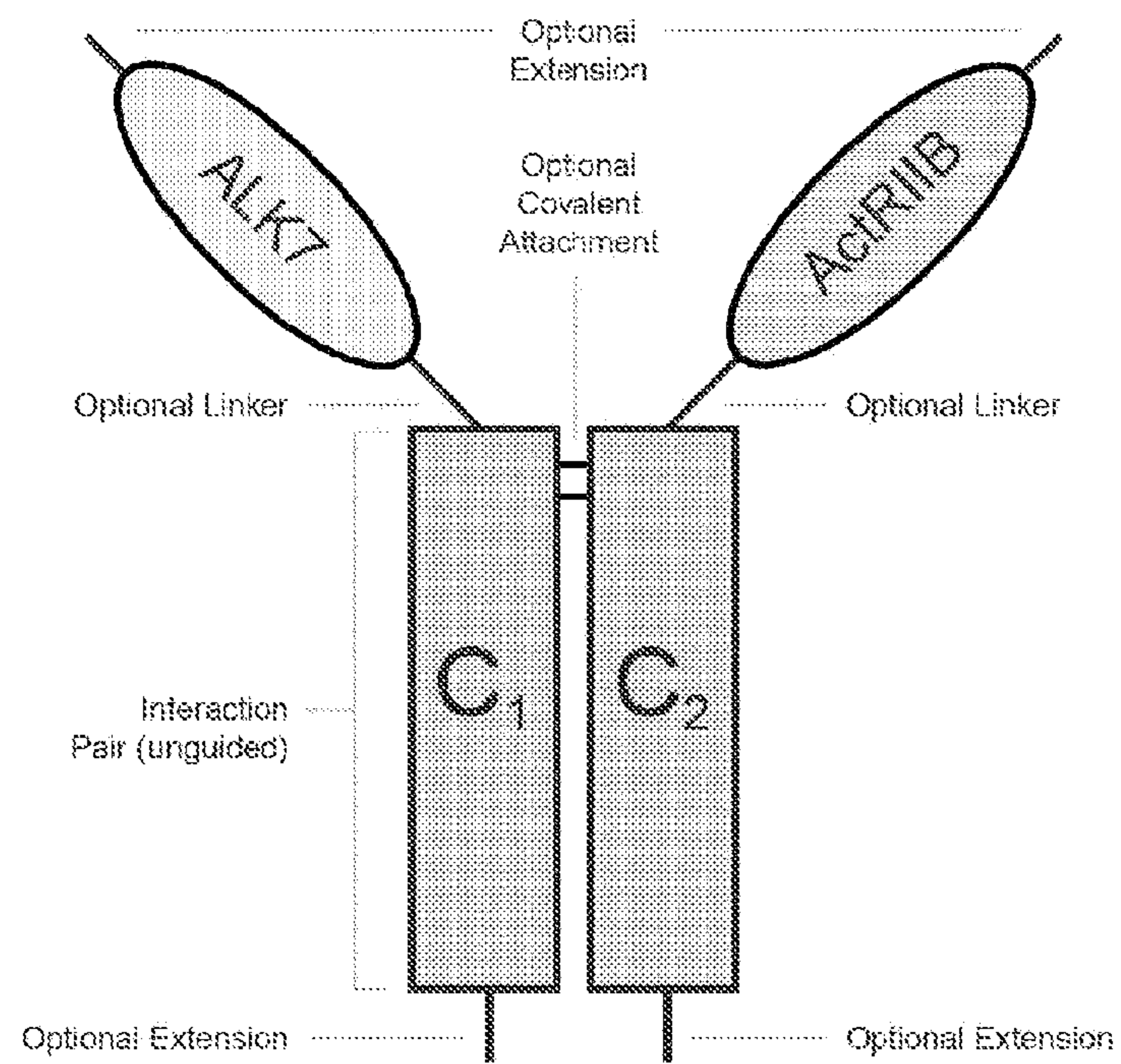


FIGURE 8A

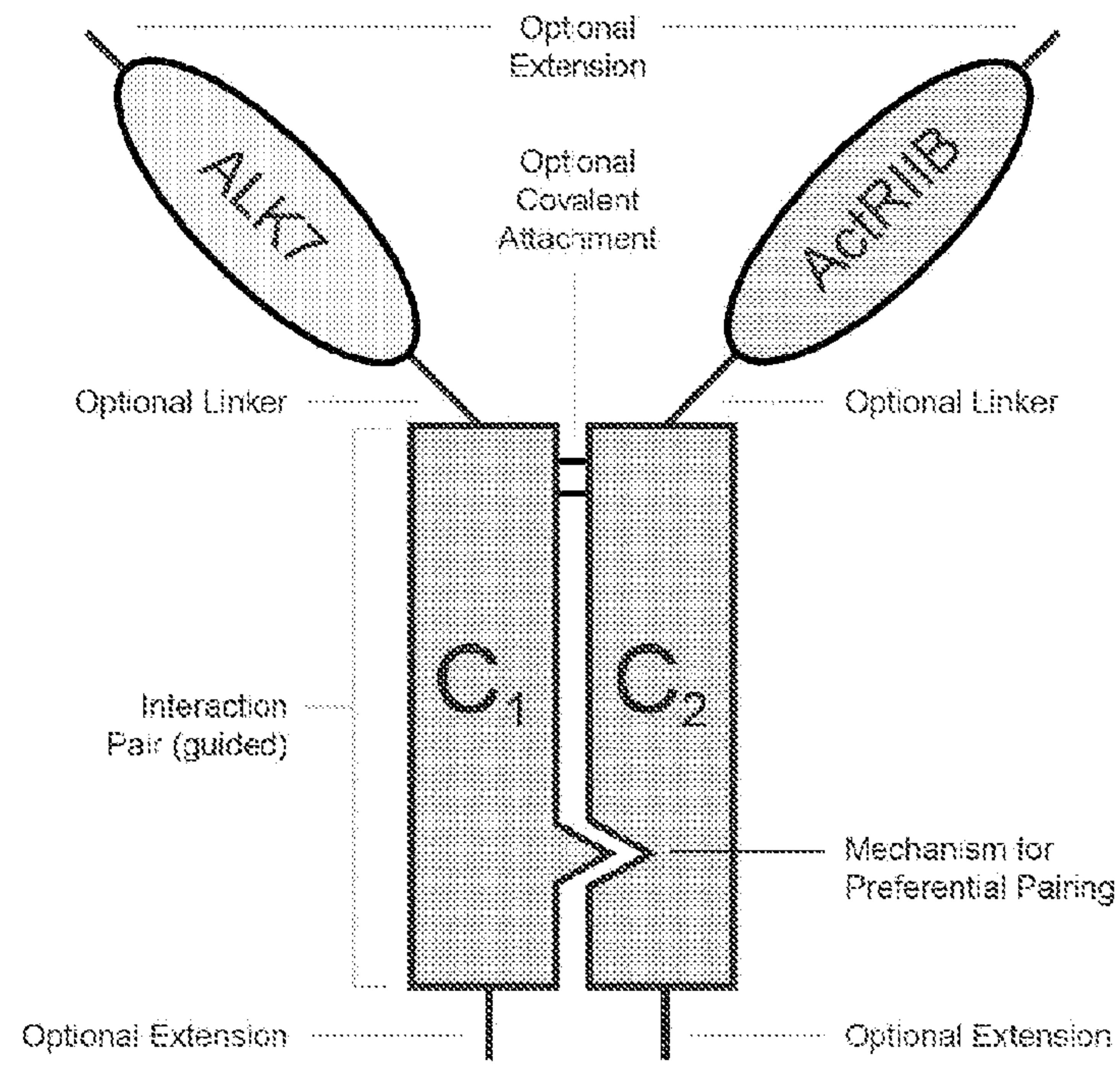


FIGURE 8B

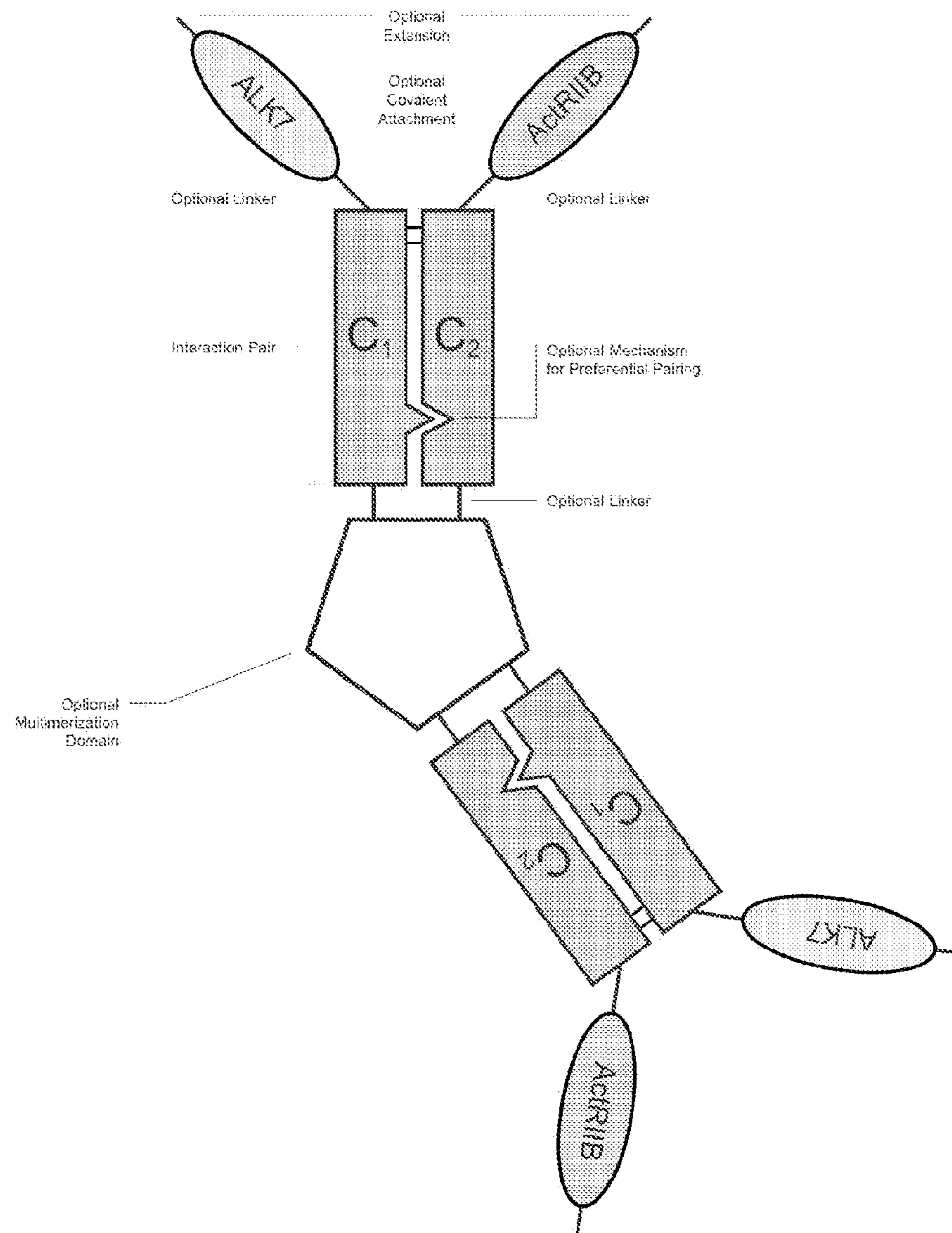


FIGURE 8C

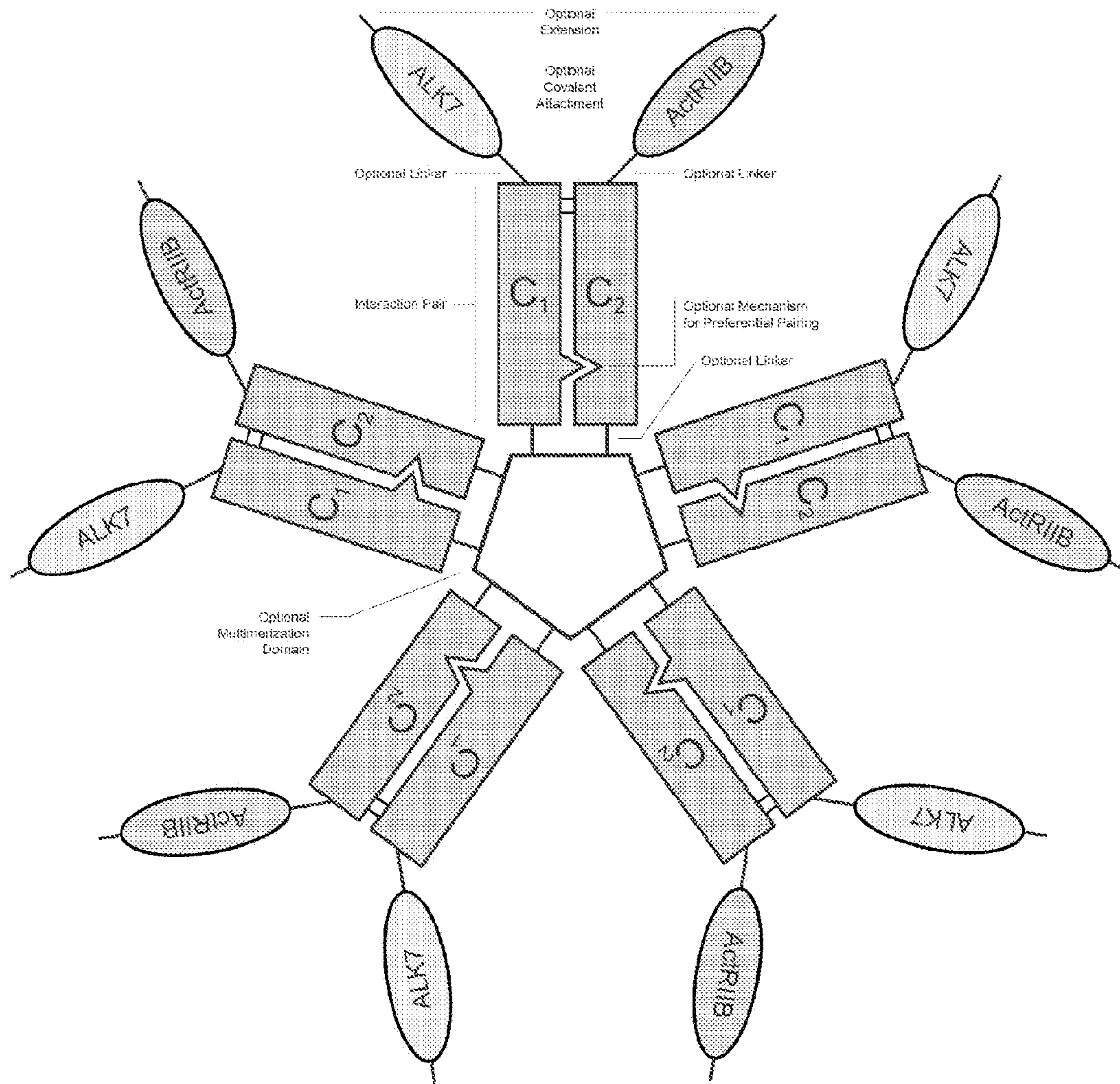


FIGURE 8D

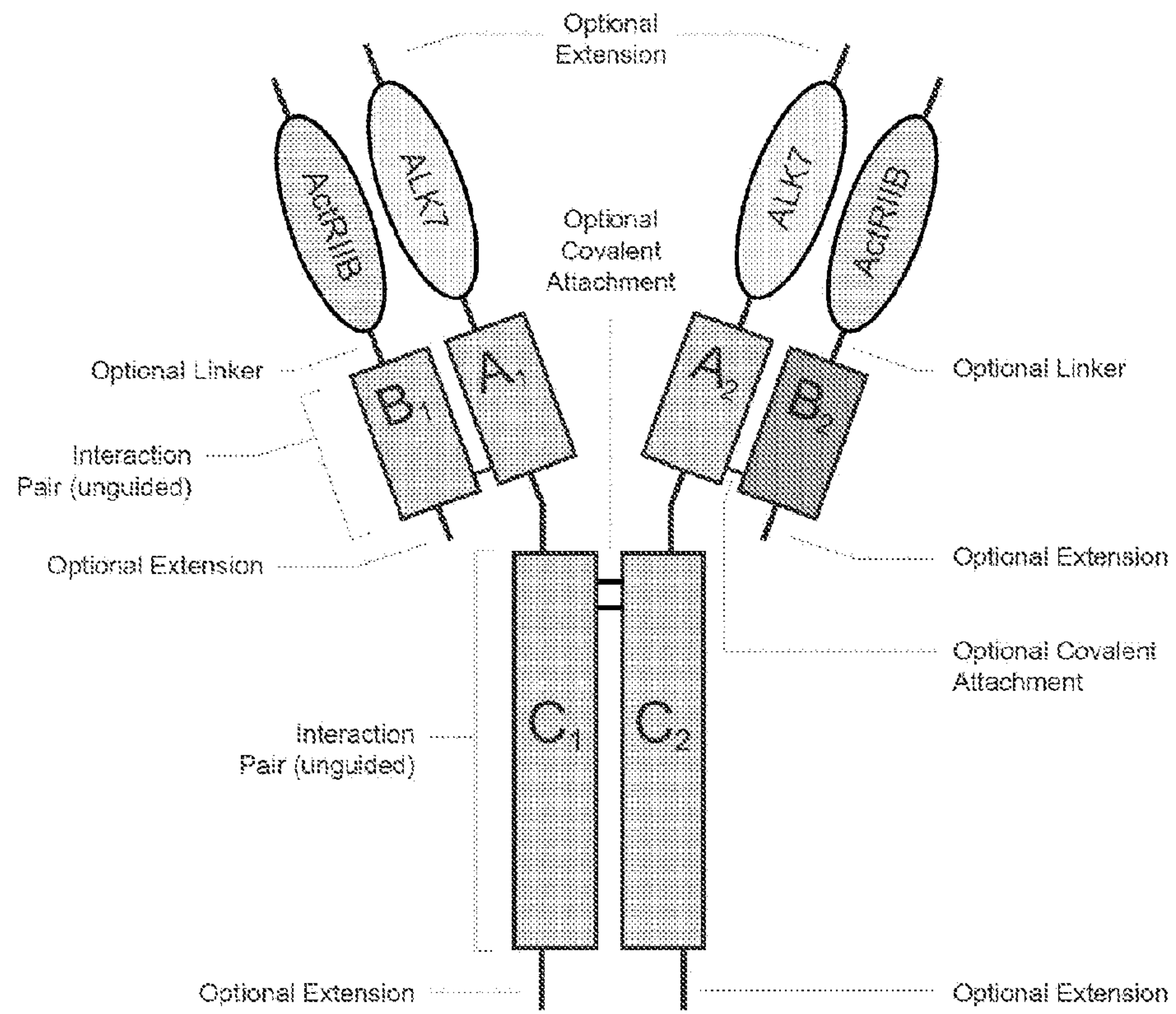


FIGURE 9A

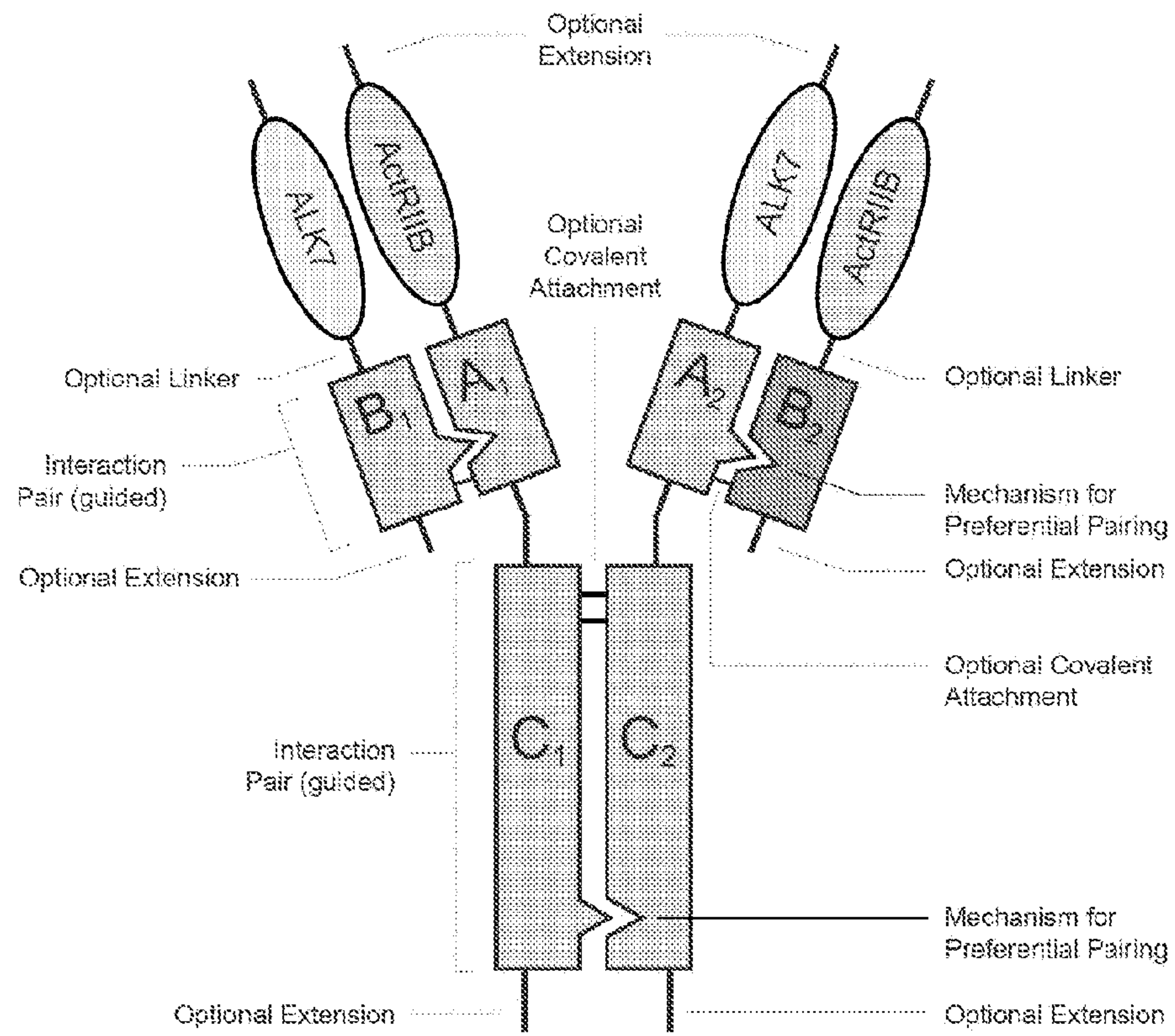


FIGURE 9B

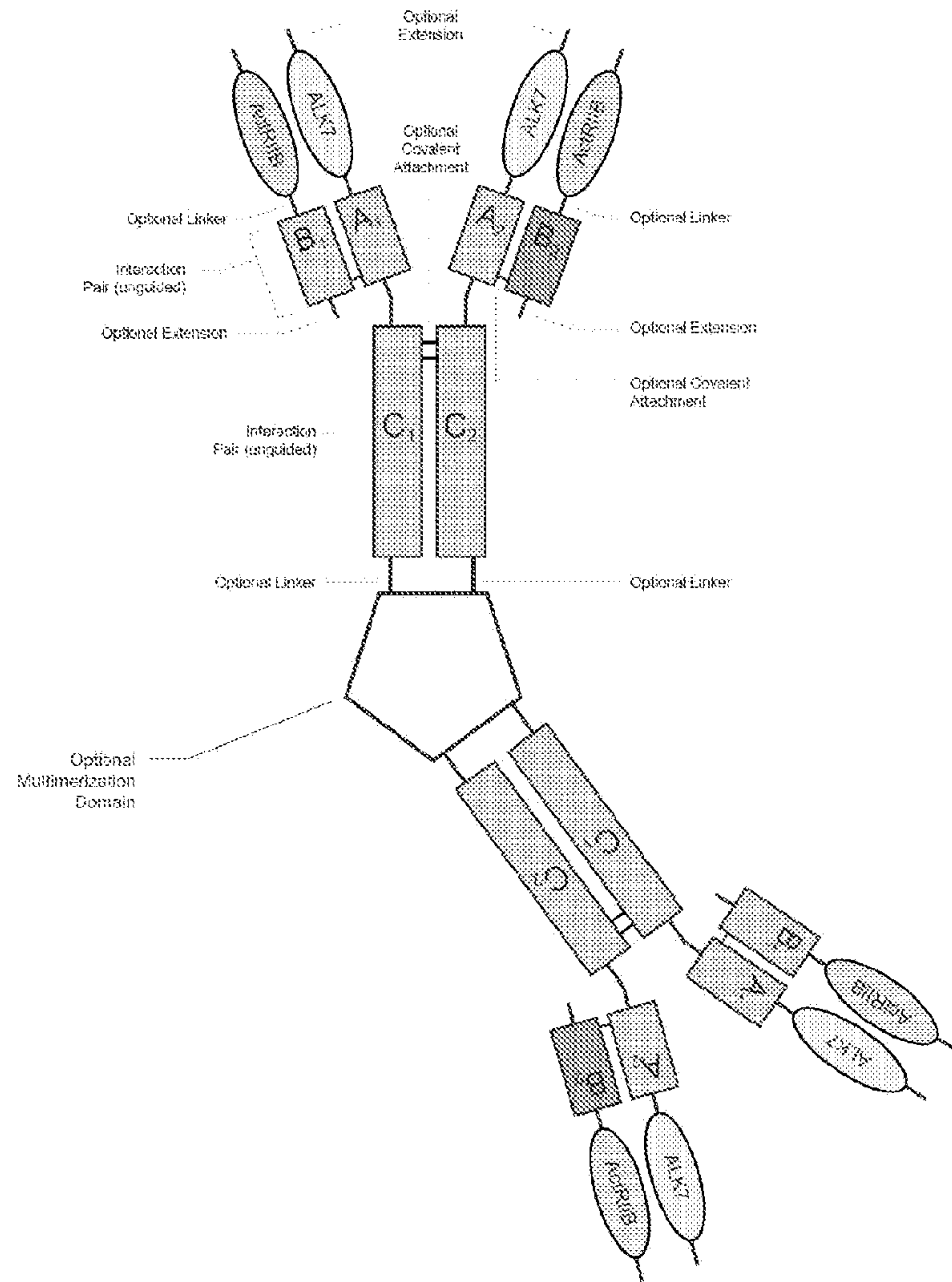


FIGURE 9C

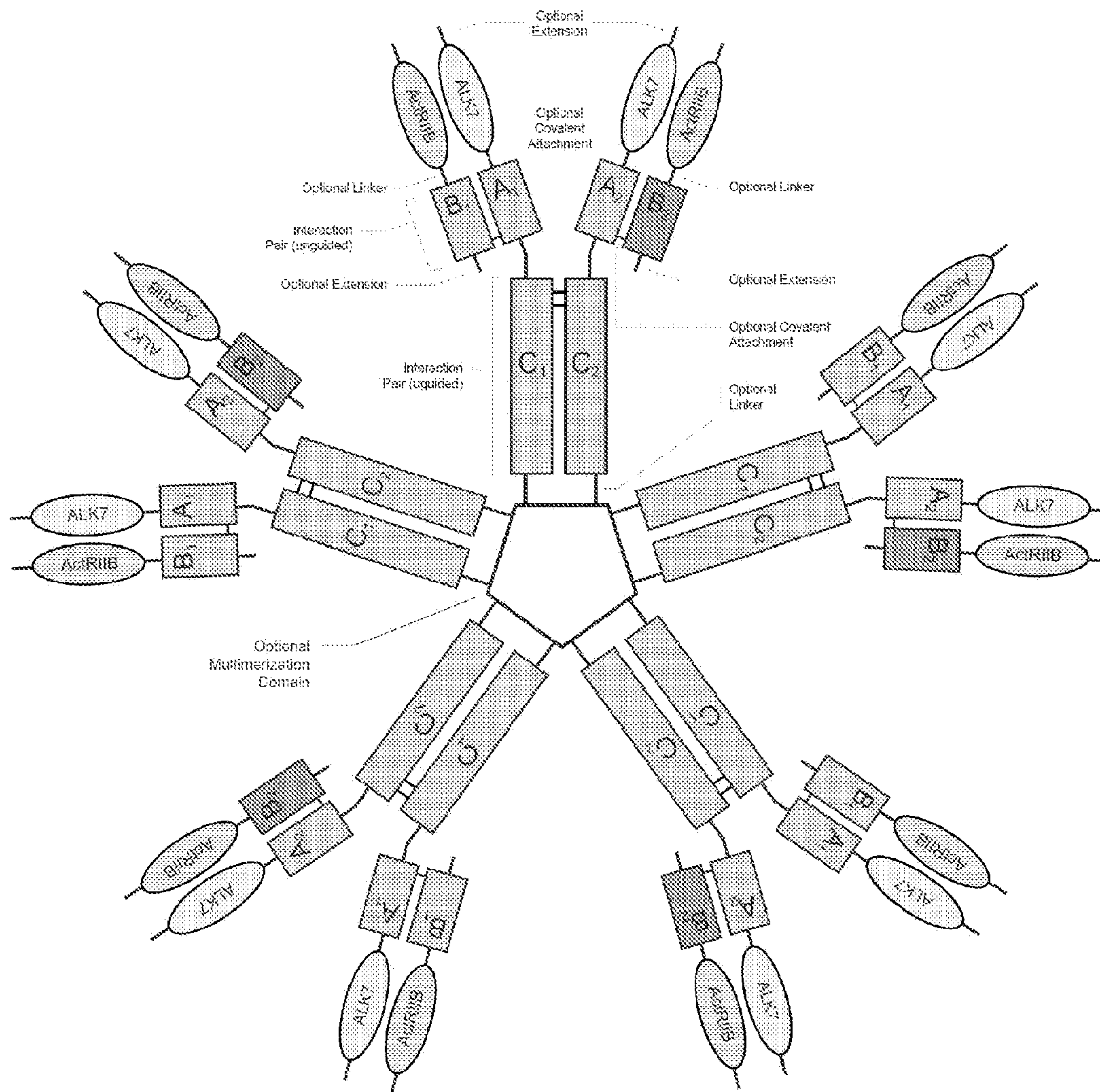


FIGURE 9D

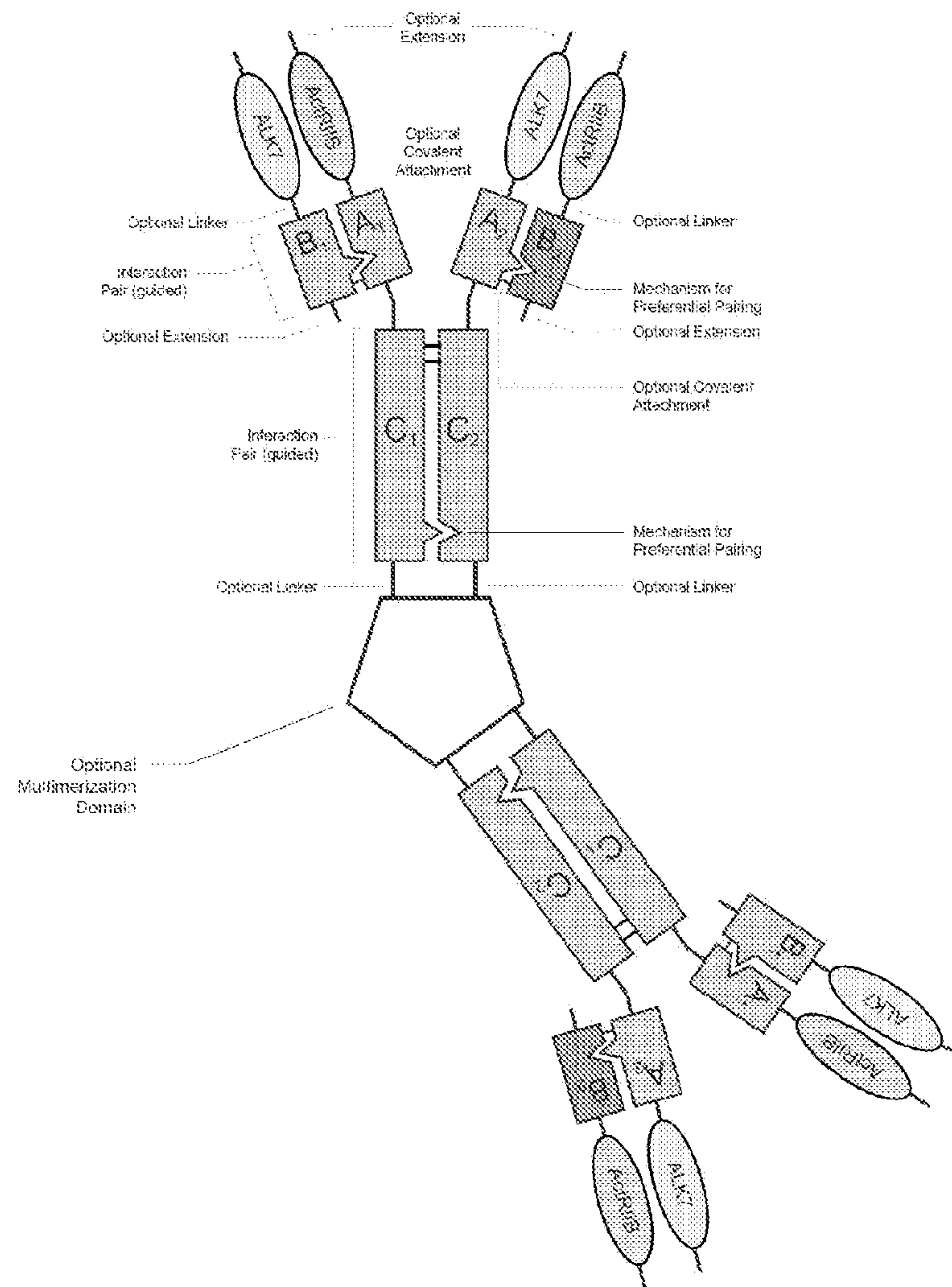


FIGURE 9E

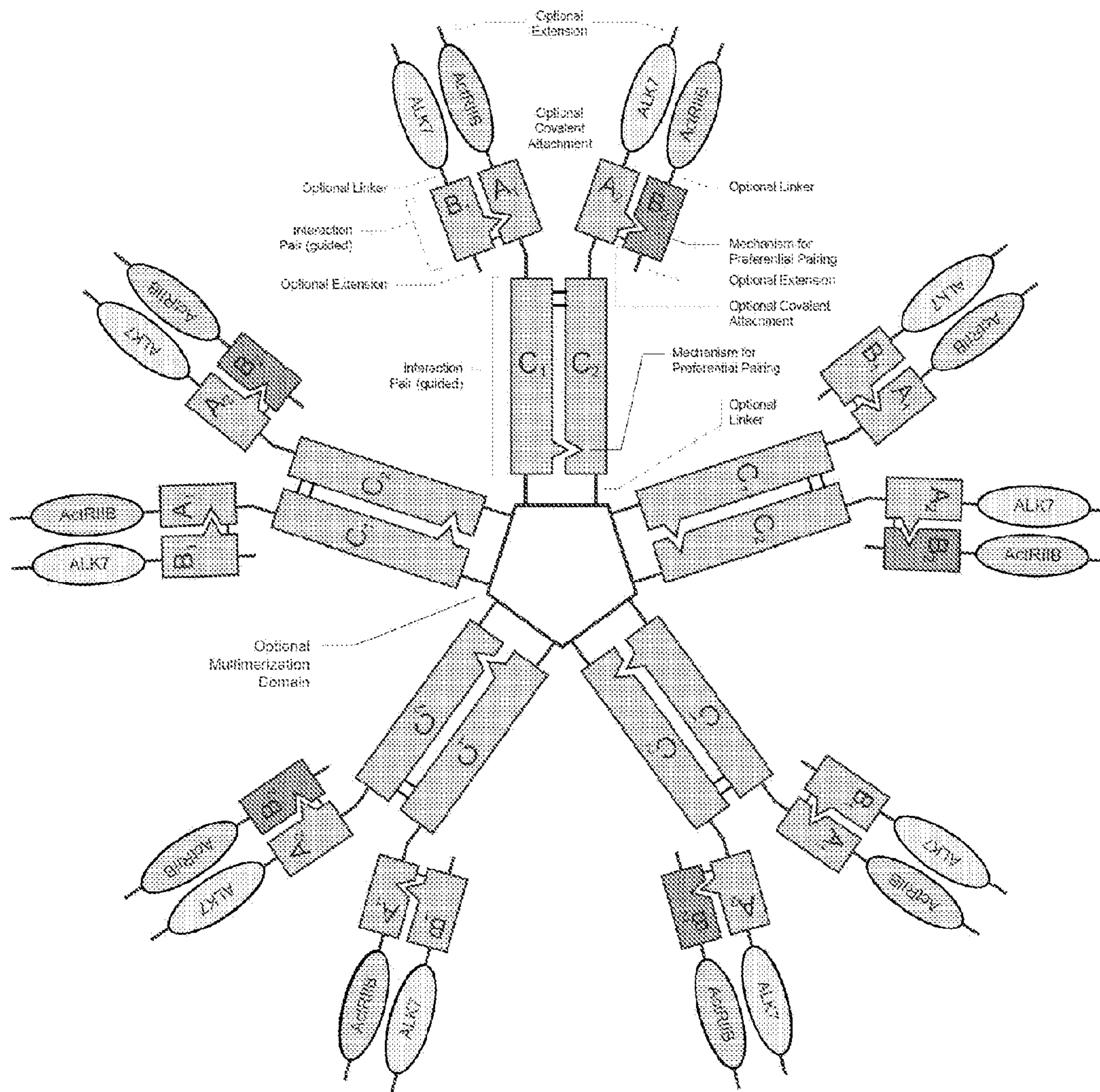


FIGURE 9F

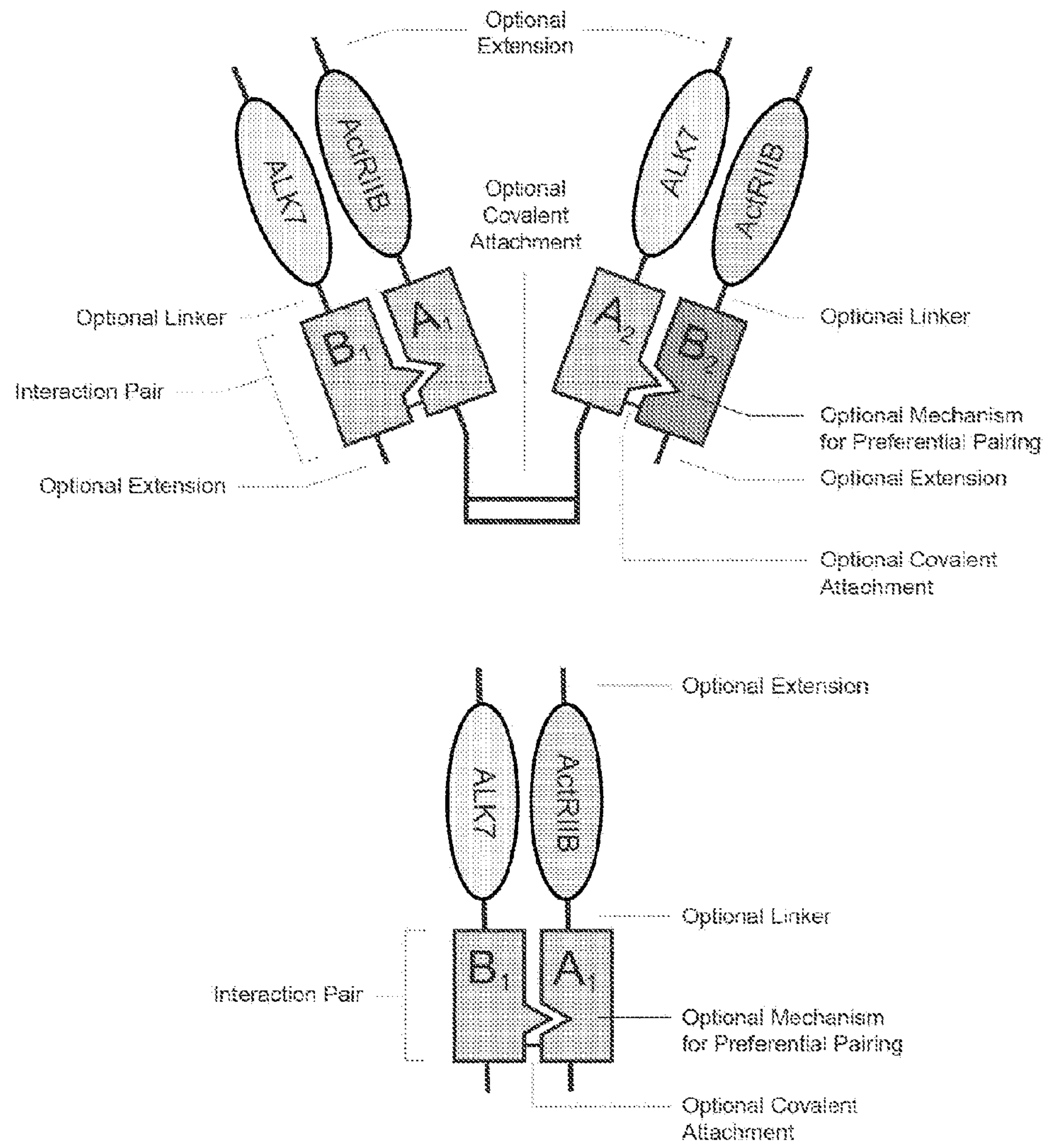


FIGURE 9G

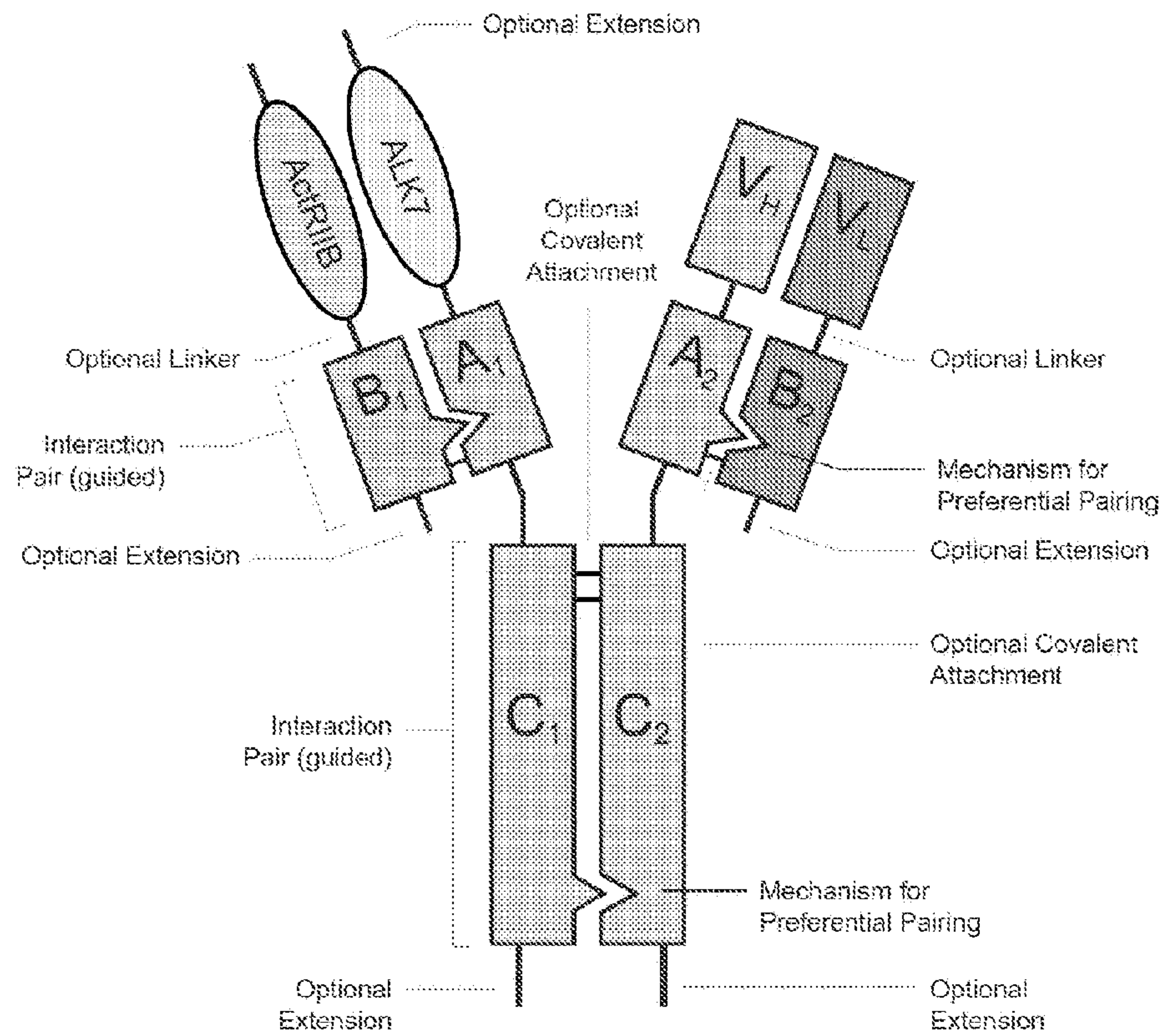


FIGURE 10A

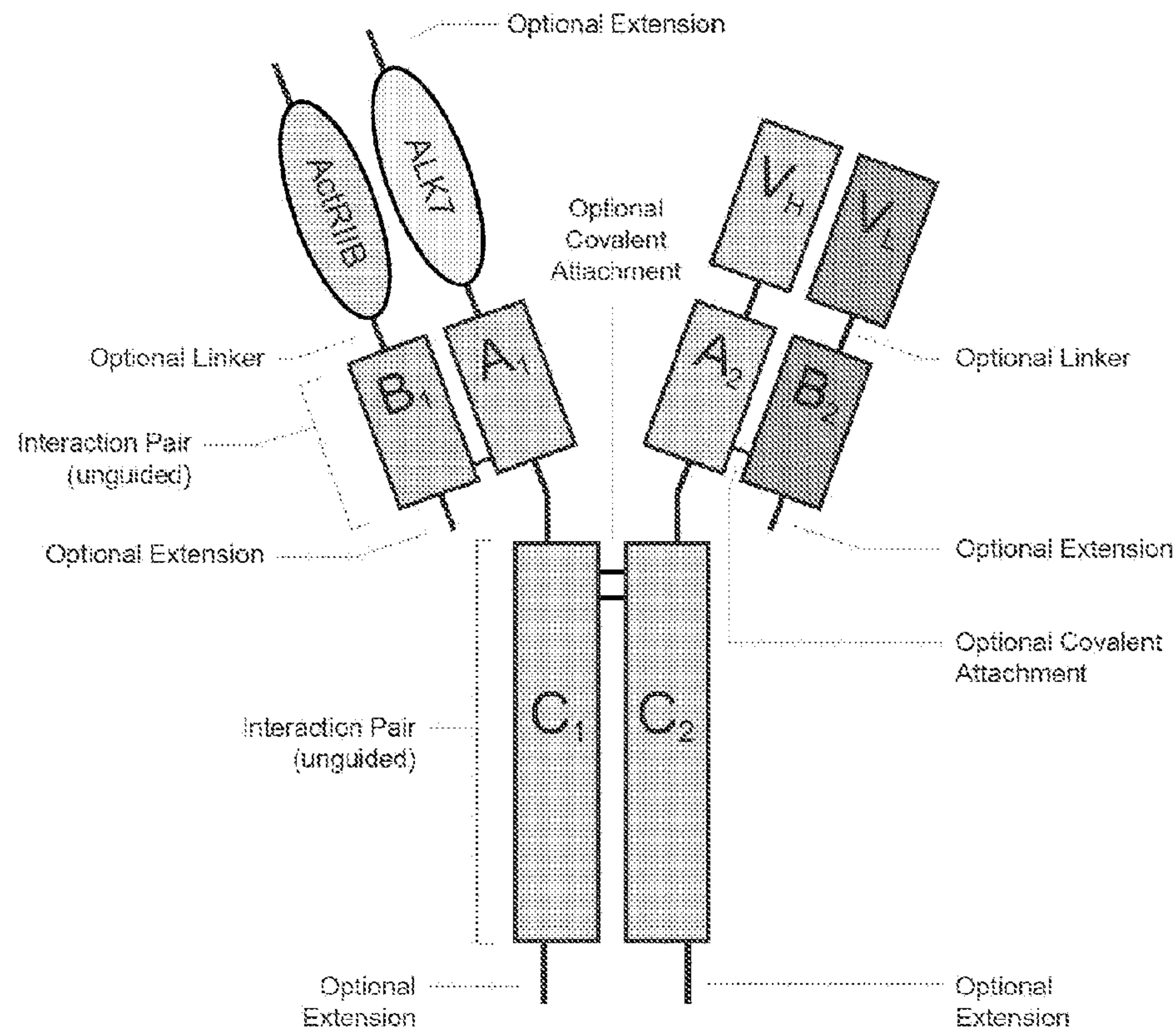


FIGURE 10B

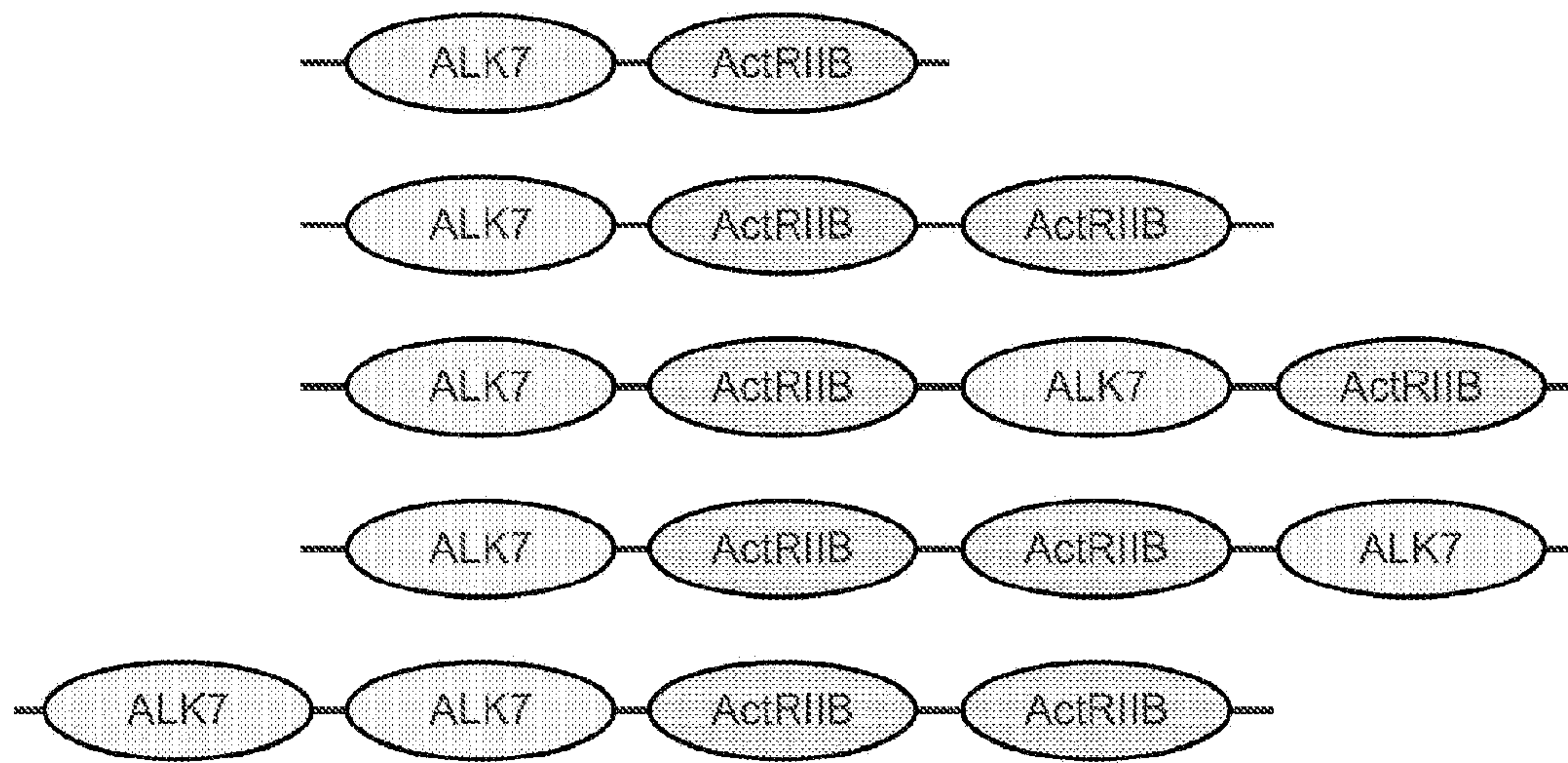


FIGURE 11

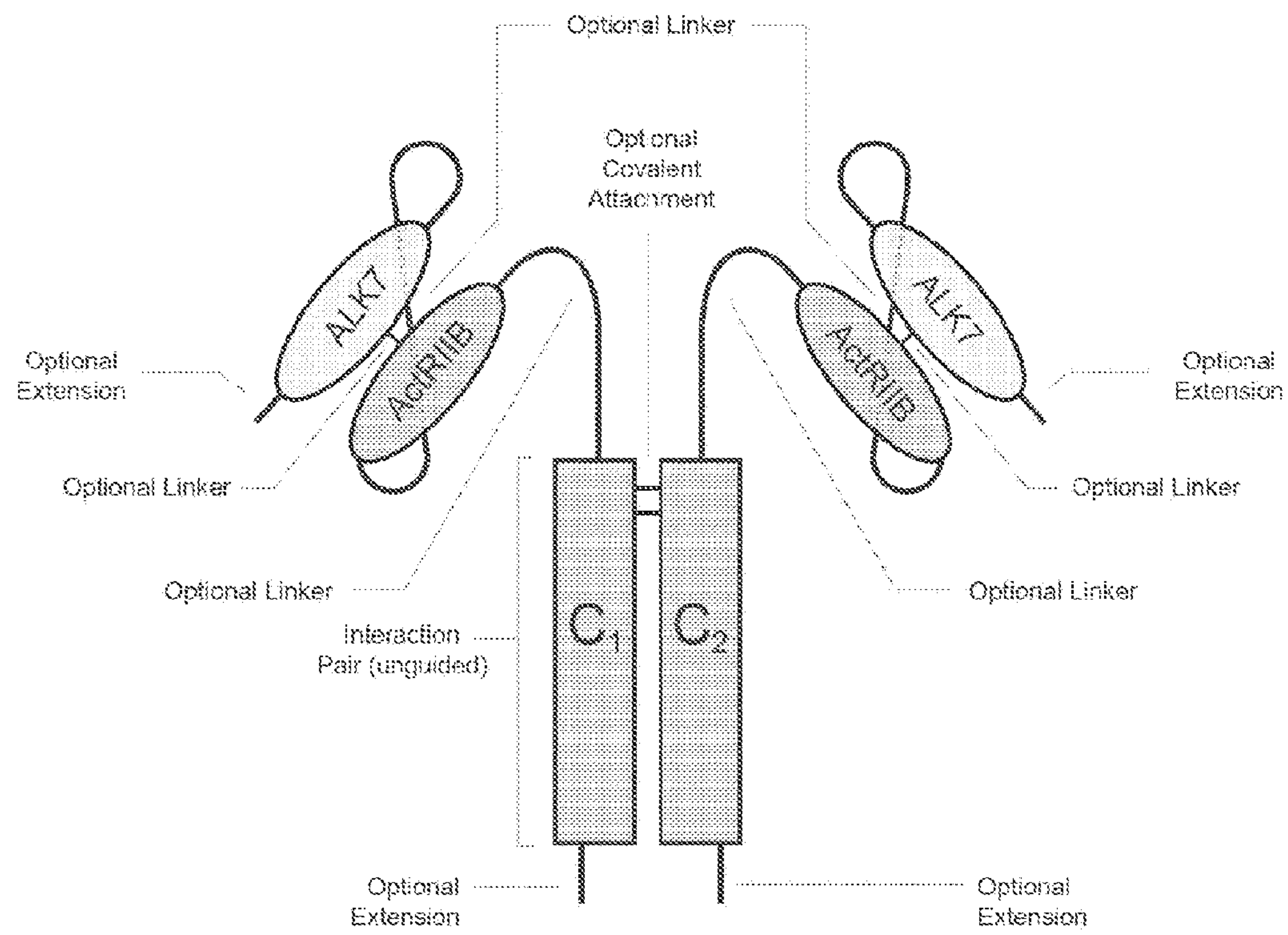


FIGURE 12A

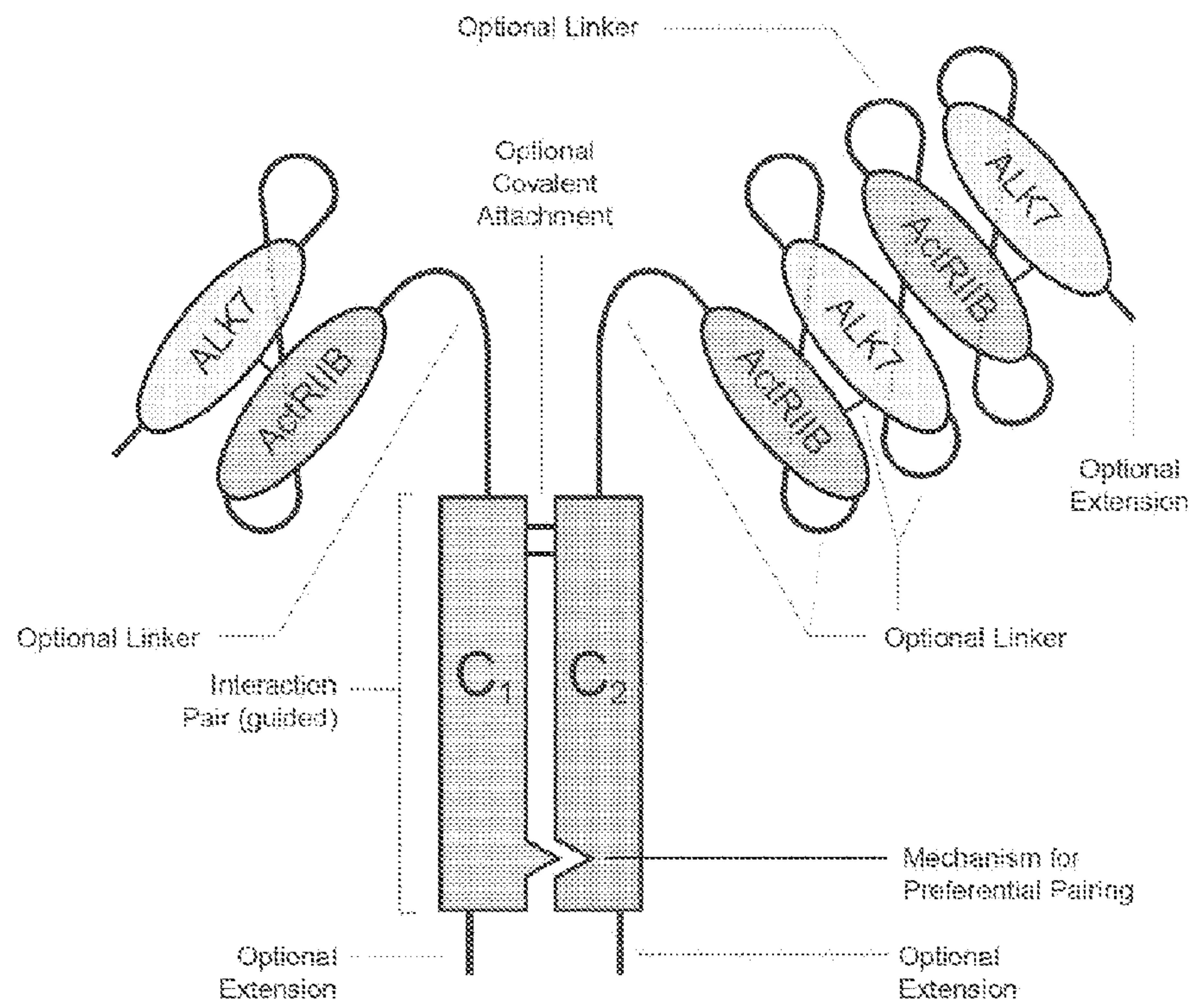


FIGURE 12B

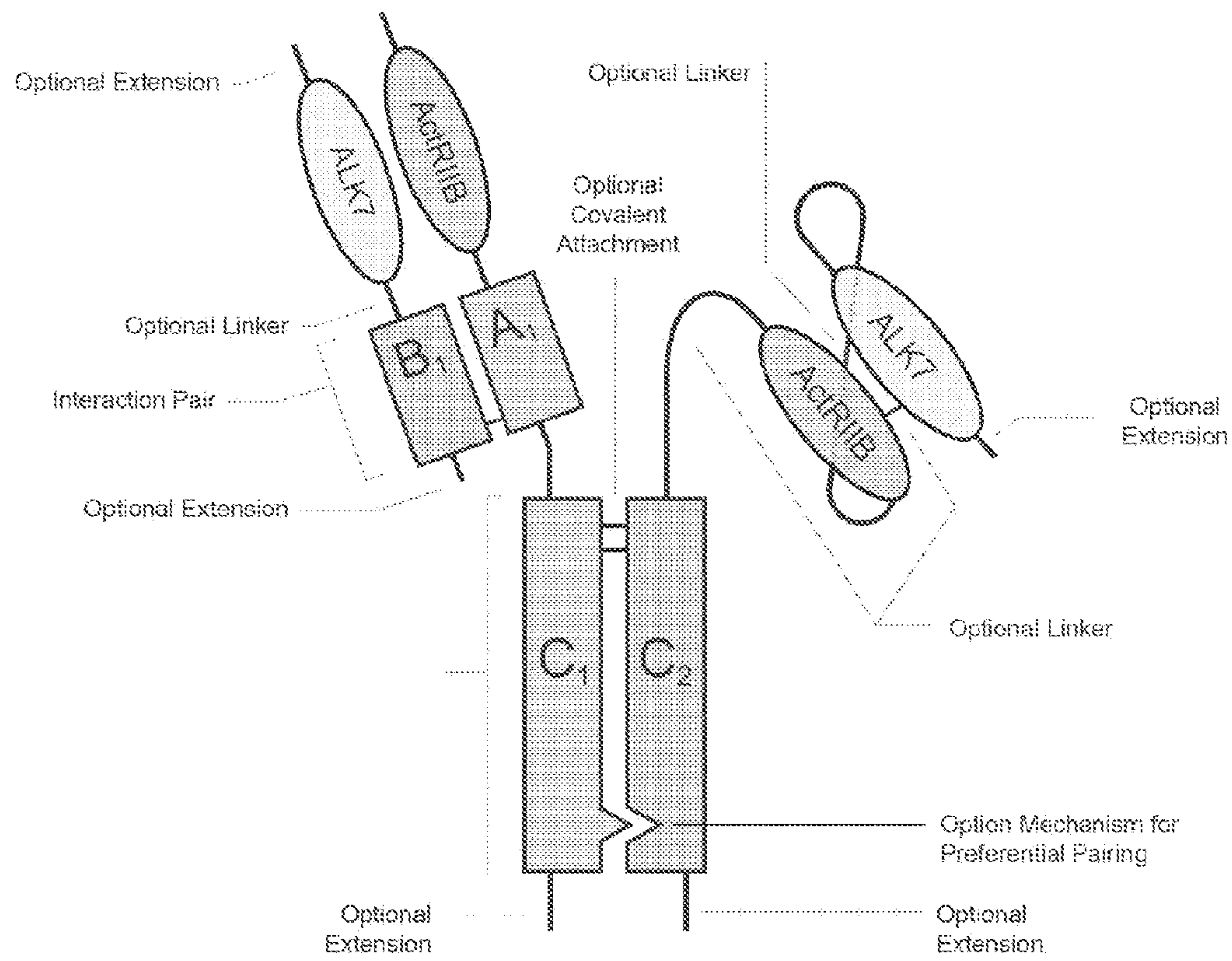


FIGURE 12C

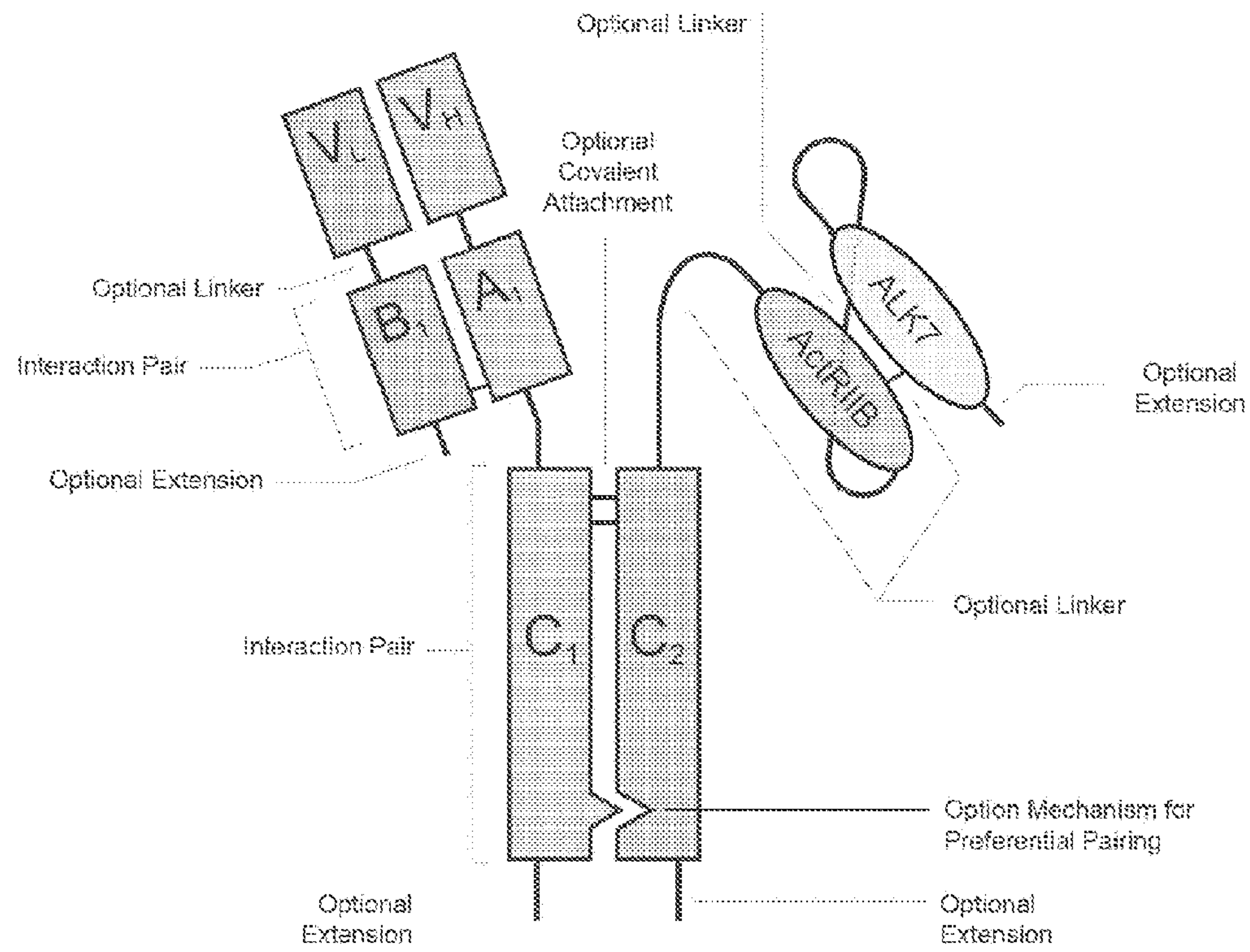


FIGURE 12D

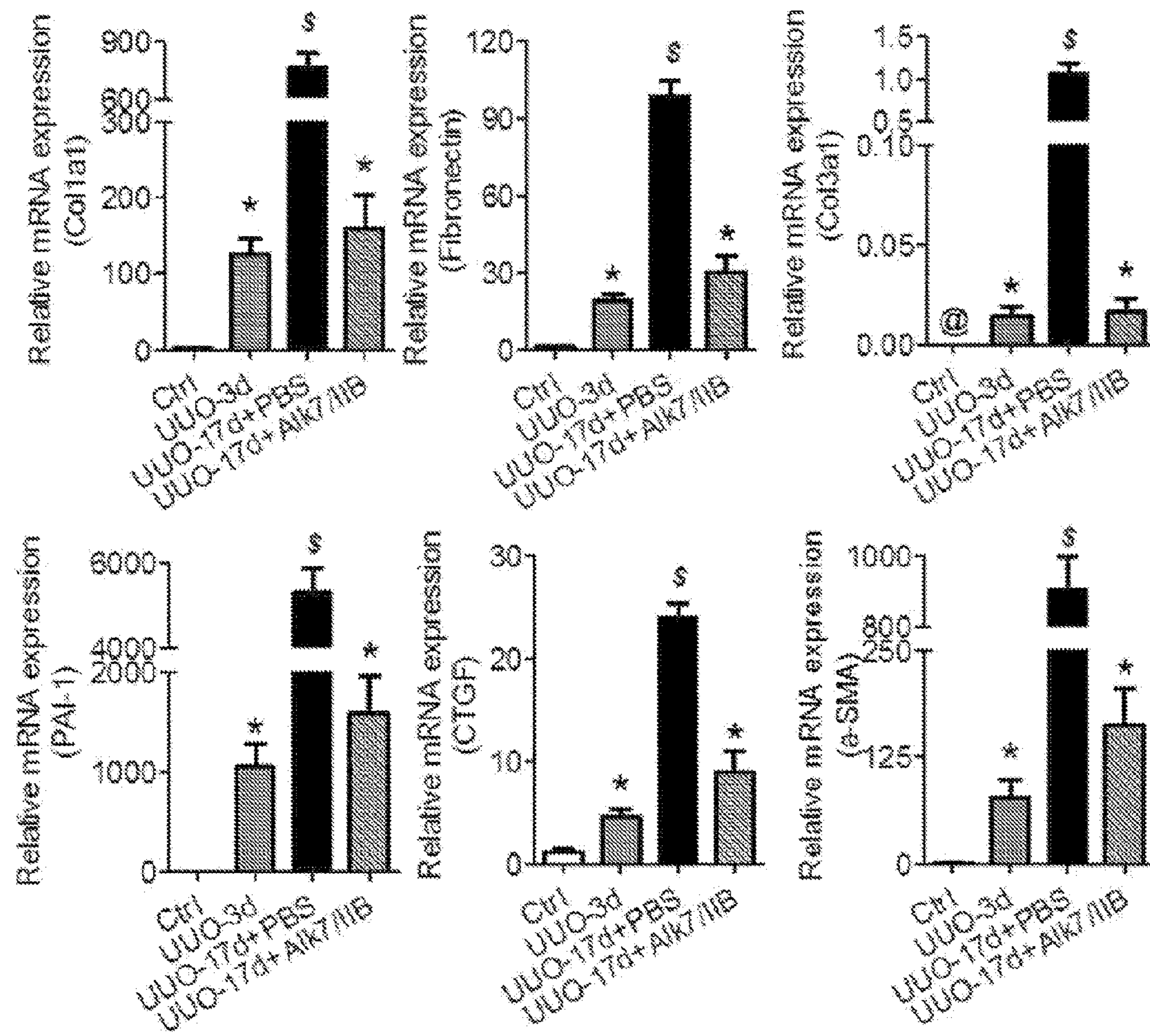


Figure 13A

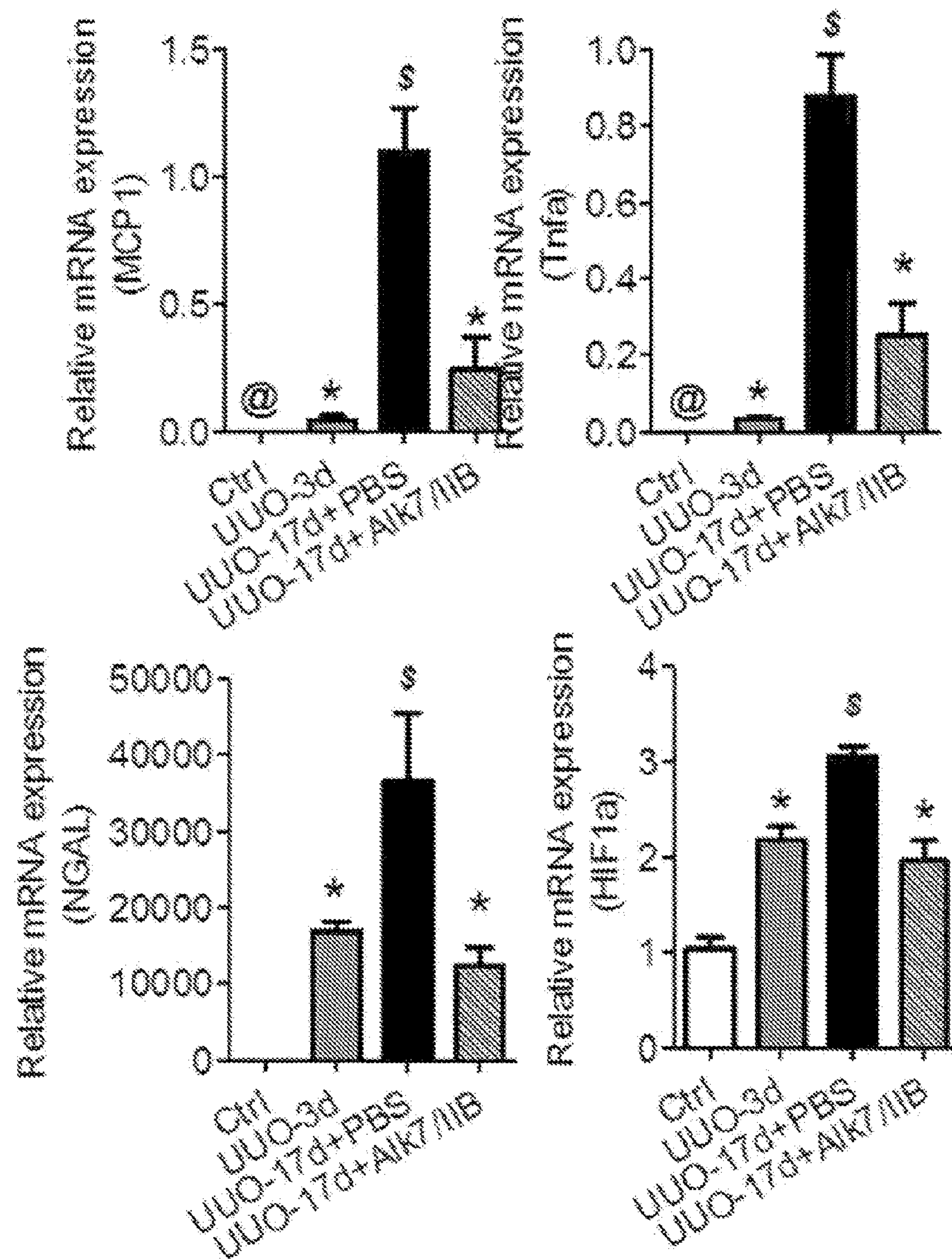


Figure 13B

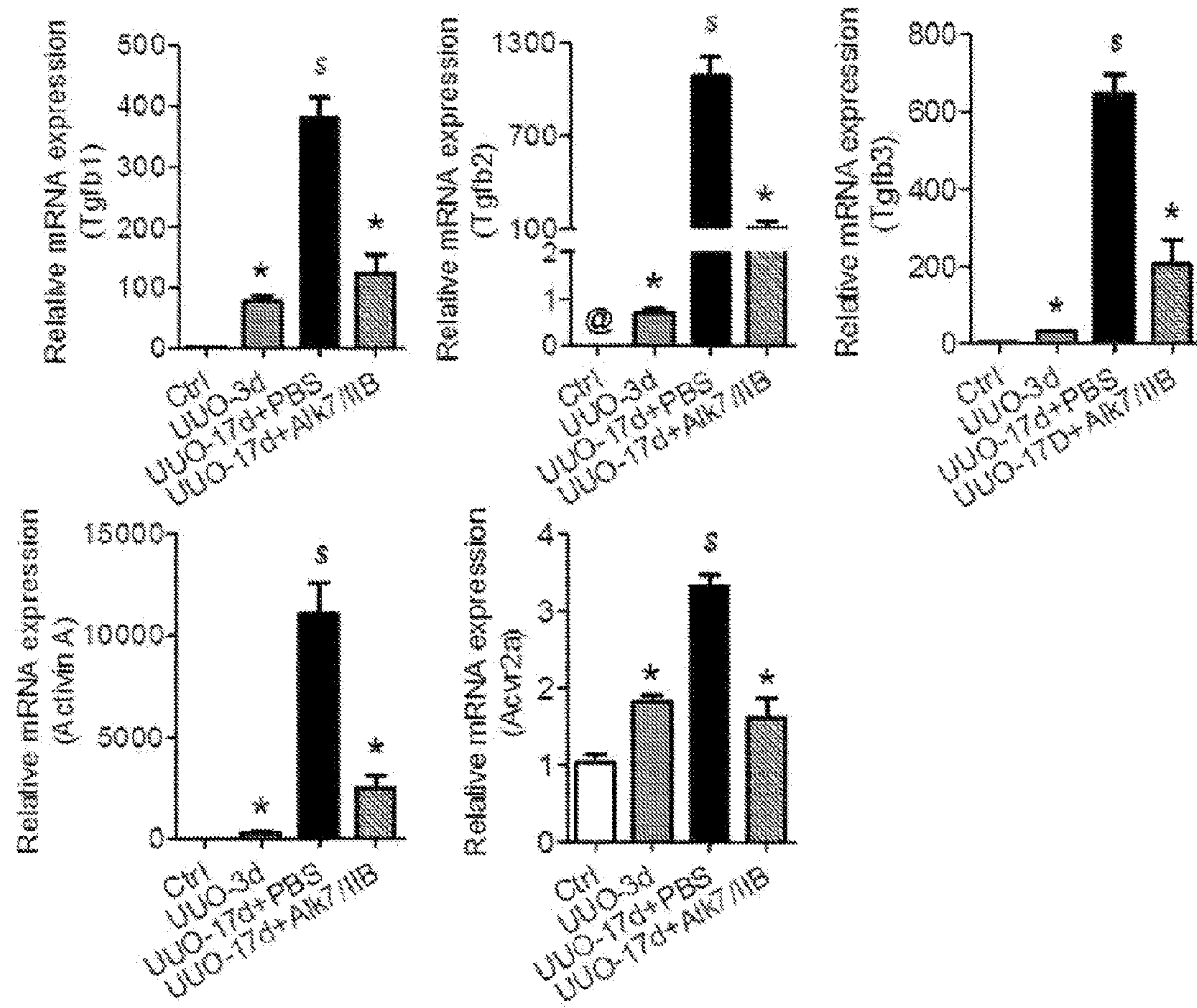


Figure 13C