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(57) Abstract

The present invention provides for an isolated nucleic acid molecule encoding a human TIE-2 ligand. In addition, the invention provides for a receptor body which specifically binds a human TIE-2 ligand. The invention also provides an antibody which specifically binds a human TIE-2 ligand. The invention further provides for an antagonist of human TIE-2. The invention also provides for therapeutic compositions as well as a method of blocking blood vessel growth, a method of promoting neovascularization, a method of promoting the growth or differentiation of a cell expressing the TIE-2 receptor, a method of blocking the growth or differentiation of a cell expressing the TIE-2 receptor and a method of attenuating or preventing tumor growth in a human.

TIE-2 LIGANDS, METHODS OF MAKING AND USES THEREOF

INTRODUCTION

The present invention relates generally to the field of genetic engineering and more particularly to genes for receptor tyrosine kinases and their cognate ligands, their insertion into recombinant DNA vectors, and the production of the encoded proteins in recipient strains of microorganisms and recipient eukaryotic cells. More specifically, the present invention is directed to novel ligands, known as the TIE-2 ligands, that bind the TIE-2 receptor, as well as to methods of making and using the TIE-2 ligands. The invention further provides nucleic acid sequences encoding TIE-2 ligands, and methods for the generation of nucleic acids encoding TIE-2 ligands and their gene products. The TIE-2 ligands, as well as nucleic acids encoding them, may be useful in the diagnosis and treatment of certain diseases involving endothelial cells and associated TIE receptors, such as neoplastic diseases involving tumor angiogenesis. wound healing, thromboembolic diseases, atherosclerosis and inflammatory diseases. In addition, the ligands may be used to promote the proliferation and/or differentiation of hematopoietic stem cells.

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More generally, biologically active TIE-2 ligands may be used to promote the growth, survival, migration, and/or differentiation and/or stabilization or destabilization of cells expressing the TIE-2 receptor. Biologically active TIE-2 ligand may be used for the in vitro maintenance of TIE-2 receptor expressing cells in culture. Cells and tissues expressing TIE-2 receptor include, for example, cardiac and vascular endothelial cells, lens epithelium and heart epicardium and early hematopoietic cells. Alternatively, such ligand may be used to support cells which are engineered to express TIE-2 receptor. Further, TIE-2 ligands and their cognate receptor may be used in assay systems to identify agonists or antagonists of the TIE-2 receptor.

BACKGROUND OF THE INVENTION

The cellular behavior responsible for the development, maintenance, and repair of differentiated cells and tissues is regulated, in large part, by intercellular signals conveyed via growth factors and similar ligands and their receptors. The receptors are located on the cell surface of responding cells and they bind peptides or polypeptides known as growth factors as well as other hormone-like ligands. The results of this interaction are rapid biochemical changes in the responding cells, as well as a rapid and a long-term readjustment of cellular gene expression. Several receptors associated with various cell surfaces may bind specific growth factors.

The phosphorylation of tyrosine residues in proteins by tyrosine kinases is one of the key modes by which signals are transduced across the plasma membrane. Several currently known protein tyrosine kinase genes encode transmembrane receptors for polypeptide growth factors and hormones such as epidermal growth factor (EGF), insulin, insulin-

like growth factor-I (IGF-I), platelet derived growth factors (PDGF-A and -B), and fibroblast growth factors (FGFs). (Heldin et al., Cell Regulation, 1: 555-566 (1990); Ullrich, et al., Cell, 61: 243-54 (1990)). In each instance, these growth factors exert their action by binding to the extracellular portion of their cognate receptors, which leads to activation of the intrinsic tyrosine kinase present on the cytoplasmic portion of the receptor. Growth factor receptors of endothelial cells are of particular interest due to the possible involvement of growth factors in several important physiological and pathological processes, such as vasculogenesis, angiogenesis, atherosclerosis, and inflammatory diseases. (Folkman, et al. Science, 235: 442-447 (1987)). Also, the receptors of several hematopoietic growth factors are tyrosine kinases; these include c-fms, which is the colony stimulating factor 1 receptor, Sherr, et al., Cell, 41: 665-676 (1985), and c-kit, a primitive hematopoietic growth factor receptor reported in Huang, et al., Cell, 63: 225-33 (1990).

The receptor tyrosine kinases have been divided into evolutionary subfamilies based on the characteristic structure of their ectodomains. (Ullrich, et al. Cell, 61: 243-54 (1990)). Such subfamilies include, EGF receptor-like kinase (subclass I) and insulin receptor-like kinase (subclass II), each of which contains repeated homologous cysteine-rich sequences in their extracellular domains. A single cysteine-rich region is also found in the extracellular domains of the eph-like kinases. Hirai, et al., Science, 238: 1717-1720 (1987); Lindberg, et al. Mol. Cell. Biol., 10: 6316-24 (1990); Lhotak, et al., Mol. Cell. Biol. 11: 2496-2502 (1991). PDGF receptors as well as c-fms and c-kit receptor tyrosine kinases may be grouped into subclass III; while the FGF receptors form subclass IV. Typical for the members of both of these subclasses are extracellular folding units stabilized by intrachain

disulfide bonds. These so-called immunoglobulin (Ig)-like folds are found in the proteins of the immunoglobulin superfamily which contains a wide variety of other cell surface receptors having either cell-bound or soluble ligands. Williams, et al., Ann. Rev. Immunol., 6: 381-405 (1988).

Receptor tyrosine kinases differ in their specificity and affinity. In general, receptor tyrosine kinases are glycoproteins which consist of (1) an extracellular domain capable of binding the specific growth factor(s); (2) a transmembrane domain which usually is an alpha-helical portion of the protein; (3) a juxtamembrane domain where the receptor may be regulated by, e.g., protein phosphorylation; (4) a tyrosine kinase domain which is the enzymatic component of the receptor; and (5) a carboxyterminal tail which in many receptors is involved in recognition and binding of the substrates for the tyrosine kinase.

Processes such as alternative exon splicing and alternative choice of gene promoter or polyadenylation sites have been reported to be capable of producing several distinct polypeptides from the same gene. These polypeptides may or may not contain the various domains listed above. As a consequence, some extracellular domains may be expressed as separate, secreted proteins and some forms of the receptors may lack the tyrosine kinase domain and contain only the extracellular domain inserted in the plasma membrane via the transmembrane domain plus a short carboxyl terminal tail.

A gene encoding an endothelial cell transmembrane tyrosine kinase, originally identified by RT-PCR as an unknown tyrosine kinase-homologous cDNA fragment from human leukemia cells, was described by Partanen, et al., Proc. Natl. Acad. Sci. USA, 87: 8913-8917 (1990). This gene and its encoded protein are called "TIE" which is an

abbreviation for "tyrosine kinase with Ig and EGF homology domains." Partanen, et al. Mol. Cell. Biol. 12: 1698-1707 (1992).

It has been reported that tie mRNA is present in all human fetal and mouse embryonic tissues. Upon inspection, tie message has been localized to the cardiac and vascular endothelial cells. Specifically, tie mRNA has been localized to the endothelia of blood vessels and endocardium of 9.5 to 18.5 day old mouse embryos. Enhanced tie expression was shown during neovascularization associated with developing ovarian follicles and granulation tissue in skin wounds. Korhonen, et al. Blood 80: 2548-2555 (1992). Thus the TIEs has been suggested to play a role in angiogenesis, which is important for developing treatments for solid tumors and several other angiogenesis-dependent diseases such as diabetic retinopathy, psoriasis, atherosclerosis and arthritis.

Two structurally related rat TIE receptor proteins have been reported to be encoded by distinct genes with related profiles of expression. One gene, termed tie-1, is the rat homolog of human tie. Maisonpierre, et al., Oncogene 8: 1631-1637 (1993). The other gene, tie-2, may be the rat homolog of the murine tek gene, which, like tie, has been reported to be expressed in the mouse exclusively in endothelial cells and their presumptive progenitors. Dumont, et al. Oncogene 8: 1293-1301 (1993). The human homolog of tie-2 is described in Ziegler, U.S. Patent No. 5,447,860 which issued on September 5, 1995 (wherein it is referred to as "ork"), which is incorporated in its entirety herein.

Both genes were found to be widely expressed in endothelial cells of embryonic and postnatal tissues. Significant levels of tie-2 transcripts were also present in other embryonic cell populations,

including lens epithelium, heart epicardium and regions of mesenchyme. Maisonpierre, et al., Oncogene 8: 1631-1637 (1993).

The predominant expression of the TIE receptor in vascular endothelia suggests that the TIEs plays a role in the development and maintenance of the vascular system. This could include roles in endothelial cell determination, proliferation, differentiation and cell migration and patterning into vascular elements. Analyses of mouse embryos deficient in TIE-2 illustrate its importance in angiogenesis, particularly for vascular network formation in endothelial cells. Sato, T.N., et al., Nature 376:70-74 (1995). In the mature vascular system, the TIEs could function in endothelial cell survival, maintenance and response to pathogenic influences.

The TIE receptors are also expressed in primitive hematopoietic stem cells, B cells and a subset of megakaryocytic cells, thus suggesting the role of ligands which bind these receptors in early hematopoiesis, in the differentiation and/or proliferation of B cells, and in the megakaryocytic differentiation pathway. Iwama, et al. Biochem. Biophys. Research Communications 195:301-309 (1993); Hashiyama, et al. Blood 87:93-101 (1996), Batard, et al. Blood 87:2212-2220 (1996).

SUMMARY OF THE INVENTION

The invention provides an isolated nucleic acid molecule comprising a nucleotide sequence selected from the group consisting of:

(a) the nucleotide sequence encoding the fibrinogen-like domain of the human TIE-2 ligand as set forth in Figure 4, 5 or 6 in isolation from the coiled coil domain of human TIE-2 ligand;

(b) a nucleotide sequence that hybridises under moderately stringent conditions to the nucleic acid sequence of (a) and which encodes the fibrinogen-like domain of a TIE-2 ligand in isolation from the coiled coil domain of a TIE-2 ligand; and

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(c) a nucleotide sequence which differs from (a) due to the degeneracy of the genetic code.

The isolated nucleic acid may be DNA, cDNA or RNA. The invention also provides for a vector comprising an isolated nucleic acid molecule of the invention. The present invention also provides a polypeptide encoded by the nucleic acid molecule of the invention, preferably substantially free of other proteins. The invention further provides for a host-vector system for the production in a suitable host cell of a polypeptide of the invention. The suitable host cell may be bacterial, yeast, insect or mammalian. The invention also provides for a method of producing a polypeptide of the invention which comprises growing cells of the host-vector system under conditions permitting production of the polypeptide and recovering the polypeptide so produced.

The invention further provides for therapeutic compositions comprising a polypeptide of the invention in a pharmaceutically acceptable vehicle.

The present invention also provides for an antibody which specifically binds a polypeptide of the invention. The antibody may be monoclonal or polyclonal. Thus the invention further provides for therapeutic compositions comprising such an antibody.

Alternatively, the invention provides that a TIE-2 ligand may be conjugated to a cytotoxic agent and a therapeutic composition prepared therefrom.

The invention yet further provides a ligandbody which comprises a polypeptide of the invention or a conjugate thereof, fused to an immunoglobulin constant region.

The invention yet further provides use of the polypeptides, conjugates, antibodies, pharmaceutical compositions and ligandbodies of the invention in the manufacture of a medicament for use in a method of treatment of a human or animal or in a diagnostic method. The invention also provides methods of treatment or diagnosis comprising administering a therapeutically or diagnostically effective amount of a polypeptide, conjugate, antibody, pharmaceutical composition or ligandbody to a patient. The polypeptides of the invention may in particular be used in a method of blocking blood vessel growth in a mammal and in attenuating or

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preventing tumour growth.

The invention further provides a method of identifying a TIE-2 receptor antagonist comprising contacting TIE-2 receptor with a test compound in the presence of a polypeptide according to the invention, under conditions permitting binding of the polypeptide to the receptor, and determining whether the test compound is capable of interfering with the binding of the polypeptide to the receptor.

The invention yet further provides use of a polypeptide of the invention or a ligandbody of the invention, in the manufacture of a medicament, for use with a second pharmaceutically active agent in a method of treatment of a human or animal body, or in a method of diagnosis.

The invention yet further provides a method of treatment or diagnosis which comprises administering to a patient a therapeutically or diagnostically effective amount of a polypeptide according to the invention or a ligandbody according to the invention with a second pharmaceutically active agent.

The invention yet further provides use of a polypeptide of the invention or a ligandbody of the invention in the manufacture of a medicament for use in a method of inhibiting hematopoiesis in a patient.

The invention yet further provides a method of inhibiting hematopoiesis comprising treating a patient with a therapeutically effective amount of a polypeptide of the invention or a ligandbody of the invention.

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FIGURES 1A and 1B - TIE-2 receptorbody (TIE-2 RB) inhibits the development of blood vessels in the embryonic chicken chorioallantoic membrane (CAM). A single piece of resorbable gelatin foam (Gelfoam) soaked with 6 μg of RB was inserted immediately under the CAM of 1-day chick embryos. After 3 further days of incubation, 4 day old embryos and surrounding CAM were removed and examined. FIGURE 1A: embryos treated with EHK-1 RB (rEHK-1 ecto/hIgG1 Fc) were viable and possessed normally developed blood vessels in their surrounding CAM. FIGURE 1B : all embryos treated with TIE-2 RB (r TIE-2 ecto / h IgG1 Fc) were dead, diminished in size and were almost completely devoid of surrounding blood vessels.

FIGURE 2 - Vector pJFE14.

FIGURE 3 - Restriction map of λgt10.

FIGURE 4 - Nucleic acid and deduced amino acid (single letter code) sequences of human TIE-2 ligand 1 from clone λgt10 encoding htie-2 ligand 1.

FIGURE 5 - Nucleic acid and deduced amino acid (single letter code) sequences of human TIE-2 ligand 1 from T98G clone.

FIGURE 6 - Nucleic acid and deduced amino acid (single letter code) sequences of human TIE-2 ligand 2 from clone pBluescript KS encoding human TIE 2 ligand 2.

FIGURE 7 - Western blot showing activation of TIE-2 receptor by TIE-2 ligand 1 (Lane L1) but not by TIE-2 ligand 2 (Lane L2) or control (Mock).

FIGURE 8 - Western blot showing that prior treatment of HAEC cells with excess TIE-2 ligand 2 (Lane 2) antagonizes the subsequent ability of dilute TIE-2 ligand 1 to activate the TIE-2 receptor (TIE2-R) as compared with prior treatment of HAEC cells with MOCK medium (Lane 1).

FIGURE 9- Western blot demonstrating the ability of TL2 to competitively inhibit TL1 activation of the TIE-2 receptor using the human cell hybrid line, EA.hy926.

FIGURE 10- Histogram representation of binding to rat TIE-2 IgG immobilized surface by TIE-2 ligand in C2C12 ras, Rat2 ras, SHEP, and T98G concentrated (10x) conditioned medium. Rat TIE-2 (rTIE2) specific binding is demonstrated by the significant reduction in the binding activity in the presence of 25 µg/ml soluble rat TIE-2 RB as compared to a minor reduction in the presence of soluble trkB RB.

FIGURE 11 - Binding of recombinant human TIE-2 ligand 1 (hTL1) and human TIE-2 ligand 2 (hTL2), in COS cell supernatants, to a human TIE-2 receptorbody (RB) immobilized surface. Human TIE-2-specific binding was determined by incubating the samples with 25 µg/ml of either soluble human TIE-2 RB or trkB RB; significant reduction in the binding activity is observed only for the samples incubated with human TIE-2 RB.

FIGURE 12 - Western blot showing that TIE-2 receptorbody (denoted TIE-2 RB or, as here, TIE2-Fc) blocks the activation of TIE-2 receptors by TIE-2 ligand 1 (TL1) in HUVEC cells, whereas an unrelated receptorbody (TRKB-Fc) does not block this activation.

FIGURE 13- Agarose gels showing serial dilutions [undiluted (1) to 10^{-4}] of the TL1 and TL2 RT-PCR products obtained from E14.5 mouse fetal liver (Lanes 1- total, Lanes 3- stromal enriched, and Lanes 4- c-kit$^+$TER119 hematopoietic precursor cells) and E14.5 mouse fetal thymus (Lanes 2- total).

FIGURE 14- Agarose gels showing serial dilutions [undiluted (1) to 10^{-3}] of the TL1 and TL2 RT-PCR products obtained from E17.5 mouse fetal thymus cortical stromal cells (Lanes 1- CDR1+/A2B5-) and medullary stromal cells (Lane CDR1-/A2B5+).

FIGURE 15- A schematic representation of the hypothesized role of the TIE-2/TIE ligands in angiogenesis. TL1 is represented by (•), TL2 is represented by (*), TIE-2 is represented by (**T**), VEGF is represented by ([]), and flk-1 (a VEGF receptor) is represented by (**Y**).

FIGURE 16- *In situ* hybridization slides showing the temporal expression pattern of TIE-2, TL1, TL2, and VEGF during angiogenesis associated with follicular development and corpus luteum formation in the ovary of a rat that was treated with pregnant mare serum. Column 1: Early pre-ovulatory follicle; Column 2: pre-ovulatory follicle; Column 3: early corpus luteum; and Column 4: atretic follicle; Row A: bright field; Row B: VEGF; Row C: TL2; Row D: TL1 and Row E: TIE-2 receptor.

FIGURE 17- Diagrammatic representation of the TIE-2 ligands, showing the "coiled coil" and fibrinogen-like domains and the engineering of multimers of the fibrinogen-like domains using antibodies to myc-tags as well as Fc tagging.

FIGURE 18- Western blot of the covalent multimeric structure of TL1 and TL2 (Panel A) and the interconversion of TL1 and TL2 by the mutation of one cysteine (Panel B).

FIGURE 19- A typical curve of TIE-2-IgG binding to immobilized TL1 in a quantitative cell-free binding assay.

FIGURE 20- A typical curve showing TIE-2 ligand 1 ligandbody comprising the fibrinogen-like domain of the ligand bound to the Fc domain of IgG (TL1-fFc) binding to immobilized TIE-2 ectodomain in a quantitative cell-free binding assay.

DETAILED DESCRIPTION OF THE INVENTION

As described in greater detail below, applicants have isolated and identified ligands that bind the TIE-2 receptor. The TIE-2 ligands may be purified from nature, or made recombinantly, are referred to herein as TIE-2 ligand 1 (or TL1) and TIE-2 ligand 2 (or TL2). TIE-2 ligand 1, which has an amino acid sequence which is encoded, *inter alia*, by the nucleic acid set forth in Figure 4 or 5, is a TIE-2 receptor agonist. TIE-2 ligand 2, which has an amino acid sequence which is encoded, *inter alia*, by the nucleic acid described in Figure 6, is a TIE-2 receptor antagonist.

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The invention contemplates compositions

wherein the TIE-2 ligand is the receptor binding domains of the TIE-2 ligands described herein. For example, TIE-2 ligand 1 consists of a "coiled coil" domain (beginning at the 5' end and extending to the nucleotide at about position 1160 of Figure 4 and about position 1157 of Figure 5) and a fibrinogen-like domain (which is encoded by the nucleotide sequence of Figure 4 beginning at about position 1161 and about position 1158 of Figure 5). The fibrinogen-like domain of TIE-2 ligand 2 is believed to begin on or around the same amino acid sequence as in ligand 1 (FRDCA) which is encoded by nucleotides beginning around 1197 of Figure 6. Multimerization of the coiled coil domains during production of the ligand hampers purification. As described in Example 19, Applicants have discovered, however, that the fibrinogen-like domain comprises the TIE-2 receptor binding domain. The monomeric forms of the fibrinogen-like domain do not, however, appear to bind the receptor. Studies utilizing myc-tagged fibrinogen-like domain, which has been "clustered" using anti-myc antibodies, do bind the TIE-2 receptor. [Methods of production of "clustered ligands and ligandbodies are described in Davis, et al. Science 266:816-819 (1994)]. Based on these finding, applicants produced "ligandbodies" which comprise the fibrinogen-like domain of the TIE-2 ligands coupled to the Fc domain of IgG ("fFc's"). These ligandbodies, which form dimers, efficiently bind the TIE-2 receptor. Accordingly, the present invention contemplates the production of TIE-2 ligandbodies which may be used as targeting agents, in diagnostics or in therapeutic applications, such as targeting agents for tumors and/or associated vasculature wherein a TIE-2 antagonist is indicated.

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TIE-2 ligands may be defined by their amino acid sequences, as well as functionally equivalent variants thereof comprising naturally occurring allelic variations, as well as proteins or peptides comprising substitutions, deletions or insertional mutants of the described sequences, which bind the TIE-2 receptors and act as agonists or antagonists thereof. Such variants include those in which amino acid residues are substituted for residues within the sequence resulting in a silent change. For example, one or more amino acid residues within the sequence can be substituted by another amino acid(s) of a similar polarity which acts as a functional equivalent, resulting in a silent alteration. Substitutes for an amino acid within the sequence may be selected from other members of the class to which the amino acid belongs. For example, the class of nonpolar (hydrophobic) amino acids include alanine, leucine, isoleucine, valine, proline, phenylalanine, tryptophan and methionine. The polar neutral amino acids include glycine, serine, threonine, cysteine, tyrosine, asparagine, and glutamine. The positively charged (basic) amino acids include arginine, lysine and histidine. The negatively charged (acidic) amino acids include aspartic acid and glutamic acid.

The TIE-2 ligands described herein, and derivatives which are differentially modified during or after translation, e.g., by glycosylation, proteolytic cleavage, linkage to an antibody molecule or other cellular ligand, etc. Functionally equivalent molecules also include molecules that contain modifications, including N-terminal modifications, which result from expression in a particular recombinant host, such as, for example, N-terminal methylation which occurs in certain bacterial (e.g. E. coli) expression systems. Functional

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equivalents also include mutants in which amino acid substitutions are made for cysteine molecules to improve stability of the molecules and to prevent unwanted crosslinking. As used herein, the term "TIE-2 ligand" also include fragments of the TIE-2 ligands which are associated with the binding of the ligands to the TIE-2 receptor. In a preferred embodiment, the TIE-2 ligand comprises the fibrinogen-like domain of TIE-2 ligands 1 and 2 as described herein.

The present invention encompasses nucleotide sequences that encode certain TIE-2 derivatives, as well as host cells, including yeast, bacteria, viruses, and mammalian cells, which are genetically engineered to produce the protein, by e.g. transfection, transduction, infection, electroporation, or microinjection of nucleic acid encoding the TIE-2 ligands described herein in a suitable expression vector. The present invention also encompasses introduction of the nucleic acids encoding TIE-2 ligand derivatives through gene therapy techniques such as is described, for example, in Finkel and Epstein FASEB J. 9:843-851 (1995); Guzman, et al. PNAS (USA) 91:10732-10736 (1994).

One skilled in the art will also recognise that the present invention encompasses DNA and RNA sequences that hybridise to a deduced TIE-2 ligand encoding sequence, under conditions of moderate stringency, as defined in, for example, Sambrook *et al.* Molecular Cloning: A Laboratory Manual, 2 ed. Vol. 1, pp. 101-104, Cold Spring Harbor Laboratory Press (1989). Thus, a nucleic acid molecule contemplated by the invention includes one having a sequence deduced from an amino acid sequence of a TIE-2 ligand prepared as described herein, as well as a molecule having a sequence of nucleic acids that hybridizes to such a nucleic acid sequence, and also a nucleic acid sequence which is degenerate of the above sequences as a result of the

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genetic code, but which encodes a ligand that binds the TIE-2 receptor and which has an amino acid sequence and other primary, secondary and tertiary characteristics that are sufficiently duplicative of the ligands described herein so as to confer on the molecule the same biological activity as one of the TIE-2 ligands described herein.

The present invention further provides for an isolated and purified human TIE-2 ligand derivative encoded by an isolated nucleic acid molecule of the invention. The invention also provides a vector which comprises an isolated nucleic acid molecule comprising a nucleic acid sequence encoding a human TIE-2 ligand derivative of the invention.

Any of the methods known to one skilled in the art for the insertion of DNA fragments into a vector may be used to construct expression vectors encoding TIE-2 ligands using appropriate transcriptional/translational control signals and the protein coding sequences. These methods may be include *in vitro* recombinant DNA and

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synthetic techniques and in vivo recombinations (genetic recombination). Expression of a nucleic acid sequence encoding a TIE-2 ligand or peptide fragments thereof may be regulated by a second nucleic acid sequence which is operably linked to the TIE-2 ligand encoding sequence such that the TIE-2 ligand protein or peptide is expressed in a host transformed with the recombinant DNA molecule. For example, expression of a TIE-2 ligand described herein may be controlled by any promoter/enhancer element known in the art. Promoters which may be used to control expression of the ligand include, but are not limited to the long terminal repeat as described in Squinto et al., (Cell 65:1-20 (1991)); the SV40 early promoter region (Bernoist and Chambon, Nature 290:304-310), the CMV promoter, the M-MuLV 5' terminal repeat, the promoter contained in the 3' long terminal repeat of Rous sarcoma virus (Yamamoto, et al., Cell 22:787-797 (1980)), the herpes thymidine kinase promoter (Wagner et al., Proc. Natl. Acad. Sci. U.S.A. 78:144-1445 (1981)), the adenovirus promoter, the regulatory sequences of the metallothionein gene (Brinster et al., Nature 296:39-42 (1982)); prokaryotic expression vectors such as the β-lactamase promoter (Villa-Kamaroff, et al., Proc. Natl. Acad. Sci. U.S.A. 75:3727-3731 (1978)), or the tac promoter (DeBoer, et al., Proc. Natl. Acad. Sci. U.S.A. 80:21-25 (1983)), see also "Useful proteins from recombinant bacteria" in Scientific American, 242:74-94 (1980); promoter elements from yeast or other fungi such as the Gal 4 promoter, the ADH (alcohol dehydrogenase) promoter, PGK (phosphoglycerol kinase) promoter, alkaline phosphatase promoter, and the following animal transcriptional control regions, which exhibit tissue specificity and have been utilized in transgenic animals; elastase I gene control region which is active in pancreatic acinar cells

(Swift et al., Cell 38:639-646 (1984); Ornitz et al., Cold Spring Harbor Symp. Quant. Biol. 50:399-409 (1986); MacDonald, Hepatology 7:425-515 (1987); insulin gene control region which is active in pancreatic beta cells [Hanahan, Nature 315:115-122 (1985)]; immunoglobulin gene control region which is active in lymphoid cells (Grosschedl et al., 1984, Cell 38:647-658; Adames et al., 1985, Nature 318:533-538; Alexander et al., 1987, Mol. Cell. Biol. 7:1436-1444), mouse mammary tumor virus control region which is active in testicular, breast, lymphoid and mast cells (Leder et al., 1986, Cell 45:485-495), albumin gene control region which is active in liver (Pinkert et al., 1987, Genes and Devel. 1:268-276), alpha-fetoprotein gene control region which is active in liver (Krumlauf et al., 1985, Mol. Cell. Biol. 5:1639-1648; Hammer et al., 1987, Science 235:53-58); alpha 1-antitrypsin gene control region which is active in the liver (Kelsey et al, 1987, Genes and Devel. 1:161-171), beta-globin gene control region which is active in myeloid cells (Mogram et al., 1985, Nature 315:338-340; Kollias et al., 1986, Cell 46:89-94); myelin basic protein gene control region which is active in oligodendrocytes in the brain (Readhead et al., 1987, Cell 48:703-712); myosin light chain-2 gene control region which is active in skeletal muscle (Shani, 1985, Nature 314:283-286), and gonadotropic releasing hormone gene control region which is active in the hypothalamus (Mason et al., 1986, Science 234:1372-1378). The invention further encompasses the production of antisense compounds which are capable of specifically hybridizing with a sequence of RNA encoding a TIE-2 ligand to modulate its expression. Ecker, U.S. Patent No. 5,166,195, issued November 24, 1992.

Thus, according to the invention, expression vectors capable of being replicated in a bacterial or eukaryotic host comprising a nucleic acid encoding a TIE-2 ligand derivative as described herein, are used to transfect

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a host and thereby direct expression of such nucleic acid to produce the TIE-2 ligand, which may then be recovered in a biologically active form. As used herein, a biologically active form includes a form capable of binding to the TIE-2 receptor and causing a biological response such as a differentiated function or influencing the phenotype of the cell expressing the receptor.

The biological activity may be an effect as an antagonist to the TIE-2 receptor, such as is the biological activity of TIE-2 ligand 2. In alternative embodiments, the active form of a TIE-2 ligand derivative is one that can recognise the TIE-2 receptor and thereby act as a targeting agent for the receptor for use in both diagnostics and therapeutics. In accordance with such embodiments, the active form need not confer upon any TIE-2 expressing cell any change in phenotype.

In an alternative embodiment, the biologically active form of the TIE-2 ligand is one in which the ligand is capable of binding the TIE-1 receptor. Preliminary data indicates that TL 2 binds TIE-1 receptor (albeit with low affinity) raising the possibility that it may be able to bind and activate the receptor, or, as in the case of the TIE-2 receptor, bind and act as antagonist.

Expression vectors containing the gene inserts can be identified by four general approaches: (a) DNA-DNA hybridization, (b) presence or absence of "marker" gene functions, (c) expression of inserted sequences and (d) PCR detection. In the first approach, the presence of a foreign gene inserted in an expression vector can be detected by DNA-DNA hybridization using probes comprising sequences that are homologous to an inserted TIE-2 ligand encoding gene. In the second approach, the recombinant vector/host system can be identified and

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selected based upon the presence or absence of certain "marker" gene functions (e.g., thymidine kinase activity, resistance to antibiotics, transformation phenotype, occlusion body formation in baculovirus, etc.) caused by the insertion of foreign genes in the vector. For example, if a nucleic acid encoding a TIE-2 ligand is inserted within the marker gene sequence of the vector, recombinants containing the insert can be identified by the absence of the marker gene function. In the third approach, recombinant expression vectors can be identified by assaying the foreign gene product expressed by the recombinant. Such assays can be based, for example, on the physical or functional properties of a TIE-2 ligand gene product, for example, by binding of the ligand to the TIE-2 receptor or portion thereof which may be tagged with, for example, a detectable antibody or portion thereof or by binding to antibodies produced against the TIE-2 ligand protein or a portion thereof. Cells of the present invention may transiently or, preferably, constitutively and permanently express TIE-2 ligands as described herein. In the fourth approach, DNA nucleotide primers can be prepared corresponding to a tie-2 specific DNA sequence. These primers could then be used to PCR a tie-2 gene fragment. (PCR Protocols: A Guide To Methods and Applications, Edited by Michael A. Innis et al., Academic Press (1990)).

The recombinant ligands may be purified by any technique which allows for the subsequent formation of a stable, biologically active protein. Preferably, the ligands are secreted into the culture medium from which they are recovered. Alternatively, the ligand may be recovered from cells either as soluble proteins or as inclusion bodies, from which they may be extracted quantitatively by 8M guanidinium hydrochloride and dialysis in accordance with well known methodology. In order to further purify the ligand, affinity chromatography,

conventional ion exchange chromatography, hydrophobic interaction chromatography, reverse phase chromatography or gel filtration may be used.

In addition, as described in greater detail in the Examples, a recombinant TIE-2 ligand encoding gene may be used to inactivate or "knock out" the endogenous gene by homologous recombination, and thereby create a TIE-2 ligand deficient cell, tissue, or animal. For example, and not by way of limitation, the recombinant TIE-2 ligand encoding gene may be engineered to contain an insertional mutation, for example the neo gene, which would inactivate the native TIE-2 ligand encoding gene. Such a construct, under the control of a suitable promoter, may be introduced into a cell, such as an embryonic stem cell, by a technique such as transfection, transduction, or injection. Cells containing the construct may then be selected by G418 resistance. Cells which lack an intact TIE-2 ligand encoding gene may then be identified, e.g. by Southern blotting, PCR detection, Northern blotting or assay of expression. Cells lacking an intact TIE-2 ligand encoding gene may then be fused to early embryo cells to generate transgenic animals deficient in such ligand. Such an animal may be used to define specific in vivo processes, normally dependent upon the ligand.

The present invention also provides for antibodies to the TIE-2 ligand derivatives described herein which are useful for detection of the ligands in, for example, diagnostic applications. For preparation of monoclonal antibodies directed toward TIE-2 ligand, any technique which provides for the production of antibody molecules by continuous cell lines in culture may be used. For example, the hybridoma technique originally developed by Kohler and Milstein (1975, Nature 256:495-497), as well as the trioma technique, the human B-cell hybridoma technique (Kozbor

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et al., 1983, Immunology Today 4:72), and the EBV-hybridoma technique to produce human monoclonal antibodies (Cole et al., 1985, in "Monoclonal Antibodies and Cancer Therapy," Alan R. Liss, Inc. pp. 77-96) and the like are within the scope of the present invention.

The monoclonal antibodies may be human monoclonal antibodies or chimeric human-mouse (or other species) monoclonal antibodies. Human monoclonal antibodies may be made by any of numerous techniques known in the art (e.g., Teng et al., 1983, Proc. Natl. Acad. Sci. U.S.A. 80:7308-7312; Kozbor et al., 1983, Immunology Today 4:72-79; Olsson et al., 1982, Meth. Enzymol. 92:3-16). Chimeric antibody molecules may be prepared containing a mouse antigen-binding domain with human constant regions (Morrison et al., 1984, Proc. Natl. Acad. Sci. U.S.A. 81:6851, Takeda et al., 1985, Nature 314:452).

Various procedures known in the art may be used for the production of polyclonal antibodies to epitopes of the TIE-2 ligands described herein. For the production of antibody, various host animals, including but not limited to rabbits, mice and rats can be immunized by injection with a TIE-2 ligand, or a fragment or derivative thereof. Various adjuvants may be used to increase the immunological response, depending on the host species, and including but not limited to Freund's (complete and incomplete), mineral gels such as aluminum hydroxide, surface active substances such as lysolecithin, pluronic polyols, polyanions, peptides, oil emulsions, keyhole limpet hemocyanins, dinitrophenol, and potentially useful human adjuvants such as BCG (Bacille Calmette-Guerin) and Corynebacterium parvum.

A molecular clone of an antibody to a selected TIE-2 ligand epitope can be prepared by known techniques. Recombinant DNA methodology (see e.g., Maniatis et al., 1982, Molecular Cloning, A Laboratory Manual, Cold Spring Harbor Laboratory, Cold Spring Harbor,

New York) may be used to construct nucleic acid sequences which encode a monoclonal antibody molecule, or antigen binding region thereof.

The present invention provides for antibody molecules as well as fragments of such antibody molecules. Antibody fragments which contain the idiotype of the molecule can be generated by known techniques. For example, such fragments include but are not limited to: the $F(ab')_2$ fragment which can be produced by pepsin digestion of the antibody molecule; the Fab' fragments which can be generated by reducing the disulfide bridges of the $F(ab')_2$ fragment, and the Fab fragments which can be generated by treating the antibody molecule with papain and a reducing agent. Antibody molecules may be purified by known techniques, e.g., immunoabsorption or immunoaffinity chromatography, chromatographic methods such as HPLC (high performance liquid chromatography), or a combination thereof.

An immunoassay may be used for measuring the amount of a TIE-2 ligand in a biological sample by

a) contacting the biological sample with at least one antibody which specifically binds the TIE-2 ligand so that the antibody forms a complex with any TIE-2 ligand present in the sample; and

b) measuring the amount of the complex and thereby measuring the amount of the TIE-2 ligand in the biological sample.

An assay for measuring the amount of TIE-2 receptor in a biological sample may comprise

a) contacting the biological sample with at least one ligand of the invention so that the ligand forms a complex with the TIE-2 receptor; and

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b) measuring the amount of the complex and thereby measuring the amount of the TIE-2 receptor in the biological sample.

A TIE-2 ligand may also be used to support the survival and/or growth and/or migration and/or differentiation of TIE-2 receptor expressing cells. Thus, the ligand may be used as a supplement to support, for example, endothelial cells in culture.

Further, the discovery by applicants of a cognate ligand for the TIE-2 receptor enables the utilization of assay systems useful for the identification of agonists or antagonists of the TIE-2 receptor. Such assay systems would be useful in identifying molecules capable of promoting or inhibiting angiogenesis. For example, in one embodiment, antagonists of the TIE-2 receptor may be identified as test molecules that are capable of interfering with the interaction of the TIE-2 receptor with a biologically active TIE-2 ligand. Such antagonists are identified by their ability to 1) block the binding of a biologically active TIE-2 ligand to the receptor as measured, for example, using BIAcore biosensor technology (BIAcore; Pharmacia Biosensor, Piscataway, NJ); or 2) block the ability of a biologically active TIE-2 ligand to cause a biological response. Such biological responses include, but are not limited to, phosphorylation of the TIE-2 receptor or downstream components of the TIE-2 signal transduction pathway, or survival, growth or differentiation of TIE-2 receptor bearing cells.

In one embodiment, cells engineered to express the TIE-2 receptor may be dependent for growth on the addition of TIE-2 ligand. Such cells provide useful assay systems for identifying additional agonists of the TIE-2 receptor, or antagonists capable of interfering with the activity of TIE-2 ligand on such cells. Alternatively, autocrine cells, engineered to be capable of co-expressing both TIE-2

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ligand and receptor, may provide useful systems for assaying potential agonists or antagonists.

Therefore, the TIE-2 receptor may be introduced into cells that do not normally express this receptor, thus allowing these cells to exhibit profound and easily distinguishable responses to a ligand which binds this receptor. The type of response elicited depends on the cell utilized, and not the specific receptor introduced into the cell. Appropriate cell lines can be chosen to yield a response of the greatest utility for assaying, as well as discovering, molecules that can act on tyrosine kinase receptors. The molecules may be any type of molecule, including but not limited to peptide and non-peptide molecules, that will act in systems to be described in a receptor specific manner.

One of the more useful systems to be exploited involves the introduction of the TIE-2 receptor (or a chimeric receptor comprising the extracellular domain of another receptor tyrosine kinase such as, for example, trkC and the intracellular domain of a TIE receptor) into a fibroblast cell line (e.g., NIH3T3 cells) thus such a receptor which does not normally mediate proliferative or other responses can, following introduction into fibroblasts, nonetheless be assayed by a variety of well established methods to quantitate effects of fibroblast growth factors (e.g. thymidine incorporation or other types of proliferation assays; see van Zoelen, 1990, "The Use of Biological Assays For Detection Of Polypeptide Growth Factors" in Progress Factor Research, Vol. 2, pp. 131-152; Zhan and M. Goldfarb, 1986, Mol. Cell. Biol., Vol. 6, pp. 3541-3544). These assays have the added advantage that any preparation can be assayed both on the cell line having the introduced receptor as well as the parental cell line lacking the receptor; only

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specific effects on the cell line with the receptor would be judged as being mediated through the introduced receptor. Such cells may be further engineered to express the TIE-2 ligands, thus creating an autocrine system useful for assaying for molecules that act as antagonists/agonists of this interaction. Thus, the present invention provides for host cells comprising nucleic acid encoding TIE-2 ligands and nucleic acid encoding TIE-2 receptor.

The TIE-2 receptor/TIE-2 ligand interaction also provides a useful system for identifying small molecule agonists or antagonists of the TIE-2 receptor. For example, fragments, mutants or derivatives of a TIE-2 ligand may be identified that bind the TIE-2 receptor but do not induce any other biological activity. Alternatively, the characterization of a TIE-2 ligand enables the determination of active portions of the molecule. Further, the identification of a ligand enables the determination of the X-ray crystal structure of the receptor/ligand complex, thus enabling identification of the binding site on the receptor. Knowledge of the binding site will provide useful insight into the rational design of novel agonists and antagonists.

The specific binding of a test molecule to the TIE-2 receptor may be measured in a number of ways. For example, the actual binding of test molecule to cells expressing TIE-2 may be detected or measured, by detecting or measuring (i) test molecule bound to the surface of intact cells; (ii) test molecule cross-linked to TIE-2 protein in cell lysates; or (iii) test molecule bound to TIE-2 in vitro. The specific interaction between test molecule and TIE-2 may be evaluated by using reagents that demonstrate the unique properties of that interaction.

As a specific, nonlimiting example, the methods of the invention may be used as follows. Consider a case in which the TIE-2 ligand in a sample is to be measured. Varying dilutions of the sample (the test molecule), in parallel with a negative control (NC) containing no TIE-2

ligand activity, and a positive control (PC) containing a known amount of a TIE-2 ligand, may be exposed to cells that express TIE-2 in the presence of a detectably labeled TIE-2 ligand (in this example, radioiodinated ligand). The amount of TIE-2 ligand in the test sample may be evaluated by determining the amount of ^{125}I-labeled TIE-2 ligand that binds to the controls and in each of the dilutions, and then comparing the sample values to a standard curve. The more TIE-2 ligand in the sample, the less ^{125}I-ligand that will bind to TIE-2.

The amount of ^{125}I-ligand bound may be determined by measuring the amount of radioactivity per cell, or by cross-linking the TIE-2 ligand to cell surface proteins using DSS, as described in Meakin and Shooter, 1991, Neuron 6:153-163, and detecting the amount of labeled protein in cell extracts using, for example, SDS polyacrylamide gel electrophoresis, which may reveal a labeled protein having a size corresponding to TIE-2 receptor/TIE-2 ligand. The specific test molecule/TIE-2 interaction may further be tested by adding to the assays various dilutions of an unlabeled control ligand that does not bind the TIE-2 receptor and therefore should have no substantial affect on the competition between labeled TIE-2 ligand and test molecule for TIE-2 binding. Alternatively, a molecule known to be able to disrupt TIE-2 receptor/TIE-2 ligand binding, such as, but not limited to, anti-TIE-2 antibody, or TIE-2 receptorbody as described herein, may be expected to interfere with the competition between ^{125}I-TIE-2 ligand and test molecule for TIE-2 receptor binding.

Detectably labeled TIE-2 ligand includes, but is not limited to, TIE-2 ligand linked covalently or noncovalently to a radioactive substance, a fluorescent substance, a substance that has enzymatic activity, a substance that may serve as a substrate for an enzyme (enzymes and substrates associated with colorimetrically detectable

reactions are preferred) or to a substance that can be recognized by an antibody molecule that is preferably a detectably labeled antibody molecule.

Alternatively, the specific binding of test molecule to TIE-2 may be measured by evaluating the secondary biological effects of TIE-2 ligand/TIE-2 receptor binding, including, but not limited to, cell growth and/or differentiation or immediate early gene expression or phosphorylation of TIE-2. For example, the ability of the test molecule fo induce differentiation can be tested in cells that lack tie-2 and in comparable cells that express tie-2; differentiation in tie-2-expressing cells but not in comparable cells that lack tie-2 would be indicative of a specific test molecule/TIE-2 interaction. A similar analysis could be performed by detecting immediate early gene (e.g. fos and jun) induction in tie-2-minus and tie-2-plus cells, or by detecting phosphorylation of TIE-2 using standard phosphorylation assays known in the art. Such analysis might be useful in identifying agonists or antagonists that do not competitively bind to TIE-2.

A molecule that has the biological activity of a TIE-2 ligand may be identified by (i) exposing a cell that express tie-2 to a test molecule and (ii) detecting the specific binding of the test molecule to TIE-2 receptor, in which specific binding to TIE-2 positively correlates with TIE-2 like activity. Specific binding may be detected by either assaying for direct binding or the secondary biological effects of binding, as discussed supra. Such a method may be particularly useful in identifying new members of the TIE ligand family or, in the pharmaceutical industry, in screening a large array of peptide and non-peptide molecules (e.g., peptidomimetics) for TIE associated biological activity. In a preferred, specific, nonlimiting embodiment of the

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invention, a large grid of culture wells may be prepared that contain, in alternate rows, PC12 (or fibroblasts, see infra) cells that are either tie-2-minus or engineered to be tie-2-plus. A variety of test molecules may then be added such that each column of the grid, or a portion thereof, contains a different test molecule. Each well could then be scored for the presence or absence of growth and/or differentiation. An extremely large number of test molecules could be screened for such activity in this manner.

TIE ligand-like activity may be detected or measured or a molecule having such activity identified by (i) exposing a test molecule to a TIE-2 receptor protein in vitro under conditions that permit binding to occur and (ii) detecting binding of the test molecule to the TIE-2 receptor protein, in which binding of test molecule to TIE-2 receptor correlates with TIE ligand-like activity. According to such methods, the TIE-2 receptor may or may not be substantially purified, may be affixed to a solid support (e.g. as an affinity column or as an ELISA assay), or may be incorporated into an artificial membrane. Binding of test molecule to TIE-2 receptor may be evaluated by any method known in the art. In preferred embodiments, the binding of test molecule may be detected or measured by evaluating its ability to compete with detectably labeled known TIE-2 ligands for TIE-2 receptor binding.

The ability of a test molecule to function as an antagonist of TIE ligand-like activity may be detected by detecting the ability of the molecule to inhibit an effect of TIE ligand binding to TIE-2 receptor on a cell that expresses the receptor. Such an antagonist may or may not interfere with TIE-2 receptor/TIE-2 ligand binding. Effects of TIE-2 ligand

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binding to TIE-2 receptor are preferably biological or biochemical effects, including, but not limited to, cell survival or proliferation, cell transformation, immediate early gene induction, or TIE-2 phosphorylation.

Antibodies or other molecules capable of neutralizing the ligand or blocking binding to the receptor may also be identified as well as the molecules identified by the method. By way of nonlimiting example, the method may be performed via an assay which is conceptually similar to an ELISA assay. For example, TIE-2 receptorbody may be bound to a solid support, such as a plastic multiwell plate. As a control, a known amount of TIE-2 ligand which has been Myc-tagged may then be introduced to the well and any tagged TIE ligand which binds the receptorbody may then be identified by means of a reporter antibody directed against the Myc-tag. This assay system may then be used to screen test samples for molecules which are capable of i) binding to the tagged ligand or ii) binding to the receptorbody and thereby blocking binding to the receptorbody by the tagged ligand. For example, a test sample containing a putative molecule of interest together with a known amount of tagged ligand may be introduced to the well and the amount of tagged ligand which binds to the receptorbody may be measured. By comparing the amount of bound tagged ligand in the test sample to the amount in the control, samples containing molecules which are capable of blocking ligand binding to the receptor may be identified. The molecules of interest thus identified may be isolated using methods well known to one of skill in the art.

Once a blocker of ligand binding is found, one of skill in the art would know to perform secondary assays to determine whether the blocker is binding to the receptor or to the ligand, as well as assays to

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determine if the blocker molecule can neutralize the biological activity of the ligand. For example, by using a binding assay which employs BIAcore biosensor technology (or the equivalent), in which either TIE-2 receptorbody or TIE-2 ligand or ligandbody is covalently attached to a solid support (e.g. carboxymethyl dextran on a gold surface), one of skill in the art would be able to determine if the blocker molecule is binding specifically to the ligand, ligandbody or to the receptorbody. To determine if the blocker molecule can neutralize the biological activity of the ligand, one of skill in the art could perform a phosphorylation assay (see Example 5) or alternatively, a functional bioassay, such as a survival assay, by using primary cultures of, for example, endothelial cells. Alternatively, a blocker molecule which binds to the receptorbody could be an agonist and one of skill in the art would know to how to determine this by performing an appropriate assay for identifying additional agonists of the TIE-2 receptor.

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The invention herein further provides for the development of the ligand, a fragment or derivative thereof, or another molecule which is a receptor agonist or antagonist, as a therapeutic for the treatment of patients suffering from disorders involving cells, tissues or organs which express the TIE-2 receptor. Such molecules may be used in a method of treatment of the human or animal body, or in a method of diagnosis.

Because TIE-2 receptor has been identified in association with endothelial cells and, as demonstrated herein, blocking of TIE-2 ligand 1 appears to prevent vascularization, applicants have demonstrated that the TIE-2 ligand 1 will be useful for the induction of vascularization in diseases or disorders where such vascularization is indicated. Such diseases or disorders would include wound healing, ischaemia and diabetes. The ligands may be tested in animal models and used therapeutically as described for other agents, such as vascular endothelial growth factor (VEGF), another endothelial cell-

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specific factor that is angiogenic. Ferrara, et al. U.S. Patent No. 5,332,671 issued July 26, 1994. The Ferrara reference, as well as other studies, describe in vitro and in vivo studies that may be used to demonstrate the effect of an angiogenic factor in enhancing blood flow to ischemic myocardium, enhancing wound healing, and in other therapeutic settings wherein neoangiogenesis is desired. [see Sudo, et al. European Patent Application 0 550 296 A2 published July 7, 1993; Banai, et al. Circulation 89:2183-2189 (1994); Unger, et al. Am. J. Physiol. 266:H1588-H1595 (1994); Lazarous, et al. Circulation 91:145-153 (1995)]. According to the invention, the TIE-2 ligands may be used alone or in combination with one or more additional pharmaceutically active compounds such as, for example, VEGF or basic fibroblast growth factor (bFGF), as well as cytokines, neurotrophins, etc.

Conversely, antagonists of the TIE-2 receptor, such as receptorbodies as described herein in Examples 2 and 3, and TIE-2 ligand 2 as described in Example 9, would be useful to prevent or attenuate vascularization, thus preventing or attenuating, for example, tumor growth. These agents may be used alone or in combination with other compositions, such as anti-VEGF antibodies, that have been shown to be useful in treating conditions in which the therapeutic intent is to block angiogenesis. The TIE-2 ligands described herein may also be used in combination with agents, such as cytokine antagonists such as IL-6 antagonists, that are known to block inflammation.

For example, applicants have determined that the TIE-2 ligands are expressed in cells within, or closely associated with, tumors. TIE-2 ligand 2 appears to be tightly associated with tumor endothelial cells. Accordingly, TIE-2 antagonists, such as TIE-2 ligand 2 or TIE-2 ligandbodies may also be useful in preventing or attenuating, for

example, tumor growth. In addition, TIE-2 ligands or ligandbodies may be useful for the delivery of toxins to a receptor bearing cell. Alternatively, other molecules, such as growth factors, cytokines or nutrients, may be delivered to a TIE-2 receptor bearing cell via TIE-2 ligands or ligandbodies. TIE-2 ligands or ligandbodies could also be used as a diagnostic reagent for the TIE-2 receptor, to detect the receptor in vivo or in vitro. Where the TIE-2 receptor is associated with a disease state, TIE-2 ligands or ligandbodies may be useful as diagnostic reagents for detecting the disease by, for example, tissue staining or whole body imaging. Such reagents include radioisotopes, flurochromes, dyes, enzymes and biotin. Such diagnostics or targeting agents may be prepared as described in Alitalo, et al. W0 95/26364 published October 5, 1995 and Burrows, F. and P. Thorpe, PNAS (USA) 90:8996-9000 (1993) which is incorporated herein in its entirety.

TIE-2 ligands may also be used as hematopoietic factors. A variety of hematopoietic factors and their receptors are involved in the proliferation and/or differentiation and/or migration of the various cells types contained within blood. Because the TIE-2 receptors are expressed in early hematopoietic cells, the TIE-2 ligands are expected to play a comparable role in the proliferation or differentiation or migration of these cells. Thus, for example, TIE-2 containing compositions may be prepared, assayed, examined in in vitro and in vivo biological systems and used therapeutically as described in any of the following: Sousa, U.S. Patent No. 4,810,643, Lee. et al., Proc. Natl. Acad. Sci. USA 82:4360-4364 (1985) Wong, et al. Science, 228:810-814 (1985); Yokota, et al. Proc. Natl. Acad. Sci (USA) 81:1070 (1984); Bosselman, et al. WO 9105795 published May 2. 1991 entitled "Stem Cell Factor" and Kirkness, et al. WO 95/19985 published July 27. 1995 entitled "Haemopoietic

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Maturation Factor." Accordingly, the ligands may be used to diagnose or treat conditions in which normal hematopoiesis is suppressed, including, but not limited to anemia, thrombocytopenia, leukopenia and granulocytopenia. TIE-2 ligands may be used to stimulate differentiation of blood cell precursors in situations where a patient has a disease, such as acquired immune deficiency syndrome (AIDS) which has caused a reduction in normal blood cell levels, or in clinical settings in which enhancement of hematopoietic populations is desired, such as in conjunction with bone marrow transplant, or in the treatment of aplasia or myelosuppression caused by radiation, chemical treatment or chemotherapy.

The peptides of the present invention may be used alone, or in combination with another pharmaceutically active agent such as, for example a cytokine, neurotrophin, interleukin, cytokine antagonist, VEGF, anti-VEGF antibody, VEGF receptorbody or bFGF.

In a particular embodiment, TIE-2 peptides of the invention or ligandbodies thereof are used to diagnose or treat patients in which the desired result is inhibition of a hematopoietic pathway, such as for the treatment of myeloproliferative or other proliferative disorders of blood forming organs such as thrombocythemias, polycythemias and leukemias.

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The present invention also provides for pharmaceutical compositions comprising the TIE-2 ligand derivatives of the invention in a pharmacologically acceptable vehicle. The TIE-2 ligand proteins, peptide fragments, or derivatives may be administered systemically or locally. Any appropriate mode of administration known in the art may be used, including, but not limited to, intravenous, intrathecal, intraarterial, intranasal, oral, subcutaneous, intraperitoneal, or by local injection or surgical implant. Sustained release formulations are also provided for.

The present invention also provides for an antibody which specifically binds such a therapeutic molecule. The antibody may be monoclonal or polyclonal. The invention also provides for a method of using such a monoclonal or polyclonal antibody to measure the amount of the therapeutic molecule in a sample taken from a patient for purposes of monitoring the course of therapy.

The invention further provides for a therapeutic composition comprising a human TIE-2 ligand or ligandbody of the invention and a cytotoxic agent conjugated thereto. In one embodiment, the cytotoxic agent may be a radioisotope or toxin.

The invention also provides for an antibody which specifically binds a human TIE-2 ligand derivative of the invention. The antibody may be monoclonal or polyclonal.

The invention further provides for a method of purifying a human TIE-2 ligand comprising:

a) coupling at least one TIE-2 binding substrate to a solid matrix;

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b) incubating the substrate of a) with a cell lysate so that the substrate forms a complex with any human TIE-2 ligand in the cell lysate;

c) washing the solid matrix; and

d) eluting the human TIE-2 ligand from the coupled substrate.

The substrate may be any substance that specifically binds the human TIE-2 ligand. In one embodiment, the substrate is selected from the group consisting of anti-TIE-2 ligand antibody, TIE-2 receptor and TIE-2 receptorbody. The invention further provides for a receptorbody which specifically binds a human TIE-2 ligand, as well as a therapeutic composition comprising the receptorbody in a pharmaceutically acceptable vehicle, and a method of blocking blood vessel growth in a human comprising administering an effective amount of the therapeutic composition.

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EXAMPLE 1 - IDENTIFICATION OF THE ABAE CELL LINE AS REPORTER CELLS FOR THE TIE-2 RECEPTOR

Adult BAE cells are registered in the European Cell Culture Repository, under ECACC#92010601. (See PNAS 75:2621 (1978)). Northern (RNA) analyses revealed moderate levels of tie-2 transcripts in the ABAE (Adult Bovine Arterial Endothelial) cell line, consistent with in situ hybridization results that demonstrated almost exclusive localization of tie-2 RNAs to vascular endothelial cells. We therefore examined ABAE cell lysates for the presence of TIE-2 protein, as well as the extent to which this TIE-2 protein is tyrosine-phosphorylated under normal versus serum-deprived growth conditions. ABAE cell lysates were harvested and subjected to immunoprecipitation, followed by Western blot analyses of immunoprecipitated proteins with TIE-2

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specific and phosphotyrosine-specific antisera. Omission or inclusion of TIE-2 peptides as specific blocking molecules during TIE-2 immunoprecipitation allowed unambiguous identification of TIE-2 as a moderately detectable protein of ~150 kD whose steady-state phosphotyrosine levels diminish to near undetectable levels by prior serum-starvation of the cells.

Culture of ABAE cells and harvest of cell lysates was done as follows. Low-passage-number ABAE cells were plated as a monolayer at a density of 2 x 10^6 cells/150mm plastic petri plate (Falcon) and cultured in Dulbecco's modified Eagle's medium (DMEM) containing 10% bovine calf serum (10 % BCS), 2 mM L-glutamine (Q) and 1% each of penicillin and streptomycin (P-S) in an atmosphere of 5% CO_2. Prior to harvest of cell lysates, cells were serum-starved for 24 hours in DMEM/Q/P-S, followed by aspiration of the medium and rinsing of the plates with ice-cold phosphate buffered saline (PBS) supplemented with sodium orthovanadate, sodium fluoride and sodium benzamidine. Cells were lysed in a small volume of this rinse buffer that had been supplemented with 1% NP40 detergent and the protease inhibitors PMSF and aprotinin. Insoluble debris was removed from the cell lysates by centrifugation at 14,000 xG for 10 minutes, at 4°C and the supernatants were subjected to immunoprecipitation with antisera specific for TIE-2 receptor, with or without the presence of blocking peptides added to ~20 µg/ml lysate. Immunoprecipitated proteins were resolved by PAGE (7.5% Laemmli gel), and then electro-transferred to PVDF membrane and incubated either with various TIE-2- or phosphotyrosine-specific antisera. TIE-2 protein was visualized by incubation of the membrane with HRP-linked secondary antisera followed by treatment with ECL reagent (Amersham).

EXAMPLE 2 - CLONING AND EXPRESSION OF TIE-2 RECEPTORBODY FOR AFFINITY-BASED STUDY OF TIE-2 LIGAND INTERACTIONS

An expression construct was created that would yield a secreted protein consisting of the entire extracellular portion of the rat TIE-2 receptor fused to the human immunoglobulin gamma-1 constant region (IgG1 Fc). This fusion protein is called a TIE-2 "receptorbody" (RB), and would be normally expected to exist as a dimer in solution based on formation of disulfide linkages between individual IgG1 Fc tails. The Fc portion of the TIE-2 RB was prepared as follows. A DNA fragment encoding the Fc portion of human IgG1 that spans from the hinge region to the carboxy-terminus of the protein, was amplified from human placental cDNA by PCR with oligonucleotides corresponding to the published sequence of human IgG1; the resulting DNA fragment was cloned in a plasmid vector. Appropriate DNA restriction fragments from a plasmid encoding the full-length TIE-2 receptor and from the human IgG1 Fc plasmid were ligated on either side of a short PCR-derived fragment that was designed so as to fuse, in-frame, the TIE-2 and human IgG1 Fc protein-coding sequences. Thus, the resulting TIE-2 ectodomain-Fc fusion protein precisely substituted the IgG1 Fc in place of the region spanning the TIE-2 transmembrane and cytoplasmic domains. An alternative method of preparing RBs is described in Goodwin, et. al. Cell 73:447-456 (1993).

Milligram quantities of TIE-2 RB were obtained by cloning the TIE-2 RB DNA fragment into the pVL1393 baculovirus vector and subsequently infecting the Spodoptera frugiperda SF-21AE insect cell line. Alternatively, the cell line SF-9 (ATCC Accession No. CRL-1711)

or the cell line BTI-TN-5b1-4 may be used. DNA encoding the TIE-2 RB was cloned as an Eco RI-NotI fragment into the baculovirus transfer plasmid pVL1393. Plasmid DNA purified by cesium chloride density gradient centrifugation was recombined into viral DNA by mixing 3 μg of plasmid DNA with 0.5 μg of Baculo-Gold DNA (Pharminigen), followed by introduction into liposomes using 30μg Lipofectin (GIBCO-BRL). DNA-liposome mixtures were added to SF-21AE cells (2x 10^6 cells/60mm dish) in TMN-FH medium (Modified Grace's Insect Cell Medium (GIBCO-BRL) for 5 hours at 27°C, followed by incubation at 27°C for 5 days in TMN-FH medium supplemented with 5% fetal calf serum. Tissue culture medium was harvested for plaque purification of recombinant viruses, which was carried out using methods previously described (O'Reilly, D.R., L.K. Miller, and V.A. Luckow, Baculovirus Expression Vectors - A Laboratory Manual. 1992, New York: W.H. Freeman) except that the agarose overlay contained 125 μg/mL X-gal (5-bromo-4-chloro-3-indolyl-β-D-galactopyranoside; GIBCO-BRL). After 5 days of incubation at 27°C, non-recombinant plaques were scored by positive chromogenic reaction to the X-gal substrate, and their positions marked. Recombinant plaques were then visualized by addition of a second overlay containing 100 μg/mL MTT (3-[4,5-dimethylthiazol-2-yl]2,5,diphenyltetrazolium bromide; Sigma). Putative recombinant virus plaques were picked by plug aspiration, and purified by multiple rounds of plaque isolation to assure homogeneity. Virus stocks were generated by serial, low-multiplicity passage of plaque-purified virus. Low passage stocks of one virus clone (vTIE-2 receptorbody) were produced.

SF-21AE cells were cultured in serum free medium (SF-900 II, Gibco BRL) containing 1X antibiotic/antimycotic solution (Gibco BRL)

and 25 mg/L Gentamycin (Gibco BRL). Pluronic F-68 was added as a surfactant to a final concentration of 1g/L. Cultures (4L) were raised in a bioreactor (Artisan Cell Station System) for at least three days prior to infection. Cells were grown at 27°C, with gassing to 50 % dissolved oxygen, at a gas flow rate of 80 mL/min (aeration at a sparge ring). Agitation was by means of a marine impeller at a rate of 100 rpm. Cells were harvested in mid-logarithmic growth phase (~2 $X10^6$ cells/mL), concentrated by centrifugation, and infected with 5 plaque forming units of vTIE-2 receptorbody per cell. Cells and inoculum were brought to 400mL with fresh medium, and virus was adsorbed for 2 hours at 27°C in a spinner flask. The culture was then resuspended in a final volume of 8L with fresh serum-free medium, and the cells incubated in the bioreactor using the previously described conditions.

Culture medium from vTIE-2 receptorbody-infected SF21AE cells were collected by centrifugation (500x g, 10 minutes) at 72 hours post-infection. Cell supernatants were brought to pH 8 with NaOH. EDTA was added to a final concentration of 10 mM and the supernatant pH was readjusted to 8. Supernatants were filtered (0.45 µm, Millipore) and loaded on a protein A column (protein A sepharose 4 fast flow or HiTrap protein A, both from Pharmacia). The column was washed with PBS containing 0.5 M NaCl until the absorbance at 280 nm decreased to baseline. The column was washed in PBS and eluted with 0.5 M acetic acid. Column fractions were immediately neutralized by eluting into tubes containing 1 M Tris pH 9. The peak fractions containing the TIE-2 receptorbody were pooled and dialyzed versus PBS.

EXAMPLE 3 - DEMONSTRATION THAT TIE-2 HAS A CRITICAL ROLE IN DEVELOPMENT OF THE VASCULATURE

Insight into the function of TIE-2 was gained by introduction of "excess" soluble TIE-2 receptorbody (TIE-2 RB) into a developing system. The potential ability of TIE-2 RB to bind, and thereby neutralize, available TIE-2 ligand could result in an observable disruption of normal vascular development and characterization of the ligand. To examine whether TIE-2 RB could be used to disrupt vascular development in early chick embryos, small pieces of a biologically resorbable foam were soaked with TIE-2 RB and inserted immediately beneath the chorioallantoic membrane at positions just lateral to the primitive embryo.

Early chicken embryos develop atop the yolk from a small disk of cells that is covered by the chorioallantoic membrane (CAM). The endothelial cells that will come to line the vasculature in the embryo arise from both extra- and intra-embryonic cell sources. Extra-embryonically-derived endothelial cells, which provide the major source of endothelial cells in the embryo, originate from accretions of mesenchyme that are situated laterally around the embryo-proper, just underneath the CAM. As these mesenchyme cells mature, they give rise to a common progenitor of both the endothelial and hematopoietic cell lineages, termed the hemangioblast. In turn, the hemangioblast gives rise to a mixed population of angioblasts (the endothelial cell progenitor) and hematoblasts (the pluripotential hematopoietic precursor). Formation of rudiments of the circulatory system begins when endothelial cell progeny segregate to form a one-cell-thick vesicle that surrounds the primitive blood cells. Proliferation and migration of these cellular components eventually produces a vast network of blood-filled microvessels under the CAM that will ultimately invade the embryo to join with limited, intra-embryonically-derived vascular elements.

Newly fertilized chicken eggs obtained from Spafas, Inc. (Boston, MA) were incubated at 99.5°F, 55 % relative humidity. At about 24 hrs. of development, the egg shell was wiped down with 70% ethanol and a dentist's drill was used to make a 1.5 cm. hole in the blunt apex of each egg. The shell membrane was removed to reveal an air space directly above the embryo. Small rectangular pieces of sterile Gelfoam (Upjohn) were cut with a scalpel and soaked in equal concentrations of either TIE-2- or EHK-1 receptorbody. EHK-1 receptorbody was made as set forth in Example 2 using the EHK-1 extracellular domain instead of the TIE-2 extracellular domain (Maisonpierre et al., Oncogene 8:3277-3288 (1993). Each Gelfoam piece absorbed approximately 6 μg of protein in 30 μl. Sterile watchmakers forceps were used to make a small tear in the CAM at a position several millimeters lateral to the primitive embryo. The majority of the piece of RB-soaked Gelfoam was inserted under the CAM and the egg shell was sealed over with a piece of adhesive tape. Other similarly-staged eggs were treated in parallel with RB of the unrelated, neuronally expressed receptor tyrosine kinase, EHK-1 (Maisonpierre et al., Oncogene 8:3277-3288 (1993). Development was allowed to proceed for 4 days and then the embryos were examined by visual inspection. Embryos were removed by carefully breaking the shells in dishes of warmed PBS and carefully cutting away the embryo with surrounding CAM. Of 12 eggs treated with each RB, 6 TIE-2 RB and 5 EHK-1 RB treated embryos had developed beyond the stage observed at the start of the experiment. A dramatic difference was seen between these developed embryos, as shown in Figures 1A and 1B. Those treated with EHK-1 RB appeared to have developed relatively normally. Four out of five EHK-1 embryos were viable as judged by the presence of a beating heart. Furthermore,

the extra-embryonic vasculature, which is visually obvious due to the presence of red blood cells, was profuse and extended several centimeters laterally under the CAM. By contrast, those treated with TIE-2 RB were severely stunted, ranging from 2-5 mm. in diameter, as compared with more than 10 mm in diameter for the EHK-1 RB embryos. All of the TIE-2 RB treated embryos were dead and their CAMs were devoid of blood vessels. The ability of TIE-2 RB to block vascular development in the chicken demonstrates that TIE-2 ligand is necessary for development of the vasculature.

EXAMPLE 4 - IDENTIFICATION OF A TIE-2-SPECIFIC BINDING ACTIVITY IN CONDITIONED MEDIUM FROM THE ras ONCOGENE-TRANSFORMED C2C12 MOUSE MYOBLAST CELL LINE

Screening of ten-fold-concentrated cell-conditioned media (10X CCM) from various cell lines for the presence of soluble, TIE-2-specific binding activity (BIAcore; Pharmacia Biosensor, Piscataway, NJ) revealed binding activity in serum-free medium from oncogenic-ras-transformed C2C12 cells (C2C12-ras), RAT 2-ras (which is a ras transformed fibroblast cell line), human glioblastoma T98G and the human neuroblastoma cell line known as SHEP-1.

The C2C12-ras 10X CCM originated from a stably transfected line of C2C12 myoblasts that was oncogenically transformed by transfection with the T-24 mutant of H-ras by standard calcium phosphate-based methods. An SV40 based neomycin-resistance expression plasmid was physically linked with the ras expression plasmid in order to permit selection of transfected clones. Resulting G418-resistant ras-C2C12 cells were routinely maintained as a monolayer on plastic dishes in DMEM/glutamine/penicillin-

streptomycin supplemented with 10 % fetal calf serum (FCS). Serum-free C2C12-ras 10X CCM was made by plating the cells at 60% confluence in a serum free defined media for 12 hours. [Zhan and Goldfarb, Mol. Cell. Biol. 6: 3541-3544 (1986)); Zhan, et al. Oncogene 1: 369-376 (1987)]. The medium was discarded and replaced with fresh DMEM/Q/P-S for 24 hours. This medium was harvested and cells were re-fed fresh DMEM/Q/P-S, which was also harvested after a further 24 hours. These CCM were supplemented with the protease inhibitors PMSF (1mM) and aprotinin (10µg/ml), and ten-fold concentrated on sterile size-exclusion membranes (Amicon). TIE-2-binding activity could be neutralized by incubation of the medium with an excess of TIE-2 RB, but not by incubation with EHK-1 RB, prior to BIAcore analysis.

Binding activity of the 10x CCM was measured using biosensor technology (BIAcore; Pharmacia Biosensor, Piscataway, NJ) which monitors biomolecular interactions in real-time via surface plasmon resonance. Purified TIE-2 RB was covalently coupled through primary amines to the carboxymethyl dextran layer of a CM5 research grade sensor chip (Pharmacia Biosensor; Piscataway, NJ). The sensor chip surface was activated using a mixture of N-hydroxysuccinimide (NHS) and N-ethyl-N'-(3-dimethylaminopropyl)carbodiimide (EDC), followed by immobilization of TIE-2 RB (25 µg/mL, pH 4.5) and deactivation of unreacted sites with 1.0 M ethanolamine (pH 8.5). A negative control surface of the EHK-1 receptorbody was prepared in a similar manner.

The running buffer used in the system was HBS (10 mM Hepes, 3.4 mM EDTA, 150 mM NaCl, 0.005% P20 surfactant, pH 7.4). The 10x CCM samples were centrifuged for 15 min at 4° C and further clarified using a sterile, low protein-binding 0.45 µm filter (Millipore; Bedford, MA).

Dextran (2mg/ml) and P20 surfactant (0.005%) were added to each CCM sample. Aliquots of 40 µL were injected across the immobilized surface (either TIE-2 or EHK-1) at a flow rate of 5 µL/min and the receptor binding was monitored for 8 min. The binding activity (resonance units, RU) was measured as the difference between a baseline value determined 30 s prior to the sample injection and a measurement taken at 30 s post-injection. Regeneration of the surface was accomplished with one 12-µL pulse of 3 M $MgCl_2$.

The instrument noise level is 20 RU; therefore, any binding activity with a signal above 20 RU may be interpreted as a real interaction with the receptor. For C2C12-ras conditioned media, the binding activities were in the range 60-90 RU for the TIE-2 RB immobilized surface. For the same samples assayed on a EHK-1 RB immobilized surface, the measured activities were less than 35 RU. Specific binding to the TIE-2 receptorbody was evaluated by incubating the samples with an excess of either soluble TIE-2 or EHK-1 RB prior to assaying the binding activity. The addition of soluble EHK-1 RB had no effect on the TIE-2 binding activity of any of the samples, while in the presence of soluble TIE-2 binding to the surface is two-thirds less than that measured in the absence of TIE-2. A repeat assay using >50x concentrated C2C12-ras CCM resulted in a four-fold enhancement over background of the TIE-2 specific binding signal.

EXAMPLE 5 - C2C12-ras CCM CONTAINS AN ACTIVITY THAT INDUCES TYROSINE PHOSPHORYLATION OF TIE-2 RECEPTOR

C2C12-ras 10X CCM was examined for its ability to induce tyrosine phosphorylation of TIE-2 in ABAE cells. Serum-starved ABAE cells were briefly incubated with C2C12-ras CCM, lysed and subjected

to immunoprecipitation and Western analyses as described above. Stimulation of serum-starved ABAE cells with serum-free C2C12-ras 10X CCM was done as follows. The medium of ABAE cells starved as described above was removed and replaced with either defined medium or 10X CCM that had been pre-warmed to 37°C. After 10 minutes, the media were removed and the cells were twice rinsed on ice with an excess of chilled PBS supplemented with orthovanadate/NaF/benzamidine. Cell lysis and TIE-2-specific immunoprecipitation was done as described above.

ABAE cells incubated for 10 minutes with defined medium showed no induction of TIE-2 tyrosine phosphorylation, whereas incubation with C2C12-ras CCM stimulated at least a 100 X increase in TIE-2 phosphorylation. This activity was almost totally depleted by pre-incubation of the C2C12-ras 10X CCM for 90 minutes at room temperature with 13 µg of TIE-2 RB coupled to protein G-Sepharose beads. Medium incubated with protein G Sepharose alone was not depleted of this phosphorylating activity.

EXAMPLE 6 - EXPRESSION CLONING OF TIE-2 LIGAND

COS-7 cells were cultured in Dulbecco's modified Eagle's medium (DMEM) containing 10% fetal bovine serum (FBS), 1% each of penicillin and streptomycin (P/S) and 2 mM glutamine in an atmosphere of 5% CO_2. The mouse myoblast C2C12 ras cell line was cultured in Eagle's minimal essential medium (EMEM) with 10% FBS, (P/S) and 2 mM glutamine. Full length mouse TIE-2 ligand cDNA clones were obtained by screening a C2C12 ras cDNA library in the pJFE14 vector expressed in COS cells. This vector, as shown in Figure 2, is a modified version of

the vector pSR_α (Takebe, et al. 1988, Mol. Cell. Biol. 8:466-472). The library was created using the two BSTX1 restriction sites in the pJFE14 vector.

COS-7 cells were transiently transfected with either the pJFE14 library or control vector by the DEAE-dextran transfection protocol. Briefly, COS-7 cells were plated at a density of 1.0×10^6 cells/100 mm plate 24 hours prior to transfection. For transfection, the cells were cultured in serum-free DMEM containing 400 µg/ml of DEAE-dextran, 1 µM chloroquine, and 2 mM glutamine, and 1 µg of the appropriate DNA for 3-4 hours at 37°C in an atmosphere of 5% CO_2. The transfection media was aspirated and replaced with PBS with 10% DMSO for 2-3 min. Following this DMSO "shock", the COS-7 cells were placed into DMEM with 10% FBS, 1% each of penicillin and streptomycin, and 2 mM glutamine for 48 hours.

Because the TIE-2 ligand is secreted it was necessary to permeabilize the cells to detect binding of the receptorbody probe to the ligand. Two days after transfection the cells were rinsed with PBS and then incubated with PBS containing 1.8% formaldehyde for 15-30 min. at room temperature. Cells were then washed with PBS and incubated for 15 min. with PBS containing 0.1% Triton X-100 and 10% Bovine Calf Serum to permeabilize the cells and block non-specific binding sites.

The screening was conducted by direct localization of staining using a TIE-2 receptorbody (RB), which consisted of the extracellular domain of TIE-2 fused to the IgG1 constant region. This receptorbody was prepared as set forth in Example 2. A 100 mm dish of transfected, fixed and permeabilized COS cells was probed by incubating them for 30 min with TIE-2 RB. The cells were then washed twice with PBS and

incubated for an additional 30 min with PBS/10% Bovine Calf Serum/anti-human IgG-alkaline phosphatase conjugate. After three PBS washes, cells were incubated in alkaline-phosphatase substrate for 30-60 min. The dish was then inspected microscopically for the presence of stained cells. For each stained cell, a small area of cells including the stained cell was scraped from the dish using a plastic pipette tip and plasmid DNA was then rescued and used to electroporate bacterial cells. Single bacterial colonies resulting from the electroporation were picked and plasmid DNA prepared from these colonies was used to transfect COS-7 cells which were probed for TIE-2 ligand expression as evidenced by binding to TIE-2 receptorbodies. This allowed identification of single clones coding for TIE-2 ligand. Confirmation of TIE-2 ligand expression was obtained by phosphorylation of the TIE-2 receptor using the method set forth in Example 5. A plasmid clone encoding the TIE-2 ligand was deposited with the ATCC on October 7, 1994 and designated as "pJFE14 encoding TIE-2 ligand" under ATCC Accession No. 75910.

EXAMPLE 7 - ISOLATION AND SEQUENCING OF FULL LENGTH cDNA CLONE ENCODING HUMAN TIE-2 LIGAND

A human fetal lung cDNA library in lambda gt-10 (see Figure 3) was obtained from Clontech Laboratories, Inc. (Palo Alto, CA). Plaques were plated at a density of 1.25 x 10^6/20x20 cm plate, and replica filters taken following standard procedures (Sambrook, et al., Molecular Cloning: A Laboratory Manual, 2nd Ed., page 8.46, Cold Spring Harbor Laboratory, Cold Spring Harbor, New York).

Isolation of human tie-2 ligand clones was carried out as follows. A 2.2 kb XhoI fragment from the deposited tie-2 ligand clone (ATCC NO.

75910 - see Example 6 above) was labeled by random priming to a specific activity of approximately $5x10^8$cpm/ng. Hybridization was carried out at 65°C in hybridization solution containing 0.5 mg/ml salmon sperm DNA. The filters were washed at 65°C in 2 x SSC, 0.1 % SDS and exposed to Kodak XAR-5 film overnight at -70°C. Positive phage were plaque purified. High titre phage lysates of pure phage were used for isolation of DNA via a Qiagen column using standard techniques (Qiagen, Inc., Chatsworth, CA, 1995 catalog, page 36). Phage DNA was digested with EcoRI to release the cloned cDNA fragment for subsequent subcloning. A lambda phage vector containing human tie-2 ligand DNA was deposited with the ATCC on October 26, 1994 under the designation λgt10 encoding htie-2 ligand 1 (ATCC Accession No. 75928). Phage DNA may be subjected directly to DNA sequence analysis by the dideoxy chain termination method (Sanger, et al., 1977, Proc. Natl. Acad. Sci. U.S.A. 74: 5463-5467).

Subcloning of the human tie-2 ligand DNA into a mammalian expression vector may be accomplished as follows. The clone λgt10 encoding htie-2 ligand 1 contains an EcoRI site located 490 base pairs downstream from the start of the coding sequence for the human TIE-2 ligand. The coding region may be excised using unique restriction sites upstream and downstream of the initiator and stop codons respectively. For example, an SpeI site, located 70 bp 5' to the initiator codon, and a Bpu1102i (also known as BlpI) site, located 265 bp 3' to the stop codon, may be used to excise the complete coding region. This may then be subcloned into the pJFE14 cloning vector, using the XbaI (compatible to the SpeI overhang) and the PstI sites (the PstI and Bpu1102i sites are both made blunt ended).

The coding region from the clone λgt10 encoding htie-2 ligand 1 was sequenced using the ABI 373A DNA sequencer and Taq Dideoxy Terminator Cycle Sequencing Kit (Applied Biosystems, Inc., Foster City, CA). The nucleotide and deduced amino acid sequence of human TIE-2 ligand from the clone λgt10 encoding htie-2 ligand 1 is shown in Figure 4.

In addition, full length human tie-2 ligand cDNA clones were obtained by screening a human glioblastoma T98G cDNA library in the pJFE14 vector. Clones encoding human TIE-2 ligand were identified by DNA hybridization using a 2.2 kb XhoI fragment from the deposited tie-2 ligand clone (ATCC NO. 75910) as a probe (see Example 6 above). The coding region was sequenced using the ABI 373A DNA sequencer and Taq Dideoxy Terminator Cycle Sequencing Kit (Applied Biosystems, Inc., Foster City, CA). This sequence was nearly identical to that of clone λgt10 encoding htie-2 ligand 1. As shown in Figure 4, the clone λgt10 encoding htie-2 ligand 1 contains an additional glycine residue which is encoded by nucleotides 1114-1116. The coding sequence of the T98G clone does not contain this glycine residue but otherwise is identical to the coding sequence of the clone λgt10 encoding htie-2 ligand 1. Figure 5 sets forth the nucleotide and deduced amino acid sequence of human TIE-2 ligand from the T98G clone.

EXAMPLE 8 - ISOLATION AND SEQUENCING OF SECOND FULL LENGTH cDNA CLONE A ENCODING HUMAN TIE-2 LIGAND

A human fetal lung cDNA library in lambda gt-10 (see Figure 3) was obtained from Clontech Laboratories, Inc. (Palo Alto, CA). Plaques were plated at a density of 1.25 x 10^6/20x20 cm plate, and replica

filters taken following standard procedures (Sambrook, et al., Molecular Cloning: A Laboratory Manual, 2nd Ed., page 8.46, Cold Spring Harbor Laboratory, Cold Spring Harbor, New York). Duplicate filters were screened at low stringency (2 x SSC, 55° C) with probes made to the human TIE-2 ligand 1 sequence. One of the duplicate filters was probed with a 5' probe, encoding amino acids 25 - 265 of human TIE-2 ligand 1 as set forth in Figure 4. The second duplicate filter was probed with a 3' probe, encoding amino acids 282 - 498 of human TIE-2 ligand 1 sequence (see Figure 4). Both probes were hybridized at 55° C in hybridization solution containing 0.5 mg/ml salmon sperm DNA. Filters were washed in 2 x SSC at 55° C and exposed overnight to X-ray film. In addition, duplicate filters were also hybridized at normal stringency (2 x SSC, 65° C) to the full length coding probe of mouse TIE-2 ligand 1 (F3-15, XhoI insert). Three positive clones were picked that fulfilled the following criteria: i. hybridization had not been seen to the full length (mouse) probe at normal stringency, and ii. hybridization was seen at low stringency to both 5' and 3' probes. EcoRI digestion of phage DNA obtained from these clones indicated two independent clones with insert sizes of approximately 2.2kb and approximately 1.8 kb. The 2.2kb EcoRI insert was subcloned into the EcoRI sites of both pBluescript KS (Stratagene) and a mammalian expression vector suitable for use in COS cells. Two orientations were identified for the mammalian expression vector. The 2.2kb insert in pBluescript KS was deposited with the ATCC on December 9, 1994 and designated as pBluescript KS encoding human TIE 2 ligand 2. The start site of the TIE-2 ligand 2 coding sequence is approximately 355 base pairs downstream of the pBluescript EcoRI site.

COS-7 cells were transiently transfected with either the expression vector or control vector by the DEAE-dextran transfection

protocol. Briefly, COS-7 cells were plated at a density of 1.0 x 10^6 cells/100 mm plate 24 hours prior to transfection. For transfection, the cells were cultured in serum-free DMEM containing 400 µg/ml of DEAE-dextran, 1 µM chloroquine, and 2 mM glutamine, and 1 µg of the appropriate DNA for 3-4 hours at 37°C in an atmosphere of 5% CO_2. The transfection media was aspirated and replaced with phosphate-buffered saline with 10% DMSO for 2-3 min. Following this DMSO "shock", the COS-7 cells were placed into DMEM with 10% FBS, 1% each of penicillin and streptomycin, and 2 mM glutamine for 48 hours.

Because the TIE-2 ligand is secreted it was necessary to permeabilize the cells to detect binding of the receptorbody probe to the ligand. Transfected COS-7 cells were plated at a density of 1.0 x 10^6 cells/100 mm plate. The cells were rinsed with PBS and then incubated with PBS containing 1.8% formaldehyde for 15-30 min. at room temperature. Cells were then washed with PBS and incubated for 15 min. with PBS containing 0.1% Triton X-100 and 10% Bovine Calf Serum to permeabilize the cells and block non-specific binding sites. The screening was conducted by direct localization of staining using a TIE-2 receptorbody, which consisted of the extracellular domain of TIE-2 fused to the IgG1 constant region. This receptorbody was prepared as set forth in Example 2. Transfected COS cells were probed by incubating them for 30 min with TIE-2 receptorbody. The cells were then washed twice with PBS, fixed with methanol, and then incubated for an additional 30 min with PBS/10% Bovine Calf Serum/anti-human IgG-alkaline phosphatase conjugate. After three PBS washes, cells were incubated in alkaline-phosphatase substrate for 30-60 min. The dish was then inspected microscopically for the presence of stained

cells. Cells expressing one orientation of the clone, but not the other orientation, were seen to bind the TIE-2 receptorbody.

One of skill in the art will readily see that the described methods may be used to further identify other related members of the TIE ligand family.

The coding region from the clone pBluescript KS encoding human TIE-2 ligand 2 was sequenced using the ABI 373A DNA sequencer and Taq Dideoxy Terminator Cycle Sequencing Kit (Applied Biosystems, Inc., Foster City, CA). The nucleotide and deduced amino acid sequence of human TIE-2 ligand from the clone pBluescript KS encoding human TIE-2 ligand 2 is shown in Figure 6.

EXAMPLE 9 - TIE-2 LIGAND 2 IS A RECEPTOR ANTAGONIST

Conditioned media from COS cells expressing either TIE-2 ligand 2 (TL2) or TIE-2 ligand 1 (TL1) were compared for their ability to activate TIE-2 receptors naturally present in human endothelial cell lines.

Lipofectamine reagent (GIBCO-BRL, Inc.) and recommended protocols were used to transfect COS-7 cells with either the pJFE14 expression vector alone, pJFE14 vector containing the human TIE-2 ligand 1 cDNA, or with a pMT21 expression vector (Kaufman, R.J., 1985, Proc. Natl. Acad. Sci. USA 82: 689-693) containing the human TIE-2 ligand 2 cDNA. COS media containing secreted ligands were harvested after three days and concentrated 20-fold by diafiltration (DIAFLO ultrafiltration membranes, Amicon, Inc.). The quantity of active TIE-2 ligand 1 and TIE-2 ligand 2 present in these media was determined and expressed as the amount (in resonance units, R.U.) of TIE-2 receptor specific binding activity measured by a BIAcore binding assay.

Northern (RNA) analyses revealed significant levels of TIE-2 transcripts in HAEC (Human Aortic Endothelial Cell) human primary endothelial cells (Clonetics, Inc.). Therefore, these cells were used to examine whether TIE-2 receptor is tyrosine-phosphorylated when exposed to COS media containing the TIE-2 ligands. HAEC cells were maintained in a complete endothelial cell growth medium (Clonetics, Inc.) that contained 5% fetal bovine serum, soluble bovine brain extract, 10 ng/ml human EGF, 1 mg/ml hydrocortisone, 50 mg/ml gentamicin and 50 ng/ml amphotericin-B. Assessment of whether TL1 and TL2 could activate TIE-2 receptor in the HAEC cells was done as follows. Semi-confluent HAEC cells were serum-starved for two hours in high-glucose Dulbecco's MEM with added L-glutamine and penicillin-streptomycin at 37°C followed by replacement of the starvation medium with ligand-containing conditioned COS media for 7 minutes at 37°C in a 5% CO2 incubator. The cells were subsequently lysed and TIE-2 receptor protein was recovered by immunoprecipitation of the lysates with TIE-2 peptide antiserum, followed by Western blotting with antiphosphotyrosine antiserum, exactly as described in example 1. The results are shown in Figure 7. Phosphotyrosine levels on the TIE-2 receptor (TIE-2-R) were induced by treatment of HEAC cells with TIE-2 ligand 1 (Lane L1) but not by TIE-2 ligand 2 (Lane L2) conditioned COS media. MOCK is conditioned media from COS transfected with JFE14 empty vector.

Evidence that both TL1 and TL2 specifically bind to the TIE-2 receptor was demonstrated by using a BIAcore to assay the TIE-2 receptor specific binding activities in transfected COS media and by immunostaining of TL1- and TL2-expressing COS cells with TIE-2 receptorbodies.

Because TL2 did not activate the TIE-2 receptor, applicants set out to determine whether TL2 might be capable of serving as an antagonist of TL1 activity. HAEC phosphorylation assays were performed in which cells were first incubated with an "excess" of TL2, followed by addition of dilute TL1. It was reasoned that prior occupancy of TIE-2 receptor due to high levels of TL2 might prevent subsequent stimulation of the receptor following exposure to TL1 present at a limiting concentration.

Semi-confluent HAEC cells were serum-starved as described above and then incubated for 3 min., at 37°C with 1-2 ml. of 20X COS/JFE14-TL2 conditioned medium. Control plates were treated with 20X COS/JFE14-only medium (MOCK). The plates were removed from the incubator and various dilutions of COS/JFE14-TL1 medium were then added, followed by further incubation of the plates for 5-7 min. at 37°C. Cells were subsequently rinsed, lysed and TIE-2-specific tyrosine phosphorylation in the lysates was examined by receptor immunoprecipitation and Western blotting, as described above. TL1 dilutions were made using 20X COS/JFE14-TL1 medium diluted to 2X, 0.5X, 0.1X, or 0.02X by addition of 20X COS/JFE14-alone medium. An assay of the initial 20X TL1 and 20X TL2 COS media using BIAcore biosensor technology indicated that they contained similar amounts of TIE-2-specific binding activities, i.e., 445 R.U. and 511 R.U. for TL1 and TL2, respectively. The results of the antiphosphotyrosine Western blot, shown in Figure 8, indicate that when compared to prior treatment of HAEC cells with MOCK medium (lane 1), prior treatment of HAEC cells with excess TIE-2 ligand 2 (lane 2) antagonizes the subsequent ability of dilute TIE-2 ligand 1 to activate the TIE-2 receptor (TIE-2-R).

The ability of TL2 to competitively inhibit TL1 activation of the TIE-2-R was further demonstrated using the human cell hybrid line,

EA.hy926 (see Example 21 for detailed description of this cell line and its maintenance). Experiments were performed in which unconcentrated COS cell media containing TL1 were mixed at varying dilutions with either MOCK- or TL2- conditioned media and placed on serum-starved EA.hy926 cell monolayers for 5 minutes at 37°C. The media were then removed, the cells were harvested by lysis and TIE-2-specific tyrosine phosphorylation was examined by Western blots, as described above. Figure 9 shows an experiment which contains three groups of treatments, as viewed from left to right. As shown in the four lanes at the left, treatment of the EA.hy926 cells with 1x COS-TL1 alone robustly activated the endogenous TIE-2-R in these cells, whereas 1x TL2 COS medium was inactive. However, mixture of TL1 with either MOCK or TL2 demonstrated that TL2 can block the activity of TL1 in a dose-dependent fashion. In the central three pairs of lanes the ratio of TL2 (or MOCK) was decreased while the amount of TL1 in the mixture was correspondingly increased from 0.1x to 0.3x. At any of these mixture ratios the TL1:TL2 lanes showed a reduced level of TIE-2-R phosphorylation compared to that of the corresponding TL1:MOCK lanes. When the amount TL1 was held steady and the amount of TL2 (or MOCK) was decreased, however (shown in the three pairs of lanes at the right), a point was reached at which the TL2 in the sample was too dilute to effectively inhibit TL1 activity. The relative amount of each ligand present in these conditioned COS media could be estimated from their binding units as measured by the BIAcore assay and from Western blots of the COS media with ligand-specific antibodies. Consequently, we can infer that only a few-fold molar excess of TL2 is required to effectively block the activity of TL1 in vitro. This is significant because we have observed distinct examples in vivo (see Example 17 and Figure 16) where TL2 mRNAs achieve considerable abundance

relative to those of TL1. Thus, TL2 may be serving an important physiological role in effectively blocking signaling by the TIE-2-R at these sites.

Taken together these data confirm that, unlike TL1, TL2 is unable to stimulate endogenously expressed TIE-2-R on endothelial cells. Furthermore, at a few fold molar excess TL2 can block TL1 stimulation of the TIE-2 receptor, indicating that TL2 is a naturally occurring TIE-2 receptor antagonist.

EXAMPLE 10 - IDENTIFICATION OF TIE-2-SPECIFIC BINDING ACTIVITY IN CONDITIONED MEDIUM AND COS CELL SUPERNATANTS

Binding activity of 10x CCM from the cell lines C2C12-ras, Rat2 ras, SHEP, and T98G, or COS cell supernatants after transfection with either human TIE-2 ligand 1 (hTL1) or human TIE-2 ligand 2 (hTL2) was measured using biosensor technology (BIAcore; Pharmacia Biosensor, Piscataway, NJ) which monitors biomolecular interactions in real-time via surface plasmon resonance (SPR). Purified rat or human TIE-2 RB was covalently coupled through primary amines to the carboxymethyl dextran layer of a CM5 research grade sensor chip (Pharmacia Biosensor; Piscataway, NJ). The sensor chip surface was activated using a mixture of N-hydroxysuccinimide (NHS) and N-ethyl-N'-(3-dimethylaminopropyl)carbodiimide (EDC), followed by immobilization of TIE-2 RB (25 µg/mL, pH 4.5) and deactivation of unreacted sites with 1.0 M ethanolamine (pH 8.5). In general, 9000-10000 RU of each receptorbody was coupled to the sensor chip.

The running buffer used in the system was HBS (10 mM Hepes, 150 mM NaCl, 0.005% P20 surfactant, pH 7.4). The samples were

centrifuged for 15 min at 4°C and further clarified using a sterile, low protein-binding 0.45 μm filter (Millipore; Bedford, MA). Dextran (2mg/ml) and P20 surfactant (0.005%) were added to each sample. Aliquots of 40 μL were injected across the immobilized surface (either rat or human TIE-2) at a flow rate of 5 μL/min and the receptor binding was monitored for 8 min. The binding activity (resonance units, RU) was measured as the difference between a baseline value determined 30 s prior to the sample injection and a measurement taken at 30 s post-injection. Regeneration of the surface was accomplished with one 15-μL pulse of 3 M $MgCl_2$.

The CCM samples (C2C12-ras, Rat2-ras, SHEP, T98G) were tested on the rat TIE-2 RB immobilized surface, while the recombinant hTL1 and hTL2 were tested on the human TIE-2 RB immobilized surface. In each case, specific binding to the TIE-2 receptorbody was evaluated by incubating the samples with 25 μg/ml of either soluble TIE-2 (rat or human) RB or trkB RB prior to assaying the binding activity. As shown in Figures 10 and 11, the addition of soluble trkB RB causes a slight decrease in the TIE-2 binding activity, while the addition of soluble TIE-2 RB significantly reduces the binding activity as compared to that measured in the absence of TIE-2 RB.

EXAMPLE 11 - TIE-2 RB SPECIFICALLY BLOCKS ACTIVATION OF THE TIE-2 RECEPTOR BY TIE-2 LIGAND 1

The applicants sought to determine whether soluble TIE-2 RB can serve as a competitive inhibitor to block activation of TIE-2 receptor by TIE-2 ligand 1 (TL1). To do this, TL1-containing COS media were preincubated with either TIE-2- or TrkB-RB and then compared for

their ability to activate TIE-2 receptors naturally present in a human endothelial cell line.

Conditioned COS media were generated from COS-7 cells transfected with either the pJFE14 expression vector alone (MOCK), or pJFE14 vector containing the human TIE-2 ligand 1 cDNA (TL1) and harvested as described in Example 9 hereinabove, with the exception that the media were sterile filtered but not concentrated. The quantity of TL1 was determined and expressed as the amount (in resonance units, R.U.) of TIE-2 receptor-specific binding activity measured by BIAcore binding assay.

Northern (RNA) analyses revealed significant levels of tie-2 transcripts in HUVEC (Human Umbilical Vein Endothelial Cell) human primary endothelial cells (Clonetics, Inc.). Therefore, these cells were used to examine whether TIE-2 receptor can be tyrosine-phosphorylated when exposed in the presence of TIE-2- or TrkB-RBs to COS media containing TL1. HUVEC cells were maintained at 37°C, 5% CO_2 in a complete endothelial cell growth medium (Clonetics, Inc.) that contained 5% fetal bovine serum, soluble bovine brain extract with 10 µg/ml heparin, 10 ng/ml human EGF, 1 ug/ml hydrocortisone, 50 µg/ml gentamicin and 50 ng/ml amphotericin-B. Assessment of whether TL1 could activate TIE-2 receptor in the HUVEC cells was done as follows. Confluent dishes of HUVEC cells were serum-starved for two-to-four hours in low-glucose Dulbecco's MEM at 37°C, 5% CO_2, followed by 10 minute incubation in starvation medium that included 0.1 mM sodium orthovanadate, a potent inhibitor of phosphotyrosine phosphatases. Meanwhile, conditioned COS media were preincubated 30 min. at room temperature with either TIE-2- or TrkB-RB added to 50 µg/ml. The starvation medium was then removed from the HUVEC dishes and

incubated with the RB-containing COS media for 7 minutes at 37°C. HUVEC cells were subsequently lysed and TIE-2 receptor protein was recovered by immunoprecipitation with TIE-2 peptide antiserum, followed by Western blotting with an anti-phosphotyrosine antibody, as described in Example 1. The results are shown in Figure 12. Phosphotyrosine levels on the TIE-2 receptor were induced by treatment of HUVEC cells with TIE-2 ligand 1 (TL1) relative to that seen with control medium (MOCK) and this induction is specifically blocked by prior incubation with TIE-2-RB (TIE-2-Fc) but not by incubation with TrkB-RB (TrkB-Fc). These data indicate that soluble TIE-2 RB can serve as a selective inhibitor to block activation of TIE-2 receptor by TIE-2 ligand 1.

EXAMPLE 12 - CONSTRUCTION OF TIE-2 LIGANDBODIES

An expression construct was created that would yield a secreted protein consisting of the entire coding sequence of human TIE-2 ligand 1 (TL1) or TIE-2 ligand 2 (TL2) fused to the human immunoglobulin gamma-1 constant region (IgG1 Fc). These fusion proteins are called TIE-2 "ligandbodies" (TL1-Fc or TL2-Fc). The Fc portion of TL1-Fc and TL2-Fc was prepared as follows. A DNA fragment encoding the Fc portion of human IgG1 that spans from the hinge region to the carboxy-terminus of the protein, was amplified from human placental cDNA by PCR with oligonucleotides corresponding to the published sequence of human IgG1; the resulting DNA fragment was cloned in a plasmid vector. Appropriate DNA restriction fragments from a plasmid encoding full-length TL1 or TL2 and from the human IgG1 Fc plasmid were ligated on either side of a short PCR-derived fragment that was designed so as to

fuse, in-frame, TL1 or TL2 with human IgG1 Fc protein-coding sequences.

Milligram quantities of TL2-Fc were obtained by cloning the TL2-Fc DNA fragment into the pVL1393 baculovirus vector and subsequently infecting the Spodoptera frugiperda SF-21AE insect cell line. Alternatively, the cell line SF-9 (ATCC Accession No. CRL-1711) or the cell line BTI-TN-5b1-4 may be used. DNA encoding the TL2-Fc was cloned as an Eco RI-NotI fragment into the baculovirus transfer plasmid pVL1393. Plasmid DNA was recombined into viral DNA by mixing 3 μg of plasmid DNA with 0.5 μg of Baculo-Gold DNA (Pharminigen), followed by introduction into liposomes using 30μg Lipofectin (GIBCO-BRL). DNA-liposome mixtures were added to SF-21AE cells (2x 106 cells/60mm dish) in TMN-FH medium (Modified Grace's Insect Cell Medium (GIBCO-BRL) for 5 hours at 27°C, followed by incubation at 27°C for 5 days in TMN-FH medium supplemented with 5% fetal calf serum. Tissue culture medium was harvested for plaque purification of recombinant viruses, which was carried out using methods previously described (O'Reilly, D.R., L.K. Miller, and V.A. Luckow, Baculovirus Expression Vectors - A Laboratory Manual. 1992, New York: W.H. Freeman) except that the agarose overlay contained 125 mg/mL X-gal (5-bromo-4-chloro-3-indolyl-b- D-galactopyranoside; GIBCO-BRL). After 5 days of incubation at 27°C, non-recombinant plaques were scored by positive chromogenic reaction to the X-gal substrate, and their positions marked. Recombinant plaques were then visualized by addition of a second overlay containing 100 mg/mL MTT (3-[4,5-dimethylthiazol-2-yl]2,5,diphenyltetrazolium bromide; Sigma). Putative recombinant virus plaques were picked by plug aspiration, and purified by multiple rounds of plaque isolation to assure homogeneity. Virus stocks were generated by serial, low-multiplicity passage of

plaque-purified virus. Low passage stocks of one virus clone (vTL2-Fc Clone #7) were produced.

SF-21AE cells were cultured in serum-free medium (SF-900 II, Gibco BRL) containing 1X antibiotic/antimycotic solution (Gibco BRL) and 25 mg/L Gentamycin (Gibco BRL). Pluronic F-68 was added as a surfactant to a final concentration of 1g/L. Cultures (4L) were raised in a bioreactor (Artisan Cell Station System) for at least three days prior to infection. Cells were grown at 27°C, with gassing to 50 % dissolved oxygen, at a gas flow rate of 80 mL/min (aeration at a sparge ring). Agitation was by means of a marine impeller at a rate of 100 rpm. Cells were harvested in mid-logarithmic growth phase (~2 X10 6 cells/mL), concentrated by centrifugation, and infected with 5 plaque forming units of vTL2-Fc per cell. Cells and inoculum were brought to 400mL with fresh medium, and virus was adsorbed for 2 hours at 27°C in a spinner flask. The culture was then resuspended in a final volume of 8L with fresh serum-free medium, and the cells incubated in the bioreactor using the previously described conditions.

Culture medium from vTL2-Fc-infected SF21AE cells were collected by centrifugation (500x g, 10 minutes) at 72 hours post-infection. Cell supernatants were brought to pH 8 with NaOH. EDTA was added to a final concentration of 10 mM and the supernatant pH was readjusted to 8. Supernatants were filtered (0.45 µm, Millipore) and loaded on a protein A column (protein A sepharose 4 fast flow or HiTrap protein A, both from Pharmacia). The column was washed with PBS containing 0.5 M NaCl until the absorbance at 280 nm decreased to baseline. The column was washed in PBS and eluted with 0.5 M acetic acid. Column fractions were immediately neutralized by eluting into

tubes containing 1 M Tris pH 9. The peak fractions containing the TL2-Fc were pooled and dialyzed versus PBS.

EXAMPLE 13- EXPRESSION OF TIE-1, TIE-2, TL1, AND TL2 IN RENAL CELL CARCINOMA

In situ hybridization experiments were performed on human renal cell carcinoma tumor tissue using TIE-1, TIE-2, TL1, and TL2 cDNA probes. TIE-2, TIE-1, TL1, and TL2 expression were all up-regulated in the tumor vasculature. Ligand expression appeared to be localized to either the vascular endothelial cells (TL2) or very near the vascular endothelial cells in the mesenchyme (TL1). VEGF has been shown to be dramatically up-regulated in this tumor tissue. Brown, et al. Am. J. Pathol. 143:1255-1262 (1993).

EXAMPLE 14- EXPRESSION OF TIE-1, TIE-2, TL1, AND TL2 IN WOUND HEALING

In situ hybridization experiments were performed on cross-sectional tissue slices obtained from a rat cutaneous wound model using TIE-1, TIE-2, TL1, and TL2 cDNA probes. The wound healing model involves pressing a small cork bore against the skin of a rat and removing a small, cylindrical plug of skin. As healing begins at the base of the wound, a vertical slice of tissue is taken and used for *in situ* hybridization. In the tested tissue sample, TL1 and TL2 appeared to be slightly up-regulated by four days post-injury. In contrast to the slightly up-regulated expression of TL1 and TL2 in this tissue, VEGF expression, which may precede TL1 and TL2 expression, is dramatically up-regulated.

EXAMPLE 15- EXPRESSION OF TIE LIGANDS IN FETAL LIVER AND THYMUS

Reverse transcription-PCR (RT-PCR) was performed on mouse E14.5 fetal liver and mouse E17.5 fetal thymus. Agarose gel electrophoresis of the RT-PCR products revealed that in the mouse fetal liver, TIE-2 ligand 1 (TL1) RNA is enriched in the stromal region, but is absent in c-kit$^+$TER119 hematopoietic precursor cells. In this same tissue, TIE-2 ligand 2 (TL2) RNA is enriched in the stromal cells, but absent in the hematopoietic precursor cells (Figure 13). In the mouse fetal thymus, TL2 is enriched in the stromal cells (Figure 14).

EXAMPLE 16- THE TIE RECEPTOR/LIGAND SYSTEM IN ANGIOGENESIS

Although the TIE-2/TIE ligand system appears to play an important role in endothelial cell biology, it has not been shown to play a significant, active role in the early to intermediate stages of vascularization (e.g. angioblast or endothelial cell proliferation and migration, tubule formation, and other early stage events in vascular modeling). In contrast to the receptors and factors known to mediate these aspects of vascular development, the temporally late pattern of expression of TIE-2 and TL1 in the course of vascularization suggests that this system plays a distinct role in the latter stages vascular development, including the structural and functional differentiation and stabilization of new blood vessels. The pattern of expression of TIE-2/TL1 also is consistent with a continuing role in the maintenance of the structural integrity and/or physiological characteristics of an established vasculature.

TIE Ligand 2 (TL2) appears to be a competitive inhibitor of TL1. The spatiotemporal characteristics of TL2 expression suggest that this single inhibitory molecule may play multiple, context-dependent roles essential to appropriate vascular development or remodeling (e.g. de-stabilization/de-differentiation of mature endothelial cells allowing the formation of new vessels from existing vasculature, inhibition of inappropriate blood vessel formation, and regression/involution of mature blood vessels). Figure 15 is a schematic representation of the hypothesized role of the TIE-2/TIE ligands in angiogenesis. In this figure TL1 is represented by (•), TL2 is represented by (*), TIE-2 is represented by (**T**), VEGF is represented by ([]), and flk-1 (a VEGF receptor) is represented by (**Y**).

EXAMPLE 17- EXPRESSION OF TIE LIGANDS IN THE FEMALE REPRODUCTIVE SYSTEM: EXPRESSION IN THE OVARY

Preliminary observations made in experiments examining the expression of the TIE receptors and ligands in the female reproductive system are consistent with the hypothesis the TL1 plays a role in neovascularization which temporally follows that of VEGF. The pattern of TL2 expression is also consistent with an antagonism of the action of TL1, and a specific role in vascular regression. To verify this, expression of relevant mRNAs can be examined following experimental induction of follicular and luteal development so that their temporal relation to various aspects of neovascularization/vascular regression can be more clearly defined (e.g. in conjunction with endothelial cell staining, vascular fills). Angiogenesis associated with follicular development and corpus luteum formation in staged ovaries of mature, female rats or following induced ovulation in pre-pubertal animals was

followed using *in situ* hybridization. Figure 16 contains photographs of *in situ* hybridization slides showing the temporal expression pattern of TIE-2, TL1, TL2, and VEGF during the ovarian cycle [Column 1: Early pre-ovulatory follicle; Column 2: pre-ovulatory follicle; Column 3: early corpus luteum; and Column 4: atretic follicle; Row A:bright field; Row B:VEGF; Row C: TL2; Row D: TL1 and Row E: TIE-2 receptor]. These studies revealed that VEGF, TL1 and TL2 are expressed in a temporally and spatially coordinate fashion with respect to the development and regression of vasculature in the ovary, specifically with respect to the establishment of the vascular system which is generated in the course of the conversion of an ovarian follicle to a corpus luteum (CL).

Briefly, VEGF expression increases in the follicular granule layer prior to its vascularization during the process of luteinization. During the process of CL formation, highest levels of VEGF expression are apparent in the center of the developing CL in the vicinity of luteinizing cells which are not yet vascularized. VEGF levels remain moderately high and are diffusely distributed in the developed CL. In contrast, noticeably enhanced expression of TIE-2 ligand 1 occurs only late in process of CL formation, after a primary vascular plexus has been established. Later, TL1 expression is apparent throughout the CL at which time the definitive capillary network of the CL has been established.

TL2 exhibits a more complex pattern of expression than either VEGF or TL1. In the developing CL, TL2 is expressed at highest levels at the front of the developing capillary plexus- between the central avascular region of the CL where VEGF expression is highest, and the most peripheral portion of the CL where TL1 expression is dominant and where the luteinization process is complete and the vascular system is most mature. TL2 also appears to be expressed at high levels in the

follicular layer of large follicles which are undergoing atresia. While TL1 is also apparent in atretic follicles, VEGF is not expressed.

The pattern of expression described above is most consistent with a role for VEGF in the initiation of angiogenesis, with TL1 acting late in this process-for example in modeling and/or stabilization of the definitive vascular network. In contrast, TL2 is present both in areas of active expansion of a newly forming vascular network (during CL formation), and in regions which fail to establish a new vasculature and vascular regression is in progress (atretic follicles). This suggests a more dynamic and complex role for TL2, possibly involving destabilization of existing vasculature (necessary for regression) or developing vasculature (necessary for the dynamic modeling of newly forming vessels).

EXAMPLE 18- CONSTRUCTION AND CHARACTERIZATION OF THE CYS-TL1 MUTANT

The TIE-2 ligands have two major structural domains, one described as a "fibrinogen-like" domain comprising the approximate C-terminal third of the protein and the other a "coiled-coil" domain comprising the approximate N-terminal two-thirds of the protein. Although the TIE-2 ligands, designated TL1 and TL2, share similar structural homology, they exhibit different physical and biological properties. Under non-reducing electrophoretic conditions, both proteins exhibit covalent, multimeric structures, with TL1 existing primarily as a trimer and TL2 existing primarily as a dimer. Figure 17 is a schematic representation of how the TIE-2 ligands may be interacting to form multimers. In terms of biological activity, TL1 has been shown to be an agonist of the TIE-2 receptor, as demonstrated by

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induction of phosphorylation in TIE-2 expressing cells. TL2, on the other hand, appears to be a competitive inhibitor of TL1. Investigations into what factors might be contributing to the different physical and biological properties of the two molecules revealed the presence of a cysteine residue (CYS265) preceding the fibrinogen-like domain in TL1 but absent in TL2. This CYS265 residue in TL1 is encoded by TGC and is located at about nucleotides 1102-1104 at the approximate junction between the coiled-coil and fibrinogen-like domains. Because cysteine residues are generally involved in disulfide bond formation, the presence of which can contribute to both the tertiary structure and biological properties of a molecule, it was thought the perhaps the presence of the CYS265 in TL1 might be at least partially responsible for the different properties of the two molecules. To test this hypothesis, an expression plasmid was constructed which contained a mutation in TL1 in which the CYS was replaced with an amino acid which does not form disulfide bonds. In addition to this TL1/CYS$^-$ mutant, a second expression plasmid was constructed which mutated the corresponding position in TL2 so that this residue was now a cysteine. Both non-mutated and mutated expression plasmids of TL1 and TL2 were transiently transfected into COS cells. Cell supernatants containing the recombinant proteins were harvested and samples subjected to both reducing and non-reducing SDS/PAGE electrophoresis and subsequent western blotting. Figure 18 contains western blots of both non-mutated and mutated TL1 and TL2 proteins under revealing that the TL1/CYS$^-$ mutant behaves more TL2-like in that it runs as a dimer and that the TL2/CYS+ mutant behaves more TL1-like in that it is able to form a trimer as well as higher-order multimers. Interestingly, when the two mutant proteins were tested for their ability to induce phosphorylation in TIE-2 expressing cells, the TL1/CYS$^-$ mutant was

able to activate the TIE-2 receptor, whereas the TL2/CYS+ mutant did not gain any activating activity.

EXAMPLE 19- CONSTRUCTION AND CHARACTERIZATION OF FIBRINOGEN-LIKE DOMAIN ONLY MUTANTS

In order to test whether the fibrinogen-like domain (F-domain) of the TIE-2 ligands contained TIE-2 activating activity, expression plasmids were constructed which deleted the coiled-coil domain, leaving only that portion of the DNA sequence encoding the F-domain (beginning at about nucleotide 1159, amino acid residue ARG284). This mutant construct was transiently transfected into COS cells. The supernatant containing the recombinant protein was harvested. The TL1/F-domain mutant was tested for it's ability to bind the TIE-2 receptor. The results showed that, as a monomer, the TL1/F-domain mutant was not able to bind TIE-2 at a detectable level. However, when the TL1/F-domain monomer was myc-tagged and subsequently clustered with an antibody directed against the myc tag, it did exhibit detectable binding to TIE-2. However, the antibody-clustered TL1/F-domain mutant was not able to induce phosphorylation in a TIE-2 expressing cell line. Figure 17 shows a schematic representation of the F-domain construct and its binding ability plus and minus antibody clustering.

EXAMPLE 20- A RECEPTORBODY BINDING ASSAY AND A LIGAND BINDING AND COMPETITION ASSAY

A quantitative cell-free binding assay with two alternate formats has been developed for detecting either TIE-2 receptorbody binding or ligand binding and competition. In the receptorbody binding

version of the assay, TIE-2 ligands (purified or partially purified; either TL1 or TL2) are coated onto an ELISA plate. Receptorbody at varying concentrations is then added, which binds to the immobilized ligand in a dose-dependent manner. At the end of 2 hours, excess receptorbody is washed away, then the amount bound to the plate is reported using a specific anti-human Fc antibody which is alkaline phosphatase tagged. Excess reporter antibody is washed away, then the AP reaction is developed using a colored substrate. The assay is quantitated using a spectrophotometer. Figure 19 shows a typical TIE-2-IgG binding curve. This assay has been used to evaluate tne integrity of TIE-2-IgG after injection into rats and mice. The assay can also be used in this format as a ligand competition assay, in which purified or partially-purified TIE ligands compete with immobilized ligand for receptorbody. In the ligand binding and competition version of the binding assay, TIE-2 ectodomain is coated onto the ELISA plate. The Fc-tagged fibrinogen-like domain fragments of the TIE ligands (TL1-fFc and TL2-fFc) then bind to the ectodomain, and can be detected using the same anti-human Fc antibody as described above. Figure 20 shows an example of TL1-fFc binding to TIE-2 ectodomain. This version of the assay can also be used to quantitate levels of TL1-fFc in serum or other samples. If untagged ligand (again, either purified or unpurified) is added at the same time as the TL1-fFc, then a competition is set up between tagged ligand fragment and full-length ligand. The full-length ligand can displace the Fc-tagged fragment, and a competition curve is generated.

EXAMPLE 21- EA.hy926 CELL LINE CAN BE USED AS A REPORTER CELL LINE FOR TIE LIGAND ACTIVITY

EA.hy926 is a cell hybrid line that was established by fusion of HUVEC with the human lung carcinoma-derived line, A549 [Edgell, et al. Proc. Natl. Acad. Sci. (USA) 80, 3734-3737 (1983). EA.hy926 cells have been found to express significant levels of TIE-2 receptor protein with low basal phosphotyrosine levels. The density at which EA.hy926 cells are passaged prior to their use for receptor assays, as well as their degree of confluency at the time of assay, can affect TIE-2 receptor abundance and relative inducibility in response to treatment with ligand. By adopting the following regimen for growing these cells the EA.hy926 cell line can be used as a dependable system for assay of TIE-2 ligand activities.

EA.hy926 cells are seeded at 1.5 x 10^6 cells in T-75 flasks (Falconware) and re-fed every other day with high-glucose Dulbecco's MEM, 10% fetal bovine serum, L-glutamine, penicillin-streptomycin, and 1x hypoxanthine-aminopterin-thymidine (HAT, Gibco/BRL). After three to four days of growth, the cells are passaged once again at 1.5 x 10^6 cells per T-75 flask and cultured an additional three to four days. For phosphorylation assays, cells prepared as described above were serum-starved by replacement of the culture medium with high-glucose DMEM and incubation for 2-3 hours at 37°C. This medium was aspirated from the flask and samples of conditioned media or purified ligand were added to the flask in a total volume of 1.5 ml followed by incubation at 37°C for 5 minutes. Flasks were removed from the incubator and placed on a bed of ice. The medium was removed and replaced with 1.25 ml Lysis Buffer containing 1% nonidet P-40, 0.5% sodium deoxycholate, 0.1% SDS in 20 mM Tris, pH 7.6, 150 mM NaCl, 50 mM NaF, 1mM sodium orthovanadate, 5 mM benzamidine, and 1mM EDTA containing the protease inhibitors PMSF, aprotinin, and leupeptin. After 10 minutes on

ice to allow membrane solubilization, plates were scraped and cell lysates were clarified by microcentrifugation at top speed for 10 minutes at 4°C. TIE-2 receptor was immunoprecipitated from the clarified supernatant by incubation in the cold with an anti-TIE-2 polyclonal antiserum and Protein G-conjugated Sepharose beads. The beads were washed three times with cold cell lysis buffer and boiled 5 minutes in Laemmli sample buffer, which was then loaded on 7.5% SDS-polyacrylamide gels. Resolved proteins were electrotransferred to PVDF (Lamblia-P) membrane and then subjected to Western blot analysis using anti-phosphotyrosine antibody and the ECL reagent. Subsequent comparison of total TIE-2 protein levels on the same blots was done by stripping the anti-phosphotyrosine antibody and reincubating with a polyclonal antiserum specific to the ectodomain of TIE-2.

DEPOSITS

The following have been deposited with the American Type Culture Collection, 12301 Parklawn Drive, Rockville, Maryland 20852 in accordance with the Budapest Treaty. A plasmid clone encoding a TIE-2 ligand was deposited with the ATCC on October 7, 1994 and designated as "pJFE14 encoding TIE-2 ligand" under ATCC Accession No. 75910. Recombinant Autographa californica baculovirus encoding TIE-2 receptorbody was deposited with the ATCC on October 7, 1994 and designated as "vTIE-2 receptorbody" under ATCC Accession No. VR2484. A lambda phage vector containing human tie-2 ligand DNA was deposited with the ATCC on October 26, 1994 and designated as λgt10 encoding htie-2 ligand 1 under ATCC Accession No. 75928. A plasmid clone encoding a second TIE-2 ligand was deposited with the ATCC on

December 9, 1994 and designated as "pBluescript KS encoding human TIE 2 ligand 2" under ATCC Accession No. 75963.

The present invention is not to be limited in scope by the specific embodiments described herein. Indeed, various modifications of the invention in addition to those described herein will become apparent to those skilled in the art from the foregoing description and accompanying figures. Such modifications are intended to fall within the scope of the appended claims.

Throughout the description and claims of this specification, the word "comprise" and variations of that word, such as "comprises" and "comprising", are not intended to exclude other additives or components or integers.

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CLAIMS

1. An isolated nucleic acid molecule comprising a nucleotide sequence selected from the group consisting of:

   (a) the nucleotide sequence encoding the fibrinogen-like domain of the human TIE-2 ligand as set forth in Figure 4, 5 or 6 in isolation from the coiled coil domain of human TIE-2 ligand;

   (b) a nucleotide sequence that hybridises under moderately stringent conditions to the nucleic acid sequence of (a) and which encodes the fibrinogen-like domain of a TIE-2 ligand in isolation from the coiled coil domain of a TIE-2 ligand; and

   (c) a nucleotide sequence which differs from (a) or (b) due to the degeneracy of the genetic code.

2. A vector which comprises a nucleic acid molecule of claim 1.

3. A vector according to claim 2, wherein the nucleic acid molecule is operatively linked to an expression control sequence capable of directing its expression in a host cell.

4. A vector according to claim 2 or 3, which is a plasmid.

5. A polypeptide encoded by the nucleic acid molecule of claim 1.

6. A host-vector system for the production of a polypeptide of claim 5, which comprises a vector according to any one of claims 2 to 4 in a host cell.

7. A host-vector system according to claim 6, wherein the host cell is a bacterial, yeast, insect or mammalian cell.

8. A host-vector system according to claim 6 or 7 which further comprises a nucleic acid encoding the TIE-2 receptor.

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9. A method of producing a polypeptide which comprises growing cells of a host-vector system according to any one of claims 6 to 8 under conditions permitting production of the polypeptide, and recovering the polypeptide so produced.

10. An antibody which specifically binds the polypeptide of claim 5.

11. An antibody according to claim 10, which is a monoclonal antibody.

12. A conjugate comprising a polypeptide according to claim 5, having a cytotoxic agent conjugated thereto.

13. A conjugate according to claim 12, wherein the cytotoxic agent is a radioisotope or toxin.

14. A pharmaceutical composition comprising a polypeptide according to claim 5, an antibody according to claim 10 or 11 or a conjugate according to claim 12 or 13 and a pharmaceutically acceptable carrier.

15. Use of a polypeptide according to claim 5 or a conjugate according to claim 12 or 13 in the manufacture of a medicament for use in a method of treatment of a human or animal body, or in a method of diagnosis.

16. Use of an antibody according to claim 10 or 11 in the manufacture of a medicament for use in a method of treatment of a human or animal body, or in a method of diagnosis.

17. Use of a polypeptide according to claim 5 or a conjugate according to claim 12 or 13 in the manufacture of a medicament for use in a method of blocking blood vessel growth in a mammal.

18. Use of a polypeptide according to claim 5 or a conjugate according to claim 12 or 13 in

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the manufacture of a medicament for use as a TIE-2 antagonist in a method of inhibiting TIE-2 activity in a mammal.

19. Use according to claim 18 wherein the mammal is a human.

20. Use of a polypeptide or conjugate according to claim 18 or 19 for use in a method of attenuating or preventing tumor growth in a human.

21. A method of treatment or diagnosis which comprises administering to a patient a therapeutically or diagnostically effective amount of a polypeptide according to claim 5, a conjugate according to claim 12 or 13, an antibody according to claim 10 or 11 or a pharmaceutical composition according to claim 14 or 15.

22. A method of blocking blood vessel growth in a mammal which comprises treating a patient with a therapeutically effective amount of a polypeptide according to claim 5 or a conjugate according to claim 12 or 13.

23. A method of inhibiting TIE-2 activity in a mammal which comprises administering to a patient a therapeutically effective amount of a polypeptide according to claim 5 or a conjugate according to claim 12 or 13.

24. A method according to claim 22 or 23 wherein the mammal is a human.

25. A method according to claim 22 or 23 which is a method of attenuating or preventing tumour growth in a human.

26. A method of identifying a TIE-2 receptor antagonist comprising contacting TIE-2 receptor with a test compound in the presence of a polypeptide according to claim 5, under conditions permitting binding of the polypeptide to the receptor, and determining

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whether the test compound is capable of interfering with the binding of the polypeptide to the receptor.

27. A ligandbody which comprises a polypeptide according to claim 5, or a conjugate according to claim 12 or 13, fused to an immunoglobulin constant region.

28. A ligandbody according to claim 27, wherein the immunoglobulin constant region is the Fc portion of human IgG1.

29. Use of a ligandbody according to claim 27 or 28 in the manufacture of a medicament for use in a method of treatment of the human or animal body, or in a method of diagnosis.

30. A method of treatment or diagnosis which comprises administering to a patient a therapeutically or diagnostically effective amount of a ligandbody according to claim 27 or 28.

31. Use of a polypeptide of claim 5 or a ligandbody of claim 27, in the manufacture of a medicament for use with a second pharmaceutically active agent in a method of treatment of a human or animal body, or in a method of diagnosis.

32. Use according to claim 31, wherein said second pharmaceutically active agent is a cytokine, neurotrophin, interleukin, cytokine antagonist, VEGF, anti-VEGF antibody, VEGF receptorbody or bFGF.

33. A method of treatment or diagnosis which comprises administering to a patient a therapeutically or diagnostically effective amount of a polypeptide according to claim 5 or a ligandbody according to claim 27 with a second pharmaceutically active agent.

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34. A method according to claim 33 wherein said second pharmaceutically active agent is a cytokine, neurotrophin, interleukin, cytokine antagonist, VEGF, anti-VEGF antibody, VEGF receptorbody or bFGF.

35. Use of a polypeptide of claim 5 or a ligandbody of claim 27 in the manufacture of a medicament for use in a method of inhibiting hematopoiesis in a patient.

36. Use according to claim 35 for treating myeloproliferative disorders or other proliferative disorders of blood forming organs.

37. A method of inhibiting hematopoiesis comprising treating a patient with a therapeutically effective amount of a polypeptide of claim 5 or a ligandbody of claim 27.

38. A method according to claim 37 for treating myeloproliferative disorders or other proliferative disorders of blood forming organs.

39. A nucleic acid according to claim 1, substantially as hereinbefore described with reference to any one of the foregoing Examples.

40. A vector according to claim 2, substantially as hereinbefore described with reference to any one of the foregoing Examples.

41. A polypeptide according to claim 5, substantially as hereinbefore described with reference to any one of the foregoing Examples.

42. A host-vector system according to claim 6, substantially as hereinbefore described with reference to any one of the foregoing Examples.

43. A method according to any one of claims 9, 21 to 26 or 30, substantially as

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hereinbefore described with reference to any one of the foregoing Examples.

44. An antibody according to claim 10, substantially as hereinbefore described with reference to any one of the foregoing Examples.

45. A conjugate according to claim 12, substantially as hereinbefore described with reference to any one of the foregoing Examples.

46. A pharmaceutical composition according to claim 14 substantially as hereinbefore described with reference to any one of the foregoing Examples.

47. Use according to any one of claims 15 to 20 or 29, substantially as hereinbefore described with reference to any one of the foregoing Examples.

48. A ligandbody according to claim 27 substantially as hereinbefore described with reference to any one of the foregoing Examples.

DATED: 18 November 1999

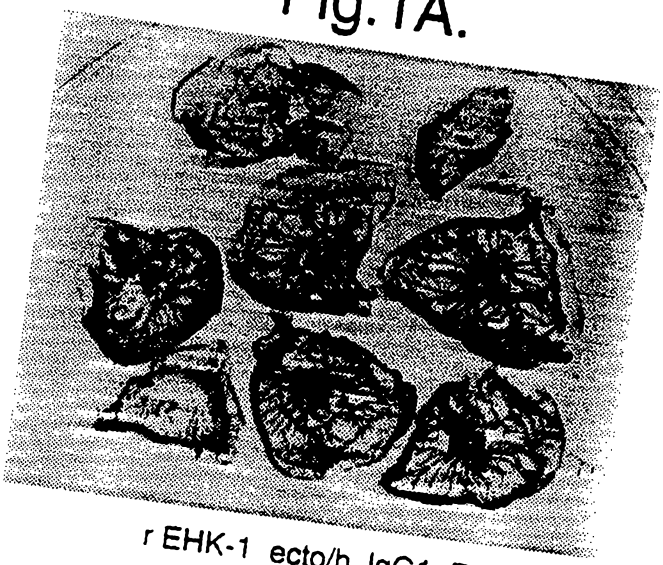
PHILLIPS ORMONDE & FITZPATRICK

Attorneys for:

REGENERON PHARMACEUTICALS, INC.

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Fig. 1A.



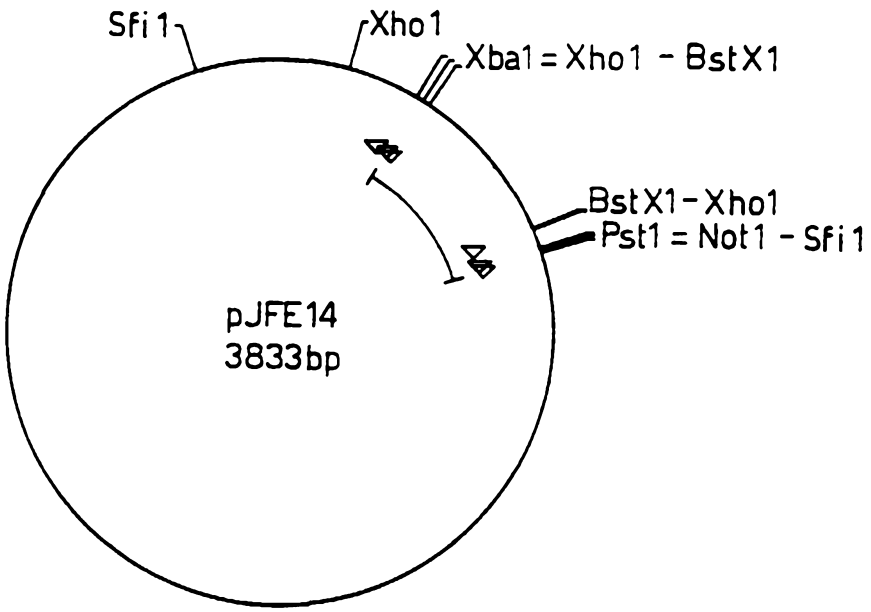
r EHK-1 ecto/h IgG1 Fc
Gelfoam (6ug)

Fig. 1B.



r TIE-2 ecto/h IgG1 Fc
Gelfoam (6ug)

Fig.2.


Sfi 1
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BstX1 - Xho1
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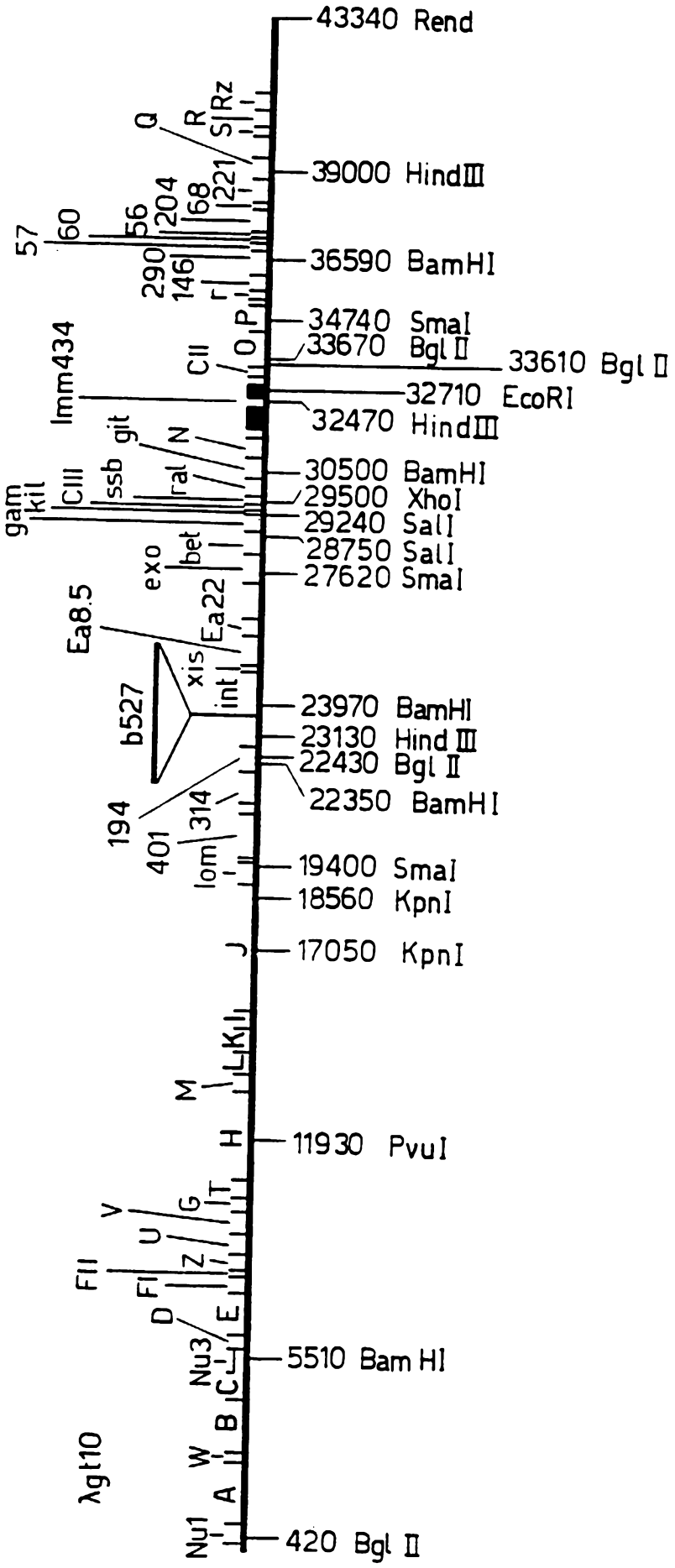

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B
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A
Nu1

Fig.3.

Fig.4.

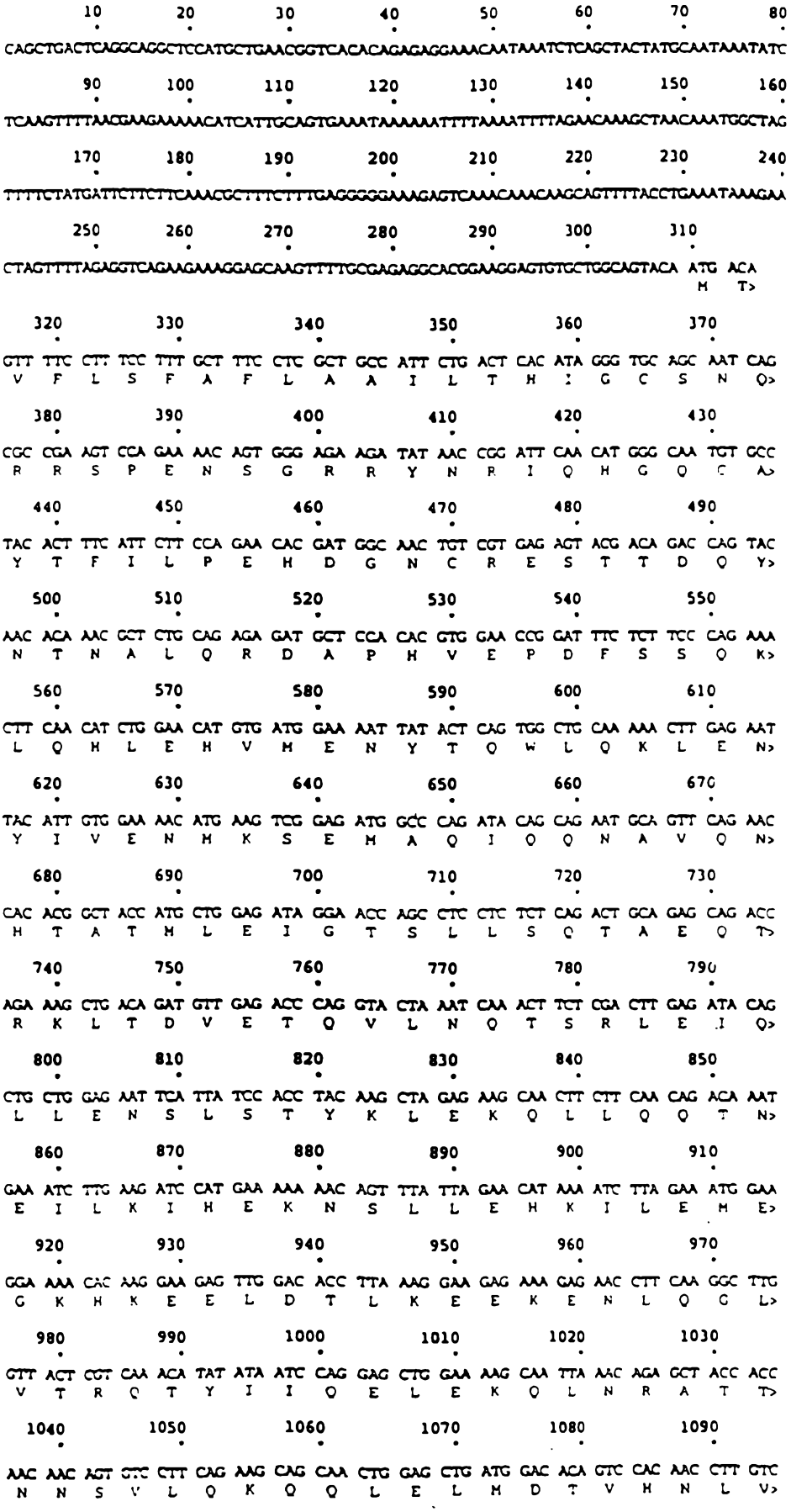

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Fig.4. (Cont.)

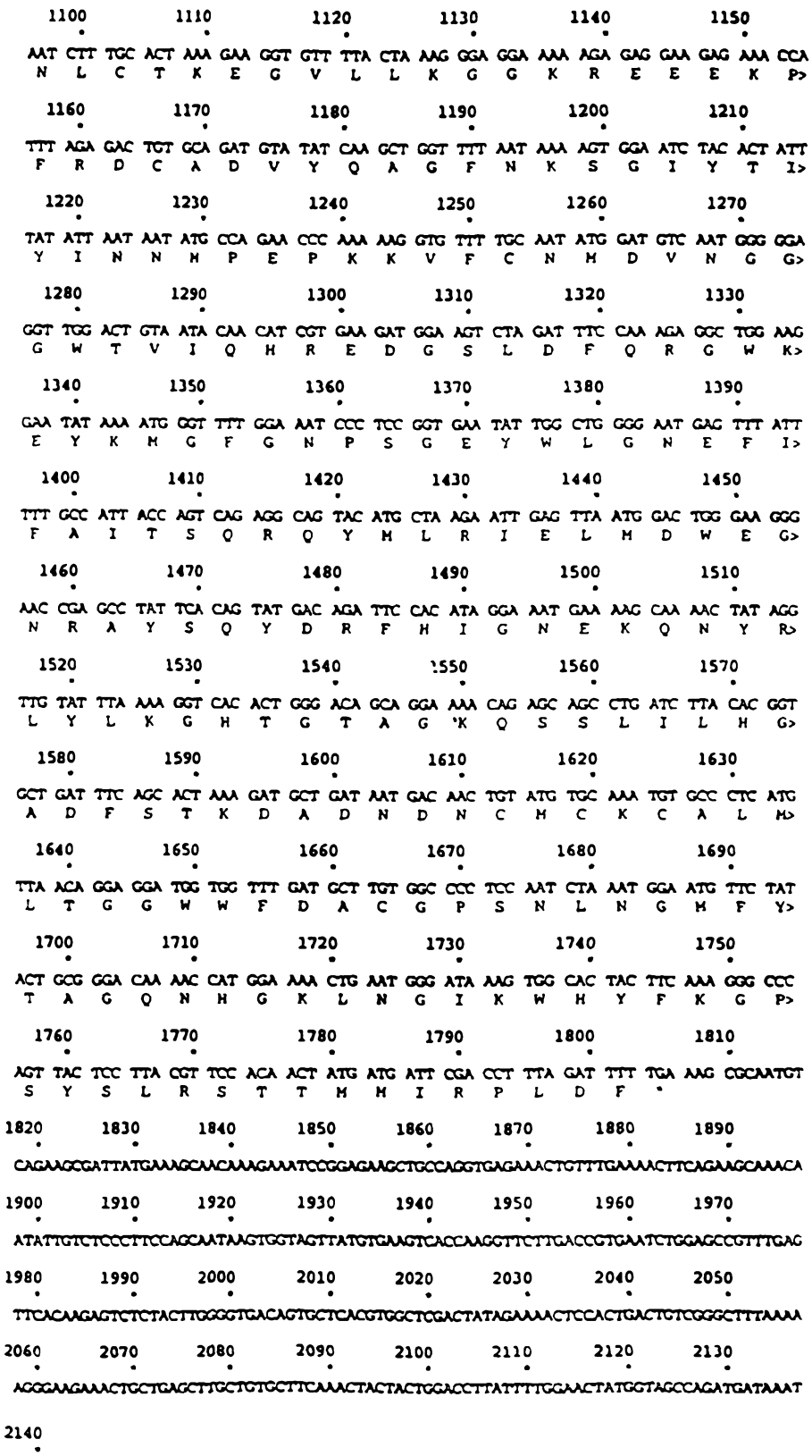

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Fig.5.

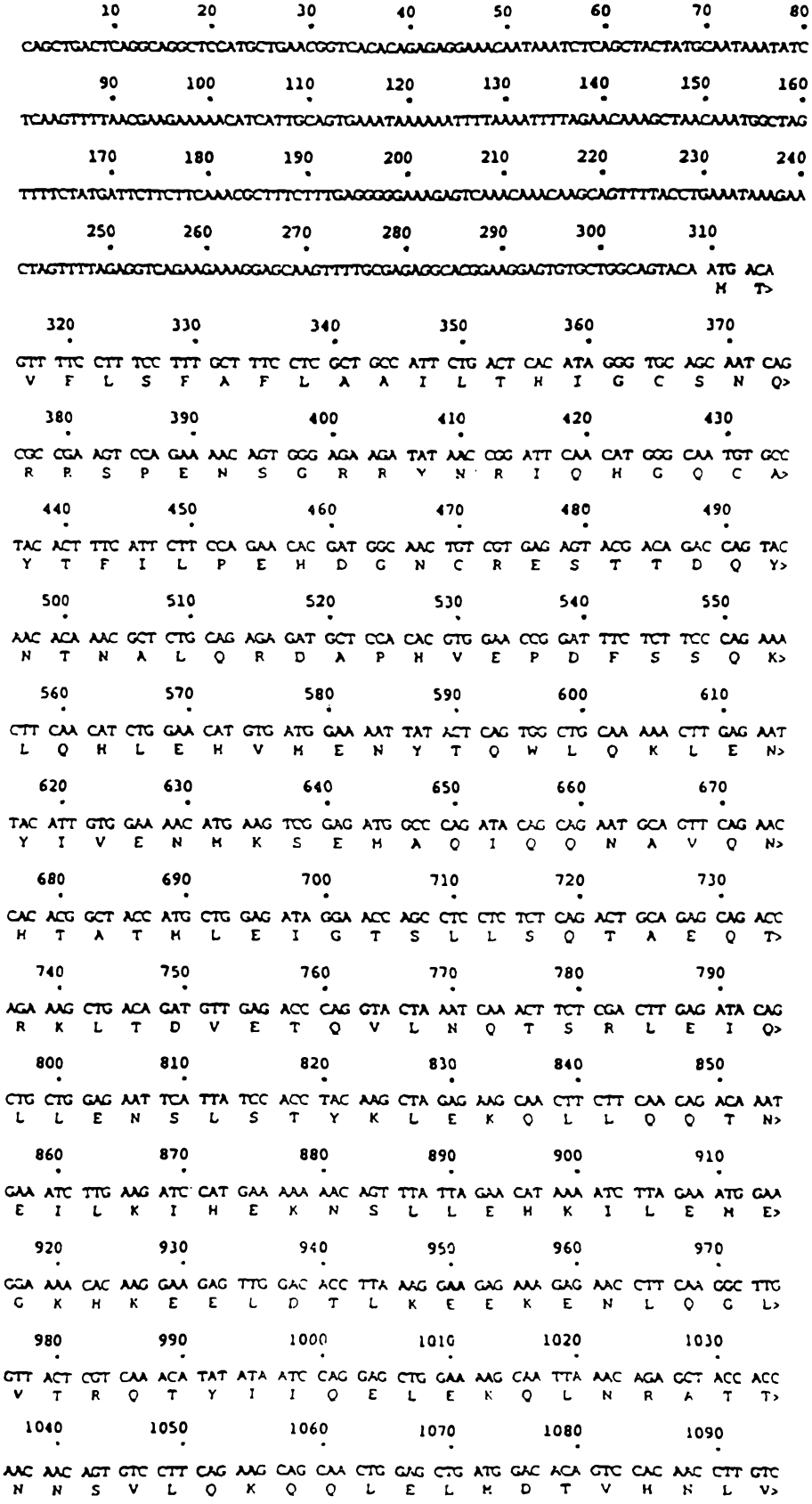

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Fig.5. (Cont.)

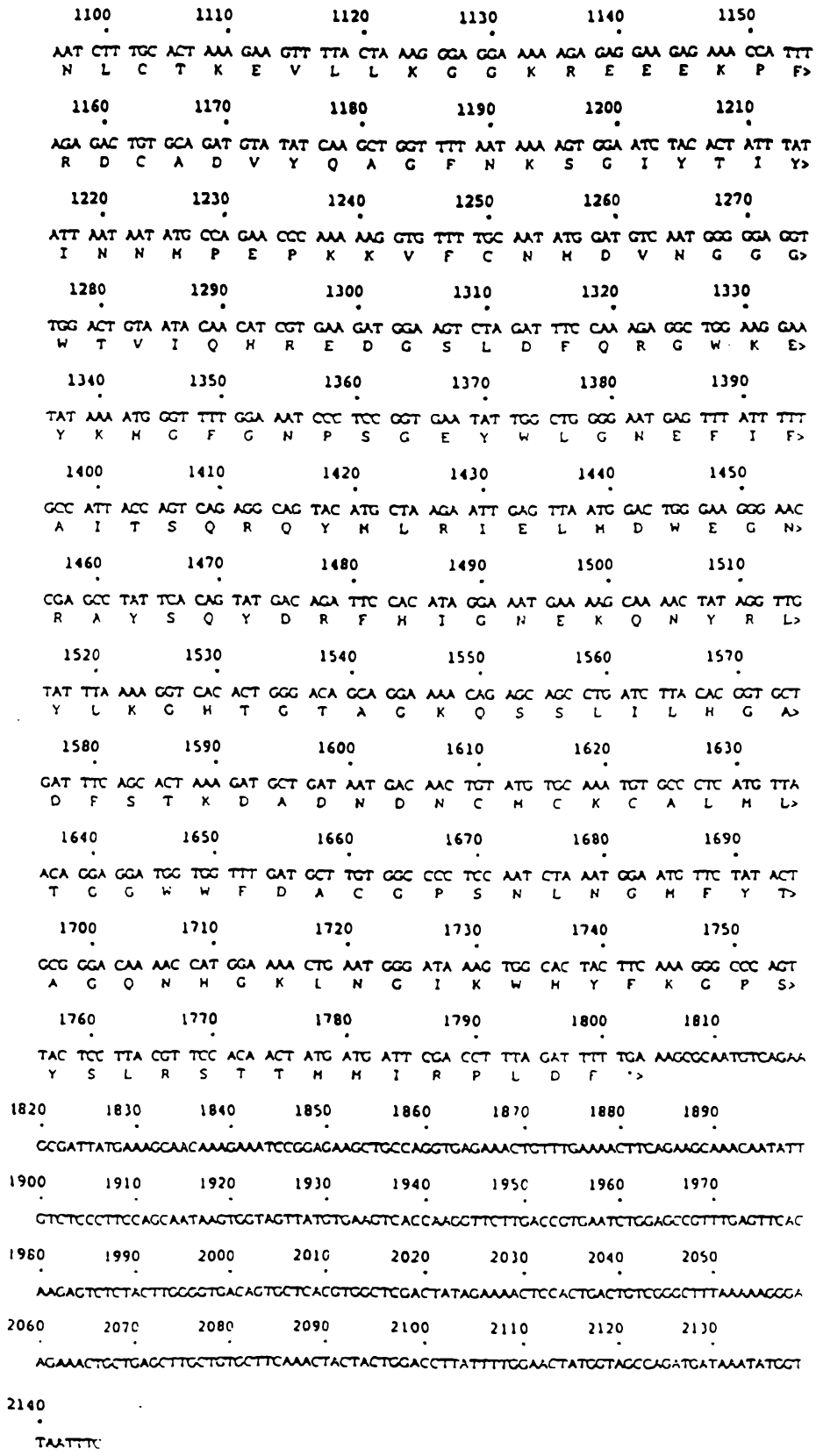

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Fig.6.

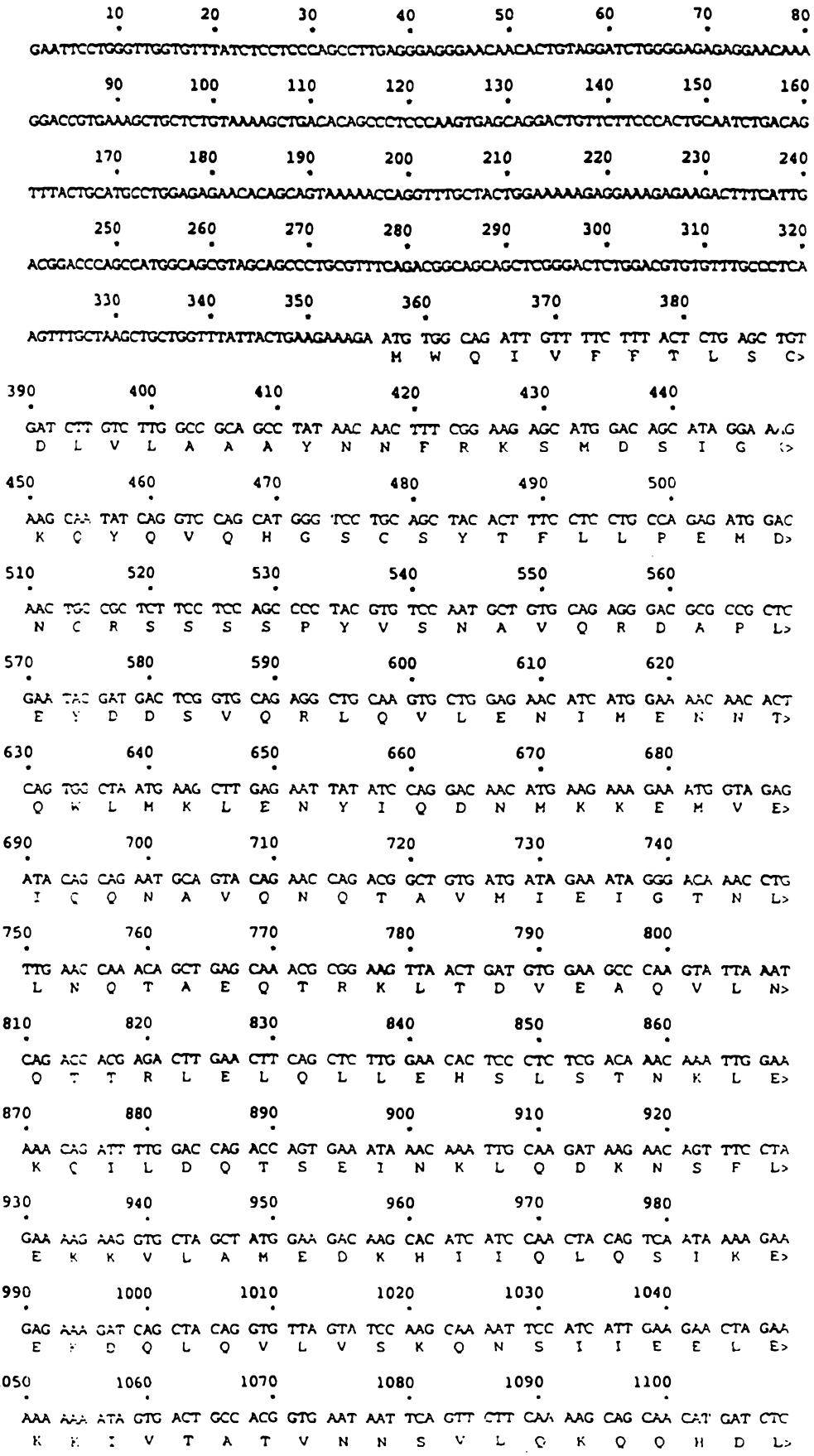

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Q T T R L E L Q L L E H S L S T N K L E>
870 880 890 900 910 920
AAA CAG ATT TTG GAC CAG ACC AGT GAA ATA AAC AAA TTG CAA GAT AAG AAC AGT TTC CTA
K Q I L D Q T S E I N K L Q D K N S F L>
930 940 950 960 970 980
GAA AAG AAG GTG CTA GCT ATG GAA GAC AAG CAC ATC ATC CAA CTA CAG TCA ATA AAA GAA
E K K V L A M E D K H I I Q L Q S I K E>
990 1000 1010 1020 1030 1040
GAG AAA GAT CAG CTA CAG GTG TTA GTA TCC AAG CAA AAT TCC ATC ATT GAA GAA CTA GAA
E K D Q L Q V L V S K Q N S I I E E L E>
1050 1060 1070 1080 1090 1100
AAA AAA ATA GTG ACT GCC ACG GTG AAT AAT TCA GTT CTT CAA AAG CAG CAA CAT GAT CTC
K K I V T A T V N N S V L Q K Q Q H D L>
SUBSTITUTE SHEET (RULE 26)

Fig.6. (Cont.)


```
1110        1120        1130        1140        1150        1160
ATG GAG ACA GTT AAT AAC TTA CTG ACT ATG ATG TCC ACA TCA AAC TCA GCT AAG GAC CCC
 M   E   T   V   N   N   L   L   T   M   M   S   T   S   N   S   A   K   D   P>

1170        1180        1190        1200        1210        1220
ACT GTT GCT AAA GAA GAA CAA ATC AGC TTC AGA GAC TGT GCT GAA GTA TTC AAA TCA GGA
 T   V   A   K   E   E   Q   I   S   F   R   D   C   A   E   V   F   K   S   G>

1230        1240        1250        1260        1270        1280
CAC ACC ACA AAT GGC ATC TAC ACG TTA ACA TTC CCT AAT TCT ACA GAA GAG ATC AAG GCC
 H   T   T   N   G   I   Y   T   L   T   F   P   N   S   T   E   E   I   K   A>

1290        1300        1310        1320        1330        1340
TAC TGT GAC ATG GAA GCT GGA GGA GGC GGG TGG ACA ATT ATT CAG CGA CGT GAG GAT GGC
 Y   C   D   M   E   A   G   G   G   G   W   T   I   I   Q   R   R   E   D   G>

1350        1360        1370        1380        1390        1400
AGC GTT GAT TTT CAG AGG ACT TGG AAA GAA TAT AAA GTG GGA TTT GGT AAC CCT TCA GGA
 S   V   D   F   Q   R   T   W   K   E   Y   K   V   G   F   G   N   P   S   G>

1410        1420        1430        1440        1450        1460
GAA TAT TGG CTG GGA AAT GAG TTT GTT TCG CAA CTG ACT AAT CAG CAA CGC TAT GTG CTT
 E   Y   W   L   G   N   E   F   V   S   Q   L   T   N   Q   Q   R   Y   V   L>

1470        1480        1490        1500        1510        1520
AAA ATA CAC CTT AAA GAC TGG GAA GGG AAT GAG GCT TAC TCA TTG TAT GAA CAT TTC TAT
 K   I   H   L   K   D   W   E   G   N   E   A   Y   S   L   Y   E   H   F   Y>

1530        1540        1550        1560        1570        1580
CTC TCA AGT GAA GAA CTC AAT TAT AGG ATT CAC CTT AAA GGA CTT ACA GGG ACA GCC GGC
 L   S   S   E   E   L   N   Y   R   I   H   L   K   G   L   T   G   T   A   G>

1590        1600        1610        1620        1630        1640
AAA ATA AGC AGC ATC AGC CAA CCA GGA AAT GAT TTT AGC ACA AAG GAT GGA GAC AAC GAC
 K   I   S   S   I   S   Q   P   G   N   D   F   S   T   K   D   G   D   N   D>

1650        1660        1670        1680        1690        1700
AAA TGT ATT TGC AAA TGT TCA CAA ATG CTA ACA GGA GGC TGG TGG TTT GAT GCA TGT GGT
 K   C   I   C   K   C   S   Q   M   L   T   G   G   W   W   F   D   A   C   G>

1710        1720        1730        1740        1750        1760
CCT TCC AAC TTG AAC GGA ATG TAC TAT CCA CAG AGG CAG AAC ACA AAT AAG TTC AAC GGC
 P   S   N   L   N   G   M   Y   Y   P   Q   R   Q   N   T   N   K   F   N   G>

1770        1780        1790        1800        1810        1820
ATT AAA TGG TAC TAC TGG AAA GGC TCA GGC TAT TCG CTC AAG GCC ACA ACC ATG ATG ATC
 I   K   W   Y   Y   W   K   G   S   G   Y   S   L   K   A   T   T   M   M   I>

1830        1840        1850        1860        1870        1880        1890        1900
CGA CCA GCA GAT TTC TAAACATCCCAGTCCACCTGAGGAACTGTCTCGAACTATTTTCAAAGACTTAAGCCCAGT
 R   P   A   D   F>

1910        1920        1930        1940        1950        1960        1970        1980
GCACTGAAAGTCACGGCTGCGCACTGTGTCCTCTTCCACCACAGAGGGCGTGTGCTCGGTGCTGACGGGACCCACATGCT

1990        2000        2010        2020        2030        2040        2050        2060
CCAGATTAGAGCCTGTAAACTTTATCACTTAAACTTGCATCACTTAACGGACCAAAGCAAGACCCTAAACATCCATAATT

2070        2080        2090        2100        2110        2120        2130        2140
GTGATTAGACAGAACACCTATGCAAAGATGAACCCGAGGCTGAGAATCAGACTGACAGTTTACAGACGCTGCTGTCACAA

2150        2160        2170        2180        2190        2200        2210        2220
CCAAGAATGTTATGTGCAAGTTTATCAGTAAATAACTGGAAAACAGAACACTTATGTTATACAATACAGATCATCTTGGA

2230        2240        2250        2260        2270        2280
ACTGCATTCTTCTGAGCACTGTTTATACACTGTGTAAATACCCATATGTCCTGAATTC
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Fig.7.

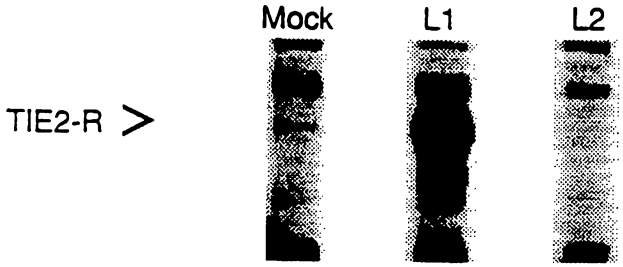


Fig.8.

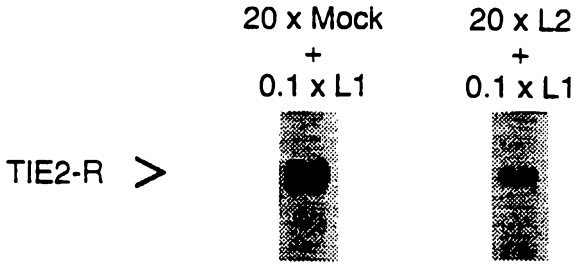


Fig.9.

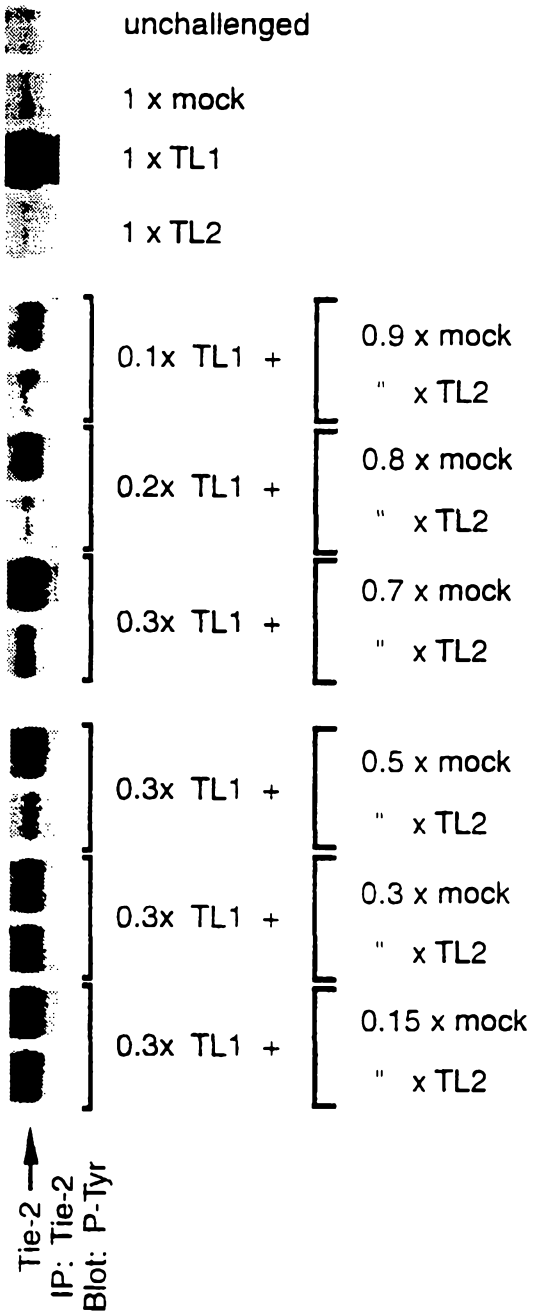

unchallenged
1 x mock
1 x TL1
1 x TL2
0.1x TL1 +
0.9 x mock
" x TL2
0.2x TL1 +
0.8 x mock
" x TL2
0.3x TL1 +
0.7 x mock
" x TL2
0.3x TL1 +
0.5 x mock
" x TL2
0.3x TL1 +
0.3 x mock
" x TL2
0.3x TL1 +
0.15 x mock
" x TL2
Tie-2
IP: Tie-2
Blot: P-Tyr

Fig.10.

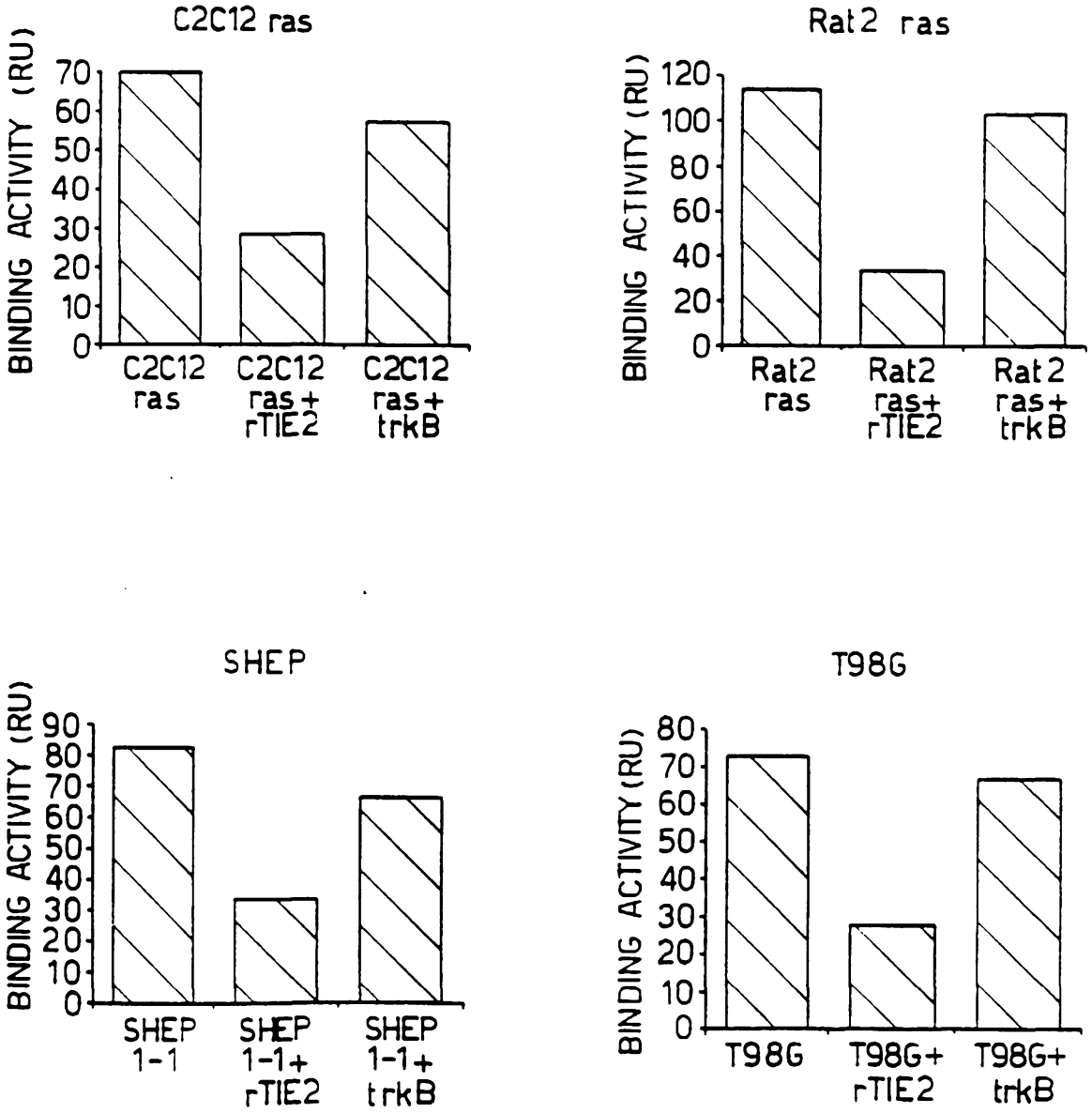
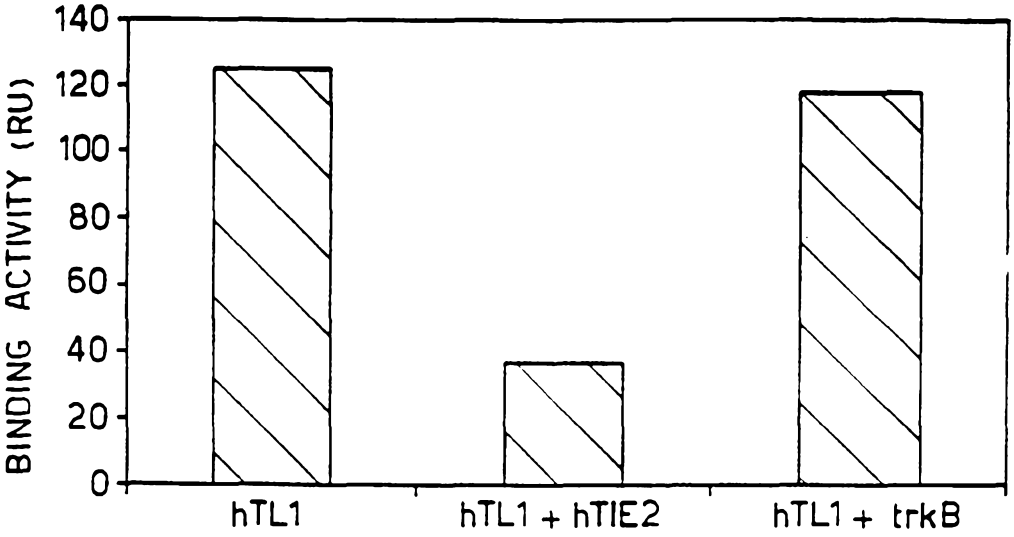

C2C12 ras
BINDING ACTIVITY (RU)
0
10
20
30
40
50
60
70
C2C12 ras
C2C12 ras+ rTIE2
C2C12 ras+ trkB
Rat2 ras
BINDING ACTIVITY (RU)
0
20
40
60
80
100
120
Rat2 ras
Rat2 ras+ rTIE2
Rat2 ras+ trkB
SHEP
BINDING ACTIVITY (RU)
0
10
20
30
40
50
60
70
80
90
SHEP 1-1
SHEP 1-1+ rTIE2
SHEP 1-1+ trkB
T98G
BINDING ACTIVITY (RU)
0
10
20
30
40
50
60
70
80
T98G
T98G+ rTIE2
T98G+ trkB

Fig.11.


BINDING ACTIVITY (RU)
140
120
100
80
60
40
20
0
hTL1
hTL1 + hTIE2
hTL1 + trkB

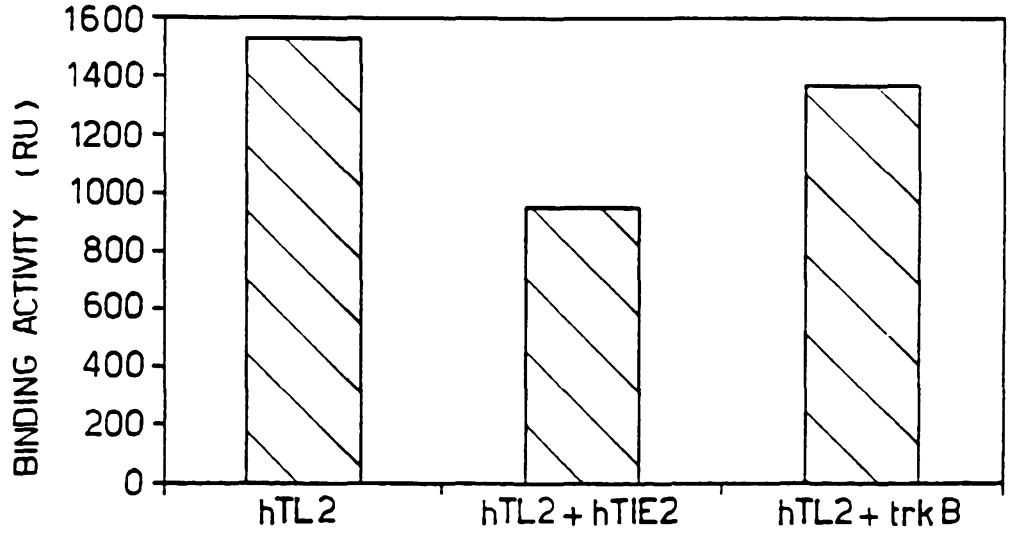

BINDING ACTIVITY (RU)
1600
1400
1200
1000
800
600
400
200
0
hTL2
hTL2 + hTIE2
hTL2 + trkB

Fig.12.

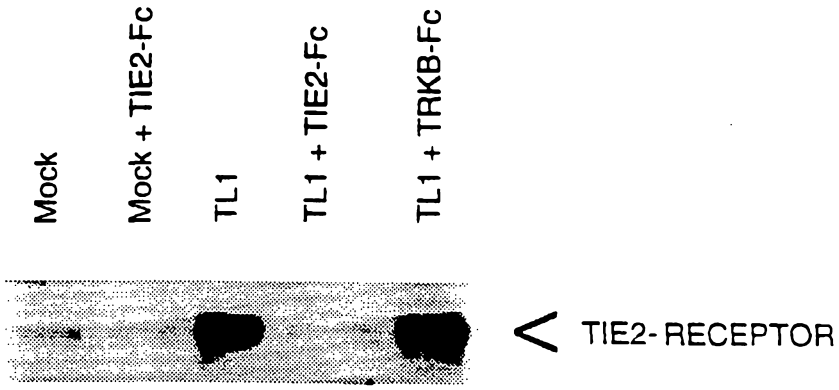
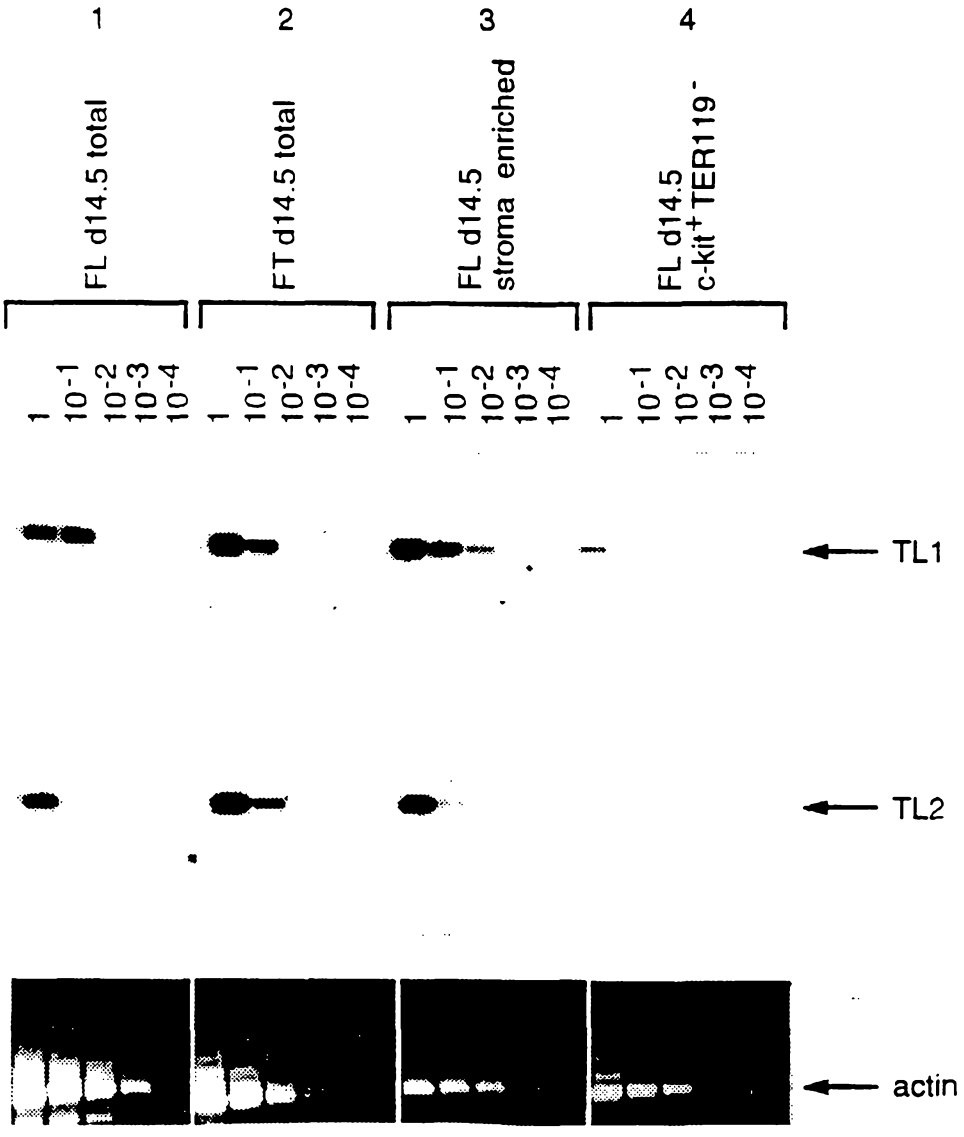
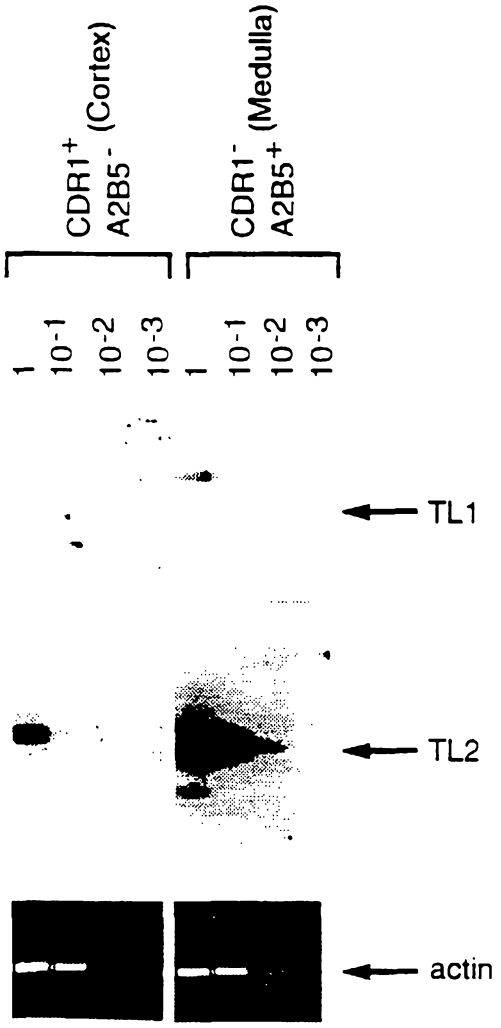


Fig.13.



FL: Fetal Liver

Fig.14.



Fetal Thymus E17.5

$CDR1^+$: Cortical stromal cells

$A2B5^+$: Medulla stromal cells

Fig.15.

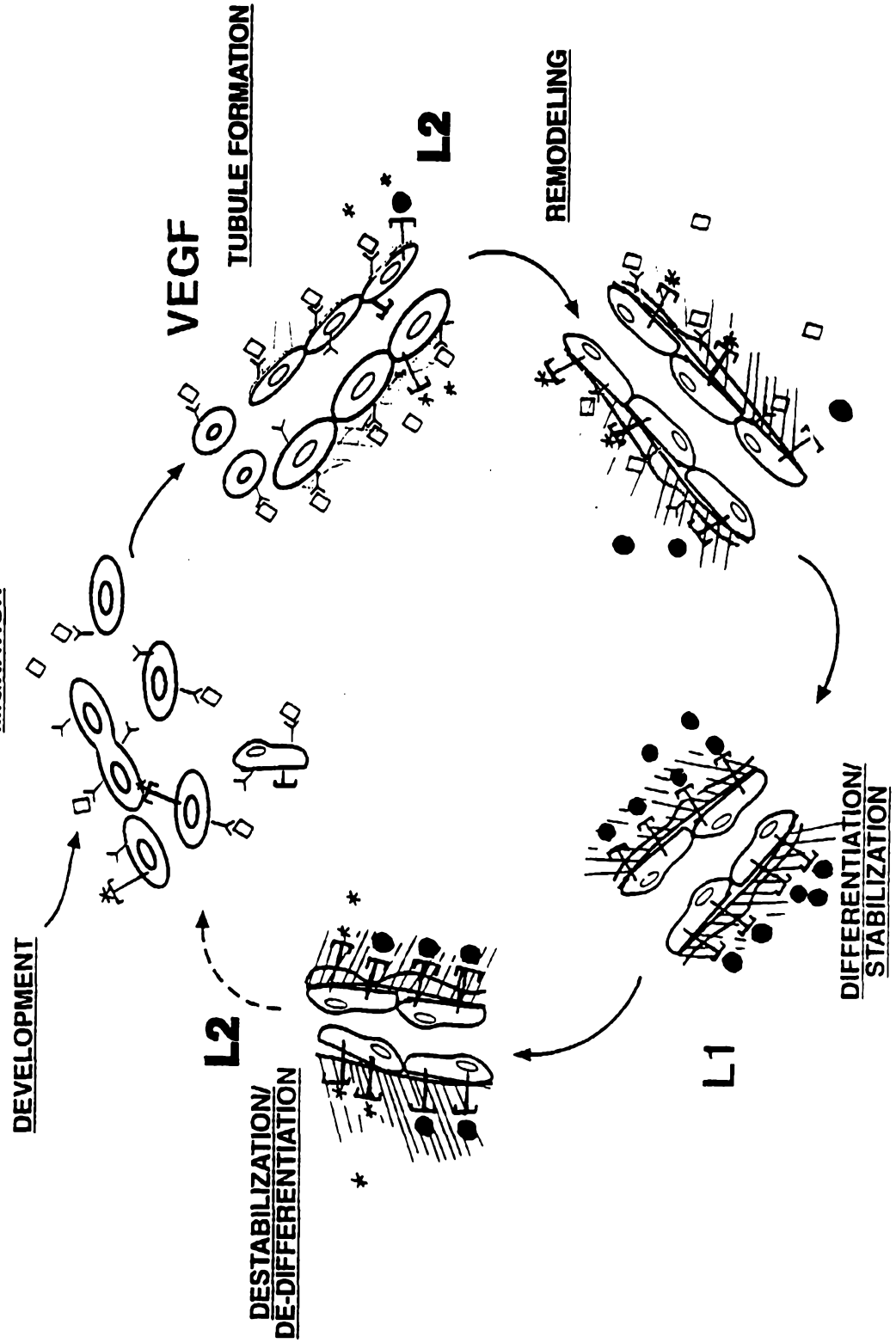

ANGIOGENESIS
DEVELOPMENT
PROLIFERATION/
MIGRATION
VEGF
TUBULE FORMATION
L2
REMODELING
DIFFERENTIATION/
STABILIZATION
L1
L2
DESTABILIZATION/
DE-DIFFERENTIATION

Fig.16.

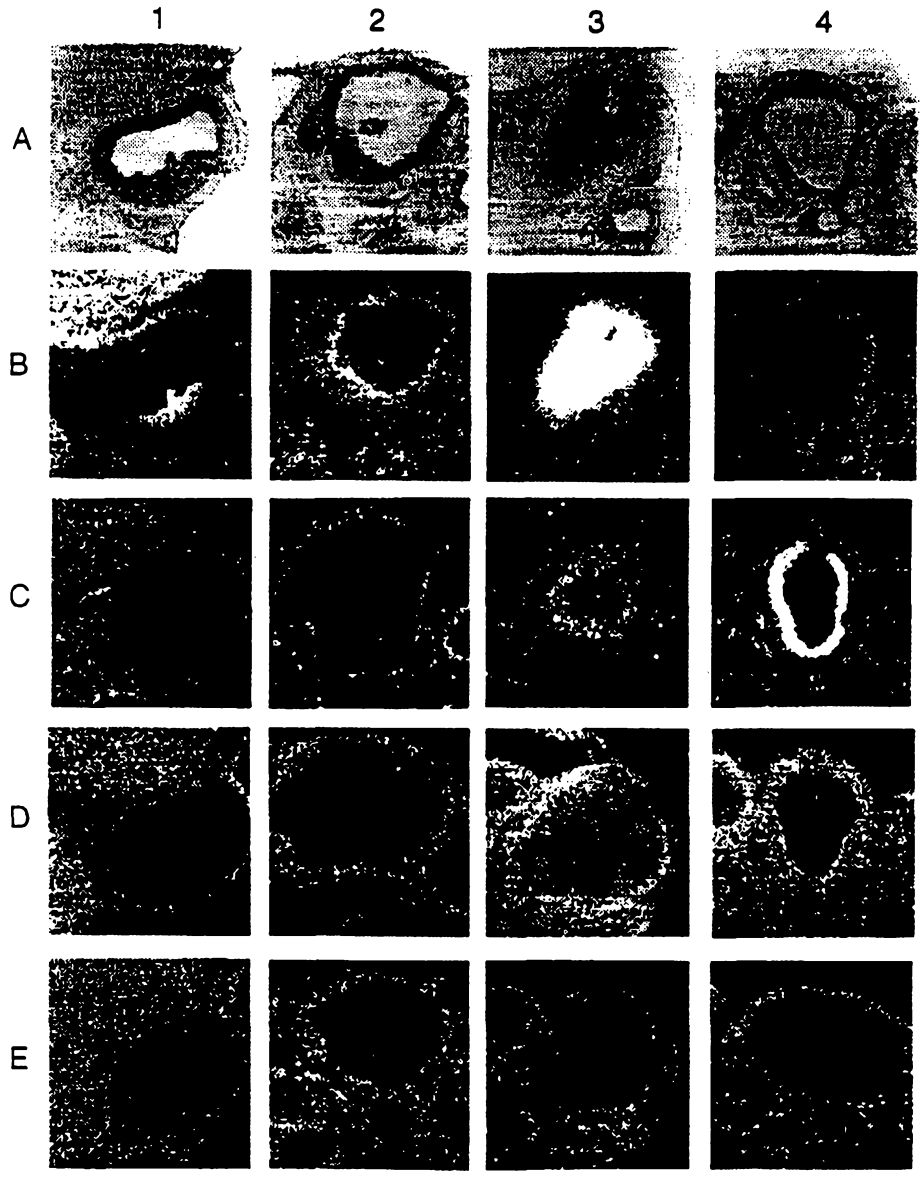


Fig.17.

ENGINEERING OF TIE2 "LIGAND-BODIES"

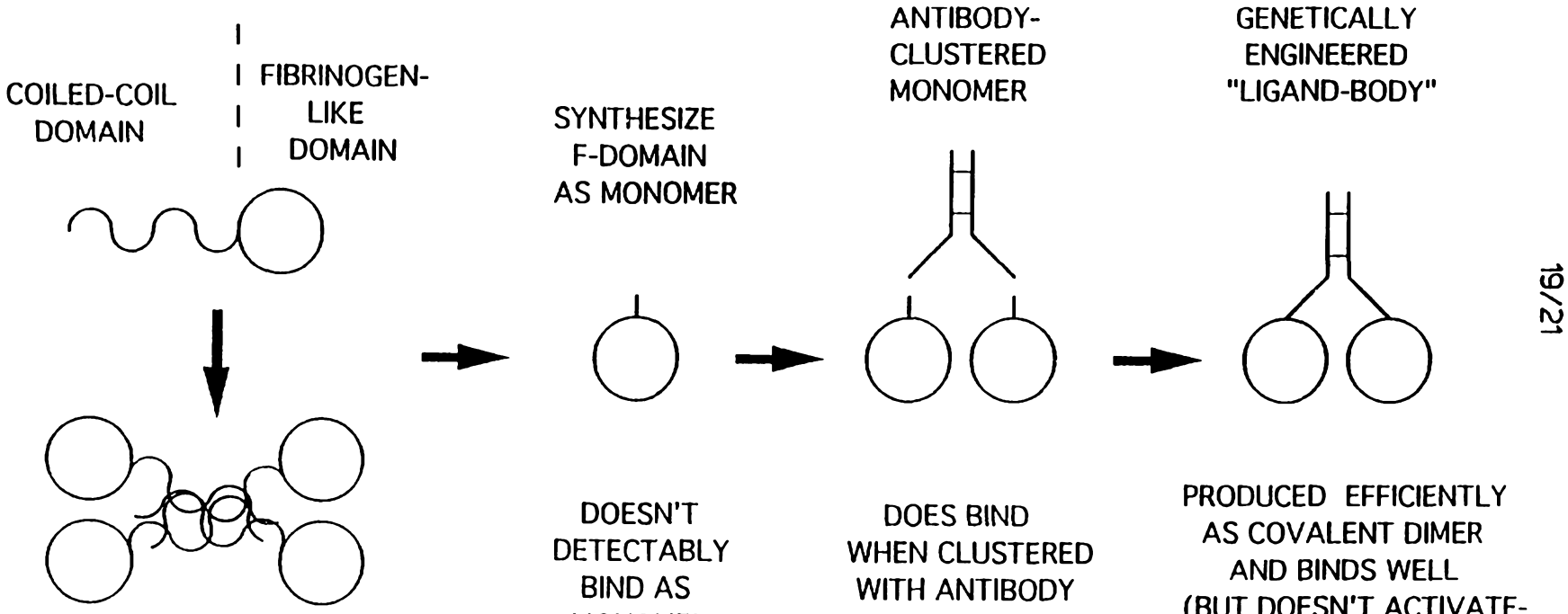


Fig.18.

COVALENT MULTIMERIC STRUCTURE OF
TL1 AND TL2 AND THEIR INTERCONVERSION
BY THE MUTATION OF ONE CYSTEINE

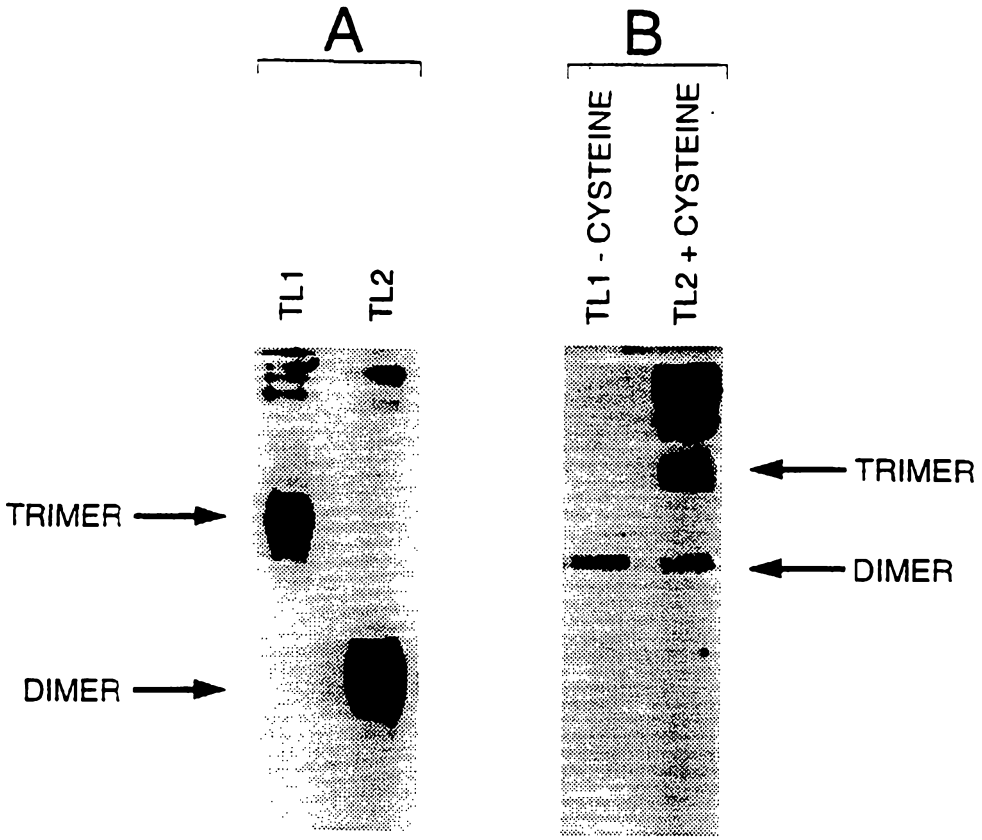


Fig.19. TIE2-IgG binding to immobilized TL1

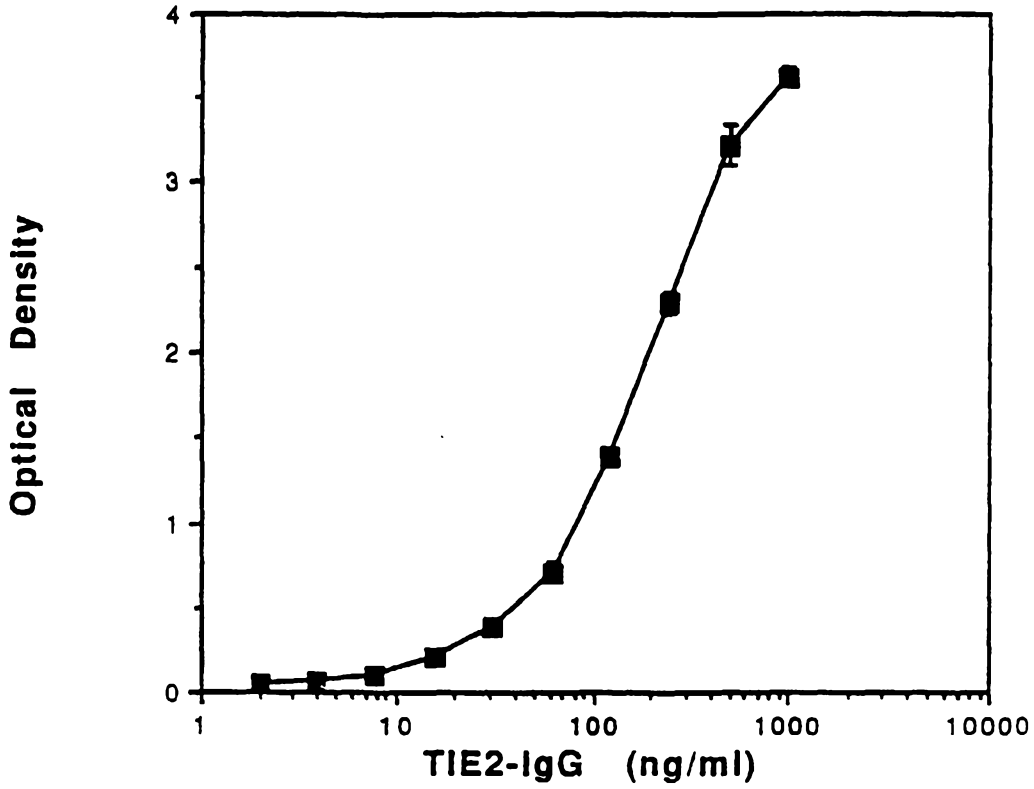


Fig.20. TL1-f-Fc binding to immobilized Tie2 ectodomain

