SYNTHETIC scFv ANALOGUE TO THE 6313/G2 (ANTI ANGIOTENSIN II TYPE 1 RECEPTOR) MONOCLONAL ANTIBODY VARIABLE REGIONS

The present invention relates to a synthetic scFv analogue (R6313/G2) of the 6313/G2 anti angiotensin II type 1 receptor monoclonal antibody variable domains.

Angiotensin-II plays a central role in mammalian electrolyte homeostasis and blood pressure control (Peach *Physiol. Rev* **57** 313-370 (1977); Vinson *et al "The Adrenal Cortex"*, Prentice Hall, Englefield Heights (1992)). Two main types of angiotensin-II receptors, designated types 1 and 2 (AT1 and AT2), have been recognised, but the majority of the well known actions of angiotensin-II occur via the AT1 subtype (Herblin *et al Am. J. Hypertens.* **4** 299S-302S (1991); Ouali *et al J. Steroid. Biochem. Mol. Biol.* **43** 271-280 (1992)).

A monoclonal antibody 6313/G2 to the AT1 receptor subtype (Barker *et al J. Mol. Endocrinol.* **11** 241-245 (1993)) has been used to study the distribution of the receptor (Vinson *et al Mol. Med. Today* **1** 35-38 (1995)). The monoclonal antibody has been suggested for use as a therapeutic agent to control vaso-constriction, for example in the treatment of hypertension or other smooth muscle cell (e.g. uterine) contraction.

The antibody has been used as a specific imaging agent in various tissues, for example laryngeal cancer (Marsigliante *et al Cancer Letters* **110** 19-27 (1996)), kidney (Harrison-Bernard *et al Am. J. Physiol.* **42** F170-F177 (1997); Cheng *et al Am. J. Physiol.* **43** F10-F17 (1998)), and brain (Yang *et al J. Neuroscience* **17** 1660-1669 (1997)). The antibody has been shown to block angiotensin-II induced AT1 receptor internalisation and PKC activation but conversely promotes the calcium response (Kapas *et al Biochem. Biophys. Res. Comm.* **204** 1292-1298 (1994); Vinson *et al J. Endocrinol.* **141** R5-R9 (1994)). The presence of AT1 and AT2 receptors in breast tumours has been reported with local production of angiotensin (Inwang *et al Brit. J. Cancer* **75** 1279-1283 (1997); Tahmasebi *et al Eur. J. Cancer* **34** 1777-1782 (1998)).

Monoclonal antibody 6313/G2 is secreted by a hybridoma cell line deposited on 22 July 1993 with the European Collection of Animal Cell Cultures (ECACC), Porton Down, United Kingdom, under the Budapest Treaty, and designated by the accession no. 93072117. The deposit was made by Dr Gavin P Vinson and Dr Stewart Barker, Department of Biochemistry, Queen Mary & Westfield College, Mile End Road, London E1 4NS. The depositor has authorised the applicant to refer to the deposited material in the application and has given his unreserved and irrevocable consent to the deposited material being made available to the public in accordance with Rule 28(1)(d) of the European Patent Convention.

The hybridoma cell line produces an antibody that specifically binds to amino acid residues 8 to 17 of the rat vascular smooth muscle AT1 receptor, which sequence is also found in the AT1 receptor of human and bovine cells. The epitope sequence is as follows:

EDGIKRIQDD

Or, alternatively expressed as,

NH_2-Glu-Asp-Gly-Ile-Lys-Arg-Ile-Gln-Asp-Asp-COOH

Monoclonal antibodies to the peptide sequence comprising the N-terminal sequence of the angiotensin-II type-1 receptor have been prepared (Barker *et al Journal of Molecular Endocrinology* **11** 241-245 (1993); WO 95/09186). It has been reported that such monoclonal antibodies have additional therapeutic uses in certain medical conditions where such uses were not previously suggested or shown (WO2004/018519). These therapeutic effects are seen in the ability of the monoclonal antibodies to block the harmful actions of angiotensin-II in the medical conditions concerned whilst preserving the beneficial actions of the molecule.

It has now been found that synthetic scFv analogues of monoclonal antibodies specific for the AT1 receptor possess advantageous and unexpected properties which

provide for the use of such analogues in the therapy or treatment of diseases. The inventors have produced both murine scFv analogues and humanised variants of the murine scFv analogues.

According to a first aspect of the invention, there is provided a specific binding molecule which specifically binds to a peptide having the amino acid sequence of EDGIKRIQDD and comprises a polypeptide having an immunoglobulin V_L domain linked to an immunoglobulin V_H domain in which the V_L domain comprises Complementarity Determining Regions (CDRs) VLCDR1, VLCDR2 and VLCDR3, and in which the V_H domain comprises Complementarity Determining Regions (CDRs) VHCDR1, VHCDR2, VHCDR3, each having a respective amino acid sequence as follows in which

VHCDR1 is GYSFTGYNMN
VHCDR2 is NIDPYYGGTTYNQKFKG
VHCDR3 is EVDY

VLCDR1 is RASKSVSTSTSGYSYMH
VLCDR2 is LVSNLES
VLCDR3 is QHIRELTRSEG

or an amino acid sequence at least 70% identical thereto.

In one embodiment, the present invention provides a specific binding molecule which specifically binds to a peptide having the amino acid sequence of EDGIKRIQDD and comprises a polypeptide having an immunoglobulin V_L domain linked to an immunoglobulin V_H domain in which the V_L domain comprises Complementarity Determining Regions (CDRs) VLCDR1, VLCDR2 and VLCDR3, and in which the V_H domain comprises Complementarity Determining Regions (CDRs) VHCDR1, VHCDR2, VHCDR3, each having a respective amino acid sequence as follows in which

VHCDR1 is GYSFTGYNMN or GYSFTGYNMS
VHCDR2 is NIDPYYGGTTYNQKFKG
VHCDR3 is EVDY

VLCDR1 is RASKSVSTSTSGYSYMH
VLCDR2 is LVSNLES
VLCDR3 is QHIRELTRSEG

or an amino acid sequence at least 80% identical thereto.

In another embodiment of the invention the CDRs of the specific binding molecule have amino acid sequences as follows

VHCDR1 is GYSFTGYNMN or GYSFTGYNMS
VHCDR2 is NIDPYYGGTTYNQKFKG
VHCDR3 is EVDY

VLCDR1 is RASKSVSTSTSGYSYMH
VLCDR2 is LVSNLES or LVSDLED
VLCDR3 is QHIRELTRSEG.

The CDRs are designated according to a combination of conserved sequence definition (Kabat *et al* in "Sequences of Proteins of Immunological Interest", Nat'l. Inst. Health, Bethesda, MD (1987)), and structural definition (Chothia and Lesk *J. Mol Biol.* **196**:901-17(1987)). These definitions were also subsequently described in Carter *et al, Proc Nat'l Acad Sci U S A.* **89**:4285-9 (1992).

Using the three letter and one letter codes the amino acids may also be referred to as follows: glycine (G or Gly), alanine (A or Ala), valine (V or Val), leucine (L or Leu), isoleucine (I or Ile), proline (P or Pro), phenylalanine (F or Phe), tyrosine (Y or Tyr), tryptophan (W or Trp), lysine (K or Lys), arginine (R or Arg), histidine (H or His), aspartic acid (D or Asp), glutamic acid (E or Glu), asparagine (N or Asn), glutamine (Q

or Gln), cysteine (C or Cys), methionine (M or Met), serine (S or Ser) and Threonine (T or Thr). Where a residue may be aspartic acid or asparagine, the symbols Asx or B may be used. Where a residue may be glutamic acid or glutamine, the symbols Glx or Z may be used. References to aspartic acid include aspartate, and glutamic acid include glutamate, unless the context specifies otherwise.

The present invention also extends to variants of peptide sequences referred to above. An example of a variant of the present invention is a fusion protein comprising a peptide as defined above, apart from the substitution of one or more amino acids with one or more other amino acids. The skilled person is aware that various amino acids have similar properties. One or more such amino acids of a substance can often be substituted by one or more other such amino acids without eliminating a desired activity of that substance.

Thus the amino acids glycine, alanine, valine, leucine and isoleucine can often be substituted for one another (amino acids having aliphatic side chains). Of these possible substitutions it is preferred that glycine and alanine are used to substitute for one another (since they have relatively short side chains) and that valine, leucine and isoleucine are used to substitute for one another (since they have larger aliphatic side chains which are hydrophobic). Other amino acids which can often be substituted for one another include: phenylalanine, tyrosine and tryptophan (amino acids having aromatic side chains); lysine, arginine and histidine (amino acids having basic side chains); aspartate and glutamate (amino acids having acidic side chains); asparagine and glutamine (amino acids having amide side chains); and cysteine and methionine (amino acids having sulphur containing side chains).

Substitutions of this nature are often referred to as "conservative" or "semi-conservative" amino acid substitutions.

Amino acid deletions or insertions may also be made relative to the amino acid sequence for the fusion protein referred to above. Thus, for example, amino acids which do not have a substantial effect on the activity of the polypeptide, or at least which do not

eliminate such activity, may be deleted. Such deletions can be advantageous since the overall length and the molecular weight of a polypeptide can be reduced whilst still retaining activity. This can enable the amount of polypeptide required for a particular purpose to be reduced - for example, dosage levels can be reduced.

Amino acid insertions relative to the sequence of the fusion protein above can also be made. This may be done to alter the properties of a substance of the present invention (e.g. to assist in identification, purification or expression, as explained above in relation to fusion proteins).

Amino acid changes relative to the sequence given above can be made using any suitable technique e.g. by using site-directed mutagenesis or solid state synthesis.

It should be appreciated that amino acid substitutions or insertions within the scope of the present invention can be made using naturally occurring or non-naturally occurring amino acids. Whether or not natural or synthetic amino acids are used, it is preferred that only L- amino acids are present.

"Identity" as known in the art is the relationship between two or more polypeptide sequences or two or more polynucleotide sequences, as determined by comparing the sequences. In the art, identity also means the degree of sequence relatedness between polypeptide or polynucleotide sequences, as the case may be, as determined by the match between strings of such sequences. While there exist a number of methods to measure identity between two polypeptide or two polynucleotide sequences, methods commonly employed to determine identity are codified in computer programs. Preferred computer programs to determine identity between two sequences include, but are not limited to, GCG program package (Devereux, et al., Nucleic acids Research, **12**, 387 (1984), BLASTP, BLASTN, and FASTA (Atschul et al., J. Molec. Biol. **215**, 403 (1990).

Preferably, the amino acid sequence of the CDRs of the invention have at least 70% identity, using the default parameters of the BLAST computer program (Atschul et

al., J. Mol. Biol. **215**, 403-410 (1990) provided by HGMP (Human Genome Mapping Project), at the amino acid level, to the amino acid sequences of the V_H and V_L CDRs described above.

More preferably, the CDR sequence may have at least 75%, 80%, 85%, 90%, 95%, 96%, 97%, 98% or at least 99% identity, at the amino acid level, to the sequences shown above.

In one embodiment of the invention, the specific binding molecule may have one of the following arrangement of CDRs

(R6313clone12D and humanised variants HuCY and var3)
VHCDR1: GYSFTGYNMN
VHCDR2: NIDPYYGGTTYNQKFKG
VHCDR3: EVDY
VLCDR1: RASKSVSTSTSGYSYMH
VLCDR2: LVSNLES
VLCDR3: QHIRELTRSEG

or

(R6313clone11B)
VHCDR1: GYSFTGYNMS
VHCDR2: NIDPYYGGTTYNQKFKG
VHCDR3: EVDY
VLCDR1: RASKSVSTSTSGYSYMH
VLCDR2: LVSNLES
VLCDR3: QHIRELTRSEG

or

(Humanised variant var4)

VHCDR1: GYSFTGYNMN
VHCDR2: NIDPYYGGTTYNQKFKG
VHCDR3: EVDY
VLCDR1: RASKSVSTSTSGYSYMH
VLCDR2: LVSDLED
VLCDR3: QHIRELTRSEG.

In one embodiment of the invention, the specific binding molecule may comprise a variable heavy chain (V_H) and a variable light chain (V_L) connected by a peptide linker. The linker may comprise from 1 to 20 amino acids, such as for example 1, 2, 3 or 4 amino acids, 5, 10 or 15 amino acids, or other intermediate numbers in the range 1 to 20 as convenient. The peptide linker may be formed from any generally convenient amino acid residues, such as glycine and/or serine. One example of a suitable linker is Gly_4Ser. Multimers of such linkers may be used, such as for example a dimer, a trimer, a tetramer or a pentamer, e.g. $(Gly_4Ser)_2$, $(Gly_4Ser)_3$, $(Gly_4Ser)_4$ or $(Gly_4Ser)_5$. However, in other embodiments of the invention no peptide linker may be present and the V_L domain may be linked to the V_H domain by a peptide bond.

The specific binding molecule may be a single-chain variable analogue (scFv). The specific binding molecule or scFv may be linked to other specific binding molecules (for example other scFvs, Fab antibody fragments, chimeric IgG antibodies (e.g. with human frameworks)) or linked to other scFvs of the invention so as to form a multimer which is a multi-specific binding protein, for example a dimer, a trimer or a tetramer. Bi-specific scFv's are sometimes referred to as diabodies, tri-specific such as triabodies and tetra-specific such as tetrabodies when each scFv in the dimer, trimer or tetramer has a different specificity. Diabodies, triabodies and tetrabodies can also be monospecific, when each scFv in the dimer, trimer or tetramer has the same specificity.

In one embodiment of the invention, the specific binding molecule may be the monoclonal antibody analogue scFv identified as R6313/G2. This scFv is also

referred to herein as R6313clone12D or clone 12D and has the sequence shown in Figure 14. In another embodiment of the invention, the specific binding molecule may be the monoclonal antibody analogue scFv identified as R6313clone11B, also referred to herein as clone 11B, whose sequence is also shown in Figure 14.

The scFv may be prepared by any suitable technique using standard chemical or molecular biology techniques. In one embodiment of the invention, the monoclonal antibody analogues can be prepared as scFv's from a naïve human antibody phage display library (McCafferty *et al., Nature* **348**, 552-554 (1990); and as described in WO 92/01047).

The monoclonal antibody analogue may be humanised by modifying the amino acid sequence of the scFv. Methods to reduce the immunogenicity of the specific binding molecules of the invention may include CDR grafting on to a suitable antibody framework scaffold or variable surface residues remodelling, e.g. by site-directed mutagenesis or other commonly used molecular biological techniques (Roguska *et al Protein Eng.* **9** 895-904 (1996)).

Other methods applicable can include the identification of potential T-cell epitopes within the molecule, and the subsequent removal of these e.g. by site-directed mutagenesis (de-immunisation). Humanisation of the specific binding molecule may be desired where the molecule is to be used as a therapeutic agent. Humanisation of the CDR regions or of the surrounding framework sequence may be carried out as desired.

The present inventors have produced humanised variants of the scFv R6313/G2, as described in the Examples.

In one embodiment of the invention, the specific binding molecule may be any one or more of the humanised scFvs identified as HuCY, var3 and/or var4. The sequences of these humanised scFvs are shown in Figure 14.

In another aspect of the invention there is provided a pharmaceutical composition comprising a specific binding molecule as described above.

The composition used in accordance with this aspect of the invention may be formulated for use by any convenient route. The medicament will usually be supplied as part of a sterile, pharmaceutical composition which will normally include a pharmaceutically acceptable carrier. The compositions of the invention may be employed in combination with a pharmaceutically acceptable carrier or carriers or a pharmaceutically acceptable adjuvant and/or diluent. Such carriers may include, but are not limited to, saline, buffered saline, dextrose, liposomes, water, glycerol, polyethylene glycol, ethanol and combinations thereof. This pharmaceutical composition may be in any suitable form (depending upon the desired method of administering it to a patient).

It may be provided in unit dosage form, will generally be provided in a sealed container and may be provided as part of a kit. Such a kit would normally (although not necessarily) include instructions for use. It may include a plurality of said unit dosage forms.

The pharmaceutical composition may be adapted for administration by any appropriate route, for example by the oral (including buccal or sublingual), rectal, nasal, topical (including buccal, sublingual or transdermal), vaginal or parenteral (including subcutaneous, intramuscular, intravenous or intradermal) route. Such compositions may be prepared by any method known in the art of pharmacy, for example by admixing the active ingredient with the carrier(s) or excipient(s) under sterile conditions.

Pharmaceutical compositions adapted for oral administration may be presented as discrete units such as capsules or tablets; as powders or granules; as solutions, syrups or suspensions (in aqueous or non-aqueous liquids; or as edible foams or whips; or as emulsions)

Suitable excipients for tablets or hard gelatine capsules include lactose, maize starch or derivatives thereof, stearic acid or salts thereof.

Suitable excipients for use with soft gelatine capsules include for example vegetable oils, waxes, fats, semi-solid, or liquid polyols etc.

For the preparation of solutions and syrups, excipients which may be used include for example water, polyols and sugars. For the preparation of suspensions oils (e.g. vegetable oils) may be used to provide oil-in-water or water in oil suspensions.

Pharmaceutical compositions adapted for transdermal administration may be presented as discrete patches intended to remain in intimate contact with the epidermis of the recipient for a prolonged period of time. For example, the active ingredient may be delivered from the patch by iontophoresis as generally described in *Pharmaceutical Research*, **3(6)**:318 (1986).

Pharmaceutical compositions adapted for topical administration may be formulated as ointments, creams, suspensions, lotions, powders, solutions, pastes, gels, sprays, aerosols or oils. For infections of the eye or other external tissues, for example mouth and skin, the compositions are preferably applied as a topical ointment or cream. When formulated in an ointment, the active ingredient may be employed with either a paraffinic or a water-miscible ointment base. Alternatively, the active ingredient may be formulated in a cream with an oil-in-water cream base or a water-in-oil base. Pharmaceutical compositions adapted for topical administration to the eye include eye drops wherein the active ingredient is dissolved or suspended in a suitable carrier, especially an aqueous solvent. Pharmaceutical compositions adapted for topical administration in the mouth include lozenges, pastilles and mouth washes.

Pharmaceutical compositions adapted for rectal administration may be presented as suppositories or enemas.

Pharmaceutical compositions adapted for nasal administration wherein the carrier is a solid include a coarse powder having a particle size for example in the range 20 to 500 microns which is administered in the manner in which snuff is taken, i.e. by rapid inhalation through the nasal passage from a container of the powder held close up to the nose. Suitable compositions wherein the carrier is a liquid, for administration as a nasal spray or as nasal drops, include aqueous or oil solutions of the active ingredient.

Pharmaceutical compositions adapted for administration by inhalation include fine particle dusts or mists that may be generated by means of various types of metered dose pressurised aerosols, nebulizers or insufflators.

Pharmaceutical compositions adapted for vaginal administration may be presented as pessaries, tampons, creams, gels, pastes, foams or spray formulations.

Pharmaceutical compositions adapted for parenteral administration include aqueous and non-aqueous sterile injection solution which may contain anti-oxidants, buffers, bacteriostats and solutes which render the formulation substantially isotonic with the blood of the intended recipient; and aqueous and non-aqueous sterile suspensions which may include suspending agents and thickening agents. Excipients which may be used for injectable solutions include water, alcohols, polyols, glycerine and vegetable oils, for example. The compositions may be presented in unit-dose or multi-dose containers, for example sealed ampoules and vials, and may be stored in a freeze-dried (lyophilized) condition requiring only the addition of the sterile liquid carried, for example water for injections, immediately prior to use. Extemporaneous injection solutions and suspensions may be prepared from sterile powders, granules and tablets.

The pharmaceutical compositions may contain preserving agents, solubilising agents, stabilising agents, wetting agents, emulsifiers, sweeteners, colourants, odourants, salts (substances of the present invention may themselves be provided in the form of a pharmaceutically acceptable salt), buffers, coating agents or antioxidants. They may also contain therapeutically active agents in addition to the substance of the present invention.

In some embodiments, the formulation of the active drug concentrate may comprise a pharmaceutically acceptable tonicity agent, a buffering agent, and a pharmaceutically acceptable surfactant.

Alternatively, the formulation may comprise the active ingredient plus sodium phosphate, monobasic, sodium phosphate dibasic, sodium chloride, polysorbate 80 or polysorbate 20 (surfactant to minimise risk of agitation-induced aggregation) and water (USP/Ph.Eur), optionally with a pH adjusted to about 6.0 to 7.0, e.g. around 6.5

The active drug concentrate may or may not be lyophilised.

Other formulations may comprise sodium acetate trihydrate as a buffering agent, sodium chloride as a tonicity modifier, acetic acid for pH adjustment, and water for injection.

The active drug concentrate may also be diluted in 0.9% sodium chloride prior to administration.

Dosages of the substance of the present invention can vary between wide limits, depending upon the disease or disorder to be treated, the age and condition of the individual to be treated, etc. and a physician will ultimately determine appropriate dosages to be used.

This dosage may be repeated as often as appropriate. If side effects develop the amount and/or frequency of the dosage can be reduced, in accordance with normal clinical practice.

For administration to mammals, and particularly humans, it is expected that the daily dosage of the active agent will be from 1μg/kg to 10mg/kg body weight, typically around 10μg/kg to 1mg/kg body weight. The physician in any event will determine the actual dosage which will be most suitable for an individual which will be

dependant on factors including the age, weight, sex and response of the individual. The above dosages are exemplary of the average case. There can, of course, be instances where higher or lower dosages are merited, and such are within the scope of this invention.

The specific binding molecules as described above can be used in medicine, for example in the treatment of cancer. Without wishing to be bound by theory, it is believed that cancers which contain the angiotensin type-1 receptor (AT1R) may be particularly susceptible to therapy using the specific binding molecules of the invention. Such cancers are numerous and include breast cancer, prostate cancer, ovarian cancer, uterine cancer, colorectal cancer, pancreatic cancer, pituitary gland cancer, choriocarcinoma, Hodgkins disease, skin cancer, kidney cancer, adrenal tumours, liver cancer, lung cancer, leukaemia and neuroblastoma cells.

This aspect of the invention therefore also includes a method for the treatment of cancer in a subject, comprising administering to the subject a specific binding molecule as described above. The invention therefore also extends to the use of a specific binding molecule as described above in the manufacture of a medicament for use in the treatment of cancer. The method of treatment may of a human or an animal subject and the invention extends equally to uses in both human and/or veterinary medicine.

In a further aspect of the invention, there is provided a combined preparation of a specific binding molecule as described above and angiotensin-II for the separate, simultaneous or subsequent administration for the treatment of cancer in a subject. The cancer may be as described above.

The invention also provides a composition comprising a specific binding molecule of the invention as defined above and angiotensin-II. Such compositions may be formulated as a pharmaceutical composition comprising a pharmaceutically acceptable adjuvant and/or diluent.

Alternatively, the invention also provides a kit of parts comprising a specific binding molecule of the invention and angiotensin II each formulated for pharmaceutical administration including, but not limited to, as tablets for oral administration, inhalers for lung administration and injectable solutions for intravenous administration.

Embodiments of the invention relating to the use of angiotensin II may comprises any generally convenient form of angiotensin suitable for use in human or veterinary medicine. Suitably, the angiotensin II may be supplied in the form of a freeze dried product in which the residue is derived from a solution that contained Angiotensin II, trehalose, human serum albumin and acetic acid. One source of pharmaceutical grade angiotensin II is NIBSC, South Mimms, UK which supplies Angiotensin II in the form of an ampoule containing freeze-dried residue prepared from 0.5ml of a solution a solution comprising 2.5μg Angiotensin II (Ileu5), 3mg trehalose, 1mg human serum albumin, 2 x 10^{-3} mol/l acetic acid.

Synthetic analogues of the variable regions of the 6313/G2 monoclonal antibody, such as the scFv referred to as R6313/G2, have unique and advantageous properties, especially when compared with the original hybridoma antibody. For example:

1. In intact nu/nu mice bearing cancer cells in hollow fibres, R6313/G2 significantly inhibited cancer cell growth. This is surprising because at concentrations of 13nmol/kg 2X per day, it had no effect on body weight, circulating aldosterone concentrations, or animal activity, i.e. other angiotensin related functions were unaffected. (Note: the original hybridoma antibody *increased* aldosterone secretion in vitro).

2. R6313/G2 alone inhibits T-47D cell invasion through reconstituted basement membrane matrix proteins (ECM) derived from the Engelbroth-Holm-Swam (EHS) mouse tumour at concentrations of 50 and 250 nmol/L (see Figure 9(b)). The purified monoclonal antibody (at 100nmol/L) has no significant inhibitory effect. Furthermore, in the presence of angiotensin II at 100nmolL (in Figure 9(b)) the effect of the R6313/G2 becomes significantly more pronounced at the

highest concentration of R6313/G2 (250nmol/L) – up to 25% inhibition of cell invasion over the 24 hour assay period.

3. In the presence of up to 100nmol angiotensin II per L R6313/G2, significantly inhibits breast cancer cell proliferation. This is surprising because the presence of angiotensin II is required, and R6313/G2 has no effect in the absence of angiotensin II

4. In intact rats *in vivo*, R6313/G2 significantly inhibits the stress-induced increases in blood pressure. This is surprising because it does not reduce and may even increase resting blood pressure.

5. In the presence, but not the absence, of up to 100nmol angiotensin II per L, R6313/G2 enhances caspase-driven apoptosis in breast cancer cells. The omission of angiotensin blocks its effects. Hence the presence of angiotensin II is surprisingly required for the activity of the R6313/G2

6. Surprisingly R6313/G2 was greatly more effective *in vivo* than *in vitro*. Thus a dose of 25nmol/Kg *in vivo* gave an anti-cancer cell effect equivalent to that achieved by 3.3micromol/L *in vitro*.

7. In intact nu/nu mice bearing xenograft cancer cell tumours, R6313/G2 significantly inhibited cancer cell growth, at 13nmol/kg, again without other effects.

8. As can be seen from Figure 12, there was increased binding to peptide antigen in resurfaced (humanised) scFv versus murine scFv. This therefore presents an advantage in terms of both potential cost per treatment and also gives benefit from having less potential to elicit an immune response in humans. Furthermore, the humanised variant var4 showed the most significantly increased binding compared to the parent murine scFv. This was surprising

since the one of the CDRs (VLCDR2) of this variant was modified with respect to the parent murine scFv.

Preferred features for the second and subsequent aspects of the invention are as for the first aspect *mutatis mutandis*.

In one embodiment, the present invention provides a specific binding molecule which comprises a polypeptide having a sequence shown in Figure 14.

The present invention will now be further described by way of example with reference to the following Examples which are present for the purposes of illustration only. In the Examples, reference is made to a number of figures in which:

FIGURE 1 shows immunoblotting for the angiotensin II receptor subtypes. AT1 receptor (A) and AT2 receptor (B) content was analysed in lysates of three breast cancer cell lines (Lane B, T47D; Lane C, MDA-MB-231; Lane D, MCF-7), and smooth muscle cells (Lane A). Only lysates from the three breast cancer cell lines (Lanes B-D) contained the AT2 receptor, though MDA-MB-231 cells contained relatively little: there was no detectable AT2 receptor in RASMC (Lane A).

FIGURE 2 shows (A) dose dependent inhibition of cell survival by R6313/G2 in the presence of 100nmol angiotensin II per L which was determined by XTT assay after48 hours. Threshold values (*) for the three cell lines (*P* <0.05 or better) were 0.05μM for MCF-7 and MDA-MB-231 cells, and 1.25μM for T47D cells; IC50 values were: 2.8μ mol/L, 1.53nmol/L and 30nmol/L for T47D, MDA-MB-231 and MCF-7 cells respectively. (B) Losartan alone produced a 43% inhibition of T47D cells at 25μmol/L, other cell types were unaffected at all concentrations used. Results are means of eight samples ± S.D.

FIGURE 3 shows (A and B) the effect of R6313/G2 on caspase-3/7 activity in T47D cells in the presence and absence of 100nmol/L angiotensin II after 12 hours and 48 hours. After 12 hours, angiotensin II inhibited caspase-3/7 activity compared with untreated control values and this inhibition was blocked by R6313/G2. This blocking action of R6313/G2 was less marked at the higher doses used, but after 48 hours R6313/G2 alone gave a dose-dependent increase of caspase-3/7 activity. (C) in MCF7 cells, R6313/G2 alone reduced caspase-3/7 activity, but in the presence of angiotensin II it dose dependently increased caspase-3/7 activity. Data are means of eight samples ± S.D. * P <0.05, ** P <0.01.

FIGURE 4 shows (A) In the *in vitro* hollow fibre assay, R6313/G2 dose dependently inhibited survival of all three breast cell lines (T47D, MCF-7 and MDA-MB-231) in the presence of angiotensin II after 48 h. (B) In the *in vivo* hollow fibre assay at the s.c. site, R6313/G2 dose dependently inhibited cell survival only in MCF-7 cells, though MDA MB 231 cells were inhibited at the highest dose. (C) In the *in vivo* hollow fibre assay at the i.p. site, R6313/G2 inhibited MCF7 cell survival in animals treated with 0.07 and 0.7 mg/kg (2.5 and 25 nmol/kg) twice per day, and in T47D and MBA MB 231 cells at 0.7 mg/kg (25 nmol/kg) twice per day. Values are expressed as means ± S.D. *P<0.05, **P<0.001. (D) Body weights of the experimental animals showed no changes during the period of treatment.

FIGURE 5 shows *in vivo* R6313/G2 treatment in the animals with MCF7 cell xenograft implants gave no weight loss at doses of 0.4 mg/kg (13 nmol/kg; —■—) and 0.8 mg/kg (27 nmol/kg; —▲—); twice per day, and there was no mortality during the treatment period, but in the 0.8 mg/kg group, four died by day 8. Body weight was significantly reduced in animals receiving 1.36 mg/kg (45.3 nmol/kg; —●— *P<0.05) and all died by day 8. Data are means ± S.E.M., n=8, except where indicated otherwise (n numbers in brackets). Control (—♦—).

FIGURE 6 shows *in vivo* actions of R6313/G2 on MCF-7 cell xenografts. (A) MCF-7 tumour volumes, means ± S.E.M. (B) Same data as for A, treated values expressed as percentages of the mean control values. $*P<0.05$, $**P<0.001$.

FIGURE 7 shows sample MCF7 cell xenografts in control (upper) and (lower) after treatment for 7 days with 0.4 mg/kg R6313/G2 twice per day for 7 days, as for Fig. 6.

FIGURE 8 shows blood pressures of rats treated with R6313/G2 (scFv, 0.4 mg/kg per day for 3 days) compared with controls (Con) receiving PBS alone. $*P<0.05$, comparison of Con and ScFv diastolic pressures.

FIGURE 9 shows a comparison between the purified monoclonal antibody from hybridoma supernatant (Mab; Figure 9a) and the scFv, R6313/G2 clone12D (scFv; Figure 9b), in a cellular invasion assay using T-47D breast cancer cells. In this assay invading cells will have broken through an established model of extracellular matrix. Figure 9b shows that scFv alone significantly inhibits T-47D cell invasion through reconstituted basement membrane matrix proteins (ECM) derived from the Engelbreth-Holm-Swam (EHS) mouse tumour at concentrations of 50 and 250 nmol/L (b). The purified monoclonal antibody (at 100nM) has no significant inhibitory effect. Furthermore, in the presence of angiotensin II (Ang II) at 100nmol/L (in b), the scFv effect becomes significantly more pronounced at the highest concentration of scFv (250nM).

FIGURE 10 shows the alignment of the full sequences of clones 12D and 11B. The effective amino acid sequence for the scFv variants begins at amino acid 9, and ends 9 residues from the end, of the sequence presented in this figure. The additional amino acids at each end include part of the pCANTAB 5E vector leader sequence (N-terminal to the scFv sequence), and peptide sequence including part of the E-tag expression peptide (C-terminal to the

scFv sequence) that was expressed using the pCANTAB 5E and used in affinity purification of the scFv. In particular, the effective amino acid sequence begins after an MA signal peptidase cleavage site that is part of the periplasmic targeting leader sequence and ends before a triple alanine bridging sequence and the GAPVPY E-tag sequence.

FIGURE 11 shows the alignment of the full sequences of clones 12D, 11B, 10D, 10E, 4F, 6C, 6E, 7F, 8B, 8C, 8D and 8E.

FIGURE 12 panels a-b represent four separate ELISA comparisons carried out in triplicate. This shows the amount of binding of five different scFv variants to peptide antigen (from AT1-receptor N-terminal region). Data shown as mean ± S.E.M. of the absorbance values at 450nm per μg protein/well after background subtraction.

FIGURE 13 shows an indirect comparison of murine scFv (12D) and engineered variant scFvs against purified IgM from original hybridoma. ELISA was carried out using an anti-His tag peroxidase secondary antibody conjugate (1:1000) for the scFvs, and an anti-IgM peroxidase secondary antibody conjugate (1:2500) for the hybridoma-derived IgM.

FIGURE 14 shows the alignment of the sequences of clones 12D, 11B and the humanised variants HuCY, variant 3 and variant 4.

FIGURE 15 Panel a) shows a comparison of change in resonance frequency, apparent on-rate in Hz/second, between the IgM and the scFv variants. These data were obtained using an Attana 100 QCM Biosensor and are expressed as mean ± S.E.M. of the resonance frequency of a streptavidin-coated QCM chip with biotinylated peptide antigen as binding target. ScFvs 12D, var3 and var4 showed significantly greater changes in resonance frequency over the 100 second injection period. Panel b) compares the apparent off-rates of the

various antibody proteins determined similarly. No significant differences in these terminal off-rates were observed under these experimental conditions.

Example 1: Preparation of scFv

The 6313/G2 mouse monoclonal antibody hybridoma was grown as previously described (Barker *et al J. Mol. Endocrinol.* **11** 241-245 (1993)). A pool of cDNA derived from mRNA was used to obtain heavy and light chains by PCR. A linker fragment encoding $(Gly_4Ser)_3$ was used to assemble the scFv library of inserts and a phage display library was created by directionally cloning these inserts into the pCANTAB 5 E phagemid vector (Amersham Pharmacia, High Wycombe, UK). An E-tag for the expressed sequence GAPVPYPDPLEPR was included in this vector and used in subsequent panning and purification steps. The phagemid library was then used to transform TG1 *E. coli,* and phagemid rescue was carried out using the M13KO7 helper phage followed by several rounds of panning. Positive expressing clones were identified by ELISA using 96 well plates coated with the original antigenic peptide (EDGIKRIQDD) and an anti-E-tag antibody (Amersham Pharmacia) detected using an HRP-linked secondary antibody. One particular clone was taken forward for expression and purification and functional assessment on the basis of giving the highest signal in the antigen ELISA.

The 6313/G2 scFv (R6313/G2, clone 12D) was purified using HiTrap E-tag columns (Amersham Pharmacia) followed by purification using a Protein L column (BD Clontech, Cowley, Oxford, UK) which binds immunoglobulins, including scFv. For in vitro and in vivo experiments it was necessary to carry out medium scale purification followed by overnight dialysis against PBS and concentration using 30 kDa cut-off concentrators (Millipore, Watford, UK). The final antibody stock was routinely reconstituted on PBS at a concentration of 10 mg/ml.

Monoclonal antibody used for comparison in invasion assay was purified using immobilised mannan binding protein column (Perbio Science UK Ltd) followed by concentration using 100 kDa molecular weight cut-off filters.

Preliminary studies seem to show highest activity is associated with clones R6313clone12D (also described as R6313/G2) and R6313clone11B, in which the CDRs are as follows:

R6313clone12D
VHCDR1: GYSFTGYNMN
VHCDR2: NIDPYYGGTTYNQKFKG
VHCDR3: EVDY
VLCDR1: RASKSVSTSTSGYSYMH
VLCDR2: LVSNLES
VLCDR3: QHIRELTRSEG

or

R6313clone11B
VHCDR1: GYSFTGYNMS
VHCDR2: NIDPYYGGTTYNQKFKG
VHCDR3: EVDY
VLCDR1: RASKSVSTSTSGYSYMH
VLCDR2: LVSNLES
VLCDR3: QHIRELTRSEG

These were significantly stronger binders to the antigen in an ELISA plate assay during panning of the cDNA library derived from RNA from the original hybridoma cell population. The only change in the CDRs is in VHCDRH1. However, there is also one other difference between the two sequences at the N-terminus, KLQQ and QLQE, respectively. An additional ten clones show other changes in CDRs and elsewhere in the structure (see Figure 11), however in the ELISA assay these bound less strongly to the ELISA antigen plate.

The full sequences of clones 12D and 11B are aligned as shown in Figure 10. The first 6 amino acids and last 8 amino acids are the leading sequences from the pCANTAB 5E vector, with the last 5 comprising part of the E-tag present in the expressed protein product used in these experiments.

The effective amino acid sequences of clones 12D and 11B are shown in Figure 14.

Example 2: Activity assays

The activity of the scFv R6313/G2 was studied in the following assays:

Cell culture procedures:

MCF-7, T47D and MDA-MB-231 breast cancer cells were obtained from The American Tissue Culture Collection (LGC Promochem, Teddington, UK). Rat aortic smooth muscle cells (RASMC) were developed from primary culture (Barker et al., 1996). MCF-7 cells were maintained in Minimal Essential Medium (MEM), T47D and MDA-MB-231 cells in RPMI 1640 medium, and RASMC were maintained in Dulbecco's Modified Eagle's Medium (DMEM). All media were supplemented with 2mM L-glutamine, 10% fetal bovine serum (FBS), 50U/ml penicillin and 0.05mg/ml streptomycin. Cells were maintained at 37°C in a humidified atmosphere (95% oxygen, 5% CO_2).

Cell viability assay:

Confluent cell monolayers were removed from tissue culture flasks using trypsin/EDTA. Cells ($15x10^3$ per well) were seeded into 96 well tissue culture plates containing the appropriate medium for each cell line. After 24 hours, cells were treated with angiotensin II (100nM) and R6313/G2 at a range of concentrations from 0.005 to 25μM, or with losartan at a similar concentration range, and incubated for a further 48 hours. Cell viability was assessed by the ability of metabolically active cells to reduce 2, 3-bis [2-Methoxy-4-nitro-5-sulphophenyl]-2H-tetrazolium-5-carboxyanilide inner salt (XTT) to the coloured formazan product. Absorbance was measured using a Multiskan Ascent microplate reader (Thermo Labsystem, Helsinki, Finland) at a wavelength of 450nm and a reference wavelength of 630nm. Each measurement was performed in triplicate. IC50s were calculated using a non-linear regression formula using GraphPad Prism v4.0 software (GraphPad Software Inc, San Diego CA, USA).

Protein Extraction and Western blotting:

Cells were grown in the presence or absence of angiotensin II (100nmol/L) for 24 hours then washed three times in sterile PBS (pH 7.4), incubated for 5 minutes in lysis buffer (PBS pH 7.4, 1% NP-40/Triton X-100, 0.1% SDS and 0.5% sodium deoxycholate, with the protease inhibitors leupeptin 10μg/ml, aprotinin 30μg/ml and 0.1mmol/L phenylmethylsulphonylfluoride), and harvested. Cell lysates were homogenised using an ultrasonicator (2x5 sec cycles; Bandelin Sonoplus, SLS, Hessle UK). After homogenisation the samples were centrifuged at 20,000 g for 10 minutes at 4°C. The supernatants were removed and stored at -80°C. Protein concentrations were estimated using the Bio-Rad protein assay (Bio-Rad Laboratories, Hemel Hempstead UK). For western blotting, samples containing 50μg of total cell lysate were loaded on to a 10% SDS-polyacrylamide gel and subjected to electrophoresis. Proteins were transferred to Hybond-C membranes (Amersham Biosciences Ltd, Chalfont St Giles UK) in transfer buffer (39mmol/L glycine, 48mmol/L Tris-Base, 20% methanol, and 0.037% SDS), using a transBlot transfer apparatus (Bio-Rad Laboratories, Hemel Hempstead UK) at 120mA for 1.5 hours at 4°C. Membranes were washed and then incubated in blocking buffer (1X Tris-Buffered Saline (TBS), 0.1% Tween 20 and 5% dried milk) for 1 hour at room temperature and subsequently washed three times for 10 minutes in washing buffer (1X TBS and 0.1% Tween 20). The membranes were incubated with polyclonal rabbit anti-AT1 receptor or anti-AT2 receptor antibodies at a dilution of 1:500 in blocking buffer. After overnight incubation at 4°C, the membranes were washed as described above and incubated with anti rabbit IgG secondary antibody (Amersham Biosciences) (1:2000) for 1 hour at room temperature. Additional washes were carried out and immune detection was performed by incubating the membranes for 1 minute in ECL western blotting detection reagent (Amersham Biosciences), and exposed to a Biomax chemiluminescence detection film (Kodak, Rochester NY, USA).

Apoptosis – Caspase-3/7 activity:

Activation of caspases during apoptosis was determined using the Apo-ONE homogenous caspase-3/7 assay (Promega Corp, Southampton UK), according to the manufacturer's instructions. Briefly, cells were grown to 90% confluence and washed

three times with sterile PBS. Cells were harvested using Trypsin/EDTA and counted. Cells (10^4 per well) were seeded into a 96 well plate and incubated with R6313/G2 at concentrations from 0.1 to 3μM in the presence or absence of 100nmol/L angiotensin II, total volume 150μl, for 24 and 48 hours. After incubation, caspase-3/7 Z-DEVD-R110 substrate (100μl) was added to each well. Blank wells contained reagent alone, and controls omitted the antibody and/or angiotensin II. Fluorescence was measured every 2 hours over an 8 hour period using a Fluostar Optima spectrofluorimeter (BMG Laboratories, Offenburg Germany), with an excitation wavelength of 485nm and an emission wavelength of 535nm.

Hollow Fibre Assay

Hollow Fibre procedures followed the method of Hollingshead. (Hollingshead *et al Life Sci* **57** 131-41(1995)).

Preparation of hollow fibres:

Polyvinylidene difluoride (PVDF) hollow fibres (500 kDa cut-off, 1mm inner diameter; Spectrum Europe B.V., Breda, Netherlands) were flushed through with 70% ethanol using a blunt 21 gauge needle and 10ml syringe. Fibres were then immersed in 70% ethanol for 72 hours, flushed through again with 70% ethanol, then distilled water, and then autoclaved at 131°C. Finally, before loading cell suspensions, fibres were flushed through with RPMI 1640 culture medium. Cells (MCF-7, T47D, and MDA-MB-231) were introduced into fibres at densities of 2.5 to 3.0 x10^6 cells/ml. Fibres were then heat-sealed at 2 cm intervals and placed in Petri dishes containing 3 ml of the cell appropriate medium.

To test the efficacy of the method before use in vivo, cell-loaded fibres were incubated in vitro for 48 hours in the presence or absence of antibody at a range of concentrations from 0.33μM to 33μmol/L and angiotensin II (100nmol/L).

In vivo hollow fibre assay:

Cell-loaded hollow fibre segments were incubated at 37°C in culture medium overnight before implantation into pure strain 5-6 week old female balb/c nu/nu mice. Fibres were implanted into the animals under anaesthesia (2% Isofluorane). Three 2cm fibres, each containing one of the cell lines MCF-7, T47D, or MDA-MB-231, were implanted at both subcutaneous (s.c.) and intraperitoneal (i.p.) sites into each animal. For i.p. implants, a small incision was made through the skin and musculature of the ventral abdominal wall. Fibres were placed into the peritoneal cavity and both incisions were closed with metallic suture clips (Harvard Instruments, Edenbridge UK). For s.c. implants, a small incision was made dorsally. The fibres were implanted to the left of the dorsal midline in a cranial direction. The small incision was closed with metallic suture clips.

Antibody treatment:

Mice (n=5/group) with hollow fibre implants were treated with R6313/G2 (0.07mg/kg (2.5nmol/kg), and 0.7mg/kg (25nmol/kg) in 0.1ml PBS, subcutaneously) twice per day for six days. Control animals (n=5) received vehicle alone. 24 hours after the last injection, animals were killed by cervical dislocation and the fibres were recovered and transferred to pre-warmed RPMI 1640 medium containing 20% FBS for 30 minutes.

Assessment of tumour cell growth within hollow fibres:

Cell viability was measured using a modified MTT assay. Fibres were incubated in RPMI 1640 with 20% FBS containing 1mg/ml MTT, and incubated at 37°C under 95% O_2, 5% CO_2 for 4 hours. The reagent was aspirated, and 2ml sterile filtered 2.5% protamine sulphate (0.9g NaCl, 2.5g protamine sulphate in 100ml water) was added. Specimens were stored at 4°C for a minimum of 24 hours in the dark to fix the formazan product. Fresh protamine sulphate (2.5%) was added and fibres were stored for a further 2 to 4 hours at 4°C. Each fibre was transferred to a well in a 24 well plate, cut in half and air-dried overnight, protected from light. Dimethyl sulphoxide (DMSO) (300µl) was added to each well and the formazan product extracted. An aliquot (190µl) from each well was transferred to a 96 well plate and absorbance read

at 540nm using a Multiskan Ascent photometric microplate reader (Thermo labsystem). Treated values were calculated as a percentage of the controls.

In vivo Xenograft Assay:

Mice were injected s.c. on the right-flank, with 150µl sterile PBS containing $7.5x10^6$ MCF-7 cells. Tumour cells were allowed to grow for 4 weeks without hormone support, thereafter mice received weekly s.c. injections of 17β-oestradiol valerate (0.1 mg/Kg body weight), in sesame oil (Kasukabe *et al., Breast Cancer Res.* 7(6) R1097-110 (2005)) for a further 8 weeks. Animals were monitored daily for general health, and body weights were measured twice-weekly. Tumour size was measured 3 times per week with slide callipers, and volumes were calculated as $(L \times W^2)/2$, where L and W are the major and minor diameters, respectively. Once tumour volumes reached 150 to 200 mm^3, mice were randomized to treatment and control groups of 8 to 10 per group. Mice were treated by subcutaneous injections of R6313/G2 in sterile PBS (0.1ml) at doses of 0.4mg/kg (13 nmol/kg), 0.8mg/kg (27 nmol/Kg), and 1.36mg/kg (45.3nmol/kg) body weight, twice per day for seven days. Control mice received sterile PBS. At the termination of the study, animals were sacrificed by cervical dislocation. Relative body weights (%) were calculated as (Wt/Wi) X 100, where Wt is the body weight at any given time and Wi is the body weight at treatment initiation. Net tumour volume was calculated as Vt-Vi, where Vt is the tumour volume at any given time and Vi is the tumour volume at the start of treatment, and expressed as a percentage of Vi.

Rat Blood pressure

Rats were chosen for this part of the study in view of their greater tractability in blood pressure assays. Female Wistar rats were first acclimatised to handling and the blood pressure equipment for 4-5 days before experimentation. Blood pressure in the conscious animals was determined using a Kent Scientific Corporation (Torrington CT, USA) Coda 6+ tail cuff system in which the animals were held in warmed restrainers while blood pressures were assessed. Animals were first stabilised and their basal blood pressure taken before treatment. They were then briefly removed from the restrainers for sc injection of R6313/G2, 0.4mg/kg in sterile PBS (0.1ml).

Controls received PBS alone. Blood pressures were then taken at intervals over a period of 1 hour, before restoring to cages. The procedures were repeated daily for 3 days.

Statistical Analysis:

All data were presented as means ± SE. Statistical analysis was performed using one-way ANOVA. In the case of a significant result in the ANOVA, Student's *t*-test was used for the dose-response curves. A *P* value less than 0.05 was considered statistically significant.

Fluorimetric Invasion assay

The method used is QCM™ Cell invasion assay (Chemicon Cat No. ECM555). This uses fluorimetric detection of cells which have broken through a reconstituted basement membrane matrix proteins (ECM) derived from the Engelbreth-Holm-Swam (EHS) mouse tumour (Repesh LA (1989) Invasion Metastasis 9: 192-208)

ECM-coated inserts were placed in 96-well plates and 100 µl of prewarmed serum-free medium added to the interior of the inserts in order to hydrate the ECM layer over 1-2h at room temperature. Media was removed and 150 µl of serum free medium added to the wells of the 96-well plate housing the inserts. 100 µl of medium containing 10^5 cells/per insert was then introduced. The plate was covered and incubated at 37C in a 5% CO2/95% air humidified incubator for 24h. After removing cells from inside the insert and rinsing with PBS, the insert was replaced into a 96-well plate containing Cell Detachment Solution and incubated at 37C for 30 min. Cells that had invaded through the ECM to the bottom of the insert were, in this way, dislodged from the insert for subsequent lysis and measurement of fluorescence using a 480/520 filter set in a Fluostar Optima fluorimeter (BMG Labtech), according to manufacturer's instructions.

Example 3: Design of humanised variants

The humanised variants were based on the murine sequence 12D described above. The amino acid substitutions were chosen by using a combination of previously

published approaches together with a degree of intellectual latitude. Firstly, the murine scFv sequence was used to find the most homologous variable heavy and variable light chains in the NCBI database using a BLAST search. Secondly, the approach described by Padlan (*Molecular Immunology* **28(4/5)** 489-498 (1991)) was used to indicate which amino acid residues were likely to be exposed (i.e. hydrophilic) or buried (hydrophobic) residues in the whole scFv molecule. Reference to the article by Padlan also provided options for which human germ-line amino acids could be used to substitute appropriately for murine residues and in this way generate a resurfaced scFv where, in general, replacement of these exposed murine residues would result in a less immunogenic whole scFv protein.

An additional two substitutions were included either side of one of the CDRs (hence CY) that were considered to be sensible to change because the human germ-line residues in these two positions were completely conserved across four subgroups of variable regions, in accordance with the disclosure of Padlan (*supra*).

All three of the humanised variants identified by this approach, HuCY, var3 and var4, bind to the peptide antigen (from the AT1-receptor N-terminal region) more strongly by ELISA than the two murine scFvs, 12D and 11B.

The murine scFv protein sequence was modified only in the framework regions contained within the variable heavy and variable light chains in order to produce the humanised variants HuCY and var3. However, the humanised variant var4 also has two further changes in CDR2 of the light chain.

The CDRs of the humanised variants are as follows:

HuCY and var3
VHCDR1: GYSFTGYNMN
VHCDR2: NIDPYYGGTTYNQKFKG
VHCDR3: EVDY
VLCDR1: RASKSVSTSTSGYSYMH

VLCDR2: LVSNLES
VLCDR3: QHIRELTRSEG

var4
VHCDR1: GYSFTGYNMS
VHCDR2: NIDPYYGGTTYNQKFKG
VHCDR3: EVDY
VLCDR1: RASKSVSTSTSGYSYMH
VLCDR2: LVSDLED
VLCDR3: QHIRELTRSEG

The sequences of clones 12D, 11B and of the humanised variants HuCY, variant 3 and variant 4 are shown in Figure 14.

Example 4: Activity assays on humanised variants

The activity of the humaised variants was studied in the following assays:

ScFv production and purification for comparative binding studies

All gene sequences were synthesised by Blue Heron Biotechnology (Bothell, WA, USA) and integrated into a bacterial protein expression vector, upstream from a His-tag encoding sequence under the control of a T7*lac* promoter. The vector used included a periplasmic targeting leader sequence that is cleaved by signal peptidase after reaching the periplasmic space in the bacterial host. The skilled person will understand that other suitable vectors can also be used to produce the scFvs of the invention.

These constructs were transformed into Rosetta 2(DE3) competent cells (Merck-Novagen), according to manufacturer's protocol. Strains were routinely grown in LB broth or LB agar at 37°C, with 30 mg/litre kanamycin and 34 mg/litre chloramphenicol. Protein expression was carried out using 1L bacterial cultures, grown for 24 hours in 2L baffled flasks at 37°C. Protein production was then induced by the addition of IPTG, at a final concentration of 0.4mM, for 5 hours at 25°C.

Bacterial cell pellets were harvested in a Beckman Coulter Avanti J-30I centrifuge at 5000 *g* (rcf) for 20 minutes at 4°C, the cell pellet was then resuspended in 10ml (per litre culture) in the following buffer, 0.4M Tris-HCL pH 8, 1mM EDTA. The resulting cell pellets were then stored at -20°C until purification.

To prepare the periplasmic fraction, the 1L pellets were thawed and the following buffers added: 10ml of 1M sucrose and 30ml of 1/5 TES buffer (40mM Tris-HCL pH 8, 0.1mM EDTA, 0.1M sucrose and 5mM $MgSO_4$). This cell suspension was then agitated on ice for 40 minutes, before centrifuging at 17418 *g* (rcf) for 20 minutes at 4°C to separate the soluble periplasmic supernatant. This osmotic shock protocol is a modified version of a method given in the Novagen manual, taken from Ausubel *et al., Current Protocols in Molecular Biology*, John Wiley & Sons, New York (1989).

Periplasmic fractions were then filtered through 0.45μM filters and applied to 1ml pre-poured His-bind columns charged with $NiSO_4$ (Merck-Novagen). The purification was performed according to pET system manual instructions, using buffers supplied in the His-Bind Buffer kit (Merck-Novagen). The resulting eluate was buffer exchanged by passage through a PD-10 column (Pharmacia), which had previously been equilibrated in phosphate buffered saline pH 7.4 (PBS; Sigma P4417). The resulting scFv fraction was then concentrated using a 10 kDa molecular weight cut off spin concentrator (Amicon). The concentration of the scFv fraction in PBS was verified by running 10-15% SDS-polyacrylamide gels, performing Bio-Rad protein assays and recording a UV absorbance at 280nm, the latter being converted to a concentration by dividing by the extinction coefficient (molar extinction coefficient divided by the molecular weight of the protein - ~25.7kDa) of 1.7.

IgM for comparative binding studies was purified as previously described for cellular invasion studies. The extinction coefficient used for IgM was 1.18 (Johnstone A, Thorpe R. *Immunochemistry in practice.* 2nd ed. Oxford: Blackwell Scientific Publications (1987)).

Testing of antigen binding using ELISA

Enzyme-linked immunosorbant assays (ELISAs) were carried out in Maxisorp 96-well plates coated with Peptide antigen EDGIKRIQDDC-biotin (2-8ug/ml in carbonate buffer pH 9.6) overnight at 4 or 37C. The coated wells were blocked using 1% alkaline soluble casein (Blocking buffer) for 1h at RT, then washed three times with PBS containing 0.1% v/v Tween 20. ScFv samples diluted between 1:1 to 1:100 in PBS-T were added and incubated for 1h at RT before washing as before. A secondary HRP-conjugated anti-His-Tag antibody was then added (diluted 1:1000 in blocking buffer) for 1h at RT. Wells were then washed three times in PBS-T then twice with PBS (without Tween 20). 100 µl of TMB substrate solution was added and colour was allowed to develop for 30 min, at which time 100 µl of 2M sulphuric acid was added to stop the reaction. Absorbance at 450 nm was read on a plate reading spectrophotometer. Protein concentrations were determined using an Eppendorf Biophotometer reading at 280 nm and using an extinction coefficient for the scFv of 1.7 as above. The results are shown in Figure 12.

As can be seen from Figure 12, there was increased binding to peptide antigen in resurfaced scFv (HuCY, var3 and var4) versus murine scFv (12D and 11B). It was unexpectedly observed that the changes made in the framework regions of the murine scFv resulted in a protein, HuCY, that bound to the antigenic peptide EDGIKRIQDDC-biotin 5-fold more avidly in an ELISA when compared with the same amount and purity of the murine scFv. Furthermore, the humanised variant var4 showed a 5-10 fold increase in binding to the antigen compared with the parent murine scFv. This is surprising since the one of the CDRs (VLCDR2) of var4 was modified with respect to the parent murine scFv.

Figure 13 shows an indirect comparison of murine scFv (12D) and engineered variant scFvs (HuCY and var4) against purified IgM from original hybridoma. As can be seen from Figure 13, the variant scFvs had higher activity than the murine scFv.

Comparison of binding characteristics using a Quartz Crystal Microbalance

Data were obtained comparing the characteristics of binding of the scFv variants and IgM to immobilised peptide antigen using the Attana 100 Quartz Crystal Microbalance. This involved use of a streptavidin (0.1mg/ml)-coated biotin "chip" (gold-plated quartz crystal in an Attana 100 Biosensor (Quartz crystal microbalance (QCM)) (Attana AB, Stockholm, Sweden). Peptide antigen corresponding to that sequence used to raise the original murine hybridoma, biotinylated at the C-terminus, was then run across the chip at a concentration of 4μg/ml to create a binding target for scFvs and IgM that were subsequently run across the surface of the QCM chip. Attester software (Attana, Sweden) was used to monitor changes in resonance frequency of the QCM chip in response to binding of a test antibody to the antigen. The magnitude of deflection in Hz over the period of sample injection of 100s in Hz/second was determined for each antibody at a concentration of 9μg/ml. The rate at which the antibody was then released from the QCM chip was also measured in Hz/second from the straight-line portion of the biosensor trace as antibody gradually departed from the chip and as the resonance frequency of the chip decreased. Running buffer was PBS containing 0.005% Tween 20 (PBST) and this was also used to make antibody dilutions to give a final protein concentration of 9μg/ml in each case. The Attana 100 was set up with a 50μl injection loop and was running with a constant pump speed of 20μl/min. Samples and PBST buffer controls were injected over 100 seconds giving a sample volume across the chip of 33μl. 100mM (6.6μl volume) phosphoric acid solution was used to regenerate the strepavidin-antigen surface between individual experimental sample runs.

The results are shown in Figure 15. ScFvs 12D, var3 and var4 showed significantly greater increases in resonance frequency over the injection period compared with that for the IgM, whilst no significant differences were observed in the rate at which the antibody was released from the QCM chip under these experimental conditions.

CLAIMS

1. A specific binding molecule which specifically binds to a peptide having the amino acid sequence of EDGIKRIQDD and comprises a polypeptide having an immunoglobulin V_L domain linked to an immunoglobulin V_H domain in which the V_L domain comprises Complementarity Determining Regions (CDRs) VLCDR1, VLCDR2 and VLCDR3, and in which the V_H domain comprises Complementarity Determining Regions (CDRs) VHCDR1, VHCDR2, VHCDR3, each having a respective amino acid sequence as follows in which

VHCDR1 is GYSFTGYNMN
VHCDR2 is NIDPYYGGTTYNQKFKG
VHCDR3 is EVDY

VLCDR1 is RASKSVSTSTSGYSYMH
VLCDR2 is LVSNLES
VLCDR3 is QHIRELTRSEG

or an amino acid sequence at least 70% identical thereto.

2. A specific binding molecule as claimed in claim 1 in which the CDRs have amino acid sequences as follows

VHCDR1 is GYSFTGYNMN or GYSFTGYNMS
VHCDR2 is NIDPYYGGTTYNQKFKG
VHCDR3 is EVDY

VLCDR1 is RASKSVSTSTSGYSYMH
VLCDR2 is LVSNLES or LVSDLED
VLCDR3 is QHIRELTRSEG.

3. A specific binding molecule as claimed in claim 1 or claim 2 in which the CDRs have amino acid sequences as follows

VHCDR1 is GYSFTGYNMN
VHCDR2 is NIDPYYGGTTYNQKFKG
VHCDR3 is EVDY
VLCDR1 is RASKSVSTSTSGYSYMH
VLCDR2 is LVSNLES
VLCDR3 is QHIRELTRSEG

or

VHCDR1 is GYSFTGYNMS
VHCDR2 is NIDPYYGGTTYNQKFKG
VHCDR3 is EVDY
VLCDR1 is RASKSVSTSTSGYSYMH
VLCDR2 is LVSNLES
VLCDR3 is QHIRELTRSEG

or

VHCDR1 is GYSFTGYNMN
VHCDR2 is NIDPYYGGTTYNQKFKG
VHCDR3 is EVDY
VLCDR1 is RASKSVSTSTSGYSYMH
VLCDR2 is LVSDLED
VLCDR3 is QHIRELTRSEG.

4. A specific binding molecule as claimed in any one of claims 1 to 3 comprising a polypeptide having an amino acid sequence as shown in Figure 14.

5. A pharmaceutical composition comprising a specific binding molecule as claimed in any one of claims 1 to 4.

6. A specific binding molecule as claimed in any one of claims 1 to 4 for use in medicine.

7. A specific binding molecule as claimed in any one of claims 1 to 4 for use in the treatment of cancer.

8. A method for the treatment of cancer in a subject, comprising administering to the subject a specific binding molecule as claimed in any one of claims 1 to 4.

9. The use of a specific binding molecule as claimed in any one of claims 1 to 4 in the manufacture of a medicament for use in the treatment of cancer.

10. A combined preparation of a specific binding molecule as claimed in any one of claims 1 to 4 and angiotensin-II for the separate, simultaneous or subsequent administration for the treatment of cancer in a subject.

11. A composition comprising a specific binding molecule as claimed in any one of claims 1 to 4 and angiotensin-II.

12. A pharmaceutical composition comprising a specific binding molecule as claimed in any one of claims 1 to 4 and angiotensin-II.