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Inhibitors of the integrin $\alpha_v\beta_6$

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The invention describes novel peptides which, as ligands of the integrin $\alpha_v\beta_6$, are biologically active. These peptides all have a common structural motif, namely - **Asp Leu Xaa Xaa Leu** -, or in a preferred form - Arg Xaa **Asp Leu Xaa Xaa Leu** Arg -, where Xaa is any desired amino acid residue. The peptides according to the invention can be employed as effective inhibitors of the $\alpha_v\beta_6$ integrin receptor and thus for the treatment of various diseases and pathological findings.

Integrins belong to the Class I family of heterodimers - transmembrane receptors which play an important part in numerous cell-matrix and cell-cell adhesion processes (Tuckwell et al., 1996, Symp. Soc. Ex. Biol. 47). They can be roughly divided into three classes: the β_1 integrins, which are receptors for the extracellular matrix, the β_2 integrins, which are activatable on leucocytes and are "triggered" during inflammatory processes, and the α_v integrins, which affect the cell response during wound healing and other pathological processes (Marshall and Hart, 1996, Semin. Cancer Biol. 7, 191).

The integrins $\alpha_5\beta_1$, $\alpha_{IIb}\beta_3$, $\alpha_8\beta_1$, $\alpha_v\beta_1$, $\alpha_v\beta_3$ and $\alpha_v\beta_6$ all bind to the Arg-Gly-Asp (RGD) peptide sequence, e.g. in the natural ligand fibronectin. Soluble RGD-containing peptides are able to inhibit the interaction of each of these integrins with fibronectin. $\alpha_v\beta_6$ is a relatively rare integrin (Busk et al., 1992 J. Biol. Chem. 267(9), 5790), which is formed in increased amounts during repair processes in epithelial tissue and preferably binds the natural matrix molecules fibronectin and tenascin (Wang et al., 1996, Am. J. Respir. Cell Mol. Biol. 15(5), 664). The physiological and pathological functions of $\alpha_v\beta_6$ are still not precisely known; however, it is suspected that this integrin plays an important part in physiological processes and disorders

(e.g. inflammations, wound healing, tumours) in which epithelial cells are involved. Thus $\alpha_v\beta_6$ is expressed on keratinocytes in wounds (Haapasalmi et al., 1996, J. Invest. Dermatol. 106(1), 42), from which it is to be assumed that in addition to wound healing processes and inflammations other pathological skin events, such as, for example, psoriasis, can also be influenced by agonists or antagonists of the said integrin. $\alpha_v\beta_6$ furthermore plays a part in respiratory tract epithelium (Weinacker et al., 1995, Am. J. Respir. Cell Mol. Biol. 12(5), 547), so that appropriate agonists/antagonists of this integrin could be successfully employed in respiratory tract disorders, such as bronchitis, asthma, pulmonary fibroses and respiratory tract tumours. Finally, it is known that $\alpha_v\beta_6$ also plays a part in the intestinal epithelium, so that appropriate integrin agonists/antagonists could be used in the treatment of inflammations, tumours and wounds of the stomach/intestinal tract.

Up to now, no low-molecular-weight inhibitor has yet been found which binds selectively to the $\alpha_v\beta_6$ integrin. It was thus the object to find, in addition to the natural high-molecular-weight ligands and antibodies known hitherto, which are difficult to handle therapeutically and diagnostically, potent, specific or selective low-molecular- weight ligands for $\alpha_v\beta_6$, preferably peptides, which can be used for the therapeutic areas mentioned but also as a diagnostic or reagent.

It has been found that the peptide compounds of the formulae presented below and their salts as soluble molecules exert an action on cells which carry the receptor mentioned, or when they are bound to surfaces are artificial ligands for $\alpha_v\beta_6$-mediated cell adhesion. They especially act as $\alpha_v\beta_6$ integrin inhibitors, particularly inhibiting the interactions of the receptor with other ligands, such as, for example, the

binding of fibronectin. This action can be demonstrated by the method which is described by J.W. Smith et al. in J. Biol. Chem. 265, 12267-12271 (1990).

The dependence of the origin of angiogenesis on the interaction between vascular integrins and extracellular matrix proteins is described by P.C. Brooks, R.A. Clark and D.A. Cheresh in Science 264, 569-71 (1994).

It was furthermore found that the new substances have very valuable pharmacological properties together with good tolerability and can be employed as medicaments. This is described in greater detail further below.

The peptide compounds according to the invention can furthermore be used *in vivo* as diagnostics for the detection and localization of pathological conditions in the epithelial system if they are equipped with the appropriate markers (e.g. the biotinyl radical) according to the prior art. The invention also encompasses conjugates with other active compounds, such as cytotoxic active compounds, as well as conjugates with radiolabels for radiotherapy or PET diagnosis but also fusion proteins with marker proteins such as GFP or antibodies, or therapeutic proteins such as IL-2.

The invention thus relates to peptide compounds of the formula **I**

$$W^1\text{-}X^1{}_n\text{Arg } X^2 \text{ Asp Leu } X^3X^4\text{Leu } X^5X^6{}_m\text{-}W^2 \qquad \textbf{I}$$

in which:

X^1, X^2, X^3, X^4, X^5, X^6 each independently of one another are an amino acid residue, the amino acids independently of one another being selected from a group consisting of Ala, Asn, Asp, Arg, Cys, Gln, Glu, Gly, Phe, His, Ile, Leu, Lys, Met, Nle, homo-Phe, Phg, Pro, Ser, Thr, Trp, Tyr or Val, and the amino acids mentioned possibly also being derivatized,

W^2 is selected from a group OH, OR, NHR, NR_2, NH_2,
W1 is H or an acyl radical

R is alkyl having 1-6 C atoms and

n,m each independently of one another are a number from 0-15. In the cases in which m or n assumes a value of greater than 1, the radicals X^1 and X^6 can each independently of one another be identical or different.

According to the invention, those amino acids or amino acid residues are also encompassed which, starting from the natural amino acids, are derivatized, or are homologues or isomers thereof. The amino acid residues are customarily linked to one another via their α-amino and α-carboxyl groups (peptide bonding).

The invention furthermore preferably relates to those peptide compounds in which X^2 is an amino acid residue which was selected from the group consisting of Thr, Ser, Asp and glycine, furthermore those peptide compounds in which X^3 is an amino acid residue which was selected from the group consisting of Asp, Glu, Arg, Lys, His and Tyr, and finally those peptide compounds in which X^4 is an amino acid residue which was selected from the group consisting of Ser, Tyr, Thr, Gly and Val.

The preferred compounds (for meanings or abbreviations see above and below) thus include those of the general formula II

W^1-X^1_nArg Thr Asp Leu X^3X^4Leu Arg X^6_m-W^2 **IIa,**
W^1-X^1_nArg Ser Asp Leu X^3X^4Leu Arg X^6_m-W^2 **IIb,**
W^1-X^1_nArg Asp Asp Leu X^3X^4Leu Arg X^6_m-W^2 **IIc,**
W^1-X^1_nArg Ser Asp Leu X^3X^4Leu Arg X^6_m-W^2 **IId,**
W^1-X^1_nArg Gly Asp Leu X^3X^4Leu Arg X^6_m-W^2 **IIe,**

and those of the general formula III

W^1-X^1_nArg X^2Asp Leu Asp X^4Leu Arg X^6_m-W^2 **IIIa,**

W^1-X^1_nArg X^2Asp Leu Glu X^4Leu Arg X^6_m-W^2 **IIIb,**

W^1-X^1_nArg X^2Asp Leu Arg X^4Leu Arg X^6_m-W^2 **IIIc,**

W^1-X^1_nArg X^2Asp Leu Lys X^4Leu Arg X^6_m-W^2 **IIId,**

W^1-X^1_nArg X^2Asp Leu His X^4Leu Arg X^6_m-W^2 **IIIe,**

W^1-X^1_nArg X^2Asp Leu Tyr X^4Leu Arg X^6_m-W^2 **IIIf,**

and those of the general formula IV

W^1-X^1_nArg X^2Asp Leu X^3Ser Leu Arg X^6_m-W^2 **IVa,**

W^1-X^1_nArg X^2Asp Leu X^3Tyr Leu Arg X^6_m-W^2 **IVb,**

W^1-X^1_nArg X^2Asp Leu X^3Thr Leu Arg X^6_m-W^2 **IVc,**

W^1-X^1_nArg X^2Asp Leu X^3Gly Leu Arg X^6_m-W^2 **IVd,**

W^1-X^1_nArg X^2Asp Leu X^3Val Leu Arg X^6_m-W^2 **IVe.**

Particularly preferred peptide compounds according to the invention are those of the formula V

W^1-X^1_nArg Thr Asp Leu Asp Ser Leu Arg X^6_m-W^2 **V**

and in this context in particular those of the formula VI

W^1-X^1_nArg Thr Asp Leu Asp Ser Leu Arg Thr X^6_{m-1}-W^2 **VI.**

Finally, the following individual compounds are particularly preferred, those also being included which are modified at the N and C termini:

(a) H-Arg-Thr-Asp-Leu-Asp-Ser-Leu-Arg-Thr-Tyr-Thr-Leu-OH

(b) H-Arg-Thr-Asp-Leu-Asp-Ser-Leu-Arg-OH

(c) Ac-Arg-Thr-Asp-Leu-Asp-Ser-Leu-Arg-Thr-OH

(d) Ac-Arg-Thr-Asp-Leu-Asp-Ser-Leu-Arg-Thr-NH_2

(e) H-Arg-Thr-Asp-Leu-Asp-Ser-Leu-Arg-Thr-OH

(f) H-Arg-Thr-Asp-Leu-Asp-Ser-Leu-Arg-Thr-NH_2

(g) H-Arg-Thr-Asp-Leu-Tyr-Tyr-Leu-Arg-Thr-Tyr-OH

(h) Ac-Arg-Thr-Asp-Leu-Asp-Ser-Leu-Arg-NH_2

The abbreviations mentioned above and below stand for the radicals of the following amino acids:

Ala	**A**	**alanine**
Asn	**N**	**asparagine**
Asp	**D**	**aspartic acid**
Arg	**R**	**arginine**
Cys	C	cysteine
Gln	Q	glutamine
Glu	E	glutamic acid
Gly	G	glycine
His	H	histidine
Ile	I	isoleucine
Leu	L	leucine
Lys	K	lysine
Met	M	methionine
Nle		norleucine
Orn		ornithine
Phe	F	phenylalanine
Phg		phenylglycine
Pro	P	proline
Ser	S	serine
Thr	T	threonine
Trp	W	tryptophan
Tyr	Y	tyrosine
Val	V	valine

If the abovementioned amino acids can occur in a number of enantiomeric forms, all these forms and also their mixtures are included above and below, e.g. as a constituent of the compounds of the formulae I-VI. Furthermore, the amino acids for example, as a constituent of compounds of the formulae I-VI, can be provided with appropriate protective groups known per se.

The compounds of the formulae In-VI can have one or more chiral centres and therefore occur in various stereoisomeric forms. The formulae indicated include all these forms, in particular the D and L forms, especially in enantiomeric and racemic mixtures. Finally, the formulae I and II mentioned above and below according to the invention also include the

corresponding salts, in particular the corresponding physiologically acceptable salts.

So-called prodrug derivatives are also included in the compounds according to the invention, i.e. compounds of the formula I modified with, for example, alkyl or acyl groups, sugars or oligopeptides, which are rapidly cleaved in the body to give the active compounds according to the invention. Furthermore, derivatives are also included in the compounds according to the invention which consist of the actual peptides according to the invention and known marker compounds which make it possible to detect the peptides easily. Examples of such derivatives are biotinylated or fluorescence-labelled peptides.

In general, the peptides according to the invention are linear, but they can also be cyclized. The invention comprises not only the peptides of the formulae I to VI mentioned but also mixtures and preparations which in addition to these compounds according to the invention also contain other pharmacological active compounds or adjuvants which can influence the primary pharmacological action of the peptides according to the invention in a desired manner.

The compounds according to the invention and also the starting substances for their preparation are otherwise prepared by methods which are known per se and frequently employed, such as are described in the literature (e.g. in the standard works such as Houben-Weyl, Methoden der organischen Chemie [Methods of Organic Chemistry], Georg-Thieme-Verlag, Stuttgart), namely under reaction conditions which are known and suitable for the reactions mentioned. Use can also be made here of variants which are known per se.

Preferably, the peptides according to the invention can be prepared by means of solid-phase synthesis and subsequent removal and purification, as has been

described, for example, by *Jonczyk and Meienhofer* (Peptides, Proc. 8th Am. Pept. Symp., Eds. V. Hruby and D.H. Rich, Pierce Comp. III, p. 73-77, 1983, or Angew. Chem. 104, 1992, 375), or according to Merrifield (J. Am. Chem. Soc. 94, 1972, 3102). Otherwise, they can be prepared by customary methods of amino acid and peptide synthesis, such as are known, for example, from Novabiochem - 1999 Catalog & Peptide Synthesis Handbook of Calbiochem-Novabiochem GmbH, D-65796 Bad Soden, from numerous standard works and published patent applications. Biotinylated or fluorescence-labelled peptides/proteins can likewise be prepared by standard methods (e.g. E.A. Bayer and M. Wilchek in Methods of Biochemical Analysis, Vol. 26, The Use of the Avidin-Biotin Complex as a Tool in Molecular Biology; and Handbook of Fluorescent Probes and Research Chemicals, 6th Edition, 1996, by R.P. Haugland, Molecular Probes, Inc.; or alternatively *WO 97/14716*).

Of course, the peptides of the formulae I-VI can also be liberated by solvolysis, in particular hydrolysis, or by hydrogenolysis of their functional derivatives. Preferred starting substances for the solvolysis or hydrogenolysis are those which, instead of one or more free amino and/or hydroxyl groups, contain corresponding protected amino and/or hydroxyl groups, preferably those which, instead of an H atom which is connected to an N atom, carry an amino protective group or which, instead of the H atom of a hydroxyl group, carry a hydroxyl protective group.
The same applies to carboxylic acids which can be protected by substitution of their -CO-OH hydroxyl function by means of a protective group, e.g. as an ester.

The expression "amino protective group" is generally known and relates to groups which are suitable for protecting (for blocking) an amino group from chemical reactions, but which are easily removable after the

desired chemical reaction has been carried out at other positions in the molecule. The expression "hydroxyl protective group" is likewise generally known and relates to groups which are suitable for protecting a hydroxyl group from chemical reactions, but which are easily removable after the desired chemical reaction has been carried out at other positions in the molecule. The liberation of the compounds from their functional derivatives is carried out - depending on the protective group used - e.g. using strong acids, expediently using TFA or perchloric acid, but also using other strong inorganic acids such as hydrochloric acid or sulfuric acid, strong organic carboxylic acids such as trichloroacetic acid or sulfonic acids such as benzene- or p-toluenesulfonic acid. Hydrogenolytically removable protective groups (e.g. CBZ or benzyl) can be removed by treating with hydrogen in the presence of a catalyst (e.g. of a noble metal catalyst such as palladium, expediently on a support such as carbon). The procedures are generally known and are not to be described in greater detail here.

As already mentioned, the peptides according to the invention include their physiologically acceptable salts, which can likewise be prepared by standard methods. Thus, a base of the formula I can be converted into the associated acid addition salt using an acid, for example by reaction of equivalent amounts of the base and of the acid in an inert solvent such as ethanol and subsequent evaporation. For this reaction, suitable acids are in particular those which yield physiologically acceptable salts. Thus inorganic acids can be used, e.g. sulfuric acid, nitric acid, hydrohalic acids such as hydrochloric acid or hydrobromic acid, phosphoric acids such as orthophosphoric acid, sulfamic acid, furthermore organic acids, in particular aliphatic, alicyclic, or araliphatic, aromatic or heterocyclic mono- or polybasic carboxylic, sulfonic or sulfuric acids, e.g.

formic acid, acetic acid, propionic acid, pivalic acid, diethylacetic acid, malonic acid, succinic acid, pimelic acid, fumaric acid, maleic acid, lactic acid, tartaric acid, malic acid, citric acid, gluconic acid, ascorbic acids, nicotinic acid, isonicotinic acid, methane- or ethanesulfonic acid, ethanedisulfonic acid, 2-hydroxyethanesulfonic acid, benzenesulfonic acid, p-toluenesulfonic acid, naphthalenemono- and disulfonic acids, laurylsulfuric acid. Salts with physiologically unacceptable acids, e.g picrates, can be used for the isolation and/or purification of the compounds according to the invention. On the other hand, an acid of the formula I can be converted into one of its physiologically acceptable metal or ammonium salts by reaction with a base. Possible salts in this case are in particular the sodium, potassium, magnesium, calcium and ammonium salts, furthermore substituted ammonium salts, e.g. the dimethyl-, diethyl- or diisopropylammonium salts, monoethanol-, diethanol- or diisopropylammonium salts, cyclohexyl- or dicyclohexylammonium salts, dibenzylethylenediammonium salts, furthermore, for example, salts with arginine or lysine.

The peptide compounds according to the invention can be employed, as already mentioned, as pharmaceutical active compounds in human and veterinary medicine, in particular for the prophylaxis and/or therapy of disorders in which epithelial cells are involved. Particularly to be emphasized in this context are disorders or inflammations or wound healing processes of the skin, the respiratory organs and the stomach and intestinal area, thus, for example, apoplexy, angina pectoris, oncoses, osteolytic illnesses such as osteoporosis, pathologically angiogenic illnesses such as, for example, inflammations, pulmonary fibrosis, ophthalmological illnesses, diabetic retinopathy, macular degeneration, myopia, ocular histoplasmosis, rheumatoid arthritis, osteoarthritis, rubeotic

glaucoma, ulcerative colitis, Crohn's disease, atherosclerosis, psoriasis, restenosis after angioplasty, in acute kidney failure or nephritis.

The invention accordingly relates to peptide compounds of the formulae defined above and below and in the claims including their physiologically acceptable salts as medicaments, diagnostics or reagents.

The invention relates in particular to appropriate medicaments as inhibitors for the control of disorders which are based indirectly or directly on expression of the $\alpha_v\beta_6$ integrin receptor, thus in particular on pathologically angiogenic disorders, thromboses, cardiac infarct, coronary heart disorders, arteriosclerosis, tumours, osteoporosis, inflammations, infections and for influencing wound healing processes.

The invention also relates to appropriate pharmaceutical preparations which comprise at least one medicament of the formulae I to VI and, if appropriate, vehicles and/or excipients.

The invention furthermore relates to the use of the peptide compounds and/or their physiologically acceptable salts according to the claims and the description for the production of a medicament for controlling disorders which are based indirectly or directly on expression of the $\alpha_v\beta_6$ integrin receptor, thus in particular in pathologically angiogenic disorders, thromboses, cardiac infarct, coronary heart disorders, arteriosclerosis, tumours, osteoporosis, inflammations, infections and for influencing wound healing processes. The medicaments according to the invention or pharmaceutical preparations comprising them can be used in human or veterinary medicine. Possible excipients are organic or inorganic substances which are suitable for enteral (e.g. oral) or parenteral administration or topical application or for

administration in the form of an inhalation spray and do not react with the new compounds, for example water, vegetable oils, benzyl alcohols, alkylene glycols, polyethylene glycols, glycerol triacetate, gelatin, carbohydrates such as lactose or starch, magnesium stearate, talc, petroleum jelly. Tablets, pills, coated tablets, capsules, powders, granules, syrups, juices or drops, in particular, are used for oral administration, suppositories are used for rectal administration, solutions, preferably oily or aqueous solutions, furthermore suspensions, emulsions or implants, are used for parenteral administration, and ointments, creams or powders are used for topical application. The new compounds can also be lyophilized and the lyophilizates obtained used, for example, for the production of injection preparations. The preparations indicated can be sterilized and/or can contain vehicles such as lubricants, preservatives, stabilizers and/or wetting agents, emulsifiers, salts for affecting the osmotic pressure, buffer substances, colourants, flavourings and/or [lacuna] more further active compounds, e.g. one or more vitamins.

For administration as an inhalation spray, sprays can be used which contain the active compound either dissolved or suspended in a propellant or propellant mixture (e.g. CO_2 or chlorofluorohydrocarbons). Expediently, the active compound is used here in micronized form, it being possible for one or more additional physiologically tolerable solvents to be present, e.g. ethanol. Inhalation solutions can be administered with the aid of customary inhalers.

The substances according to the invention can as a rule be administered in analogy to other known, commercially available peptides (e.g. described in US-A-4 472 305), preferably in doses between approximately 0.05 and 500 mg, in particular between 0.5 and 100 mg, per dose unit. The daily dose is preferably between approximately 0.01 and 20 mg/kg of body weight. The

specific dose for each patient depends, however, on all sorts of factors, for example on the efficacy of the specific compound employed, on the age, body weight general state of health and sex, on the diet, on the time and route of administration, on the excretion rate, pharmaceutical combination and severity of the particular disorder to which the therapy applies. Parenteral administration is preferred.

The invention finally also comprises recombinant DNA sequences which contain sections which code for peptide regions which contain the peptide structural motifs of the formulae I to VI according to the invention.

Such DNA can be transferred to cells by particles, as is described in Ch. Andree et al. Proc. Natl. Acad. Sci. 91, 12188-12192 (1994), or the transfer to cells can be increased by other vehicles, such as liposomes (A.I. Aronsohn and J.A. Hughes J. Drug Targeting, 5, 163-169 (1997)).

The transfer of such a DNA could accordingly be used in yeasts, by means of bacculoviruses or in mammalian cells, for the production of the peptide substances of this invention.

If an animal or human body is infected with such a recombinant DNA, the peptides according to the invention finally themselves formed by the infected cells can bind directly to the $\alpha_v\beta_6$ integrin receptor, for example of tumour cells, and block it.

Appropriate recombinant DNA, which can be prepared by known and customary techniques, can, for example, however also be present in the form of virus DNA which contains sections which code for the virus coat protein. By infection of a host organism with recombinant, preferably non-pathogenic viruses of this

type, host cells which express the integrin $\alpha_v\beta_6$ can preferably be attacked (targeting).

Suitable viruses are, for example, adenovirus species which have been used a number of times already as vectors for foreign genes in mammalian cells. A number of properties make them good candidates for gene therapy, as can be inferred from S.J. Watkins et al. Gene Therapy 4, 1004-1012 (1997) (see also J. Engelhardt et al. Hum. Gene Ther. 4, 759-769 (1993)). As can be found in A. Fasbender et al. J. Clin. Invest. 102, 184-193 (1998), the limited efficiency of the gene transfer is a common problem in gene therapy by viral and non-viral vectors. Using the above-described additional ligand sequence for $\alpha_v\beta_6$ integrin in the coat protein of the adenoviruses, an improvement in the transfer, for example, of cystic fibrosis transmembrane conductance regulator (CFTR) cDNA can be achieved.

Similarly to the work of T. Tanaka et al. Cancer Research 58, 3362-3369 (1998), instead of the DNA for angiostatin the DNA for the sequences of this invention can also be used for cell transfections by means of retroviral or adenoviral vectors.

The peptides according to the invention can also be employed for use in gene therapy in man within a liposome complex of lipid/peptide/DNA prepared for transfection of cell cultures together with a liposome complex consisting of lipid/DNA (without peptide). The preparation of a liposome complex of lipid/DNA/peptide is described, for example, in Hart S.L., et al 1998: Lipid-Mediated Enhancement of Transfection by a Non-Viral Integrin-Targeting Vector, Human Gene Therapy 9, 575-585.

A liposome complex of lipid/peptide/DNA can be prepared, for example, from the following stock solutions: 1 μg/μl of lipofectin (equimolar mixture of

DOTMA (= N-[1-(2,3-dioleyloxy)propyl]-N,N,N-trimethylammonium chloride) and DOPE (dioleylphosphatidylethanolamine), 10 µg/ml of plasmid DNA and 100 µg/ml of peptide. For this, both DNA and peptide are dissolved in cell culture medium. The liposome complex is prepared by mixing the three components in a specific weight ratio (lipid:DNA:peptide, for example, 0.75:1:4). Liposome DNA complexes for gene therapy in man have already been described (Caplen N.J., et al 1995: Liposome-mediated CFTR gene transfer to the nasal epithelium of patients with cystic fibrosis, Nature Medicine 1, 39-46).

The invention thus also relates to the use of appropriately modified recombinant DNA of gene-releasing systems, in particular virus DNA, for the control of illnesses which are based indirectly or directly on an expression of $\alpha_v\beta_6$ integrin receptors, thus in particular in pathologically angiogenic disorders, thromboses, cardiac infarcts, coronary heart disorders, arteriosclerosis, tumours, osteoporosis, inflammations, infections and for influencing wound healing processes.

The new compounds according to the invention can also be used as integrin ligands for the preparation of columns for affinity chromatography for preparing integrins in pure form. The complex of an avidin-derivatized support material, e.g. Sepharose, and the new compounds of the formula I is formed by methods known per se (e.g. E.A. Bayer and M. Wilchek in Methods of Biochemical Analysis, Vol. 26, The Use of the Avidin-Biotin Complex as a Tool in Molecular Biology). Suitable polymeric support materials in this case are the polymeric solid phases known per se in peptide chemistry and having preferably hydrophilic properties, for example crosslinked polysugars such as cellulose, Sepharose or Sephadex®, acrylamide, polymers based on polyethylene glycol or Tentakel polymers®.

Example 1

Preparation and purification of peptides according to the invention:

In principle, the preparation and purification was carried out by means of Fmoc strategy with protection of acid-labile side chains on acid-labile resins using a commercially obtainable continuous flow peptide synthesizer according to the details of Haubner et al. (J. Am. Chem. Soc. 118, 1996, 17703).

In the following, the synthesis and purification is described by way of example for the peptide amide Ac-RTDLDSLR-NH_2. For the synthesis of peptide acids, an o-chlorotrityl chloride resin (Novabiochem) was coated with the appropriate C-terminal Fmoc amino acid according to the manufacturer's instructions and used in the synthesis apparatus according to the manufacturer's instructions (Milligen). The principal steps are washing - Fmoc protective group removal - washing - coupling with the next Fmoc amino acid - capping (acetylation) - washing. If an N-terminal acylation is desired after the last amino acid coupling, this is carried out after removal of the last Fmoc protective group using the appropriate activated acyl radical, e.g. the acetic anhydride.

2 g of 9-Fmoc-aminoxanthenyloxy resin (Novabiochem, 0.37 mmol/g) were subjected to a coupling step, for 60 min in each case, in succession with 0.45 g each of hydroxybenzotriazole hydrate (HOBt), 0.5 ml of ethyldiisopropylamine, 4 equivalents each of diisopropylcarbodiimide (DIC) and Fmoc-amino acid in dimethylformamide (DMF), in a commercial synthesis apparatus and a typical procedure (apparatus and Milligen 9050 PepSynthesizer™ Handbook, 1987). Washing steps were carried out in DMF for 10 min, removal steps in piperidine/DMF (1:4 vol) for 5 min, N-terminal acetylations (capping) were carried out for 15 min using acetic anhydride/pyridine/DMF (2:3:15 vol). The

amino acids Fmoc-Arg (Pmc), then Fmoc-Leu, then Fmoc-Ser(But), then Fmoc-Asp(OBut), then Fmoc-Leu, then Fmoc-Asp(OBut), then Fmoc-Thr(But), and finally Fmoc-Arg(Pmc) were used. After washing with DMF and isopropanol and subsequent drying in vacuo, 3.48 g of the N-terminally acetylated peptidyl resin, Ac-Arg(Pmc)-Thr(But)-Asp(OBut)-Leu-Asp(OBut)-Ser(But)-Leu-Arg(Pmc)-aminoxanthenyloxy resin, were obtained.

By treatment of this peptidyl resin with trifluoroacetic acid/anisole/dichloromethane (74 ml/3.7 ml/74 ml) for 4 h at room temperature, filtration, concentration in vacuo and trituration with diethyl ether, it was possible to obtain a precipitate of 0.6 g of peptide, Ac-Arg-Thr-Asp-Leu-Asp-Ser-Leu-Arg-NH_2. Purification of the product was carried out by RP-HPLC on Lichrosorb RP18 (250-25, 7 µm, Merck KGaA) in 0.3% TFA using a gradient of 4% on 24% 2-propanol in 2 h at 8 ml/min and assessment by means of a UV flow-through photometer at 215 nm.

The product-containing fractions were freeze-dried. According to FAB-MS (Fast Atom Bombardment Mass Spectroscopy), the product obtained corresponded to the expectations: $C_{41}H_{73}N_{15}O_{15}M$ 1015.5 g/mol; $(M+H)^+$ is 1016. In the analytical HPLC on SuperSpher RP18e (250-4, Merck KGaA) in a gradient of 0-99% A (0.08 M phosphate pH 3.5, 15% acetonitrile) to B (0.03 M phosphate pH 3.5, 70% acetonitrile) in 50 min, at 1 ml/min, and detection at 215 nm, the purified product Ac-Arg-Thr-Asp-Leu-Asp-Ser-Leu-Arg-NH_2 has a retention time of 7.22 min.

Further HPLC analyses were carried out in the two following systems:

System A: 0.3% trifluoroacetic acid having a gradient of 0-80% 2-propanol in 50 min on LichroSpher 60 RP-Select B® (250-4) (Merck KGaA, Darmstadt, Germany), at 1 ml/min, and detection at 215 nm.

System B: 0.1% trifluoroacetic acid having a gradient of 30-70% acetonitrile in 50 min on SuperSpher 100 RP18e® (250-4) (Merck KGaA, Darmstadt, Germany), at 1 ml/min and detection at 215 nm.

Example 2

The following peptides shown in Table 1 were prepared and purified analogously to Example 1.

Table 1:

Structure	**MW** (g/mol)	**FAB-MS** [M+H] found	**Rt** (HPLC) **/min (System A)**	**Rt** (HPLC) **/min (System A)**
RTDLDSLRTYTL	1453.6	1456	21.9	
DSLRTYTL	968.1	969	18.6	
RTDLDSL	818.9	820	18.6	23.6
DLDSLRTY	982.1	983	16.6	
RTDLDSLR	975.1	975	13.5	
RTDLDSLRTY	1239.3	1239	16.6	
Ac-RTDLDSLRT	1118.2	1119	16.2	15.6
RTDLDSLRT	1076.2	1076	13.9	
RTDLPSLRTY	1221.4	1221	19.2	
RTDLDLRT-NH_2	988.1	989	13.4	
Ac-RTDLDLRT-NH_2	1030.2	1031	15.3	
RTDLYYLMDL	1302.5	1302		28.2
RTDLDSLRT-NH_2	1075.2	1076	11.1	13.8
RTDLDPLRTY	1249.4	1250	16.3	
RTDLYYLRTY	1363.5	1363		11.5
Ac-RTDLDSLRT-NH_2	1117.2	1118	13.2	15.0
Ac-RTDLDSLR-NH_2	1015.5	1016	See Example 1	
TDLDSLRT	920.0	920		14.8
PVDLYYLMDL	1241.5	1241	36.1	

The comparison compounds used were known RGD peptides such as GRGDSPK, cyclo-(RGDfV), and the linear peptide DLYYLMDL.

Example 3

Preparation of an $\alpha_v\beta_6$ integrin preparation:

$\alpha_v\beta_6$ was obtained and purified in soluble transmembrane truncated form (Weinacker et al. 1994, J. Biol. Chem. 269, 6940) from a Baculovirus expression system according to recombination techniques known for $\alpha_v\beta_3$ (Mehta et al., 1998, Biochem. J. 330, 861) using 14D9.F8 antibody affinity chromatography (Mitjans et al., 1995, J Cell Sci. 108, 2825). Human α_v and β_6 cDNA clones are generally known and commonly accessible. The transfer vector pAcUW31 (Clontech Lab. Inc., USA), which allows simultaneous expression of two different target cDNAs, was employed in order to express transmembrane truncated $\alpha_v\beta_6$ from recombinant Baculovirus cells. To this end, an α_v transfer vector was prepared and transmembrane truncated (ΔTM)α_v was excised from the plasmid $\alpha_v\Delta$TM (pBAc9) using the restriction enzymes EcoRI and XbaI (Mehta et al., for reference see above) and cloned into the BamHI cleavage site of pAcUW31 downstream of the polyhedrin promoter by means of blunt-end ligation. Transmembrane truncated β_6 cDNA was excised from the plasmid pCDNAneoβ_6 (Weinacker et al., for reference see above) using the restriction enzymes EcoRI and XbaI and likewise cloned into the BamHI cleavage site of pAcUW31 downstream of the polyhedrin promoter by means of blunt-end ligation. The tandem vectors containing truncated α_v and β_6 were used in order to obtain recombinant Baculovirus (Mehta et al., for reference see above). The recombinant Baculoviruses were employed in order to infect High Five insect cells. The soluble receptor was obtained after culturing for 48-71 hours by passing the supernatant from the cell culture through affinity columns of the type indicated above and eluting at pH 3.1. All process steps were carried out at room temperature and in the absence of any detergents. The peak fractions were neutralized, concentrated and dialysed at 40°C and finally stored at -80°C. The

recombinant soluble human receptor thus obtained is biologically active and retains its ligand specificity. A similar preparation method used for soluble $\alpha_v\beta_3$ was described in EP 0846 702.

Example 4:

$\alpha_v\beta_6$/Fibronectin receptor binding test:

The prepared peptides according to the invention were bonded to the immobilized $\alpha_v\beta_6$ receptor in solution together with competitively acting fibronectin and the Q value was determined as a measure of the selectivity of the binding of the peptide to be tested to $\alpha_v\beta_6$. The Q value is in this case calculated from the quotient of the IC_{50} values of test peptide and a standard. The standard used was the linear hepta-RGD peptide GRGDSPK (ref./Patent cf. Pytela et al. Science 231, 1559, (1986)).

In detail, the binding test was carried out as follows:

The immobilization of soluble $\alpha_v\beta_6$ receptor on microtitre plates was carried out by dilution of the protein solution in TBS++ and subsequent incubation overnight at 4°C (100 µl/well). Non-specific binding sites were blocked by incubation (2 h, 37°C) with 3% (w/v) BSA in TBS++ (200 µl/well). Excess BSA was removed by washing three times with TBSA++. Peptides were serially diluted (1:10) in TBSA++ and incubated with the immobilized integrin (50 µl of peptide + 50 µl of ligand per well; 2 h; 37°C) together with biotinylated fibronectin (2 µg/ml). Unbound fibronectin and peptides were removed by washing three times with TBSA++. The detection of the bound fibronectin was carried out by incubation (1 h; 37°C) with an alkaline phosphatase-coupled anti-biotin antibody (Biorad) (1:20,000 in TBSA++; 100 µl/well). After washing three times with TBSA++, the colorimetric detection was carried out by incubation (10-15 min; 25°C, in the dark) with substrate solution (5 mg of nitrophenyl

phosphate, 1 ml of ethanolamine, 4 ml of H_2O; 100 µl/well). The enzyme reaction was stopped by addition of 0.4 M NaOH (100 µl/well). The colour intensity was determined at 405 nm in an ELISA measuring apparatus and made equal to the zero value. Wells which were not coated with receptor were used as a zero value. The standard employed was GRGDSPK. The IC_{50} values for the tested peptides were read off from a graph and the Q value of the peptide according to the invention was determined from this together with the IC_{50} value of the standard peptide. The results of the test described are summarized in the following table:

Table 2

Structure	**Q value =** IC_{50} test peptide/ IC_{50} standard peptide
GRGDSPK	1.0 (IC_{50} = 400 nM)
cyclo-(RGDfV)	0.6
DLYYLMDL	Inactive (IC_{50}>50 µM)
RTDLDSLRTYTL	0.27
DSLRTYTL	Inactive (IC_{50}>50 µM)
RRDLDSL	2.5
DLDSLRTY	Inactive (IC_{50}>50 µM)
RTDLDSLR	0.17
RTDLDSLRTY	0.10
Ac-RTDLDSLRT	0.029
RTDLDSLRT	0.11
RTDLDLRT-NH_2	1.1
Ac-RTDLDLRT-NH_2	0.5
RTDLYYLMDL	0.33
RTDLDSLRT-NH_2	0.056
RTDLDPLRTY	0.50
RTDLYYLRTY	0.042
Ac-RTDLDSLRT-NH_2	0.013
TDLDSLRT	66
PVDLYYLMDL	Inactive (IC_{50}>50 µM)

Q values of less than 1 mean that they exhibit a relatively better binding to the receptor than, comparatively, the standard peptide, which seen in absolute terms already has a good binding in competition with the natural ligand fibronectin.

Example 5

Analogously to the preceding example, for comparison purposes integrin ligand binding tests were carried out with different integrins (e.g. $\alpha_v\beta_3$, $\alpha_v\beta_5$) and their corresponding ligands (e.g. vitronectin, fibrinogen).

Example 6:

General preparation of a DNA-liposome complex and use for gene therapy:

Lipid and DNA are mixed in the weight ratio 5:1 (lipid:DNA) in Krebs-HEPES solution (140mM NaCl, 1mM $MgCl_2$, 2mM $CaCl_2$, 6mM KCl, 10mM HEPES, 10mM D-glucose; pH 9.0). The individual dose here is 30 µg of DNA/200 µl. 200 µl of this lipid-DNA complex are applied to the nasal epithelium using a pump atomizer. This is repeated 10 times at an interval of 15 min. The total dose of DNA is 300 µg.

The following examples relate to pharmaceutical preparations:

Example A: Inection vials

A solution of 100 g of an active compound of the formula I and 5 g of disodium hydrogenphosphate are adjusted to pH 6.5 in 3 l of double-distilled water using 2 N hydrochloric acid, sterile-filtered, filled into injection vials, lyophilized under sterile conditions and aseptically sealed. Each injection vial contains 5 mg of active compound.

Example B: Suppositories

A mixture of 20 g of an active compound of the formula I is fused with 100 g of soya lecithin and 1400 g of cocoa butter, poured into moulds and allowed to cool. Each suppository contains 20 mg of active compound.

Example C: Solution

A solution of 1 g of an active compound of the formula I, 9.38 g of $NaH_2PO_4 \cdot 2H_2O$, 28.48 g of $Na_2HPO_4 \cdot 12H_2O$ and 0.1 g of benzalkonium chloride in 940 ml of double-distilled water is prepared. It is adjusted to pH 6.8, made up to 1 l and sterilized by irradiation. This solution can be used in the form of eye drops.

Example D: Ointment

500 mg of an active compound of the formula I are mixed with 99.5 g of petroleum jelly under aseptic conditions.

Example E: Tablets

A mixture of 1 kg of active compound of the formula I, 4 kg of lactose, 1.2 kg of potato starch, 0.2 kg of talc and 0.1 kg of magnesium stearate is compressed to give tablets in a customary manner such that each tablet contains 10 mg of active compound.

Example F: Coated tablets

Analogously to Example E, tablets are pressed and are then coated in a customary manner with a coating of sucrose, potato starch, tragacanth and colourant.

Example G: Capsules

2 kg of active compound of the formula I are filled into hard-gelatin capsules in a customary manner such that each capsule contains 20 mg of the active compound.

Example H: Ampoules

A solution of 1 kg of active compound of the formula I in 60 l of double-distilled water is sterile-filtered, filled into ampoules, lyophilized under sterile conditions and aseptically sealed. Each ampoule contains 10 mg of active compound.

Example I: Inhalation spray

14 g of active compound of the formula I are dissolved in 10 l of isotonic NaCl solution and the solution is filled into customary spray containers having a pump mechanism. The solution can be sprayed into the mouth or nose. One puff of spray (approximately 0.1 ml) corresponds to a dose of approximately 0.14 mg.

Patent Claims

1. Peptide compounds of the formula I

W^1-X^1_nArg X^2 Asp Leu X^3X^4Leu $X^5X^6_m$-W^2 **I**

in which:
X^1, X^2, X^3, X^4, X^5, X^6 each independently of one another are an amino acid residue, the amino acids independently of one another being selected from a group consisting of Ala, Asn, Asp, Arg, Cys, Gln, Glu, Gly, Phe, His, Ile, Leu, Lys, Met, Nle, homo-Phe, Phg, Pro, Ser, Thr, Trp, Tyr or Val, and the amino acids mentioned possibly also being derivatized,
W^1 is H or Ac,
W^2 is OH, OR, NHR, NR_2, NH_2,
R is alkyl having 1-6 C atoms and
n, m each independently of one another are a number from 0-15.

2. Peptide compounds according to Claim 1, in which X^2 is an amino acid residue which is selected from the group consisting of Thr, Ser, Asp or glycine.

3. Peptide compounds according to Claim 1, in which X^3 is an amino acid residue selected from the group consisting of Asp, Glu, Arg, Lys, His or Tyr.

4. Peptide compounds according to Claim 1, in which X^4 is an amino acid residue selected from the group consisting of Ser, Tyr, Thr, Gly or Val.

5. Peptide compounds according to Claim 1 as in the formula V

W^1-X^1_nArg Thr Asp Leu Asp Ser Leu Arg X^6_m-W^2 **V**

* C L M S *

having the meanings indicated in Claim 1.

6. Peptide compound according to Claim 5 as in formula VI

W^1-$X^1{}_n$Arg Thr Asp Leu Asp Ser Leu Arg Thr $X^6{}_{m-1}$-W^2 **VI**

7. Peptide compounds of the formula I or II according to Claims 1 to 6 and their physiologically acceptable salts as medicaments.

8. Medicament according to Claim 7 as an inhibitor for the control of disorders which are based on an expression and pathological function of $\alpha_v\beta_6$ integrin receptors.

9. Medicament according to Claim 8 for the control of thromboses, cardiac infarct, coronary heart disorders, arteriosclerosis, tumours, osteoporosis, fibrosis, inflammations, infections, psoriasis and for influencing wound healing processes.

10. Pharmaceutical preparation comprising at least one medicament according to one of Claims 7 to 9 and, if appropriate, vehicles and/or excipients and, if appropriate, other active compounds.

11. Use of peptide compounds according to Claims 1 to 6 and/or their physiologically acceptable salts for the production of a medicament for controlling disorders which are based on an expression and pathological function of $\alpha_v\beta_6$ integrin receptors.

12. Use according to Claim 11 for the production of a medicament for controlling thromboses, cardiac infarct, coronary heart disorders, arteriosclerosis, tumours, osteoporosis, fibrosis,

inflammations, infections, psoriasis and for influencing wound healing processes.

13. Recombinant DNA comprising a sequence which codes for a peptide section which corresponds to a peptide compound of Claims 1-6.

14. Recombinant virus DNA according to Claim 13.

15. Virus, characterized in that it possesses a coat protein which has a sequence which corresponds to a peptide compound of Claims 1-6.

16. Use of a virus according to Claim 15 for the production of a medicament for controlling disorders which are based on an expression and pathological function of $\alpha_v\beta_6$ integrin receptors.