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(21) International Application Number: PCT/CA97/00582 (22) International Filing Date: 14 August 1997 (14.08.97) (30) Priority Data: 60/023,971 19 August 1996 (19.08.96) US (71) Applicant (for all designated States except US): UNIVERSITE DE SHERBROOKE [CA/CA]; University Boulevard, Sherbrooke, Quebec J1R 2R1 (CA). (72) Inventors; and (75) Inventors/Applicants (for US only): REGOLI, Domenico [CA/CA]; 1169 Georgeville Road, Magog, Quebec J1X 3W4 (CA). PLANTE, Gérard, E. [CA/CA]; 600 Chambly Street, Sherbrooke, Quebec J1J 2Y2 (CA). GOBEIL, Fernand [CA/CA]; 489 90th Avenue Chomedey, Laval, Quebec H7W 3L1 (CA). NEUGEBAUER, Witold, A. [CA/CA]; Provender Avenue, Ottawa, Ontario K1K 4N7 (CA). ZUC-COLLO, Adriana [AR/AR]; 2853 Lavalle, Vicente Lopez, 1602 Buenos Aires (AR). CATANZARO, Orlando, L. [CA/CA]; 5126 Rivadavia, 1424 Buenos Aires (AR).		(74) Agents: DUBUC, Jean, H. et al.; Goudreau Gage Dubuc & Martineau Walker, Stock Exchange Tower, Suite 3400, 800 Place Victoria, P.O. Box 242, Montreal, Quebec H4Z 1E9 (CA). (81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, HU, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG). Published <i>With international search report.</i> <i>Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i>
(54) Title: B ₁ -BRADYKININ RECEPTOR ANTAGONISTS AND USE THEREOF (57) Abstract The present invention relates to novel antagonists to a B₁-bradykinin (B₁-BK) receptor which have a good affinity and selectivity therefor, some of which being at least partially resistant to enzymatic degradation. The synthesis of the B₁ receptors is induced during inflammation. Symptoms associated with inflammation (elevated hydrostatic pressure and plasma leakage or extravasation) have been observed in diabetic animal models (streptozotocin-induced diabetes (STZ)) as well as in spontaneously hypertensive rats (SHR). The present inventors confirm the presence of B₁-BK receptors in these two models. B₁-BK antagonists abolished the vasocontraction induced by B₁-BK in SHR and STZ, and reduced the glycemia of diabetic animals to normal levels. The present B₁-antagonists are useful for treating any condition wherein B₁-receptor is expressed, particularly during inflammation, and more particularly wherein B₁-receptor expression results in diabetic vasculopathy, other diabetic symptoms associated with an insulinitis and a post-capillary resistance building as a consequence of the presence of a B₁-receptor.		

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TITLE OF THE INVENTION:

B₁ - BRADYKININ RECEPTOR ANTAGONISTS AND USE THEREOF

FIELD OF THE INVENTION:

This invention relates to B₁-antagonists that have a good affinity and selectivity for a
5 B₁-receptor; a subset thereof at least partially resistant to enzymatic degradation.

BACKGROUND OF THE INVENTION:

The synthesis of B₁ bradykinin (B₁-BK) receptor is induced during inflammation
in blood vessel muscular layers. This receptor is not present in normal conditions. This
is in contrast with the B₂-BK receptor which is normally present on many cell types or
10 tissues. B₁ receptor is present in the muscular layer of blood vessels and appears to
be a factor involved in the vasoconstriction, the enhanced hydrostatic pressure and
plasma leakage observed in an animal model of spontaneous hypertension (SHR) and
in streptozotocin-induced diabetic rat model (STZ).

Many patent publications describe antagonists of bradykinin receptors.
15 However, these antagonists all have an activity towards B₂-receptors. If, amongst
these agonists, one may find antagonists that may be converted into B₁-antagonists
by the action of carboxypeptidases, it remains that their verified activity towards B₂-
receptors indicates that such antagonists would not be selective for B₁-receptors.

Recent reports point to an important role of kinin B₁ receptors in
20 physiopathology. Dray and Perkins¹ have reviewed the possible implication of B₁
receptors in various inflammatory states, tissue reactions and hyperalgesia, particularly
the chronic phases of these experimental diseases. This has been further supported
by some recent findings from Davis and coworkers² in inflammatory hyperalgesia in the
rat. Using B₁ receptor antagonists, Alvarez *et al.*³ have suggested that B₁ receptors
25 may be present in spontaneous hypertensive rats whereas Chakir *et al.*⁴ and Zuccollo
*et al.*⁵, have obtained strong evidence that B₁ receptors may play a relevant role in
streptozotocin-induced diabetes in rat and mouse models, respectively. It thus appears
that B₁ receptors are formed *de novo* and take part in the induction and/or the
maintenance of pathological states. Or, as pointed out by Marceau⁶, "it is conceivable
30 that B₁ receptors can amplify the responses of injured tissues to kinins and, in some
cases, take the relay of B₂ receptors in chronic pathologies". B₁ receptor antagonists
have been discovered in the late seventies^{7,8} but no substantial progress has been
made in this area, despite the evidence of their usefulness in basic pharmacology and
in various experimental pathologies.

We already demonstrated that capillary permeability was augmented in streptozocin (STZ) diabetic rat model⁴⁹. The vascular BK receptors of the portal veins of these animals have been shown to present enhanced contractibility and capillary permeability in response to B₁-agonist desArg⁹BK, when compared to normal animals.

5 This effect was abolished by B₁-antagonist Lys[Leu⁸]desArg⁹BK while the B₂-antagonist HOE140 had no effect thereon. A similar increased sensitivity to desArg⁹BK was observed in untreated SHR animals, prior to the establishment of hypertension, which was reversed by the same B₁-antagonist. Even if these results indicate that B₁-receptor is a target for a drug-preventive approach to diabetic or hypertensive vasculopathy, 10 clinical testing becomes possible in as much as B₁-antagonists capable of resisting to a very rapid enzymatic degradation are obtained. Substitutions in the natural B₁-agonist desArg⁹-BK at amino acid residue proline have provided antagonists resistant to ACE degradation²³. Further protection against amino peptidases is provided by adding non-hydrolysable amino acid residues at the N-terminal end. However, 15 modifications at both residue 7 and N-terminal end also resulted in a loss of affinity for B₁-receptor and even showed antagonistic activity towards B₂-receptor.

Commercially available bradykinin antagonists also exist: D-Arg[Hyp³,Thi⁵,D-Tic⁷,Oic⁸]desArg⁹BK (S0765), [Hyp³,Thi⁵,D-Tic⁷,Oic⁸]desArg⁹BK (S1629) both developed by Hoechst, D-Arg[Hyp³,D-Hyp⁷(transpropyl),Oic⁸]desArg⁹BK (NPC18565) and 20 D-Arg[Hyp³,D-Hyp⁷(trans thiophenyl), Oic⁸]desArg⁹BK (NPC18828), both developed by Scios Inc., are antagonists completely resistant to ACE degradation. However, none of them are selective for B₁-receptor when tested in model tissues.

From the foregoing, it is apparent that there is a need for B₁-antagonists which would be at least partially resistant to proteolytic enzymes, while the affinity and 25 selectivity thereof for a B₁-receptor would be preserved.

STATEMENT OF THE INVENTION

It is an object of the present invention to provide B₁-antagonists which have an acceptable affinity and selectivity for a B₁-receptor, some of which are at least partially resistant to proteolytic degradation. These antagonists are used as therapeutic agents 30 for treating any condition wherein a B₁-receptor mediated response is expressed.

Pharmaceutical compositions comprising these B₁-antagonists and a pharmaceutically acceptable carrier are also an object of the invention.

It is further another object of the invention to provide methods of treating a subject affected by a condition wherein a B₁-receptor mediated response is building.

Such a condition is particularly an inflammatory condition, more particularly a diabetic vasculopathy, other diabetic symptoms associated with an insulitis or a post-capillary resistance consequent to the presence of a B₁-receptor.

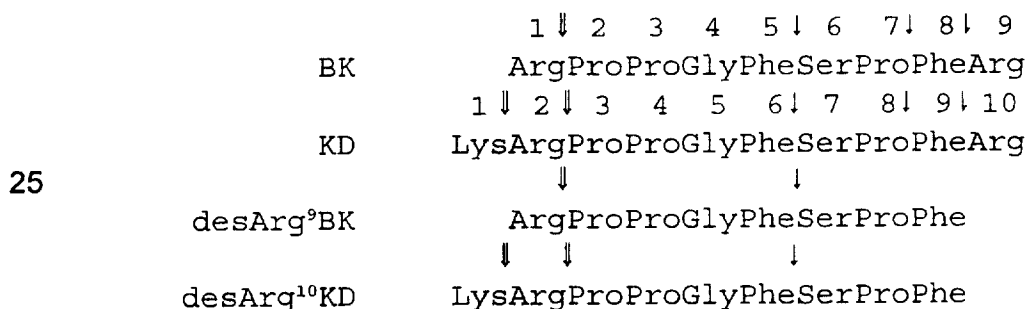
It is also another object of this invention to provide a new use for the commercially available non-selective B₁ antagonists as selective B₁-antagonists in humans.

DESCRIPTION OF THE INVENTION:

The present inventors have focused their attention on the B₁-BK blockade and the therapeutic effects of that blockade. Novel B₁-BK receptor antagonists are provided. These antagonists are selective to B₁-BK receptors, and some of them are partially or totally resistant to enzymatic degradation.

Previous studies with the B₁ antagonist Lys[Leu⁸]desArg⁹BK completely abolished the contraction induced by a B₁ agonist desArg⁹-BK in perfused tissues expressing this receptor as well as in an animal model of spontaneous hypertension (SHR) and in streptozotocin-induced diabetic rat model (STZ). It is contemplated that the B₁-antagonists of the present invention have the same effect on these tissues and animal models as the previous B₁-antagonist used for these experiments.

To facilitate understanding of the design of the B₁-antagonists of this invention, the structure of bradykinin (BK), kallidin (KD) and their naturally encountered C-terminal truncated forms are given below:



The vertical arrows illustrate the sites of proteolytic cleavage by a carboxy peptidase (↓), ACE (↓) and an aminopeptidase (↓). In order to uniformize the nomenclature of the peptides, kallidin and its desArg⁹ metabolite will be named with reference to BK as [Lys] BK and [Lys] des-Arg⁹BK. All substitutions and additions of amino acids in the N-terminal are designated as follows: substitutions are given within brackets by naming substituents and their amino acid position, while additions in the N-terminal precede the opening bracket without numerotation. For example, addition

of a N-terminal lysine residue and substitution of a leucine for the phenylalanine at position 8 of desArg⁹bradykinin is designated Lys[Leu⁸]desArg⁹BK.

LysBK and BK are agonists of B₂-receptors, normally present at the membrane surface of numerous cells. C-terminal truncated metabolites [Lys]desArg⁹BK and desArg⁹BK are agonists of a B₁-receptor, not present on normal cells, but synthesized *de novo* during inflammation. B₁-antagonists of the present invention are peptide analogs of desArg⁹BK.

The present invention is the result of a study that was undertaken to search for new peptidic B₁ receptor antagonists, starting with the most active known structure Lys[Leu⁸]desArg⁹BK⁵ and trying to improve it. Changes were made at the N-terminal end to find the most suitable group that maintains affinity and protects from degradation by aminopeptidases and in positions 7 and 8 to improve affinity and resistance to kininase II or ACE (EC 3.4.15.1), the enzyme that plays a major role in the inactivation of the kinins and their desArg⁹-metabolites^{8,9}. New compounds were prepared and tested in several isolated organs to provide precise pharmacologic profiles and assess affinity and selectivity for the B₁ receptor.

This invention will be described hereinbelow by way of specific Examples, Tables and Figures, which purpose is to support and illustrate the invention rather than to limit its scope.

20 **BRIEF DESCRIPTION OF FIGURES**

Figures 1a), 1b) and 1c) represent the effect of HOE140 (a selective B₂ bradykinin receptor antagonist) on glycemia, proteinuria and kallikrein excretion, respectively, in control mice and streptozotocin-induced diabetes type I in mice.

Figures 2a), 2b) and 2c) represent the effect of [Leu⁸]desArg⁹BK (a selective B₁ bradykinin receptor antagonist) on glycemia, proteinuria and kallikrein excretion, respectively, in control mice and streptozotocin-induced diabetes type I in mice.

EXAMPLE 1:

DESIGN AND ACTIVITY OF desArg⁹BK ANALOGS

Peptide synthesis

30 All peptides were synthesized with an Applied Biosystems 430 A peptide synthesizer using Merrifield type resins with the first amino acid attached. Amino acids were activated by dicyclohexylcarbodiimide 1-hydroxybenzotriazole (Peptides International, Louisville, KY) on 1-methyl-2-pyrrolidinone. Peptides were cleaved from

the resins with anhydrous HF in the presence of appropriate scavengers. The resulting peptides were purified by medium pressure reversed-phase (C₁₈) chromatography and if necessary by HPLC. Peptide purity was assessed by analytical HPLC and identity confirmed by ion spray mass spectrometry (VG Quattro, Manchester, U.K.).

5 Bioassays

Tissues were taken from New Zealand white rabbits (1.5-2.5 kg) and Dunken Hartley guinea pigs (250-350 g) of either sex, killed by stunning and exsanguination. Umbilical cords were taken from healthy women 22-40 years old after spontaneous delivery at term. The rabbit jugular vein (RbJV), the guinea pig ileum (GPI), two
10 preparations containing B₂ receptors, the rabbit aorta (RbA) (B₁ receptor) and the human umbilical vein (HUV), a mixed preparation containing both B₁ and B₂ receptors¹⁰, were used. Helical strips of RbJV treated with 1 µmol/L of captopril to avoid peptide degradation by the angiotensin-converting enzyme (ACE), alias kininase II were prepared according to Gaudreau *et al.*¹¹ Helical strips of RbA devoid of
15 endothelium were prepared according to Furchgott and Bhadrakom¹². Longitudinal segments of GPI were prepared with the procedure described by Rang¹³. Helical strips of HUV were prepared according to Gobeil *et al.*¹⁰. The tissues were suspended in 10-ml organ baths containing warm (37°C), oxygenated (95% O₂-5% CO₂) Krebs solution of the following composition in mmol/L; NaCl: 118.1; KCl: 4.7; CaCl₂·6H₂O: 2.5;
20 KH₂PO₄: 1.2; MgSO₄·7H₂O: 1.18; NaHCO₃: 25.0 and D-Glucose: 5.5. The RbA and the HUV were stretched with an initial tension of 2 g, whereas the RbJV and the GPI were loaded with 0.5 g. Changes of tension produced by the various agents were measured with Grass isometric transducers (model FT 03C, Grass Instrument Co., Quincy, Mass.). Myotropic contractions were displayed on a Grass polygraph (model 7D).
25 Before testing the drugs, the tissues were allowed to equilibrate for 60-120 min during which time the tissues were repeatedly washed and the tension readjusted every 15 min.

At the beginning of each experiment, a submaximal dose of bradykinin (BK) (9 nmol/L), was applied repeatedly on the RbJV, the GPI or the HUV to ensure that
30 tissues responded with stable contractions. In the RbA, the B₁ preparation whose response has been shown to increase during the incubation *in vitro*⁷, desArg⁹BK (550 nmol/L) was applied 1,3 and 6 h after the equilibration period, in order to monitor the progressive increase of sensitivity of the tissue which generally reaches the maximum after 3-6 h. A similar protocol was used for the HUV.

Repeated applications of a single and double concentration of BK (on RbJV, GPI and HUV) and of desArg⁹BK (RbA and HUV) were made in the absence and in presence of the various peptides to evaluate their apparent affinities as antagonists, in terms of pA_2 ($-\log_{10}$ of the molar concentration of antagonist that reduces the effect of a double concentration of agonist to that of a single one)¹⁴. The antagonists were applied 10 min before measuring the myotropic effects of either BK (the B₂ receptor agonist) or desArg⁹BK (the B₁ receptor agonist). Pharmacological assays on the HUV (a mixed B₁ and B₂ receptor preparation) were done in presence of either HOE140 (400 nmol/L) (a potent B₂ receptor antagonist) or Lys[Leu8]des Arg⁹BK (1 μ mol/L) (a potent B₁ receptor antagonist) (applied 10 min prior to the tested agents) to study the B₁ and the B₂ receptors, respectively¹⁰. All kinin antagonists were initially applied to tissues at concentration of 10 μ g/mL to measure their potential agonistic activities (α^E) in comparison with BK (in the B₂ receptor preparations) or desArg⁹BK (in the B₁ receptor preparations).

Experimental protocol for biochemical assays

The metabolic stability of various kinin-related peptides was evaluated by incubating the peptide in the presence of purified angiotensin-converting enzyme (ACE) from rabbit lungs (purchased from Sigma, St-Louis, MO) dissolved in phosphate buffered saline (PBS) (50 mmol/L, pH 7.5 containing 300 mmol/L NaCl); the final concentration of enzyme was 45 μ g/mL. The experimental protocol for the measurement of ACE activity has been described elsewhere^{15,16}. Briefly, 200 μ mol/L of peptides (40 μ L) were placed in a PBS buffer and incubated for 5 min at 37°C before adding 8.5 μ L of ACE (total volume of the reaction medium; 190 μ L). Samples were withdrawn at 30 min intervals, immersed in boiling water for 5 min, then cooled on ice and centrifuged (5 min) before proceeding to analysis of peptides by high pressure liquid chromatography (HPLC). Results of ACE metabolism are expressed in percent of kinin degradation following the incubation (30 min) of kinin substrates with the enzyme. In these experimental conditions and at the enzymatic dilution indicated above, naturally-occurring kinins (e.g. BK and desArg⁹BK) were found to be fully metabolised after 30 min¹⁶.

HPLC analysis of peptide digests

Pure peptides and metabolic products were analysed by reverse-phase HPLC on a C₁₈ μ Bondapak column (4.6 mm x 25 cm) (Waters) of 10- μ m particle size. The peptides and their fragments were eluted at the rate of 2.0 mL/min. with a linear gradient ranging from 5 to 65% of acetonitrile/TFA 0.05%/water over 20 min. at room temperature. The elution positions of these peptides were determined by following the absorbance at 214 nm. For each assay, 50 μ L of the reaction medium (treated or not with ACE) were extracted and injected into the column. Concentrations of the peaks products, different from the peaks of the peptide substrate, were estimated using a computer software program (Baseline 810; Waters) that controlled also all the chromatography operations. Isolated metabolites and substrates were collected and identified by Electrospray mass spectrometry (positive mode).

Drugs

The B₂ antagonist D-Arg[Hyp³, Thi⁵, D-Tic⁷, Oic⁸]BK (HOE140), and HOE140 derivatives (D-Arg[Hyp³, Thi⁵, D-Tic⁷, Oic⁸]desArg⁹BK (S 0765) and [Hyp³, Thi⁵, D-Tic⁷, Oic⁸]desArg⁹BK) (S 1629))¹⁷ were given by Dr. B. Schölkens (Hoechst, Frankfurt, Germany) and two other peptides (D-Arg[Hyp³, D-Hyp⁷ (trans propyl), Oic⁸]desArg⁹BK (NPC 18565) and D-Arg[Hyp³, D-Hyp⁷ (trans thiophenyl), Oic⁸]desArg⁹BK) (NPC 18828)) were supplied by Dr. D.J. Kyle (Scios Inc., Mountain View, Cal.). The peptide AcLys[N-MeAla⁶, Leu⁸]desArg⁹BK¹⁵ was donated by Dr. G. Drapeau (Centre de recherche Hôtel-Dieu de Québec, Québec, Canada). A series of new peptide analogues of Lys[Leu⁸]desArg⁹BK (see abbreviated structures in Table 1) were prepared in our laboratory with the procedure described by Drapeau and Regoli¹⁸ and they were analysed as described above. Abbreviations follow the recommendations of the IUPAC-IUB Commission on Biochemical Nomenclature¹⁹. Other abbreviations are described as follows: Hyp: trans-4-hydroxy-L-proline; Thi: p-(2-thienyl)L-alanine; Tic: L- (1,2,3,4-tetrahydroisoquinoline-3carboxylic acid); Oic: L-(3aS, 7aS)-octahydro-indol-2-carboxylic acid; β Nal: β -3-(2-naphthyl) alanine; Sar: sarcosine (N-methyl-glycine); eAhx: e-aminohexanoic acid. Captopril was purchased from Squibb Canada (Montreal, Canada). All chemical agents, were obtained from either Bachem CA (Torrance, CA) or Novabiochem (La Jolla, CA). Concentrated solutions (1 to 5 mg/mL) of peptides and other agents were made in bidistilled and deionized water and kept at -20°C until used.

Results

The results obtained with three series of compounds designed to a) improve antagonistic affinity, b) eliminate residual agonistic activities and c) prevent the degradation of B₁ receptor antagonists by ACE, are presented in Table 1, 2 and 3. The first series (Table 1) includes compounds (containing a Hyp residue in position 3), which may derive from the conversion by carboxypeptidases of classical B₂ receptor antagonists into C-terminal desArg⁹-fragments. The results, summarized in Table 1, present the pharmacological profile of each compound in terms of affinities (pA₂) for the B₁ receptor (RbA) and affinities (if any), as well as residual agonistic activities on two B₂ receptor subtypes (RbJV, GPI). Percent of degradation (after 30 min of incubation) by ACE is also indicated.

Pharmacological profiles of compounds 1 and 2 are in agreement with those reported by others^{7,8} and indicate that the presence of a Lys residue at the N-terminal is favourable for antagonism on the B₁ receptor, since Lys[Leu⁸]desArg⁹BK is 10 fold more active than [Leu⁸]desArg⁹BK. These peptides are rapidly inactivated by ACE. The presence of Hyp residue in position 3 and that of a D-Arg at the N-terminal (two modifications that favour antagonistic affinity on B₂ receptors)^{20,21,22} bring a loss of the antagonistic affinity on B₁ receptors (see compound 4) and eventually evoke some residual agonistic activities, especially on the guinea pig B₂ receptor subtype. Most of the changes at the N-terminal neither protect from degradation by ACE nor improve affinity for the rabbit B₁ receptor. The desArg⁹-metabolites of B₂ receptor antagonists of the first generation (compounds 6 and 7)^{20,21} also show low affinity on the B₁ receptor and eventually exert weak antagonism on the B₂ receptor of the RbJV. These compounds are expected to be resistant to ACE degradation because of the presence of a D-residue in position 7, which has been shown to protect bradykinin analogues from ACE²³.

Results obtained with compounds in which Pro in position 7 was replaced by D-Tic are summarized in Table 2. Thus, D-Tic in position 7 prevents the proteolytic activity of ACE, and also reduces affinity for the B₁ receptor markedly. Furthermore, two compounds (# 17 of Table 2 and #26 of Table 3) were tested as inhibitors of ACE and were found (at concentrations up to 10⁻⁴ M) not to interact with the degradation of desArg⁹BK by the enzyme (C. Filteau and F. Gobeil, personal communication). To restore antagonistic affinity, various residues (Sar, Lys, AcLys or D-Arg) were added at the N-terminal of the [D-Tic⁷, Leu⁸]desArg⁹BK (compound 8). An increase of

antagonistic affinity by 0.8 log unit is obtained with the inclusion of a D-Arg (see compound 12). Moreover, the two compounds containing Lys (compounds 10 and 11) act as partial agonists in the B₂ receptor preparations (especially on the GPI); these myogenic effects can not be abolished by HOE140 (10 µg/mL), a potent B₂ receptor antagonist (not shown). For this series of compounds, the most suitable chemical modifications appear to be D-Arg at the N-terminal and Ile position 8 (compound 13). In fact, D-Arg[D-Tic⁷, Ile⁸]desArg⁹BK is an antagonist on the B₁ receptor showing a pA₂ value of 6.97 with no agonistic activity on the B₂ receptor and negligible degradation by ACE. Replacement of the D-Tic stereoisomer (compound 14) in position 7 causes a diminution of the antagonistic potency (pA₂ < 5.04) on the B₁ receptor as well as regaining its susceptibility of being metabolized by ACE. The same results have been obtained when the D-Tic residue in position 7 has been replaced by a smaller residue such as an Ala (see compound 15). The presence of a Hyp residue in position 3 does not seem to play any particular role (see compounds 16, 17).

In a third series of compounds, presented in Table 3, Pro in position 7 was substituted by a βNal and the N-terminal was prolonged either with a single residue or with a short peptidic chain, containing a Tyr residue for iodine labelling. In this series, the residue of choice for the N-terminal appears to be AcLys (see compounds 18, 19), since D-Arg, D-Lys or Sar, although suitable for protection from aminopeptidases, reduce antagonistic affinity for the B₁ receptor to an extent of 0.5 to 1 log unit. Moreover, compounds 19, 22, 23, 25 and 26 (containing Ile in position 8) are partial agonists on the GPI. Again, these contractile effects are not prevented by HOE140 (10 µg/mL), and thus, should be considered as non specific. As to position 8, Leu has the advantage over Ile in eliminating partial agonistic activities on the GPI (and RJV) as well as conferring better protection against ACE hydrolysis (see Table 3). However, this latter substitution causes a slight reduction of antagonism potency compared to those containing an Ile (see Table 3). The AcLys[D-βNal⁷, Ile⁸]desArg⁹BK (compound 19) represents the most potent B₁ receptor antagonist (pA₂ 8.40±0.12) with little residual agonistic effect on the GPI (α^E 0.38) and is partially metabolized by ACE in our experimental conditions. Furthermore, electrospray mass spectrometry analysis of the composition of the degradation mixture of the AcLys[D-βNal⁷, Ile⁸]desArg⁹BK is in agreement with the proteolysis pattern of desArg⁹-peptides by ACE and led to the identification of C-terminal tetrapeptidyl fragments (not shown). Complete protection from ACE is obtained by replacing Ser in position 6 with an N-MeAla but this is

accompanied by a marked loss of B₁ receptor antagonism (compounds 21, 22). These data are consistent with those reported by Drapeau *et al.*¹⁵. A second series of B₁ receptor antagonists, designed for labelling, was prepared following the report by Lévesque *et al.*²⁴ (see compounds 27, 28, 29 and 30 of Table 3). The four compounds
5 maintain high affinity for the B₁ receptors of the RbA (pA₂ values of 8.10 to 8.5) and little, if any, residual agonistic activities on the B₂ receptors of the RbJV and the GPI. They are however broken down by ACE, especially those (compounds 27, 28) which do not possess D-amino acid in position 7.

B₁ and B₂ receptor antagonists containing Oic in position 8 are presented in
10 Table 4. These compounds, prepared by investigators at Hoechst and Scios were tested in the same assays as those of Tables 1, 2 and 3. All compounds exhibit complete resistance to ACE metabolism. All compounds are devoid of partial agonistic activity on both B₁ and B₂ receptor preparations. The presence of a D-residue in position 7 and of Oic in position 8 appear to be essential inasmuch for metabolic
15 protection than for inactivity as agonists. All compounds presented in Table 4 are non selective and represent a new class of antagonists which are able to block both B₁ and B₂ receptors. The spectrum of biological activities shows some differences in that compounds 33 and 34 are more active on the B₁ receptor while compound 31 is more potent on the B₂ receptor (see Table 4). Worthy of mention is the interesting
20 pharmacological characteristics of compounds 31, 32, 33 and 34 which are active on the bradykinin B₂ receptor of the RbJV as well as on the RbA while being almost inactive on the B₂ receptor of the GPI.

Activities of some B₁ receptor antagonists on human B₁ and B₂ receptors.

Some peptidic compounds mentioned earlier were also tested on the HUV, a
25 preparation that contains B₁ and B₂ receptors for the kinins¹⁰. The results summarized in Table 5, indicate that all compounds selected are pure B₁ receptor antagonists, showing no agonistic or antagonistic activities on the human B₂ functional site, with the exception of NPC 18828. The presence of a Lys at the N-terminal is important for the B₁ receptor antagonist since the affinity of Lys[Leu⁸]desArg⁹BK is higher than that of
30 [Leu⁸]desArg⁹BK by at least 1.5 log units which is in agreement with the results of Menke *et al.*²⁵ who have cloned and characterized the human B₁ receptor. The presence of a D-Tic in position 7 is unfavourable for B₁ receptor antagonism, but the affinity of the antagonist can be markedly increased by the addition of a D-Arg at the N-terminal. Other substitutions in this position (with Sar, Ac Lys) are equally favourable

in a series of compounds containing D-βNal in position 7. A significant gain of affinity for the B₁ receptor is observed when position 8 is occupied by Ile. Indeed, AcLys[D-βNal⁷, Ile⁸]desArg⁹BK is the most active antagonist, showing a pA₂ of 8.49 ± 0.10, which is almost 1.5 log units higher than those of all precedent compounds. The stereospecificity of the residue βNal in position 7 is again crucial, likewise in the rabbit, since the isomeric form L-βNal shows 3 orders of magnitude less antagonistic activity than the D-βNal form. Two of the compounds designed for labelling through an elongation of the N-terminal show very high affinities for the human B₁ receptor and are inactive on the human B₂ receptor. These results are similar to what have been observed on the rabbit B₁ receptor. The Hoechst compound (S 0765) is a pure B₁ receptor antagonist (pA₂ 7.29) which is in contrast with its mixed B₁ and B₂ antagonistic activities on the rabbit tissues. The NPC 18828 behaves as an antagonist on both human B₁ and B₂ receptors with a marked predominance for the former. Worthy of notice is the overall resemblance in the pharmacological profiles of the human and the rabbit B₁ receptors described in the present study.

Discussion

The present analysis concerns four series of peptides designed to improve B₁ receptor antagonism and obtain compounds with high affinity, full selectivity for the B₁ receptor and resistance to degradation by ACE and possibly aminopeptidases. To these goals, substitutions were made in positions 3, 7 and 8 of [Leu⁸]desArg⁹BK and one residue or more were added to the N-terminal end, since Lys[Leu⁸]desArg⁹BK has been shown to be at least 10 times more active than [Leu⁸]desArg⁹BK in the rabbit^{7,8} and the human^{10,25}.

Recent studies have shown that human kinins have a Hyp residue in position 3^{26,27}. The reasons of this naturally-occurring hydroxylation of the proline at position 3 in the kinin analog sequences still awaits to be explained. It has been shown, by means of functional assays, that [Hyp³] contained in bradykinin and its analogues may increase the affinity for the B₂ receptor of certain species such as rabbits^{22,28} and dogs^{22,28}. The majority of B₂ receptor antagonists of the first and second generation also contain a Hyp residue in position 3 (e.g. D-Arg[Hyp³,D-Phe⁷]BK²⁰, D-Arg[Hyp³,D-Phe⁷,Leu⁸]BK²¹), and may be converted to desArg⁹-derivatives (antagonists of the B₁ receptors) even *in vitro* by the intramural carboxypeptidases of some isolated organs²⁹. The first series of compounds was therefore designed to

evaluate the role of Hyp³ and the results presented in Table 1 indicate that the Hyp in position 3 does not influence the antagonist affinities in the rabbit B₁ receptor.

Human and animal kallidins have a Lys residue at the N-terminal end, which may probably be the most abundant naturally-occurring kinin analogues present in human plasma and urine³⁰. Furthermore, kallidin and desArg¹⁰-kallidin are sensitive to aminopeptidases (e.g. Aminopeptidase M; EC 3.4.11.2) and can be protected by N-acetylation¹⁵. First and second generation of antagonists have however a D-Arg at the N-terminal, a substitution which has also been shown to protect against degradation by aminopeptidases (see Stewart and Vavrek)³¹. In the first three series (see Tables 1, 2 and 3), the role of the N-terminal position and the C-terminal portion, especially the positions 7 and 8, were conjointly investigated. Because of the predominant role played by ACE, the endothelial enzyme of the pulmonary circulation³², in the inactivation of both the kinins and their desArg⁹-metabolites, B₁ receptor antagonists must be protected if one wishes to prolong their *in vivo* activities. To this goal, D-Tic, a rigid phenylalanine surrogate which has been shown to be protective in HOE140³³ and D-βNal, a non-natural aromatic aminoacid, were used in the peptide sequence. Results summarized in Tables 2 and 3 clearly indicate that the presence of D-Tic in position 7 not only completely prevents the ACE from acting, but a D-residue is also essential for antagonism on the B₁ receptor (compare the two diastereoisomeric compounds 13 and 14 of Table 2). The major limitation of the D-Tic series is however their modest antagonistic affinity, which remains 1.5 log units below that of Lys[Leu⁸]desArg⁹BK. The fundamental role of a D-residue in position 7 for B₁ receptor antagonism is supported by the D-βNal series (Table 3) and especially by the comparison between compound 19 (which contains D-βNal) and compound 20 (which contains L-βNal). The presence of a D-βNal in position 7 not only protects (quite efficiently) from degradation by ACE, but confers higher affinity (by three log units) and selectivity for the rabbit and human B₁ receptors. The only limitation of compound 19 is its residual agonistic activity on the GPI, which appears to be due to a contractile effect of unknown nature, since it is not antagonized either by HOE140 (a β-2 receptor antagonist), or by Losartan (a AT₁ receptor antagonist), indomethacin (a cyclooxygenase inhibitor) and atropine (a muscarinic receptor antagonist) (data not shown). As for the Phe at position 8, several substitutions were made with Leu, Ile or Ala (in the second and third series) with the results of Ile being the most favourable residue for B₁ receptor antagonism. The presence of Ala in position 8 eliminates

antagonistic activity, suggesting that a hydrophobic bulky residue is needed in position 8 for B₁ receptor antagonism. Lacking any knowledge of the geometrical topography of the B₁ receptor interacting sites, one can only speculate on the reasons of differential antagonistic potency observed between the [D-Tic⁷]desArg⁹BK analogs (second series) and the [D-βNal⁷]desArg⁹BK derivatives (third series). Indeed, the D-Tic residue because of its rigid and cyclic structure may exert a greater influence on peptide conformation than the D-βNal residue which has its side chain more flexible. Additionally, both residues because of their hydrophobic nature and their opposite stereochemical configuration may enable the accessibility on the receptor via a hydrophobic pouch.

Few peptidic compounds, designed to obtain potential radioligands (to be labelled with ¹²⁵I), were developed (see Table 3) following the recent report of Lévesque *et al.*²⁴ Two analogues (compounds 27, 28) based on Lys[Leu⁸]desArg⁹BK, the prototypic B₁ receptor antagonist, with an additionally extended N-terminal side, were developed. The results have demonstrated that they maintained high affinities on the human and rabbit B₁ receptors and they are subject to catabolism by ACE. The insertion at the C-terminal end of enzymatically protecting residues such as D-βNal in position 7 (compounds 29, 30) gave rise to more resistant and still selective B₁ receptor antagonists. The non radioactive iodinated peptide (compound 30) was synthesized in order to assess possible changes in affinity and enzymatic resistance of this latter peptide. No significant changes were seen on the pharmacological and biochemical properties of compound 29, thus the SarTyr¹Arg²Pro³His⁴Met⁵Asp⁶Leu⁸Arg⁹BK (compound 29) may have its usefulness in binding studies on the kinin B₁ receptors.

Use of Oic (a non-aromatic tryptophan-like derivative) in position 8 conjointly with a D-stereorientation aminoacid in position 7, have been shown to possess important effects such as preservation of B₂ receptor antagonism, at least on the rabbit B₂ receptor subtype, and thus provides a new category of antagonists acting on both B₁ and B₂ receptors. These findings are consistent with previous studies^{34,35} and can be extended with the results obtained with the antagonists NPC 18565 (compound 33; Scios) and NPC 18828 (compound 34; Scios). Considering the important role that is played by kinins in the acute (via the B₂ receptor) and chronic (via the B₁ receptor) phases of inflammation and pain^{1,2}, this type of compounds may become very useful to assess the role of kinins in experimental pathology. In fact, blockade of only one

kinin receptor type, when both B₁ and B₂ receptors are involved will generally lead to partial protection and underestimation of antagonist affinities. The D-Arg[Hyp³, Thi⁵, D-Tic⁷, Oic⁸]desArg⁹BK (S 0765) and the D-Arg[Hyp³, D³-Tic⁷ (trans thiophenyl), Oic⁸]desArg⁹BK (NPC 18828) have shown dissimilarity between human and rabbit B₂ receptor antagonism (see Tables 4 and 5). This may be explained by the existence of heterogenous bradykinin B₂ receptors between species and/or tissues. Furthermore, this is supported by previous studies which have demonstrated that the S 0765 compound shows differential antagonistic potency between species^{34,35}. In fact, the S 0765 compound is a poor B₂ receptor antagonist in humans (present study), rats³⁵ and guinea pigs^{34,35} (present study) whereas it shows high potency in rabbit tissues³⁵ (present study). As shown in Table 5, NPC 18828 is a very active and quite selective antagonist of the human B₁ receptor, and interacts with the rabbit but not with the guinea pig B₂ receptor subtype (Table 4). The present structure-activity study has therefore provided indications on the stereochemical requirements that might contribute to high potency and selectivity for B₁ receptor antagonism. From the results presented above, it appears that the chemical features favouring affinity of antagonists on the human B₁ receptor are similar to those for the rabbit B₁ receptor, as already emphasized by Regoli *et al.*³⁶ and Gobeil *et al.*¹⁰.

In summary, several peptides related to desArg⁹-bradykinin were tested as stimulants or inhibitors of B₁ (rabbit aorta, human umbilical vein) and B₂ (rabbit jugular vein, guinea pig ileum, human umbilical vein) receptors. The compounds were also incubated with purified angiotensin converting enzyme from rabbit lung to test their resistance to degradation. Apparent affinities (in terms of pA₂) of compounds and their potential residual agonistic activities (α^E) were evaluated. Bradykinin and desArg⁹-bradykinin were used as agonists for the B₂ or the B₁ receptors, respectively. Degradation of peptides by the angiotensin-converting enzyme was prevented in the presence of a D-residue in position 7 of desArg⁹-bradykinin. Replacement of Pro⁷ with D-Tic combined with Leu, Ile, Ala or D-Tic in position 8 led to weak B₁ receptor antagonists, some of which with strong residual agonistic activities on the B₂ receptors preparations. Use of D- β Nal in position 7, combined with Ile in position 8 and Ac-Lys at the N-terminal (e.g. AcLys[D β -Nal⁷, Ile⁸]desArg⁹BK) gave the most active B₁ receptor antagonist (pA₂ of 8.5 on the rabbit aorta and the human umbilical vein), which is also partially resistant to enzymatic degradation. Extension of the N-terminal end by Sar-Tyr- ϵ Ahx (used for labelling purpose) and even cold labelling of Tyr with Iodine

were compatible with high, selective and specific antagonism of the B₁ receptors. Some compounds were compared with those of some already known B₁ receptor antagonists to underline the novelty of new peptidic compounds.

EXAMPLE 2:

5 B1-BRADYKININ RECEPTOR BLOCKADE MAY PREVENT DIABETES-ASSOCIATED VACULOPATHY

Capillary permeability is known to be selectively augmented in the streptozotocin (STZ) diabetic rat model⁴⁹. The vascular BK receptors in the STZ-induced diabetic rat was examined. Segments of the portal vein (a known
10 preparation for BK studies) from these rats were mounted in organ baths for isometric contraction studies. The response to desArg⁹BK, a specific BK-B₁ receptor agonist, was enhanced by 118% in the diabetic tissue, compared to normal portal veins (0.48 vs 0.22g: P<0.001). This enhanced sensitivity was abolished by Lys[Leu⁸]desArg⁹BK, a specific antagonist of the BK-B₁ receptor. HOE140, the BK-B₂ receptor antagonist,
15 had no effect on the diabetic portal vein abnormality. Evans blue (EB: 20mg/kg), a marker of albumin extravasation, was injected to unanesthetized diabetic rats. In two selected tissues where EB leakage was enhanced in diabetes (the skin and the pancreas (from 11 to 48, and from 44 to 92 ug/g dry tissue)), the BK-B₁ receptor antagonist normalized capillary permeability. HOE140 failed to correct EB
20 extravasation in the two affected organs. Therefore, it was concluded that post-capillary hypercontractility to BK (via its B₁ receptor) forces EB extravasation, and likely contributed to the diabetic vasculopathy. From these results, it is contemplated that the B₁-antagonists described in Example 1, particularly those that are proteolysis-resistant, are now suitable for a drug-preventive approach to diabetic vasculopathy, by
25 targeting B₁-receptor without being extensively degraded prior to reaching this receptor.

EXAMPLE 3:

HYPERGLYCEMIA, DIURESIS, PROTEINURIA, NITRITE AND KALLIKREIN URINARY EXCRETION ARE ALL NORMALIZED BY B₁-BK RECEPTOR BLOCKADE:

30 Streptozotocin has been extensively used to produce type I diabetes in animals. This experimental disease is characterized by a mild inflammatory reaction in the Langerhans islets. Because kinins have been proposed as prominent inflammatory

mediators in the pathogenesis of several diseases, we evaluated the role of kinins and their receptors in the evolution of insulinitis. Male C57BL/Ks mdb mice were injected with streptozotocin (40 mg/kg) for 5 consecutive days. The kinin B₁ receptor antagonist [Leu⁸]desArg⁹BK or the B₂ antagonist HOE140 were injected subcutaneously to STZ mice at 300 ug/Kg bw twice a day and 500 ug/Kg per day, respectively. Treatment with antagonists was started 3 days after STZ and lasted for 10 days. Plasma glucose was determined by the glucose oxidase method, and 13 days urinary samples were assayed for proteins, nitrites and kallikreins. Diabetic mice showed hyperglycemia and increased diuresis, marked proteinuria and increased excretion of nitrites and kallikreins. The treatment with B₂ receptor antagonist did not show any effect on glycemia, but it reduced significantly water and protein excretion, compared to STZ group. STZ mice treated with B₁ receptor antagonist showed normal glycemia and complete normalization of diuresis, protein, nitrite and kallikrein excretion. The results obtained in the investigation support the assumption that the kallikrein kinin system intervenes in the maintenance of diabetic lesions and also indicates that B₁ kinin receptors play the most significant role in this experimental disease.

Repeated injections of streptozotocin over 5 days in the mouse have been shown to induce diabetes⁴⁴. This experimental disease is characterized by a mild inflammatory reaction in the Langerhans islets (insulinitis) and by changes of renal functions. Because of the important role that is played by kinins in various inflammatory states or tissue reactions¹, even in the pancreas⁴¹ we raised the hypothesis that these peptides and their receptors could be implicated in the streptozotocin-induced diabetes. Recent findings indicate that B₂ receptors may play a role in the acute phases of inflammatory processes⁴² while B₁ receptors are rather involved in the chronic phases of pain and inflammation³⁹. The purpose of the present investigation was therefore to evaluate the possible role of kinins and their receptors in diabetic mice by the use of potent, selective and specific antagonists of the B₂ or the B₁ receptors.

Methods

Animals

Male C57BL/Ksmdb mice, 3 month old were provided by National Institute of Genetic, Buenos Aires. The animals were housed at a constant room temperature, with a 12 h light-dark cycle.

Animals were randomly divided into the following groups:

A: control treated with solvent.

B: treated with streptozotocin (STZ), 40 mg/kg, during 5 consecutive days

C: treated with STZ + B₁ antagonist: 3 days after the beginning of the treatment with STZ, the animals were injected twice a day with the B₁ receptor antagonist [Leu⁸]desArg⁹BK (300 ug/kg) subcutaneously for 10 days

- 5 D: treated with STZ + B₂ antagonist: 3 day after treatment with STZ, the animals received D-Arg[Hyp³, Thi⁵, D Tic⁷, Oic⁸]BK (HOE140) 500 ug/Kg/day subcutaneously during 10 days.

E and F groups received only [Leu⁸]desArg⁹BK and HOE140 respectively.

Biochemical assays

- 10 Blood (50-60 ul) was collected from the tail vein of non fasting animals in heparinized capillary tubes. Blood samples were taken one day before starting the STZ injection and at the day 13, just before sacrifice. Blood samples were centrifuged and the plasma immediately diluted into the appropriate buffer. Plasma glucose was determined by a glucose oxidase method (the kit was obtained from Wiener, 15 Argentina). Urinary samples were collected over 24 h in housed metabolic cages on the day 13. Urinary volume was determined gravimetrically and urinary samples were assayed for proteins⁴⁵, nitrites⁴⁰ and kallikrein⁴⁷.

Chemicals

- Streptozotocin was purchased from the Sigma Chem Co., St. Louis, Mo. It was dissolved in 0.02 M citrate buffer pH, 4.5 and immediately injected intraperitoneally. 20 [Leu⁸]desArg⁹BK was purchased from Sigma Chem Co., and HOE140 was kindly provided by Dr. B. Schölkens from HOECHST, Frankfurt, Germany. Kallikrein assay was performed using synthetic chromogenic substrate H-D-Val-Leu-Arg-pNA(S-2266) from Kabi, Stockholm, Sweden. The paranitroanilide (pNA) released by enzymatic 25 action on the substrate was measured colorimetrically to determine kallikrein activity

Statistical analysis

All data were expressed as mean + S.E. Analysis of Variance (ANOVA) was performed to evaluate differences among the groups. $p < 0.05$ was considered as significant.

30 Results

Effects of the B₂ receptor antagonist, HOE140

The results obtained in the groups of animals used to evaluate the role of B₂ receptors are presented in Fig. 1. The effect of HOE140 in control and diabetic mice was evaluated by measuring body weight, glycemia and renal functions, particularly

urinary volume, proteinuria, kallikrein and nitrites urinary excretion. No changes of body weight were observed between the various groups of mice.

The two groups treated with STZ showed a significant increase of blood glucose: the treatment with B₂ receptor antagonist did not show any effect on glycemia.

5 Diabetic mice (STZ) showed increased diuresis, marked proteinuria, as well as increased excretion of nitrites and kallikreins. When treated with HOE140, the diabetic animals showed significant reduction in the renal functions, compared to the STZ group. Urinary volume was however reduced only by half and still remained significantly elevated with respect to controls; the same was found to be true for protein and nitrite excretion. Kallikrein excretion was brought back to normal by the treatment
10 with HOE140.

Effects of the B₁ receptor antagonist, [Leu⁸]desArg⁹BK.

Results obtained in the group of mice used to evaluate the effects of B₁ receptor antagonist are summarized in Figure 2. Body weight was similar in all groups STZ
15 treated mice showed significant increase of glycemia, urinary volume, as well as protein, nitrite and kallikrein excretion, similar to those of the group analysed in Fig. 1. STZ mice treated with the B₁ receptor antagonist, showed normal glycemia, thus indicating that blockage of B₁ receptors is associated with a normalization of the blood glucose. Treatment with the B₁ antagonist was effective also in preventing the increase
20 of the urinary volume, as well as those of protein, nitrite and kallikrein in the urine, that is normally observed in diabetic mice.

Discussion

Streptozotocin-induced diabetes in the mouse is associated with an inflammatory reaction³⁸ of the Langerhans islets⁴⁶ with incremented production of NO³⁷
25 and with modifications of renal functions. We hypothesized that the kallikrein-kinin system may intervene in the pathogenesis of this experimental disease, both at the pancreas and at the renal levels. The results obtained in the present investigation support entirely our assumption and also indicate that the kinin receptor that plays the most significant role may be the B₁. This conclusion is based on the observation that
30 prolonged (10 days) treatment with [Leu⁸]desArg⁹BK is associated with a correction of the biochemical parameters that characterize STZ-induced diabetes. Blood glucose of STZ + B₁ antagonist group was normal, indicating that B₁ receptors play a determinant role in the inflammatory reaction of the Langerhans islets and that this reaction is responsible for the elevation of the blood glucose. When the islet

inflammation (insulitis) is prevented, glycemia will remain within normal values. At the kidney level, the two most important changes are the increase of urinary volume and protein excretion, which depend on an augmented permeability of the glomerular membrane. The present results support the interpretation that STZ-induced diabetes is associated with the appearance of B₁ receptor in the glomerular membrane and that stimulation of this receptor leads to diuresis and proteinuria. Indeed appearance of B₁ receptors has been demonstrated in STZ diabetic rats. If B₁ receptors are blocked the two renal parameters are brought back to normal. How can these receptors be activated? Probably by kinins and their metabolites whose production in the pancreas may be increased during insulitis. If insulitis is prevented, glycemia remains normal, the kallikrein-kinin system is not activated and the renal function are not modified. The determinant role of B₁ receptors is confirmed by the comparison with the B₂ antagonist treated group.

Block of B₂ receptors does not lead to correction of glycemia, supporting the interpretation that insulitis is a slowly developing inflammatory reaction, primarily mediated by B₁ receptors. B₂ receptors may play a role at the kidney level, in the glomerular membrane, where their activation may lead to increase of permeability. This mechanism is invoked to explain the partial correction of diuresis, proteinuria and the total correction of kallikrein which was found in the HOE140 treated mice. Together with the changes of the kallikrein-kinin excretion, which increases, in accord with Harvey et al, 1990, and with the induction of the B₁ receptor, NO excretion in urines was also found to be increased: this probably reflects increased production of NO from inflammatory (the Langerhans islets) sites as already reported by Catanzaro et al, 1994. In conclusion, STZ treatment leads to insulitis, which is probably associated with the activation of the kallikrein-kinin system and with the *de novo* formation of B₁ receptors, which appear to play the major role in the inflammatory reaction and in hyperglycemia. Kinins produced at the pancreas level may reach the kidney and activate B₂ and B₁ receptors in the glomerular membrane; such activation results in an increase of permeability which is responsible for diuresis and proteinuria.

EXAMPLE 4:ENHANCED RESPONSE OF THE B₁-BRADYKININ RECEPTOR IN THE SPONTANEOUSLY HYPERTENSIVE RAT

We have previously examined the contractile response of the portal vein (a suitable preparation for B₁-BK studies) obtained from untreated 8-week old spontaneously hypertensive rats (SHR)⁴⁸, in order to document an eventual exaggerated contraction of this post-capillary vascular preparation, susceptible to enhance capillary hydrostatic pressure and plasma leakage described in the SHR⁵⁰.

Desendothelialized portal vein segments obtained from SHR were mounted in organ baths containing a Krebs solution supplemented with captopril (3uM), for isometric contraction studies (baseline tension: 0.5 g). The selective B₁-BK agonist, des-Arg⁹-BK was administered on portal vein segments obtained from normal rats and SHR, to establish dose-response curves to DesArg⁹BK, from 10⁻⁹ to 10⁻⁵ M.

For all values higher than 10⁻⁸M, the contraction curves obtained with portal vein samples from SHR were 72% to 100% higher than those observed in control rats. However, the apparent affinity of the agonist for its receptor, defined as the EC₅₀ remained unchanged. Addition to the bath of a specific B₁-BK receptor antagonist, Lys[Leu⁸]-des-Arg⁹-BK (2 ug/ml), completely blocked the portal vein contraction induced by the B₁-BK receptor agonist in the control rats and in the SHR.

These results revealed for the first time, an abnormality of the B₁-BK receptor on the venous side of the splanchnic microcirculation in the untreated SHR. This defect was characterized by an enhanced sensitivity of the B₁-BK receptor, which likely resulted in a twofold increment in the splanchnic post-capillary resistance. As a result, hydrostatic pressure rises in this, and presumably, other microcirculation beds. Enhanced plasma extravasation from the vascular to the interstitial compartment previously described in the SHR, could well be related to this unique abnormality of the B₁-BK receptor.

In view of the above results (Examples 2 to 4), it is contemplated that the preferred B₁-antagonists described in Example 1 can be advantageously used in replacement of Lys[Leu⁸]desArgBK. Particularly, compounds 8, 9, 12, 13, 17 to 19, and 23 to 30, which appear to be at least 2 to 5 times less susceptible to ACE proteolytic degradation, may be dosed to achieve an effect equivalent to the one observed *in vivo* in STZ-mice with a dosage regimen of 300 µg/Kg b.i.d. subcutaneously (see Example

3). The doses of the novel B₁-antagonists need to be adjusted to take into account the pharmacokinetic and pharmacodynamic principles well known in the art: mode of administration, absorption, distribution, clearance, effective dose, side effects, etc. The antagonists of the present invention are the first to be usable for conducting more
5 extensive clinical studies, since they combine acceptable affinity, selectivity and, in some instances, resistance to degradation.

This invention has been described hereinabove, and it is apparent that modifications can be made thereto, without departing from the teachings and the spirit of the invention. These modifications are under the scope of this invention, as defined
10 in the appended claims.

TABLE 1: Pharmacological characterization and metabolic degradation (by ACE) of synthetic peptides

	Abbreviated structure	Rb.A.		Rb.J.V.		G.P.I.		ACE
		pA ₂	α ^E	pA ₂	α ^E	pA ₂	α ^E	(% degradation)
1-	[Leu ⁸]desArg ⁹ BK	7.24±0.10	0	Inactive	0	Inactive	0.07	83±2
2-	Lys[Leu ⁸]desArg ⁹ BK	8.45±0.12	0	Inactive	0	Inactive	0	74±2
3-	Lys[Hyp ³ , Leu ⁸]desArg ⁹ BK	8.16±0.05	0.02	Inactive	0.02	Inactive	0	40±3
4-	D-Arg[Hyp ³ , Leu ⁸]desArg ⁹ BK	6.47±0.15	0	Inactive	0	<5.02	0.38	83±2
5-	AcLys[Hyp ³ , Leu ⁸]desArg ⁹ BK	6.75±0.21	0	Inactive	0.03	<5.02	0.30	66±1
6-	D-Arg[Hyp ³ , D-Phe ⁷]desArg ⁹ BK	6.44±0.05	0	5.63±0.05	0	<5.05	0.15	n.d.
7-	D-Arg[Hyp ³ , D-Phe ⁷ , Leu ⁸]des Arg ⁹ BK	6.56±0.15	0	5.68±0.04	0	Inactive	0	n.d

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Data of bioassays are means ± s.e.m. of 4-7 experiments. Data from biochemical assays are means ± s.e.m. of 2-3 experiments.

Abbreviations: Rb.A. (rabbit aorta); Rb.J.V. (rabbit jugular vein); G.P.I. (guinea pig ileum); n.d. (not determined).

pA₂: - Log₁₀ of the molar concentration of the antagonist required to reduce the effect of a double concentration of agonist to a single one.

Degradation by ACE was evaluated after 30 min of incubation of peptide (200 µmol/L) with ACE (9 µg) (see Methods). Inactive means that the compound shows no detectable antagonistic effect at concentration ≤ 10 µg/ml.

TABLE 2: Pharmacological characterization and metabolic degradation (by ACE) of synthetic peptides

	Abbreviated structure	Rb.A.		Rb.J.V.		G.P.I.		ACE
		pA ₂	α ^E	pA ₂	α ^E	pA ₂	α ^E	(% degradation)
8-	[D-Tic ⁷ , Leu ⁸]desArg ⁹ BK	5.86±0.03	0	Inactive	0.10	Inactive	0.18	0
9-	Sar[D-Tic ⁷ , Leu ⁸]desArg ⁹ BK	6.16±0.01	0	Inactive	0	Inactive	0.07	0
10-	Lys[D-Tic ⁷ , Leu ⁸]desArg ⁹ BK	6.50±0.02	0	<5.20	0.44	F.ag.	1.01	n.d.
11-	AcLys[D-Tic ⁷ , Leu ⁸]desArg ⁹ BK	5.17±0.04	0	Inactive	0.37	5.85±0.11	1.02	0
12-	D-Arg[D-Tic ⁷ , Leu ⁸]desArg ⁹ BK	6.70±0.06	0	5.35±0.12	0	Inactive	0.02	0
13-	D-Arg[D-Tic ⁷ , Ile ⁸]desArg ⁹ BK	6.97±0.04	0	5.34±0.01	0	Inactive	0.02	9±1
14-	D-Arg[L-Tic ⁷ , Ile ⁸]desArg ⁹ BK	<5.04	0	5.19±0.06	0	Inactive	0	77±3
15-	D-Arg[D-Tic ⁷ , Ala ⁸]desArg ⁹ BK	<5.02	0	Inactive	0	P.ag.	0.47	21±1
16-	D-Arg[Hyp ³ , D-Tic ⁷]desArg ⁹ BK	6.73±0.02	0	<5.66	0.51	P.ag.	0.63	0
17-	D-Arg[Hyp ³ , D-Tic ⁷ , Leu ⁸]desArg ⁹ BK	6.64±0.01	0	<5.04	0	Inactive	0.09	0

Abbreviations as in TABLE 1

* pD₂ indicating apparent affinity as an agonist. n.d.: not determined; F.ag.: full agonist; P.ag.: partial agonist.

TABLE 3: Pharmacological characterization and metabolic degradation (by ACE) of synthetic peptides

	Abbreviated structure	Rb.A.		Rb.J.V.		G.P.I.		ACE
		pA ₂	α ^E	pA ₂	α ^E	pA ₂	α ^E	
18-	AcLys[D-βNal ⁷ , Leu ⁸]desArg ⁹ BK	7.91±0.08	0	<5.06	0	Inactive	0	22±1
19-	AcLys[D-βNal ⁷ , Ile ⁸]desArg ⁹ BK	8.40±0.12	0	Inactive	0.09	P.ag.	0.38	34±1
20-	AcLys[L-βNal ⁷ , Ile ⁸]desArg ⁹ BK	5.30±0.03	0	5.11±0.05	0	Inactive	0.06	99±1
21-	^a AcLys[N-MeAla ⁶ , Leu ⁸]desArg ⁹ BK	6.55±0.06	0.01	Inactive	0	Inactive	0.19	0
22-	AcLys[N-MeAla ⁶ , D-βNal ⁷ , Ile ⁸]desArg ⁹ BK	6.27±0.06	0	Inactive	0.03	P.ag.	0.52	0
23-	D-Arg[D-βNal ⁷ , Ile ⁸]desArg ⁹ BK	7.72±0.11	0.02	6.37±0.12	0.10	P.ag.	0.48	8±1
24-	D-Arg[D-βNal ⁷ , Leu ⁸]desArg ⁹ BK	7.30±0.03	0	5.44±0.09	0	Inactive	0	5±1
25-	D-Lys[D-βNal ⁷ , Ile ⁸]desArg ⁹ BK	7.71±0.05	0	5.43±0.11	0.02	P.ag.	0.33	9±2
26-	Sar[D-βNal ⁷ , Ile ⁸]desArg ⁹ BK	7.42±0.06	0	5.04±0.01	0.11	P.ag.	0.68	0
27-	AcTyrεAhxLys[Leu ⁸]desArg ⁹ BK	8.10±0.08	0	Inactive	0.03	P.ag.	0.30	52±1
28-	SarTyrεAhxLys[Leu ⁸]desArg ⁹ BK	8.17±0.06	0	Inactive	0	Inactive	0.19	34±3
29-	SarTyrεAhxLys[D-βNal ⁷ , Ile ⁸]desArg ⁹ BK	8.48±0.03	0	5.20±0.13	0.02	Inactive	0	15±1
30-	SarTyr(3,5-I)εAhxLys[D-βNal ⁷ , Ile ⁸]desArg ⁹ BK	8.14±0.05	0	5.13±0.05	0	Inactive	0	13±1

Abbreviations as in TABLE 1

^a from ref. Drapeau *et al.*, 1994. P.ag.: partial agonist

TABLE 4: Pharmacological characterization and metabolic degradation (by ACE) of synthetic peptides

Abbreviated structure	Rb.A.		Rb.J.V.		G.P.I.		ACE
	pA ₂	α ^E	pA ₂	α ^E	pA ₂	α ^E	
31- ^a D-Arg[Hyp ³ , Thi ⁵ , D-Tic ⁷ , Oic ⁸] desArg ⁹ BK (S 0765)	6.80±0.10	0	7.38±0.02	0	<5.12	0	0
32- ^a [Hyp ³ , Thi ⁵ , D-Tic ⁷ , Oic ⁸] desArg ⁹ BK (S 1629)	6.32±0.02	0	6.35±0.02	0	<5.12	0	0
33- D-Arg[Hyp ³ , D-Hyp ⁷ (trans propyl), Oic ⁸]desArg ⁹ BK (NPC 18565)	7.94±0.06	0	6.99±0.04	0	<5.12	0	0
34- D-Arg[Hyp ³ , D-Hyp ⁷ (trans thiophenyl), Oic ⁸]desArg ⁹ BK (NPC 18828)	8.27±0.14	0	7.52±0.05	0	<5.14	0	0

Abbreviations as in TABLE 1

^a from ref. Wirth *et al.*, 1991.

TABLE 5: Biological activities of desArg⁹BK related peptides on the human B₁ and B₂ receptors of the umbilical vein

Abbreviated structure	Human umbilical vein		
	B ₁ receptor	B ₂ receptor	
	pA ₂	α ^E	pA ₂
[Leu ⁸]desArg ⁹ BK	^a 6.37±0.06	0	^a Inactive
Lys[Leu ⁸]desArg ⁹ BK	^a 7.99±0.01	0	^a Inactive
[D-Tic ⁷ , Leu ⁸]desArg ⁹ BK	5.56±0.04	0	Inactive
D-Arg[D-Tic ⁷ , Ile ⁸]desArg ⁹ BK	7.64±0.12	0	Inactive
D-Arg[L-Tic ⁷ , Ile ⁸]desArg ⁹ BK	5.33±0.17	0	Inactive
D-Arg[D-βNal ⁷ , Leu ⁸]desArg ⁹ BK	7.30±0.07	0	Inactive
Sar[D-βNal ⁷ , Ile ⁸]desArg ⁹ BK	7.32±0.01	0	Inactive
Ac-Lys[D-βNal ⁷ , Leu ⁸]desArg ⁹ BK	7.45±0.04	0	Inactive
Ac-Lys[D-βNal ⁷ , Ile ⁸]desArg ⁹ BK	8.49±0.10	0	Inactive
Ac-Lys[L-βNal ⁷ , Ile ⁸]desArg ⁹ BK	5.16±0.05	0	Inactive
SarTyr ¹ εAhxLys[D-βNal ⁷ , Ile ⁸]desArg ⁹ BK	8.39±0.16	0	Inactive
SarTyr(3,5-I)εAhxLys[D-βNal ⁷ , Ile ⁸]desArg ⁹ BK	8.32±0.20	0	Inactive
D-Arg[Hyp ³ , Thi ⁵ , D-Tic ⁷ , Oic ⁸]desArg ⁹ BK (S 0765)	7.29±0.07	0	Inactive
D-Arg[Hyp ³ , D-Hyp ⁷ (trans thiophenyl), Oic ⁸]desArg ⁹ BK (NPC 18828)	8.55±0.09	0	5.12±0.20

Abbreviations as in TABLE 1.

^a data from Gobeil *et al.* 1996. n=4-7 experiments.

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WE CLAIM:

1. A B₁-bradykinin receptor antagonist which has the following structure:



wherein

5 A is D-Arginyl, Acetyl Lysyl, D-Lysyl, Sarcosyl, Acetyl Tyrosyl ϵ -aminohexanoyl lysyl, sarcosyl tyrosyl ϵ -aminohexanoyl lysyl, or sarcosyl tyrosyl (3,5-iodine) ϵ -aminohexanoyl lysyl;

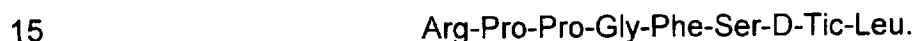
B is prolyl or hydroxyprolyl;

10 C is prolyl, D-(1,2,3,4,-tetrahydroisoquinoline-3-carboxyl, or D- β -3-(2-naphtyl) alanyl; and

D is leucine or isoleucine,

with the proviso that C is not prolyl when A does not comprise a ϵ -aminohexanoyl moiety.

2. A B₁-bradykinin receptor antagonist which has the following structure:



3. A B₁-bradykinin receptor antagonist according to claim 1, which is selected from the group consisting of:

Sar[D-Tic⁷, Leu⁸]desArg⁹ Bradykinin

Sar[D-Tic⁷, Ile⁸]desArg⁹ Bradykinin

20 AcLys[D-Tic⁷, Leu⁸]desArg⁹ Bradykinin

AcLys[D-Tic⁷, Ile⁸]desArg⁹ Bradykinin

D-Arg[D-Tic⁷, Leu⁸]desArg⁹ Bradykinin

D-Arg[D-Tic⁷, Ile⁸]desArg⁹ Bradykinin

AcLys[D- β NaI⁷, Leu⁸]desArg⁹ Bradykinin

25 AcLys[D- β NaI⁷, Ile⁸]desArg⁹ Bradykinin

D-Arg[D- β NaI⁷, Ile⁸]desArg⁹ Bradykinin

D-Arg[D- β NaI⁷, Leu⁸]desArg⁹ Bradykinin

D-Lys[D- β NaI⁷, Leu⁸]desArg⁹ Bradykinin

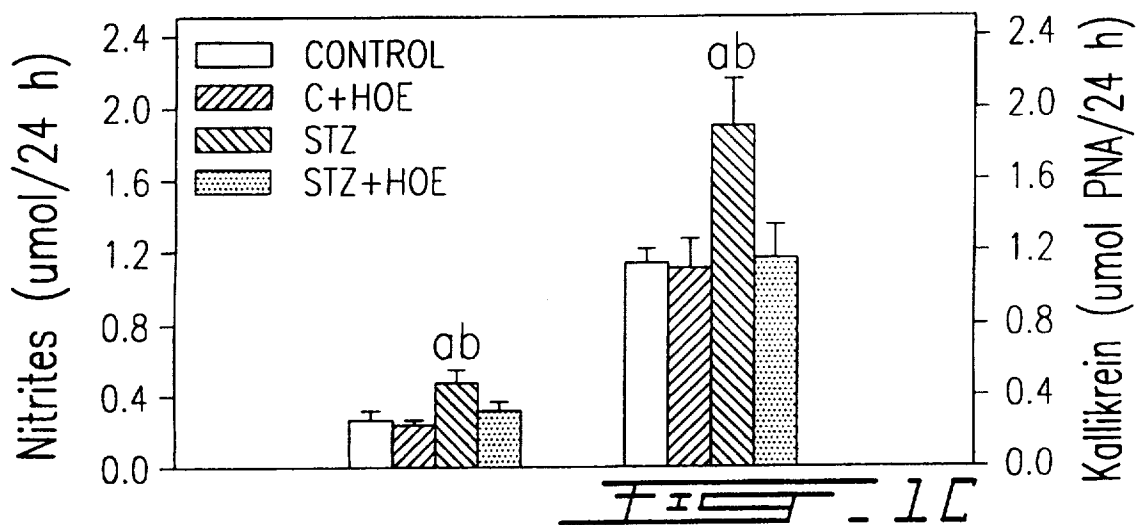
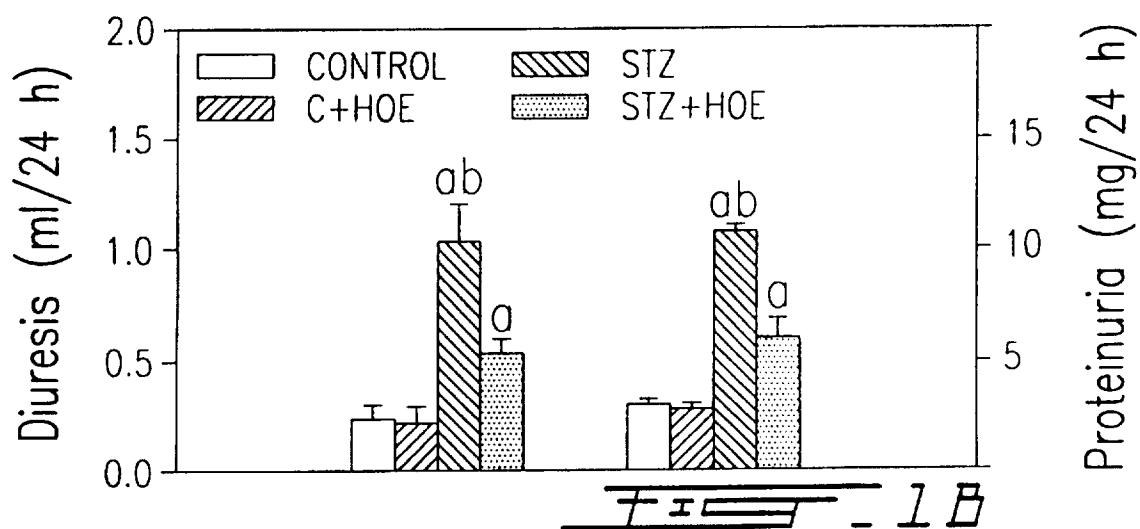
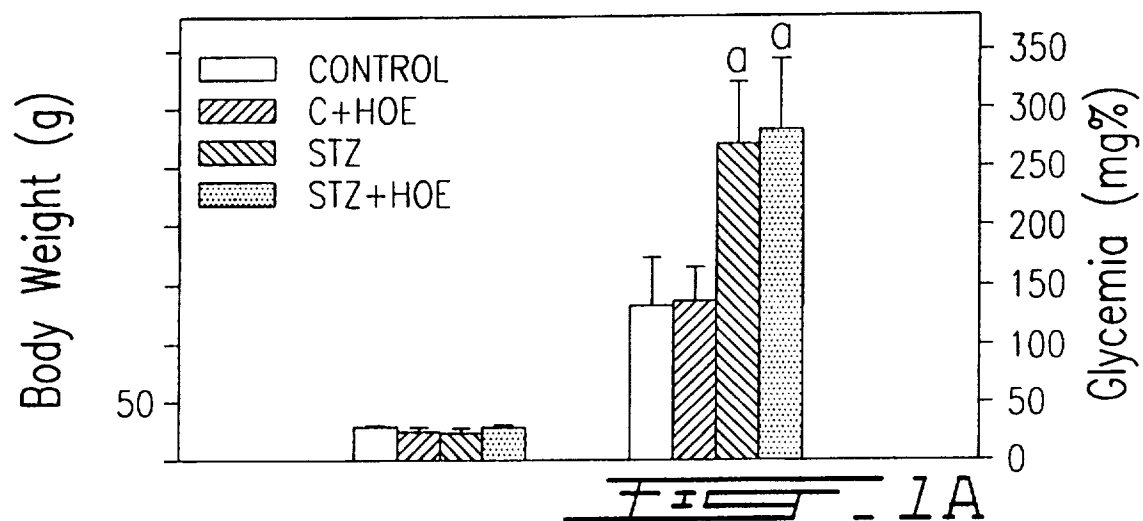
D-Lys[D- β NaI⁷, Ile⁸]desArg⁹ Bradykinin

30 Sar[D- β NaI⁷, Ile⁸]desArg⁹ Bradykinin

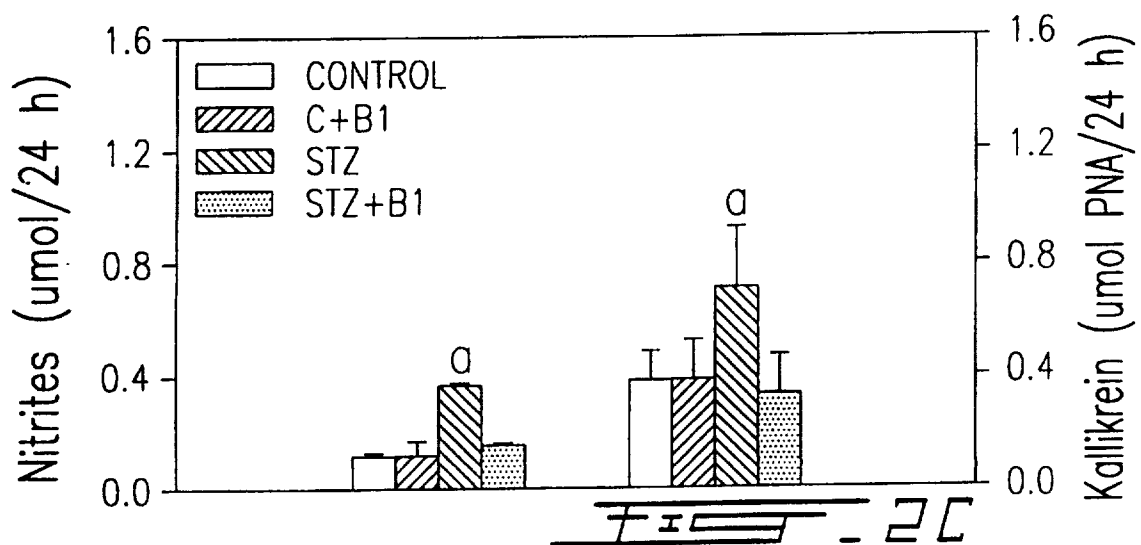
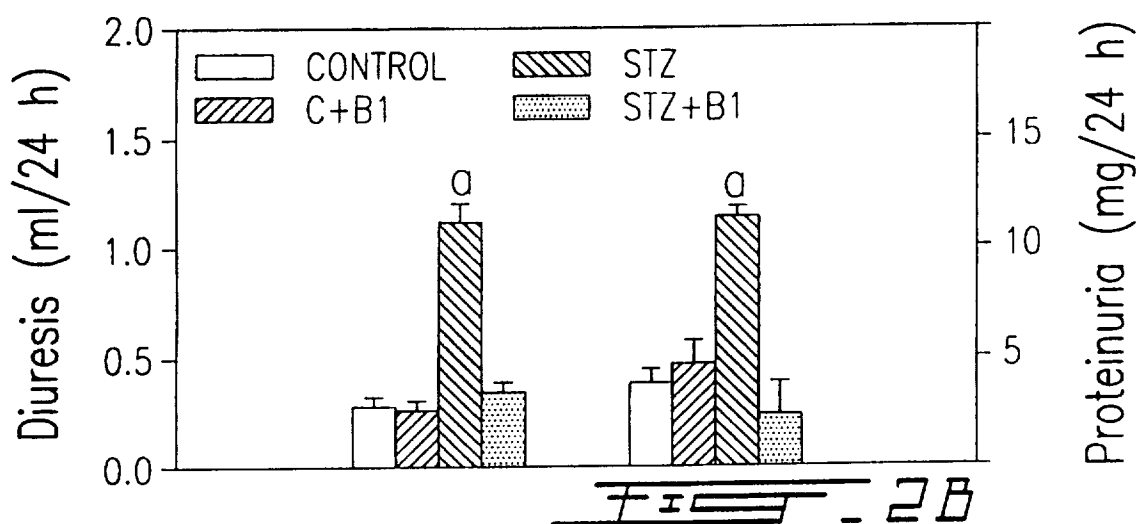
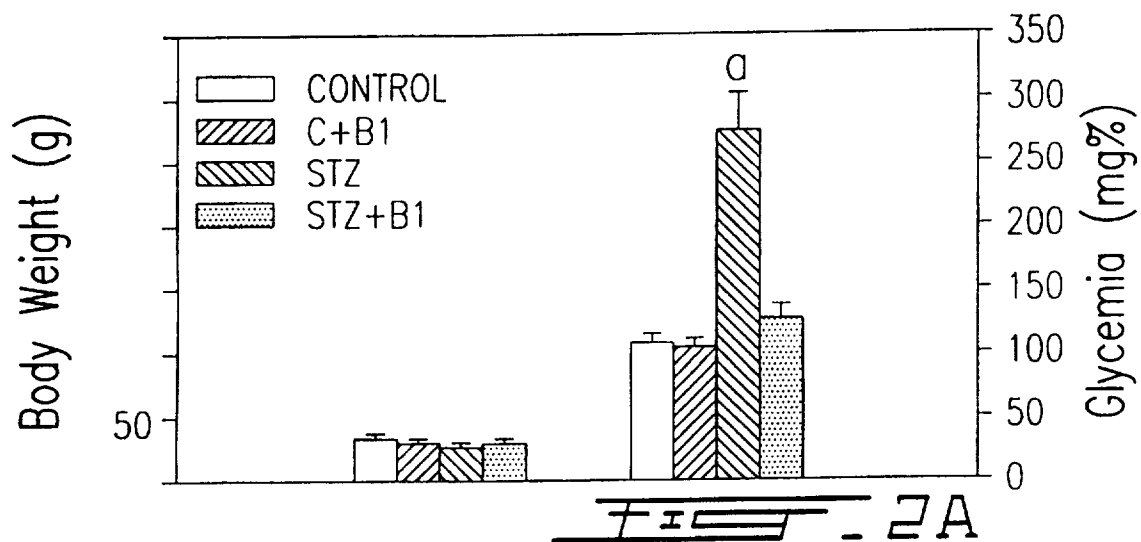
Sar[D-βNal⁷, Leu⁸]desArg⁹ Bradykinin
 AcTyrεAhxLys[Leu⁸]desArg⁹ Bradykinin
 AcTyrεAhxLys[Ile⁸]desArg⁹ Bradykinin
 SarTyrεAhxLys[Leu⁸]desArg⁹ Bradykinin
 5 SarTyrεAhxLys[Ile⁸]desArg⁹ Bradykinin
 SarTyrεAhxLys[D-Nal⁷, Ile⁸]desArg⁹ Bradykinin
 SarTyrεAhxLys[D-Nal⁷, Leu⁸]desArg⁹ Bradykinin
 SarTyr(3,5-iodine)AhxLys[D-Nal⁷, Ile⁸]desArg⁹ Bradykinin, and
 SarTyr(3,5-iodine)AhxLys[D-Nal⁷, Leu⁸]desArg⁹ Bradykinin.

- 10 4. A composition comprising a therapeutically effective amount of B₁-bradykinin receptor antagonist as defined in any one of claim 1 to 3 and a pharmaceutically acceptable carrier.
5. A use of the composition of claim 4 for treating a condition wherein a B₁-bradykinin receptor mediated response is building.
- 15 6. A use as defined in claim 5, wherein said condition is an inflammatory condition.
7. A use as defined in claim 5 or 6, wherein said condition is a diabetic vasculopathy, diabetic symptoms associated with an insulinitis or a post-capillary resistance consequent to the presence of B₁-bradykinin receptor.
8. A use as defined in claim 7, wherein said diabetic symptoms comprising
 - 20 hyperglycemia, diuresis, proteinuria, increased nitrite and kallikrein urinary excretion are normalized as a result of said treatment.
9. A use of a bradykinin receptor antagonist selected from the group consisting of D-Arg[Hyp³, Thi⁵, D-Tic⁷, Oic⁸]desArg⁹BK (S 0765), D-Arg[Hyp³, D-Hyp⁷(trans propyl), Oic⁸]desArg⁹BK (NPC 18565), D-Arg[Hyp³, D-Hyp⁷(trans thiophenyl), Oic⁸]desArg⁹BK(NPC 18828) as a selective B₁ antagonist for treating a human patient
 - 25 affected by a condition wherein a B₁-bradykinin receptor mediated response is building.

1/2



2/2



INTERNATIONAL SEARCH REPORT

In national Application No
PCT/CA 97/00582

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 C07K7/18 A61K38/08

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 C07K A61K

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	ALLOGHO E.A.: "Kinin B1 and B2 receptors in the mouse" CAN.J.PHYS.PHARMACOL., vol. 73, 1995, pages 1759-1764, XP002050648	1,3-8
Y	see the whole document ---	1-8
X	STEWART E.A.: "A new generation of bradykinin antagonists" IMMUNOPHARMACOLOGY, vol. 33, June 1996, pages 51-60, XP000610702	9
Y	see the whole document ---	1-9
	-/-	



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

° Special categories of cited documents :

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier document but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed

- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- "Z" document member of the same patent family

Date of the actual completion of the international search

18 December 1997

Date of mailing of the international search report

21.01.98

Name and mailing address of the ISA

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Groenendijk, M

INTERNATIONAL SEARCH REPORT

International Application No
PCT/CA 97/00582

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WIRTH E.A.: "DesArg(10)-HOE140 is a potent bradykinin B1 receptor antagonist" EUR.J.PHARMACOL., vol. 205, 1991, pages 217-218, XP002050649 cited in the application see the whole document ---	9
Y	WO 92 18156 A (NOVA TECH LP) 29 October 1992 see the whole document ---	9
A	DRAPEAU E.A.: "Development and in vivo evaluation of metabolically resistant antagonists of B1 receptors for kinins" J.PHARMACOL.EXP.THERAP., vol. 266, no. 1, 1993, pages 192-199, XP002050650 see the whole document ---	1-9
P,X	GOBEIL E.A.: "Structure-activity studies of B1 receptor-related peptides" HYPERTENSION, vol. 28, no. 5, November 1996, pages 833-839, XP002050651 see the whole document ---	1-9
P,X	GOBEIL E.A.: "Pharmacological profiles of the human and rabbit B1 receptors" CAN.J.PHYSIOL.PHARMACOL., vol. 75, no. 6, June 1997, pages 591-595, XP002050652 see the whole document -----	1-9

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CA 97/00582

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☒ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

Although claims 5-9 are directed to a method of treatment of the human/animal body, the search has been carried out and based on the alleged effects of the compound/composition.
2. ☐ Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.
2. ☒ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
- ☐ No protest accompanied the payment of additional search fees.

International application No.

PCT/CA 97/00582

1. Claims: 1-8

2. Claim : 9

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/CA 97/00582

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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