(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
16 July 2009 (16.07.2009)

PCT

(10) International Publication Number
WO 2009/087379 A2

(51) International Patent Classification:
C07D 491/04 (2006.01) *A61P 19/00* (2006.01)
A61K 31/407 (2006.01)

(21) International Application Number:
PCT/GB2009/000039

(22) International Filing Date: 7 January 2009 (07.01.2009)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
0800338.6 9 January 2008 (09.01.2008) GB
0808669.6 13 May 2008 (13.05.2008) GB

(71) Applicant *(for all designated States except US)*: **AMURA THERAPEUTICS LIMITED** [GB/GB]; Highfield Court, Church Lane, Madingley, Cambridge CB23 8AG (GB).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **QUIBELL, Martin** [GB/GB]; Amura Therapeutics Limited, Highfield Court, Church Lane, Madingley, Cambridge CB23 8AG (GB). **WATTS, John, Paul** [GB/GB]; Amura Therapeutics Limited, Highfield Court, Church Lane, Madingley, Cambridge CB23 8AG (GB).

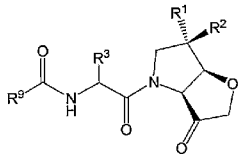
(74) Agent: **CLYDE-WATSON, Zoe**; D Young & Co, 120 Holborn, London EC1N 2DY (GB).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

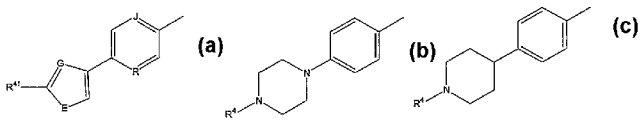
(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *without international search report and to be republished upon receipt of that report*

(54) Title: COMPOUNDS



(I)



(57) Abstract: A compound of formula (I), or a pharmaceutically acceptable salt, hydrate, complex or pro-drug thereof, wherein one of R^1 and R^2 is H, and the other is selected from C_{1-8}-alkyl, C_{3-6}-cycloalkyl and C_{1-8}-alkyl-C_{5-10}-aryl; R^3 is selected from *tert*-butylmethyl, zso-propylmethyl, sec- butyl, tert-butyl, cyclopentyl, cyclohexyl and 1-methylcyclopentyl; R^9 is selected from the following: wherein: R^4 is selected from C_{1-8}-alkyl and C_{3-8}-cycloalkyl; G is selected from:) CH,) CMe and N; E is selected from: O, S,) SO_2,)NH,)NMe and N-oxide ()N->O); J and R are independently selected from:)CH, N and N-oxide ()N-^O); and R^{41} is selected from amino, methylamino, dimethylamino, isopropylamino, isopropyl(methyl)amino, cyclopropylamino, cyclopropyl(methyl)amino, cyclopentylamino, morpholino, piperidin-1-yl, piperidin-1-ylmethyl, morpholinomethyl, 4-methylpiperazin-l-yl, 4-(2-methoxyethyl)piperazin-l-yl, 1- moϕholinoethyl, l-(dimethylamino)ethyl, l-(methylamino)ethyl, 4-fluoro-l- methylpyrrolidin-2-yl, 4,4-difluoropiperidin-l-yl, piperidin-4-yl, l-methylpiperidin-4- yl, pyridin-3-ylamino, pyridin-2-ylamino, l-methylpyrrolidin-3-yl, methyl, isopropyl. The invention further relates to pharmaceutical compositions comprising compounds of formula (I), and the use of such compounds in the treatment of various diseases.

WO 2009/087379 A2

COMPOUNDS

The present invention relates to compounds that are inhibitors of cysteine proteinases, pharmaceutical compositions containing said compounds, and their use in therapy. More specifically, but not exclusively, the invention relates to compounds that are inhibitors of cathepsin K and related cysteine proteinases of the CA clan. Such compounds are particularly useful for the *in vivo* therapeutic treatment of diseases in which participation of a cysteine proteinase is implicated.

BACKGROUND TO THE INVENTION

Proteinases form a substantial group of biological molecules which to date constitute approximately 2% of all the gene products identified following analysis of several completed genome sequencing programmes. Proteinases have evolved to participate in an enormous range of biological processes, mediating their effect by cleavage of peptide amide bonds within the myriad of proteins found in nature. This hydrolytic action is performed by initially recognising, then binding to, particular three-dimensional electronic surfaces displayed by a protein, which align the bond for cleavage precisely within the proteinase catalytic site. Catalytic hydrolysis then commences through nucleophilic attack of the amide bond to be cleaved either *via* an amino acid side-chain of the proteinase itself, or through the action of a water molecule that is bound to and activated by the proteinase. Proteinases in which the attacking nucleophile is the thiol side-chain of a Cys residue are known as cysteine proteinases. The general classification of 'cysteine proteinase' contains many members found in a wide range of organisms from viruses, bacteria, protozoa, plants and fungi to mammals.

Cathepsin K and indeed many other crucial proteinases belong to the papain-like CAC1 family. Cysteine proteinases are classified into 'clans' based upon a similarity in the three-dimensional structure or a conserved arrangement of catalytic residues within the proteinase primary sequence. Additionally, 'clans' may be further classified into 'families' in which each proteinase shares a statistically significant relationship with other members when comparing the portions of amino acid sequence which constitute

the parts responsible for the proteinase activity (see Barrett, A.J *et al,* in 'Handbook of Proteolytic Enzymes', Eds. Barrett, A. J., Rawlings, N. D., and Woessner, J. F. Publ. Academic Press, 1998, for a thorough discussion).

To date, cysteine proteinases have been classified into five clans, CA, CB, CC, CD and CE (Barrett, A. J. *et al,* 1998). A proteinase from the tropical papaya fruit 'papain' forms the foundation of clan CA, which currently contains over 80 distinct and complete entries in various sequence databases, with many more expected from the current genome sequencing efforts. Proteinases of clan CA / family C1 have been implicated in a multitude of house-keeping roles and disease processes. e.g. human proteinases such as cathepsin K (osteoporosis, osteoarthritis), cathepsin S (multiple sclerosis, rheumatoid arthritis, autoimmune disorders), cathepsin L (metastases), cathepsin B (metastases, arthritis), cathepsin F (antigen processing), cathepsin V (T-cell selection), dipeptidyl peptidase I (granulocyte serine proteinase activation) or parasitic proteinases such as falcipain (malaria parasite *Plasmodium falciparum*) and cruzipain (*Trypanosoma cruzi* infection). Recently a bacterial proteinase, staphylopain (*S. aureus* infection) has also been tentatively assigned to clan CA.

X-ray crystallographic structures are available for a range of the above mentioned proteinases in complex with a range of inhibitors e.g. papain (PDB entries, 1pad, 1pe6, 1pip, 1pop, 4pad, 5pad, 6pad, 1ppp, 1the, 1csb, 1huc), cathepsin K (1au0, 1au2, 1au3, 1au4, 1atk, 1mem, 1bgo, 1ayw, 1ayu, 1nl6, 1nlj, 1q6k, 1snk, 1tu6), cathepsin L (1cs8, 1mhw), cathepsin S (1glo, 1ms6, 1npz), cathepsin V (1fh0), dipeptidyl peptidase I (1jqp, 1k3b), cathepsin B (1gmy, 1csb), cathepsin F (1m6d), cruzain (a recombinant form of cruzipain see Eakin, A. E. *et al*, 268(9), 6115-6118, 1993) (1ewp, 1aim, 2aim, 1F29, 1F2A, 1F2B, 1F2C), staphylopain (1cv8). Each of the structures displays a similar overall active-site topology, as would be expected by their 'clan' and 'family' classification and such structural similarity exemplifies one aspect of the difficulties involved in discovering a selective inhibitor of cathepsin K suitable for human use. However, subtle differences in terms of the depth and intricate shape of the active site groove of each CAC1 proteinase are evident, which may be exploited for selective

inhibitor design. Additionally, many of the current substrate-based inhibitor complexes of CAC1 family proteinases show a series of conserved hydrogen bonds between the inhibitor and the proteinase backbone, which contribute significantly to inhibitor potency. Primarily a bidentate hydrogen-bond is observed between the proteinase Gly66 (C=O)/ inhibitor N-H and the proteinase Gly66(NH)/inhibitor (C=O), where the inhibitor (C=O) and (NH) are provided by an amino acid residue NHCHRCO that constitutes the S2 sub-site binding element within the inhibitor (see Berger, A. and Schecter, I. *Philos. Trans. R. Soc. Lond. [Biol.]*, 257, 249-264, 1970 for a description of proteinase binding site nomenclature). A further hydrogen-bond between the proteinase main-chain (C=O) of asparagine or aspartic acid (158 to 163, residue number varies between proteinases) and an inhibitor (N-H) is often observed, where the inhibitor (N-H) is provided by the S1 sub-site binding element within the inhibitor. Thus, the motif X-NHCHRCO-NH-Y is widely observed amongst the prior art substrate-based inhibitors of CAC1 proteinases.

Cathepsin K is thought to be significant in diseases involving excessive loss of bone or cartilage. Bone consists of a protein matrix incorporating hydroxyapatite crystals. About 90% of the structural protein of the matrix is type I collagen, with the remainder comprising various non-collagenous proteins such as osteocalcin, proteoglycans, osteopontin, osteonectin, thrombospondin, fibronectin and bone sialoprotein.

Skeletal bone is not a static structure but continually undergoes a cycle of bone resorption and replacement. Bone resorption is carried out by osteoclasts, which are multinuclear cells of haematopoietic lineage. Osteoclasts adhere to the bone surface and form a tight sealing zone. The membrane on the apical surface of the osteoclasts is folded so as to create a closed extracellular compartment between the osteoclast and the bone surface, which is acidified by proton pumps in the osteoclast membrane. Proteolytic enzymes are secreted into the compartment from the osteoclast. The high acidity in the compartment causes the hydroxyapatite at the surface of the bone to be dissolved and the proteolytic enzymes break down the protein matrix causing a

resorption lacuna to be formed. Following bone resorption, osteoblasts produce a new protein matrix that is subsequently mineralised.

In disease states such as osteoporosis and Paget's disease, the bone resorption and replacement cycle is disrupted leading to a net loss of bone with each cycle. This leads to weakening of the bone and therefore to increased risk of bone fracture.

Cathepsin K is expressed at a high level in osteoclasts and is therefore thought to be essential for bone resorption. Thus, selective inhibition of cathepsin K is likely to be effective in the treatment of diseases involving excessive bone loss. These include osteoporosis, gingival diseases such as gingivitis and periodontitis, Paget's disease, hypercalaemia of malignancy and metabolic bone disease.

In addition to osteoclasts, high levels of cathepsin K are also found in chondroclasts from the synovium of osteoarthritic patients. It therefore appears that cathepsin K inhibitors will be of use in the treatment of diseases involving matrix or cartilage degradation, in particular osteoarthritis and rheumatoid arthritis.

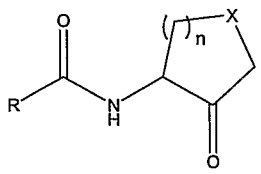
Elevated levels of cathepsin K are also found in metastatic neoplastic cells which suggests that cathepsin K inhibitors may also be useful for treating certain neoplastic diseases.

In the prior art, the development of cysteine proteinase inhibitors for human use has recently been an area of intense activity (e.g. see Deaton, D. N. and Kumar, S., Prog. Med. Chem. 42, 245-375, 2004; Bromme, D. and Kaleta, J., Curr. Pharm. Des., 8, 1639-1658, 2002; Kim, W. and Kang, K., Expert Opin. Ther. Patents, 12(3), 419-432, 2002; Leung-Toung, R. et al. Curr. Med. Chem., 9, 979-1002, 2002; Lecaille, F. et al., Chem. Rev., 102, 4459-4488, 2002; Hernandez, A. A. and Roush, W. R., Curr. Opin. Chem. Biol., 6, 459-465, 2002). Considering the CAC1 family members, particular emphasis has been placed upon the development of inhibitors of human cathepsins, primarily cathepsin K (osteoporosis), cathepsin S (autoimmune disorders), cathepsin L

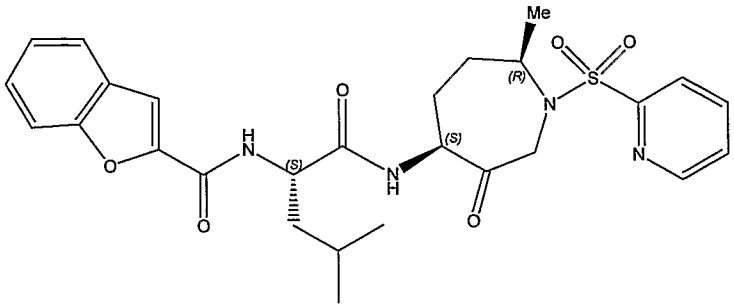
(metastases), cathepsin B (metastases, arthritis), cathepsin F (antigen processing), cathepsin V (T-cell selection) and dipeptidyl peptidase I (granulocyte serine proteinase activation), through the use of peptide and peptidomimetic nitriles (e.g. see WO-A-03041649, WO-A-03037892, WO-A-03029200, WO-A-02051983, WO-A-02020485, US-A-20020086996, WO-A-01096285, WO-A-0109910, WO-A-0051998, WO-A-0119816, WO-A-9924460, WO-A-0049008, WO-A-0048992, WO-A-0049007, WO-A-0130772, WO-A-0055125, WO-A-0055126, WO-A-0119808, WO-A-0149288, WO-A-0147886), linear and cyclic peptide and peptidomimetic ketones (e.g. see Veber, D. F. and Thompson, S. K., Curr. Opin. Drug Discovery Dev., 3(4), 362-369, 2000, WO-A-02092563, WO-A-02017924, WO-A-01095911, WO-A-0170232, WO-A-0178734, WO-A-0009653, WO-A-0069855, WO-A-0029408, WO-A-0134153 to WO-A-0134160, WO-A-0029408, WO-A-9964399, WO-A-9805336, WO-A-9850533), ketoheterocycles (e.g. see WO-A-02080920, WO-A-03042197, WO-A-WO-A-03024924, WO-A-0055144, WO-A-0055124), monobactams (e.g. see WO-A-0059881, WO-A-9948911, WO-A-0109169), α-ketoamides (e.g. see WO-A-03013518), cyanoamides (WO-A-01077073, WO-A-01068645), dihydro pyrimidines (e.g. see WO-A-02032879) and cyanoaminopyrimidines (e.g. see WO-A-03020278, WO-A-03020721).

The prior art describes potent *in vitro* inhibitors, but also highlights the many difficulties in developing a human therapeutic. For example, WO-A-9850533 and WO-A-0029408 describe compounds that may be referred to as cyclic ketones (e.g. 1'a-f) and are inhibitors of cysteine proteinases with a particular reference towards papain family proteinases and as a most preferred embodiment, cathepsin K. WO-A-9850533 describes compounds subsequently detailed in the literature as potent inhibitors of cathepsin K with good oral bioavailability (Witherington, J., 'Tetrahydrofurans as Selective Cathepsin K Inhibitors', RSC meeting, Burlington House, London, 1999). The compounds of WO-A-9850533 were reported to bind to cathepsin K through the formation of a reversible covalent bond between the tetrahydrofuran carbonyl and the active site catalytic cysteine residue (Witherington, J., 1999). Additionally, the same cyclic ketone compounds are described in WO-A-9953039 as part of a wide-ranging

description of inhibitors of cysteine proteinases associated with parasitic diseases, with particular reference to the treatment of malaria by inhibition of falcipain.



[1'a] X = O, n = 1
[1'b] X = NR', n = 1
[1'c] X = O, n = 2
[1'd] X = NR', n = 2
[1'e] X = NR', n = 3



[1'f] SB-462795, relacatib

Prior art cyclic inhibitors of cathepsin K

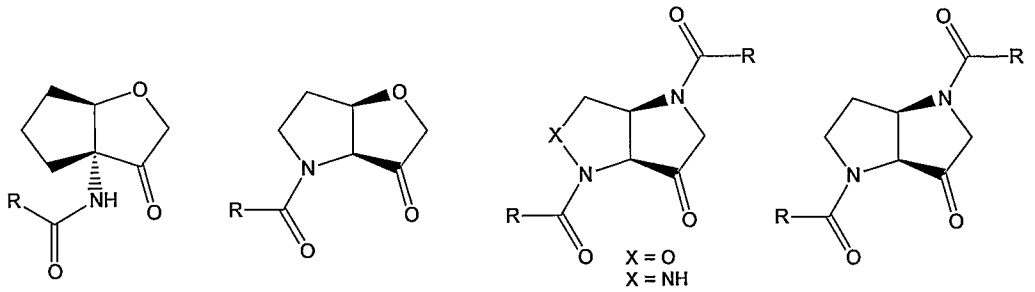
The initial cyclic inhibitors of GSK were based upon potent, selective and reversible 3-amido-tetrahydrofuran-4-ones [1'a], 3-amidopyrrolidin-4-ones [1'b], 4-amido-tetrahydropyran-3-ones [1'c], 4-amidopiperidin-3-ones [1'd] and 4-amidoazepan-3-ones [1'e, 1'f] (shown above) [see (a) Marquis, R. W. *et al*, J. Med. Chem. 2001, 44, 725, and references cited therein; (b) Marquis, R. W. *et al*, J. Med. Chem. 2001, 44, 1380, and references cited therein; (c) Yamashita, D. S. *et al*, J. Med. Chem. 2006, 49(5), 1597-1612].

Further studies revealed that cyclic ketones [1'], in particular the five-membered ring analogues [1'a] and [1'b], suffered from configurational instability due to facile epimerisation at the centre situated α to the ketone [Marquis, R. W. *et al*, J. Med. Chem. 2001, 44, 1380; Fenwick, A. E. *et al*, J. Bioorg. Med. Chem. Lett. 2001, 11, 199; WO 00/69855]. This precluded the pre-clinical optimisation of inhibitors of formulae [1'a-d] and led to the development of the configurationally more stable azepanone series [1'e], providing the cathepsin K inhibitor clinical candidate relacatib [1'f]. However, literature clearly states that azepanones are still prone to epimerisation and indeed relacatib [1'f] is reported to exist as a 9:1 thermodynamic mixture of 4-*S* and 4-*R* isomers [Yamashita, D. S. *et al*, J. Med. Chem., 2006, 49(5), 1597-1612]. As

an alternative to the ring expansion approach, alkylation of the α-carbon removes the ability of cyclic ketones [1'] to undergo α-enolisation and hence leads to configurational stability. However, studies have shown that α-methylation in the 3-amidopyrrolidin-4-one [1'b] system results in a substantial loss in potency versus cathepsin K from $K_{i,app} \approx 0.18$ to 50 nM.

The cyclic ketone compounds of WO-A-0069855 are considered to be an advance on compounds of WO-A-9850533 due to the presence of the β-substituent on the cyclic ketone ring system that provides improved chiral stability to the α-carbon of the cyclic ketone ring system. However, the compounds of WO-A-0069855 and indeed those of WO-A-9850533 describe a requirement for the presence of the potential hydrogen-bonding motif X-NHCHRCO-NH-Y that is widely observed amongst the prior art substrate-based inhibitors of CAC1 proteinases.

More recent studies have investigated 5,5-bicyclic systems as inhibitors of CAC1 proteinases, for example, *N*-(3-oxo-hexahydrocyclopenta[*b*]furan-3*a*-yl)acylamide bicyclic ketones [2'] [(a) Quibell, M.; Ramjee, M. K., WO 02/57246; (b) Watts, J. *et al*, Bioorg. Med. Chem. 2004, 12, 2903-2925], tetrahydrofuro[3,2-*b*]pyrrol-3-one based scaffolds [3'] [(a) Quibell, M. WO02/57270; (b) Quibell, M. *et al*, Bioorg. Med. Chem., 2004, 12, 5689-5710], *cis*-6-oxohexahydro-2-oxa-1,4-diazapentalene and *cis*-6-oxo-hexahydropyrrolo[3,2-*c*]pyrazole based scaffolds [4'] [Wang, Y. *et al*, Bioorg. Med. Chem. Lett., 2005, 15, 1327-1331], and *cis*-hexahydropyrrolo[3,2-*b*]pyrrol-3-one based scaffolds [5'] [a) Quibell, M. WO04/07501; (b) Quibell, M. *et al*, Bioorg. Med. Chem., 2005, 13, 609-625].



[2'] [3'] [4'] [5']

5,5-bicyclic inhibitors of CAC1 cysteinyl proteinases

Studies have shown that the above-described 5,5-bicyclic systems exhibit promising potency as inhibitors of a range of therapeutically attractive mammalian and parasitic CAC1 cysteinyl proteinase targets. Moreover, the 5,5-bicyclic series are chirally stable due to a marked energetic preference for a *cis*-fused rather than a *trans*-fused geometry. This chiral stability provides a major advance when compared to monocyclic systems that often show limited potential for preclinical development due to chiral instability.

PCT applications WO-A-02057270 and WO-A-04007501 describe bicyclic compounds in which the chirality of the α-aminoketone is stabilised (for a review of energetic considerations within fused ring systems see (a) Toromanoff, E. *Tetrahedron Report No 96*, 36, 2809-2931, 1980; (b) Eliel, E. L. *et. al. Stereochemistry of Organic Compounds,* Wiley: New York, 1-1267, 1994). These compounds do not contain the X-NHCHRCO-NH-Y motif and yet the compounds are highly potent inhibitors across a broad range of CAC1 cysteine proteinases. In particular, certain of the compounds are potent and selective inhibitors of a range of mammalian and parasitic CAC1 proteinases.

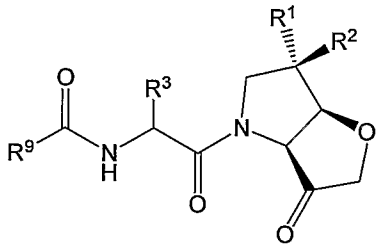
More recently, Quibell, M. *et al* (*Bioorg. Med. Chem.* 12, 5689-5710, 2004) disclosed two potent and selective cathepsin K inhibitors having a tetrahydrofuro[3,2-*b*]pyrrol-3-one core, along with *in vitro* potency and *in vitro* selectivity data. Further kinetic parameters such as enzyme association (*kon*) and dissociation (*koff*) rates were

disclosed, as well as basic physiochemical parameters such as plasma and microsome stability, Caco-2 permeability and LogD ($pH_{7.4}$) measurements.

The present inventors have now discovered a small genus of 6-alkyltetrahydrofuro[3,2-*b*]pyrrol-3-ones that exhibit potent *in vitro* inhibition versus human cathepsin K.

STATEMENT OF INVENTION

A first aspect of the invention relates to a compound of formula (I), or a pharmaceutically acceptable salt, hydrate, complex or pro-drug thereof,



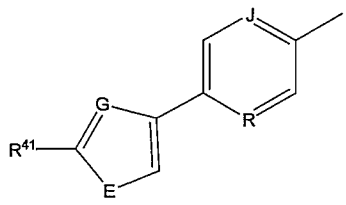
(I)

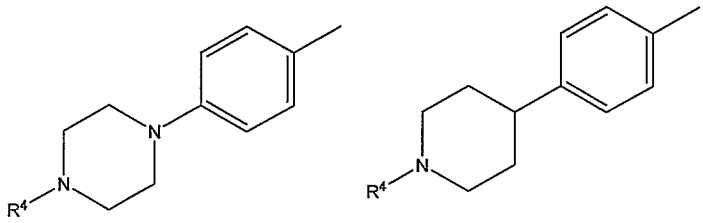
wherein:

one of R^1 and R^2 is H, and the other is selected from C_{1-8}-alkyl, C_{3-6}-cycloalkyl and C_{1-8}-alkyl-C_{5-10}-aryl;

R^3 is selected from *tert*-butylmethyl, *iso*-propylmethyl, *sec*-butyl, *tert*-butyl, cyclopentyl, cyclohexyl and 1-methylcyclopentyl;

R^9 is selected from the following:





wherein:

R^4 is selected from C_{1-8}-alkyl and C_{3-8}-cycloalkyl;

G is selected from:

$\backslash/$CH, $\backslash/$CMe and N;

E is selected from:

O, S, $\backslash/SO_2$, $\backslash/$NH, $\backslash/$NMe and N-oxide ($\backslash/N\rightarrow O$);

J and R are independently selected from:

$\backslash/$CH, N and N-oxide ($\backslash/N\rightarrow O$); and

R^{41} is selected from amino, methylamino, dimethylamino, isopropylamino, isopropyl(methyl)amino, cyclopropylamino, cyclopropyl(methyl)amino, cyclopentylamino, morpholino, piperidin-1-yl, piperidin-1-ylmethyl, morpholinomethyl, 4-methylpiperazin-1-yl, 4-(2-methoxyethyl)piperazin-1-yl, 1-morpholinoethyl, 1-(dimethylamino)ethyl, 1-(methylamino)ethyl, 4-fluoro-1-methylpyrrolidin-2-yl, 4,4-difluoropiperidin-1-yl, piperidin-4-yl, 1-methylpiperidin-4-yl, pyridin-3-ylamino, pyridin-2-ylamino, 1-methylpyrrolidin-3-yl, methyl, isopropyl..

As mentioned above, compounds of formula (I) exhibit surprisingly high efficacies for human cathepsin K. In addition, preferred compounds of formula (I) exhibit surprisingly good stability in plasma and microsome assays.

A second aspect of the invention relates to a pharmaceutical or veterinary composition comprising a compound of formula (I) and a pharmaceutically acceptable or veterinarily acceptable diluent, excipient and/or carrier.

A third aspect of the invention relates to a process for preparing a pharmaceutical or veterinary composition as defined above, said process comprising admixing a compound of the invention with a pharmaceutically acceptable or veterinarily acceptable diluent, excipient and/or carrier.

A fourth aspect of the invention relates to compounds of formula (I) for use in medicine.

A fifth aspect of the invention relates to the use of a compound of formula (I) in the preparation of a medicament for treating a disease selected from osteoporosis, Paget's disease, Chagas's disease, malaria, gingival diseases, hypercalaemia, metabolic bone disease, diseases involving matrix or cartilage degradation, and bone cancer disorders such as bone metastases and associated pain.

A sixth aspect of the invention relates to a method of inhibiting a cysteine proteinase in a cell, said method comprising contacting said cell with a compound of formula (I).

A seventh aspect of the invention relates to method of inhibiting a cysteine proteinase in a subject, said method comprising administering to the subject a pharmacologically effective amount of a compound of formula (I).

An eighth aspect of the invention relates to a method of treating a disease selected from osteoporosis, Paget's disease, Chagas's disease, malaria, gingival diseases,

hypercalaemia, metabolic bone disease, diseases involving matrix or cartilage degradation, and bone cancer disorders such as bone metastases and associated pain, in a subject, said method comprising administering to the subject a pharmacologically effective amount of a compound of formula (I).

A ninth aspect of the invention relates to the use of a compound according to the invention in an assay for identifying further candidate compounds capable of inhibiting one or more cysteine proteinases.

A tenth aspect of the invention relates to the use of a compound of formula (I) in the validation of a known or putative cysteine proteinase as a therapeutic target.

An eleventh aspect of the invention relates to a process of preparing a compound of formula (I).

DETAILED DESCRIPTION

The term 'alkyl' as applied herein includes stable straight and branched chain aliphatic carbon chains which may be optionally substituted. Preferred examples include methyl, ethyl, n-propyl, isopropyl, n-butyl, isobutyl, t-butyl, pentyl, isopentyl, hexyl, heptyl and any simple isomers thereof. Suitable substituents include, for example, one or more C_{1-6} alkoxy, OH, COOH, COOMe, NH_2, NMe_2, NHMe, NO_2, CN, CF_3 and/or halo groups. Additionally, where the alkyl group contains two or more contiguous carbon atoms, an alkene group (-CH=CH-) or alkyne group (-C≡C-) may be present. Furthermore, the alkyl group may optionally contain one or more heteroatoms for example, to give ethers, thioethers, sulphones, sulphonamides, substituted amines, amidines, guanidines, carboxylic acids, carboxamides. If the heteroatom is located at a chain terminus then it is appropriately substituted with one or two hydrogen atoms. For example, the group CH_3-CH_2-O-CH_2-CH_2- is defined within 'alkyl' as a C_4 alkyl that contains a centrally positioned heteroatom whereas the group CH_3-CH_2-CH_2-CH_2- is defined within 'alkyl' as an unsubstituted C_4 alkyl.

Preferably, the alkyl group is a C_{1-8} alkyl group, more preferably a C_{1-6} group, even more preferably a C_{1-4} alkyl group.

As used herein, the term "cycloalkyl" refers to a cyclic alkyl group (i.e. a carbocyclic ring) which may be substituted (mono- or poly-) or unsubstituted. Suitable substituents include, for example, one or more C_{1-6} alkyl, C_{1-6} alkoxy, OH, COOH, COOMe, NH_2, NMe_2, NHMe, NO_2, CN, CF_3 and/or halo groups. Preferably, the cycloalkyl group is a C_{3-8} cycloalkyl group, more preferably a C_{3-6}-cycloalkyl, even more preferably a C_{3-4} cycloalkyl group. Examples include cyclopropyl, cyclobutyl, cyclopentyl, cyclohexyl and the like. In addition, the carbocyclic ring itself may optionally contain one or more heteroatoms, for example, to give a heterocycloalkyl group such as tetrahydrofuran, pyrrolidine, piperidine, piperazine or morpholine.

The term 'alkyl-aryl' as applied herein includes an alkyl group as defined above in combination with an aryl group. The aryl group may be an aromatic ring, for example, a stable 5 or 6-membered monocylic or a stable 9 or 10-membered bicyclic ring which is unsaturated. The aryl group may optionally comprise one or more heteroatoms selected from O, N and S. In addition, the aryl group may be optionally substituted, for example, by one or more C_{1-6} alkoxy, OH, COOH, COOMe, NH_2, NMe_2, NHMe, NO_2, CN, CF_3 and/or halo groups.

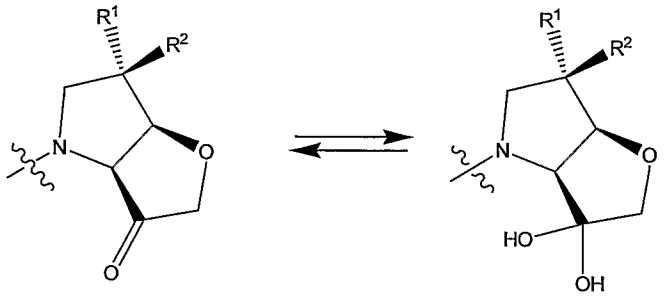
Preferably, the alkyl-aryl group is a C_{1-8}-alkyl-C_{5-10}-aryl group, even more preferably a C_{1-8}-alkyl-phenyl group. More preferably still, the alkyl-aryl group is selected from CH_2Ph and CH_2OCH_2Ph.

'Halogen' or 'halo' as applied herein encompasses F, Cl, Br, I.

'Heteroatom' as applied herein encompasses O, S, P and N, more preferably, O, S and N.

The present invention includes all salts, hydrates, solvates, complexes and prodrugs of the compounds of this invention. The term "compound" is intended to include all such salts, hydrates, solvates, complexes and prodrugs, unless the context requires otherwise.

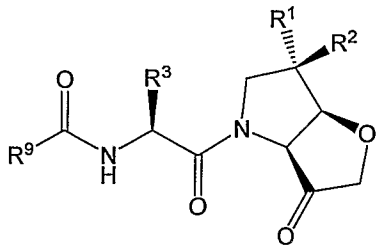
In particular, the skilled person will appreciate that the ketone group of the bicycle core of compounds of formula (I) may exist in alternative forms such as the hydrate (as shown below), and the invention extends to all such alternative forms.



Hydrate

Abbreviations and symbols commonly used in the peptide and chemical arts are used herein to describe compounds of the present invention, following the general guidelines presented by the IUPAC-IUB Joint Commission on Biochemical Nomenclature as described in *Eur. J. Biochem.*, 158, 9-, 1984. Compounds of formula (I) and the intermediates and starting materials used in their preparation are named in accordance with the IUPAC rules of nomenclature in which the characteristic groups have decreasing priority for citation as the principle group.

In one preferred embodiment, the compound of the invention is of formula Ia



(Ia)

wherein R^1, R^2 and R^9 are as defined above, and R^3 is selected from *tert*-butylmethyl, *iso*-propylmethyl, *sec*-butyl, *tert*-butyl, cyclopentyl and cyclohexyl.

In one preferred embodiment of the invention, one of R^1 and R^2 is H, and the other is selected from methyl, ethyl, propyl, iso-propyl, *tert*-butyl, cyclopropyl, cyclopropylmethyl, iso-propylmethyl, *tert*-butylmethyl, CH_2OH, CH_2OMe, CH_2OCH_2Ph, CH_2Ph, CH_2F and CHF_2.

In another preferred embodiment, one of R^1 and R^2 is H, and the other is C_{1-8}-alkyl, optionally substituted by halo.
In one particularly preferred embodiment, one of R^1 and R^2 is H, and the other is selected from methyl, ethyl, iso-propyl and CHF_2.

In an even more preferred embodiment, one of R^1 and R^2 is H, and the other is methyl.

R^3 is selected from *tert*-butylmethyl, *iso*-propylmethyl, *sec*-butyl, *tert*-butyl, cyclopentyl, cyclohexyl and 1-methylcyclopentyl.

In one particularly preferred embodiment, R^3 is cyclopentyl, *tert*–butyl or 1-methylcyclopentyl.

In another preferred embodiment, R^3 is selected from *tert*-butylmethyl, *iso*-propylmethyl, *sec*-butyl, *tert*-butyl, cyclopentyl and cyclohexyl.

In another even more preferred embodiment, R^3 is cyclopentyl or *tert*-butyl.

In one preferred embodiment, R^3 is cyclohexyl such that the central moiety is the amino acid (*S*)-cyclohexylglycine.

In another preferred embodiment, R^3 is cyclopentyl such that the central moiety is the amino acid (*S*)-cyclopentylglycine.

In another preferred embodiment, R^3 is *iso*-propylmethyl such that the central moiety is the amino acid (*S*)-leucine.

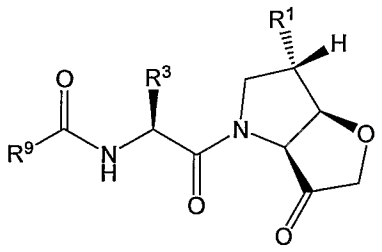
In another preferred embodiment, R^3 is *tert*-butyl such that the central moiety is the amino acid (*S*)-*tert*-butylglycine.

In another preferred embodiment, R^3 is *sec*-butyl of *S*-configuration such that the central moiety is the amino acid (2*S*, 3*S*)-isoleucine.

In another preferred embodiment, R^3 is *tert*-butylmethyl such that the central moiety is the amino acid (*S*)-*tert*-butylalanine.

In another preferred embodiment, R^3 is 1-methylcyclopentyl such that the central moiety is derived from the amino acid (*S*)-β-methylcyclopentylglycine ((*S*)-2-amino-2-(1-methylcyclopentyl)acetic acid).

In a more preferred embodiment, the compound of the invention is of formula Ib



(Ib)

wherein R^1, R^3 and R^9 are as defined above.

In one preferred embodiment, with respect to the definition of R^9:
G is selected as N;
E is selected from O, S and NH;
J and R are independently selected from CH and N.

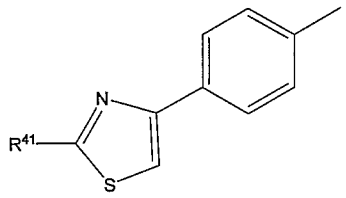
In one particularly preferred embodiment, with respect to the definition of R^9:

G is selected as N;

J and R are CH;

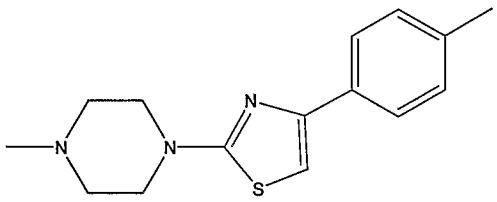
E is selected as S;

In one preferred embodiment, R^9 is chosen from:

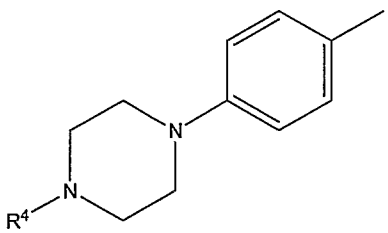


In another preferred embodiment, R^{41} is selected from 4-methylpiperazin-1-yl, 4-(2-methoxyethyl)piperazin-1-yl.

Even more preferably, R^9 is chosen from:



In another preferred embodiment, R^9 is chosen from:



wherein R^4 is C_{1-8}-alkyl

More preferably, R^4 is selected from methyl, ethyl and propyl. Even more preferably, R^4 is methyl.

In one highly preferred embodiment, the compound of the invention is selected from the following:

N-((*S*)-4-methyl-1-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

4-(4-ethylpiperazin-1-yl)-*N*-((*S*)-4-methyl-1-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-oxopentan-2-yl)benzamide

N-((*S*)-4-methyl-1-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-4-methyl-1-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((S)-1-((3aS,6R,6aR)-6-ethyl-3-oxodihydro-2H-furo[3,2-b]pyrrol-4(5H,6H,6aH)-yl)-4-methyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-4-methyl-1-oxo-1-((3*aS*,6*R*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)pentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

4-(4-ethylpiperazin-1-yl)-*N*-((*S*)-4-methyl-1-oxo-1-((3*aS*,6*R*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)pentan-2-yl)benzamide

N-((*S*)-4-methyl-1-oxo-1-((3*aS*,6*R*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)pentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-4-methyl-1-oxo-1-((3*aS*,6*R*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)pentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-4,4-dimethyl-1-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-4,4-dimethyl-1-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-4,4-dimethyl-1-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-4,4-dimethyl-1-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-4,4-dimethyl-1-oxo-1-((3*aS*,6*R*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)pentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-4,4-dimethyl-1-oxo-1-((3*aS*,6*R*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)pentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-4,4-dimethyl-1-oxo-1-((3*aS*,6*R*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)pentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-4,4-dimethyl-1-oxo-1-((3*aS*,6*R*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)pentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

4-(4-ethylpiperazin-1-yl)-*N*-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((2*S*,3*S*)-3-methyl-1-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

4-(4-ethylpiperazin-1-yl)-*N*-((2*S*,3*S*)-3-methyl-1-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-oxopentan-2-yl)benzamide

N-((2*S*,3*S*)-3-methyl-1-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((2*S*,3*S*)-3-methyl-1-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*R*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*R*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*R*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*R*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((2*S*,3*S*)-3-methyl-1-oxo-1-((3*aS*,6*R*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)pentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

4-(4-ethylpiperazin-1-yl)-*N*-((2*S*,3*S*)-3-methyl-1-oxo-1-((3*aS*,6*R*,6*aR*)-3-oxo-6-propyldihydro-2H-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)pentan-2-yl)benzamide

N-((2*S*,3*S*)-3-methyl-1-oxo-1-((3*aS*,6*R*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)pentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((2*S*,3*S*)-3-methyl-1-oxo-1-((3*aS*,6*R*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)pentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*R*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

4-(4-ethylpiperazin-1-yl)-*N*-((2*S*,3*S*)-1-((3a*S*,6*R*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3-methyl-1-oxopentan-2-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*R*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*R*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*R*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((2*S*,3*S*))-1-((3*aS*,6*R*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((2*S*,3*S*))-1-((3*aS*,6*R*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((2*S*,3*S*))-1-((3*aS*,6*R*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*R*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*R*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*R*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*R*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*R*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*R*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*R*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*R*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-3,3-dimethyl-1-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-3,3-dimethyl-1-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-3,3-dimethyl-1-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-3,3-dimethyl-1-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-3,3-dimethyl-1-oxo-1-((3*aS*,6*R*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)pentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-3,3-dimethyl-1-oxo-1-((3*aS*,6*R*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)pentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-3,3-dimethyl-1-oxo-1-((3*aS*,6*R*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)pentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-3,3-dimethyl-1-oxo-1-((3*aS*,6*R*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)pentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

4-(4-ethylpiperazin-1-yl)-*N*-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*R*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*R*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*R*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*R*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-cyclopentyl-2-oxo-2-((3*aS*,6*R*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6aH)-yl)ethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-oxo-2-((3*aS*,6*R*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6aH)-yl)ethyl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-oxo-2-((3*aS*,6*R*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6aH)-yl)ethyl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-oxo-2-((3*aS*,6*R*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6aH)-yl)ethyl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*R*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*R*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*R*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*R*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-2-((3*aS*,6*R*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-cyclopentyl-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-2-((3*aS*,6*R*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-cyclopentyl-2-oxoethyl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-2-((3*aS*,6*R*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-cyclopentyl-2-oxoethyl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-2-((3*aS*,6*R*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-cyclopentyl-2-oxoethyl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*R*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*R*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*R*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*R*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*R*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*R*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*R*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*R*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*R*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*R*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*R*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*R*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-cyclohexyl-2-oxo-2-((3*aS*,6*R*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6aH)-yl)ethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-oxo-2-((3*aS*,6*R*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6aH)-yl)ethyl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-oxo-2-((3*aS*,6*R*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6aH)-yl)ethyl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-oxo-2-((3*aS*,6*R*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6aH)-yl)ethyl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*R*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*R*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*R*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*R*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-2-((3*aS*,6*R*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-cyclohexyl-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-2-((3*aS*,6*R*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-cyclohexyl-2-oxoethyl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-2-((3*aS*,6*R*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-cyclohexyl-2-oxoethyl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-2-((3*aS*,6*R*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-cyclohexyl-2-oxoethyl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*R*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*R*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*R*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*R*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*R*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*R*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*R*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*R*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-4-methyl-1-((3*aS*,6*S*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

4-(4-ethylpiperazin-1-yl)-*N*-((*S*)-4-methyl-1-((3*aS*,6*S*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-oxopentan-2-yl)benzamide

N-((*S*)-4-methyl-1-((3*aS*,6*S*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-4-methyl-1-((3*aS*,6*S*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-4-methyl-1-oxo-1-((3*aS*,6*S*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)pentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

4-(4-ethylpiperazin-1-yl)-*N*-((*S*)-4-methyl-1-oxo-1-((3*aS*,6*S*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)pentan-2-yl)benzamide

N-((*S*)-4-methyl-1-oxo-1-((3*aS*,6*S*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)pentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-4-methyl-1-oxo-1-((3*aS*,6*S*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)pentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,S6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-4,4-dimethyl-1-((3*aS*,6*S*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-4,4-dimethyl-1-((3*aS*,6*S*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-4,4-dimethyl-1-((3*aS*,6*S*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-4,4-dimethyl-1-((3*aS*,6*S*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-4,4-dimethyl-1-oxo-1-((3*aS*,6*S*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)pentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-4,4-dimethyl-1-oxo-1-((3*aS*,6*S*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)pentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-4,4-dimethyl-1-oxo-1-((3*aS*,6*S*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)pentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-4,4-dimethyl-1-oxo-1-((3*aS*,6*S*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)pentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

4-(4-ethylpiperazin-1-yl)-*N*-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((2*S*,3*S*)-3-methyl-1-((3*aS*,6*S*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

4-(4-ethylpiperazin-1-yl)-*N*-((2*S*,3*S*)-3-methyl-1-((3*aS*,6*S*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-oxopentan-2-yl)benzamide

N-((2*S*,3*S*)-3-methyl-1-((3*aS*,6*S*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((2*S*,3*S*)-3-methyl-1-((3*aS*,6*S*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*S*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*S*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*S*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*S*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((2*S*,3*S*)-3-methyl-1-oxo-1-((3*aS*,6*S*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)pentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

4-(4-ethylpiperazin-1-yl)-*N*-((2*S*,3*S*)-3-methyl-1-oxo-1-((3*aS*,6*S*,6*aR*)-3-oxo-6-propyldihydro-2H-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)pentan-2-yl)benzamide

N-((2*S*,3*S*)-3-methyl-1-oxo-1-((3*aS*,6*S*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)pentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((2*S*,3*S*)-3-methyl-1-oxo-1-((3*aS*,6*S*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)pentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*S*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

4-(4-ethylpiperazin-1-yl)-*N*-((2*S*,3*S*)-1-((3a*S*,6*S*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3-methyl-1-oxopentan-2-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*S*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*S*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*S*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((2*S*,3*S*))-1-((3*aS*,6*S*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((2*S*,3*S*))-1-((3*aS*,6*S*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((2*S*,3*S*))-1-((3*aS*,6*S*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*S*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*S*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*S*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*S*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*S*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*S*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*S*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*S*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-3,3-dimethyl-1-((3*aS*,6*S*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-3,3-dimethyl-1-((3*aS*,6*S*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-3,3-dimethyl-1-((3*aS*,6*S*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-3,3-dimethyl-1-((3*aS*,6*S*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-3,3-dimethyl-1-oxo-1-((3*aS*,6*S*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)pentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-3,3-dimethyl-1-oxo-1-((3*aS*,6*S*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)pentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-3,3-dimethyl-1-oxo-1-((3*aS*,6*S*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)pentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-3,3-dimethyl-1-oxo-1-((3*aS*,6*S*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)pentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

4-(4-ethylpiperazin-1-yl)-*N*-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*S*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*S*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*S*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*S*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*S*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*S*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*S*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*S*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-cyclopentyl-2-oxo-2-((3*aS*,6*S*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6aH)-yl)ethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-oxo-2-((3*aS*,6*S*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6aH)-yl)ethyl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-oxo-2-((3*aS*,6*S*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6aH)-yl)ethyl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-oxo-2-((3*aS*,6*S*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6aH)-yl)ethyl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*S*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*S*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*S*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*S*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-2-((3*aS*,6*S*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-cyclopentyl-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-2-((3*aS*,6*S*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-cyclopentyl-2-oxoethyl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-2-((3*aS*,6*S*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-cyclopentyl-2-oxoethyl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-2-((3*aS*,6*S*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-cyclopentyl-2-oxoethyl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*S*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*S*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*S*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*S*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*S*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*S*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*S*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*S*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*S*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*S*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*S*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*S*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*S*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*S*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*S*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*S*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-cyclohexyl-2-oxo-2-((3*aS*,6*S*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6aH)-yl)ethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-oxo-2-((3*aS*,6*S*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6aH)-yl)ethyl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-oxo-2-((3*aS*,6*S*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6aH)-yl)ethyl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-oxo-2-((3*aS*,6*S*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6aH)-yl)ethyl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*S*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*S*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*S*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*S*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-2-((3*aS*,6*S*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-cyclohexyl-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-2-((3*aS*,6*S*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-cyclohexyl-2-oxoethyl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-2-((3*aS*,6*S*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-cyclohexyl-2-oxoethyl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-2-((3*aS*,6*S*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-cyclohexyl-2-oxoethyl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*S*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*S*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*S*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*S*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*S*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*S*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*S*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*S*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-cyclopentyl-2-oxo-2-((3*aS*,6*S*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)ethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*S*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-2-((3*aS*,6*S*,6*aR*)-6-benzyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-cyclopentyl-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-2-((3*aS*,6*S*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-(1-methylcyclopentyl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide and

N-((*S*)-2-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-(1-methylcyclopentyl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide.

In one particularly preferred embodiment, the compound of the invention is selected from Examples 1-30 and 38-42 described hereinbelow.

Even more preferably, the compound of the invention is selected from Examples 1-8, 12, 16-18, 22-30 and 38-42 described hereinbelow.

PHARMACEUTICAL COMPOSITIONS

A further aspect of the invention relates to a pharmaceutical composition comprising a compound of the invention admixed with one or more pharmaceutically acceptable diluents, excipients or carriers. Other active materials may also be present, as may be

considered appropriate or advisable for the disease or condition being treated or prevented.

Even though the compounds of the present invention (including their pharmaceutically acceptable salts, esters and pharmaceutically acceptable solvates) can be administered alone, they will generally be administered in admixture with a pharmaceutical carrier, excipient or diluent, particularly for human therapy. The pharmaceutical compositions may be for human or animal usage in human and veterinary medicine.

Examples of such suitable excipients for the various different forms of pharmaceutical compositions described herein may be found in the "Handbook of Pharmaceutical Excipients, 2nd Edition, (1994), Edited by A Wade and PJ Weller. The carrier, or, if more than one be present, each of the carriers, must be acceptable in the sense of being compatible with the other ingredients of the formulation and not deleterious to the recipient.

Acceptable carriers or diluents for therapeutic use are well known in the pharmaceutical art, and are described, for example, in Remington's Pharmaceutical Sciences, Mack Publishing Co. (A. R. Gennaro edit. 1985).

Examples of suitable carriers include lactose, starch, glucose, methyl cellulose, magnesium stearate, mannitol, sorbitol and the like. Examples of suitable diluents include ethanol, glycerol and water.

The choice of pharmaceutical carrier, excipient or diluent can be selected with regard to the intended route of administration and standard pharmaceutical practice. The pharmaceutical compositions may comprise as, or in addition to, the carrier, excipient or diluent any suitable binder(s), lubricant(s), suspending agent(s), coating agent(s), solubilising agent(s).

Examples of suitable binders include starch, gelatin, natural sugars such as glucose, anhydrous lactose, free-flow lactose, beta-lactose, corn sweeteners, natural and synthetic gums, such as acacia, tragacanth or sodium alginate, carboxymethyl cellulose and polyethylene glycol.

Examples of suitable lubricants include sodium oleate, sodium stearate, magnesium stearate, sodium benzoate, sodium acetate, sodium chloride and the like.

Preservatives, stabilizers, dyes and even flavoring agents may be provided in the pharmaceutical composition. Examples of preservatives include sodium benzoate, sorbic acid and esters of p-hydroxybenzoic acid. Antioxidants and suspending agents may be also used.

According to a further aspect of the invention, there is provided a process for the preparation of a pharmaceutical or veterinary composition as described above, the process comprising bringing the active compound(s) into association with the carrier, for example by admixture.

In general, the formulations are prepared by uniformly and intimately bringing into association the active agent with liquid carriers or finely divided solid carriers or both, and then if necessary shaping the product. The invention extends to methods for preparing a pharmaceutical composition comprising bringing a compound of general formula (I) in conjunction or association with a pharmaceutically or veterinarily acceptable carrier or vehicle.

SALTS/ESTERS

The compounds of the invention can be present as salts or esters, in particular pharmaceutically and veterinarily acceptable salts or esters.

Pharmaceutically acceptable salts of the compounds of the invention include suitable acid addition or base salts thereof. A review of suitable pharmaceutical salts may be

found in Berge et al, J Pharm Sci, 66, 1-19 (1977). Salts are formed, for example with strong inorganic acids such as mineral acids, e.g. hydrohalic acids such as hydrochloride, hydrobromide and hydroiodide, sulphuric acid, phosphoric acid sulphate, bisulphate, hemisulphate, thiocyanate, persulphate and sulphonic acids; with strong organic carboxylic acids, such as alkanecarboxylic acids of 1 to 4 carbon atoms which are unsubstituted or substituted (e.g., by halogen), such as acetic acid; with saturated or unsaturated dicarboxylic acids, for example oxalic, malonic, succinic, maleic, fumaric, phthalic or tetraphthalic; with hydroxycarboxylic acids, for example ascorbic, glycolic, lactic, malic, tartaric or citric acid; with aminoacids, for example aspartic or glutamic acid; with benzoic acid; or with organic sulfonic acids, such as (C_1-C_4)-alkyl- or aryl-sulfonic acids which are unsubstituted or substituted (for example, by a halogen) such as methane- or p-toluene sulfonic acid. Salts which are not pharmaceutically or veterinarily acceptable may still be valuable as intermediates.

Preferred salts include, for example, acetate, trifluoroacetate, lactate, gluconate, citrate, tartrate, maleate, malate, pantothenate, adipate, alginate, aspartate, benzoate, butyrate, digluconate, cyclopentanate, glucoheptanate, glycerophosphate, oxalate, heptanoate, hexanoate, fumarate, nicotinate, palmoate, pectinate, 3-phenylpropionate, picrate, pivalate, proprionate, tartrate, lactobionate, pivolate, camphorate, undecanoate and succinate, organic sulphonic acids such as methanesulphonate, ethanesulphonate, 2-hydroxyethane sulphonate, camphorsulphonate, 2-naphthalenesulphonate, benzenesulphonate, p-chlorobenzenesulphonate and p-toluenesulphonate; and inorganic acids such as hydrochloride, hydrobromide, hydroiodide, sulphate, bisulphate, hemisulphate, thiocyanate, persulphate, phosphoric and sulphonic acids.

Esters are formed either using organic acids or alcohols/hydroxides, depending on the functional group being esterified. Organic acids include carboxylic acids, such as alkanecarboxylic acids of 1 to 12 carbon atoms which are unsubstituted or substituted (e.g., by halogen), such as acetic acid; with saturated or unsaturated dicarboxylic acid, for example oxalic, malonic, succinic, maleic, fumaric, phthalic or tetraphthalic; with hydroxycarboxylic acids, for example ascorbic, glycolic, lactic, malic, tartaric or citric

acid; with aminoacids, for example aspartic or glutamic acid; with benzoic acid; or with organic sulfonic acids, such as (C_1-C_4)-alkyl- or aryl-sulfonic acids which are unsubstituted or substituted (for example, by a halogen) such as methane- or p-toluene sulfonic acid. Suitable hydroxides include inorganic hydroxides, such as sodium hydroxide, potassium hydroxide, calcium hydroxide, aluminium hydroxide. Alcohols include alkanealcohols of 1-12 carbon atoms which may be unsubstituted or substituted, e.g. by a halogen).

ENANTIOMERS/TAUTOMERS

In all aspects of the present invention previously discussed, the invention includes, where appropriate all enantiomers, diastereoisomers and tautomers of the compounds of the invention. The person skilled in the art will recognise compounds that possess optical properties (one or more chiral carbon atoms) or tautomeric characteristics. The corresponding enantiomers and/or tautomers may be isolated/prepared by methods known in the art.

Enantiomers are characterised by the absolute configuration of their chiral centres and described by the *R*- and *S*-sequencing rules of Cahn, Ingold and Prelog. Such conventions are well known in the art (e.g. see 'Advanced Organic Chemistry', 3rd edition, ed. March, J., John Wiley and Sons, New York, 1985).

Compounds of the invention containing a chiral centre may be used as a racemic mixture, an enantiomerically enriched mixture, or the racemic mixture may be separated using well-known techniques and an individual enantiomer may be used alone.

STEREO AND GEOMETRIC ISOMERS

Some of the compounds of the invention may exist as stereoisomers and/or geometric isomers – e.g. they may possess one or more asymmetric and/or geometric centres and so may exist in two or more stereoisomeric and/or geometric forms. The present invention contemplates the use of all the individual stereoisomers and geometric

isomers of those inhibitor agents, and mixtures thereof. The terms used in the claims encompass these forms, provided said forms retain the appropriate functional activity (though not necessarily to the same degree).

The present invention also includes all suitable isotopic variations of the agent or a pharmaceutically acceptable salt thereof. An isotopic variation of an agent of the present invention or a pharmaceutically acceptable salt thereof is defined as one in which at least one atom is replaced by an atom having the same atomic number but an atomic mass different from the atomic mass usually found in nature. Examples of isotopes that can be incorporated into the agent and pharmaceutically acceptable salts thereof include isotopes of hydrogen, carbon, nitrogen, oxygen, phosphorus, sulphur, fluorine and chlorine such as ^{2}H, ^{3}H, ^{13}C, ^{14}C, ^{15}N, ^{17}O, ^{18}O, ^{31}P, ^{32}P, ^{35}S, ^{18}F and ^{36}Cl, respectively. Certain isotopic variations of the agent and pharmaceutically acceptable salts thereof, for example, those in which a radioactive isotope such as ^{3}H or ^{14}C is incorporated, are useful in drug and/or substrate tissue distribution studies. Tritiated, i.e., ^{3}H, and carbon-14, i.e., ^{14}C, isotopes are particularly preferred for their ease of preparation and detectability. Further, substitution with isotopes such as deuterium, i.e., ^{2}H, may afford certain therapeutic advantages resulting from greater metabolic stability, for example, increased *in vivo* half-life or reduced dosage requirements and hence may be preferred in some circumstances. For example, the invention includes compounds of general formula (I) where any hydrogen atom has been replaced by a deuterium atom. Isotopic variations of the agent of the present invention and pharmaceutically acceptable salts thereof of this invention can generally be prepared by conventional procedures using appropriate isotopic variations of suitable reagents.

PRODRUGS

The invention further includes the compounds of the present invention in prodrug form, i.e. covalently bonded compounds which release the active parent drug according to general formula (I) *in vivo*. Such prodrugs are generally compounds of the invention wherein one or more appropriate groups have been modified such that the modification may be reversed upon administration to a human or mammalian subject. Reversion is

usually performed by an enzyme naturally present in such subject, though it is possible for a second agent to be administered together with such a prodrug in order to perform the reversion *in vivo*. Examples of such modifications include ester (for example, any of those described above), wherein the reversion may be carried out be an esterase etc. Other such systems will be well known to those skilled in the art.

A prodrug may for example constitute a ketal or hemiketal derivative of the exocyclic ketone functionality present in the 6-alkyltetrahydrofuro[3,2-*b*]pyrrol-3-one scaffold.

SOLVATES

The present invention also includes solvate forms of the compounds of the present invention. The terms used in the claims encompass these forms.

POLYMORPHS

The invention further relates to the compounds of the present invention in their various crystalline forms, polymorphic forms and (an)hydrous forms. It is well established within the pharmaceutical industry that chemical compounds may be isolated in any of such forms by slightly varying the method of purification and or isolation form the solvents used in the synthetic preparation of such compounds.

ASSAYS

Another aspect of the invention relates to the use of a compound of the invention as defined hereinabove in an assay for identifying further candidate compounds that influence the activity of a cysteine proteinase.

Preferably, the assay is capable of identifying candidate compounds that are capable of inhibiting one or more CAC1 cysteine proteinases.

More preferably, the assay is a competitive binding assay.

Preferably, the candidate compound is generated by conventional SAR modification of a compound of the invention.

As used herein, the term "conventional SAR modification" refers to standard methods known in the art for varying a given compound by way of chemical derivatisation.

Thus, in one aspect, the identified compound may act as a model (for example, a template) for the development of other compounds. The compounds employed in such a test may be free in solution, affixed to a solid support, borne on a cell surface, or located intracellularly. The abolition of activity or the formation of binding complexes between the compound and the agent being tested may be measured.

The assay of the present invention may be a screen, whereby a number of agents are tested. In one aspect, the assay method of the present invention is a high through-put screen.

This invention also contemplates the use of competitive drug screening assays in which neutralising antibodies capable of binding a compound specifically compete with a test compound for binding to a compound.

Another technique for screening provides for high throughput screening (HTS) of agents having suitable binding affinity to the substances and is based upon the method described in detail in WO 84/03564.

It is expected that the assay methods of the present invention will be suitable for both small and large-scale screening of test compounds as well as in quantitative assays.

Preferably, the competitive binding assay comprises contacting a compound of the invention with a cysteine proteinase in the presence of a known substrate of said enzyme and detecting any change in the interaction between said cysteine proteinase and said known substrate.

A further aspect of the invention provides a method of detecting the binding of a ligand to a cysteine proteinase, said method comprising the steps of:

(i) contacting a ligand with cysteine proteinase in the presence of a known substrate of said enzyme;

(ii) detecting any change in the interaction between said enzyme and said known substrate;

and wherein said ligand is a compound of the invention.

One aspect of the invention relates to a process comprising the steps of:

(a) performing an assay method described hereinabove;

(b) identifying one or more ligands capable of binding to a ligand binding domain; and

(c) preparing a quantity of said one or more ligands.

Another aspect of the invention provides a process comprising the steps of:

(a) performing an assay method described hereinabove;

(b) identifying one or more ligands capable of binding to a ligand binding domain; and

(c) preparing a pharmaceutical composition comprising said one or more ligands.

Another aspect of the invention provides a process comprising the steps of:

(a) performing an assay method described hereinabove;

(b) identifying one or more ligands capable of binding to a ligand binding domain;

(c) modifying said one or more ligands capable of binding to a ligand binding domain;

(d) performing the assay method described hereinabove;

(e) optionally preparing a pharmaceutical composition comprising said one or more ligands.

The invention also relates to a ligand identified by the method described hereinabove.

Yet another aspect of the invention relates to a pharmaceutical composition comprising a ligand identified by the method described hereinabove.

Another aspect of the invention relates to the use of a ligand identified by the method described hereinabove in the preparation of a pharmaceutical composition for use in the treatment of one or more disorders selected from osteoporosis, Paget's disease, Chagas's disease, malaria, gingival disease such as gingivitis or periodontitis, hypercalaemia, metabolic bone disease and diseases involving matrix or cartilage degradation, such as osteoarthritis, rheumatoid arthritis and neoplastic diseases.

The above methods may be used to screen for a ligand useful as an inhibitor of one or more cysteine proteinases.

Compounds of general formula (I) are useful both as laboratory tools and as therapeutic agents. In the laboratory certain compounds of the invention are useful in establishing whether a known or newly discovered cysteine proteinase contributes a critical or at least significant biochemical function during the establishment or progression of a disease state, a process commonly referred to as 'target validation'.

According to a further aspect of the invention, there is provided a method of validating a known or putative cysteine proteinase as a therapeutic target, the method comprising:

(a) assessing the *in vitro* binding of a compound as described above to an isolated known or putative cysteine proteinase, providing a measure of potency; and optionally, one or more of the steps of:

(b) assessing the binding of the compound to closely related homologous proteinases of the target and general house-keeping proteinases (e.g. trypsin) to provide a measure of selectivity;

(c) monitoring a cell-based functional marker of a particular cysteine proteinase activity, in the presence of the compound; and

(d) monitoring an animal model-based functional marker of a particular cysteine proteinase activity in the presence of the compound.

The invention therefore provides a method of validating a known or putative cysteine proteinase as a therapeutic target. Differing approaches and levels of complexity are appropriate to the effective inhibition and 'validation' of a particular target. In the first instance, the method comprises assessing the *in vitro* binding of a compound of general formula (I) to an isolated known or putative cysteine proteinase, providing a measure of 'potency'. An additional assessment of the binding of a compound of general formula (I) to closely related homologous proteinases of the target and general house-keeping proteinases (e.g. trypsin) provides a measure of 'selectivity'. A second level of complexity may be assessed by monitoring a cell-based functional marker of a particular cysteine proteinase activity, in the presence of a compound of general formula (I). For example, an 'osteoclast resorption assay' has been utilised as a cell-based secondary *in vitro* testing system for monitoring the activity of cathepsin K and the biochemical effect of proteinase inhibitors (e.g. see WO-A-9850533). An 'MHC-II processing – T-cell activation assay' has been utilised as a cell-based secondary *in vitro* testing system for monitoring the activity of cathepsin S and the biochemical effect of proteinase inhibitors (Shi, G-P., *et al*, *Immunity,* 10, 197-206, 1999). When investigating viral or bacterial infections such a marker could simply be a functional assessment of viral (e.g. count of mRNA copies) or bacterial loading and assessing the biochemical effect of proteinase inhibitors. A third level of complexity may be assessed by monitoring an animal model-based functional marker of a particular cysteine proteinase activity, in the presence of a compound of general formula (I). For example, murine models of *Leishmania* infection, *P. vinckei* infection, malaria (inhibition of falcipain) and *T. cruzi* infection (cruzipain), indicate that inhibition of cysteine proteinases that play a key role in pathogen propagation is effective in arresting disease symptoms, 'validating' said targets.

The invention therefore extends to the use of a compound of general formula (I) in the validation of a known or putative cysteine proteinase as a therapeutic target.

BIOLOGICAL ACTIVITY

The compounds of the present invention are structurally distinct from the prior art (e.g. WO-A-02057270; Quibell, M. *et. al.,* Bioorg. Med. Chem. 13, 609-625, 2005; Quibell M, *et al* Bioorg. Med. Chem, 12, 5689-5710, 2004) in that a 6-alkyl substituent is an integral part of the present invention and this provides surprisingly high efficacies for human cathepsin K. Indeed, all of the compounds of the present invention prepared to date exhibit potent *in vitro* inhibition versus human cathepsin K with Ki < 10 nM. In contrast, the majority of the eighty-two prior art compounds detailed in WO-A-02057270 are significantly less potent against human cathepsin K than the compounds of the present invention and in the majority of examples greater than 1000-fold less potent (for example see table 2). The closest prior art, compound (42) (Quibell, M. *et. al.,* Bioorg. Med. Chem. 13, 609-625, 2005), exhibits a 3.5-fold improvement in *in vitro* potency against human cathepsin K upon addition of a 6-(*R*)-Me substituent (EXAMPLE 1); an 11.6-fold improvement upon addition of a 6-(*S*)-Me substituent (EXAMPLE 5); a 5.7-fold improvement upon addition of a 6-(*R*)-CHF_2 substituent (EXAMPLE 8) and a 10.9-fold improvement upon addition of a 6-(*S*)-CHF_2 substituent (EXAMPLE 12). Introduction of other structural changes, that are integral to the present invention, when compared to closest prior art compound (42) (Quibell, M. *et. al.,* Bioorg. Med. Chem. 13, 609-625, 2005), e.g. changing the P2 aminoacid from *L*-leucine to *L*-cyclopentylglycine and addition of a 6-(*R*)-Me substituent gives a 8.7-fold improvement (EXAMPLE 4); whilst addition of a 6-(*S*)-Me substituent gives a 24.9-fold improvement upon (EXAMPLE 7); whilst addition of a 6-(*S*)-Et substituent gives a 22.9-fold improvement upon (EXAMPLE 29); whilst addition of a 6-(*R*)-Et substituent gives a 7.3-fold improvement upon (EXAMPLE 27); whilst addition of a 6-(*S*)-iPr substituent gives a 18.9-fold improvement upon (EXAMPLE 30); whilst addition of a 6-(*R*)-iPr substituent gives a 5.8-fold improvement upon (EXAMPLE 28).

Preferably, the compounds exhibit *in vitro* inhibition versus human cathepsin K with Ki < 10 nM, more preferably < 5 nM, even more preferably < 2 nM and more preferably still < 1 nM. The compounds of the invention exhibit high selectivity against other mammalian cathepsins displaying little or no inhibitory activity for cathepsins S, L, B and V at 1μM compound.

THERAPEUTIC USE

Compounds of general formula (I) are useful for the *in vivo* treatment or prevention of diseases in which participation of a cysteine proteinase is implicated.

Preferably, the compound of general formula I is selective for cathepsin K. As used herein, the term "selective for cathepsin K" means that the inhibitor is selective for cathepsin K over one or more other mammalian CAC1 cysteinyl proteinases for example cathepsin S, cathepsin L, cathepsin F, cathepsin B and cathepsin V. Preferably, the inhibitor exhibits a selectivity ratio for cathepsin K over other mammalian CAC1 cysteinyl proteinases of greater than 2-fold, more preferably greater than 5-fold, more preferably greater than 10-fold, even more preferably greater than 25-fold, more preferably still, greater than 50-fold or 100-fold.

According to a further aspect of the invention, there is provided a compound of general formula (I) for use in medicine, especially for preventing or treating diseases in which the disease pathology may be modified by inhibiting a cysteine proteinase.

According to a further aspect of the invention, there is provided the use of a compound of general formula (I) in the preparation of a medicament for preventing or treating diseases in which the disease pathology may be modified by inhibiting a cysteine proteinase.

Certain cysteine proteinases function in the normal physiological process of protein degradation in animals, including humans, *e.g.* in the degradation of connective tissue. However, elevated levels of these enzymes in the body can result in pathological

conditions leading to disease. Thus, cysteine proteinases have been implicated in various disease states, including but not limited to, infections by *Pneumocystis carinii*, *Trypsanoma cruzi*, *Trypsanoma brucei brucei* and *Crithidia fusiculata*; as well as in osteoporosis, osteoarthritis, rheumatoid arthritis, multiple sclerosis, chronic pain, autoimmunity, schistosomiasis, malaria, tumour metastasis, metachromatic leukodystrophy, muscular dystrophy, amytrophy, and the like (see WO-A-9404172 and EP-A-0603873 and references cited therein). Additionally, a secreted bacterial cysteine proteinase from *S. Aureus* called staphylopain has been implicated as a bacterial virulence factor (Potempa, J., *et al.* J. Biol. Chem, 262(6), 2664-2667, 1998).

The invention is useful in the prevention and/or treatment of each of the disease states mentioned or implied above. The present invention also is useful in a method of treatment or prevention of diseases caused by pathological levels of cysteine proteinases, particularly cysteine proteinases of the papain superfamily, which methods comprise administering to an animal, particularly a mammal, most particularly a human, in need thereof a compound of the present invention. The present invention particularly provides methods for treating diseases in which cysteine proteinases are implicated, including infections by *Pneumocystis carinii*, *Trypsanoma cruzi*, *Trypsanoma brucei*, *Leishmania mexicana*, *Clostridium histolyticum*, *Staphylococcus aureus*, foot-and-mouth disease virus and *Crithidia fusiculata*; as well as in osteoporosis, osteoarthritis, rheumatoid arthritis, multiple sclerosis, chronic pain, autoimmunity, schistosomiasis, malaria, tumour metastasis, metachromatic leukodystrophy, muscular dystrophy, amytrophy.

Inhibitors of cathepsin K, particularly cathepsin K-specific compounds, are useful for the treatment of osteoporosis, Paget's disease, gingival diseases such as gingivitis and periodontitis, hypercalaemia of malignancy, metabolic bone disease, diseases involving matrix or cartilage degradation, in particular osteoarthritis and rheumatoid arthritis and neoplastic diseases.

Preferred features for each aspect of the invention are as for each other aspect *mutatis mutandis*.

ADMINISTRATION

The pharmaceutical compositions of the present invention may be adapted for rectal, nasal, intrabronchial, topical (including buccal and sublingual), vaginal or parenteral (including subcutaneous, intramuscular, intravenous, intraarterial and intradermal), intraperitoneal or intrathecal administration. Preferably the formulation is an orally administered formulation. The formulations may conveniently be presented in unit dosage form, i.e., in the form of discrete portions containing a unit dose, or a multiple or sub-unit of a unit dose. By way of example, the formulations may be in the form of tablets and sustained release capsules, and may be prepared by any method well known in the art of pharmacy.

Formulations for oral administration in the present invention may be presented as: discrete units such as capsules, gellules, drops, cachets, pills or tablets each containing a predetermined amount of the active agent; as a powder or granules; as a solution, emulsion or a suspension of the active agent in an aqueous liquid or a non-aqueous liquid; or as an oil-in-water liquid emulsion or a water-in-oil liquid emulsion; or as a bolus etc. Preferably, these compositions contain from 1 to 250 mg and more preferably from 10-100 mg, of active ingredient per dose.

For compositions for oral administration (e.g. tablets and capsules), the term "acceptable carrier" includes vehicles such as common excipients e.g. binding agents, for example syrup, acacia, gelatin, sorbitol, tragacanth, polyvinylpyrrolidone (Povidone), methylcellulose, ethylcellulose, sodium carboxymethylcellulose, hydroxypropylmethylcellulose, sucrose and starch; fillers and carriers, for example corn starch, gelatin, lactose, sucrose, microcrystalline cellulose, kaolin, mannitol, dicalcium phosphate, sodium chloride and alginic acid; and lubricants such as magnesium stearate, sodium stearate and other metallic stearates, glycerol stearate stearic acid, silicone fluid, talc waxes, oils and colloidal silica. Flavouring agents such

as peppermint, oil of wintergreen, cherry flavouring and the like can also be used. It may be desirable to add a colouring agent to make the dosage form readily identifiable. Tablets may also be coated by methods well known in the art.

A tablet may be made by compression or moulding, optionally with one or more accessory ingredients. Compressed tablets may be prepared by compressing in a suitable machine the active agent in a free flowing form such as a powder or granules, optionally mixed with a binder, lubricant, inert diluent, preservative, surface-active or dispersing agent. Moulded tablets may be made by moulding in a suitable machine a mixture of the powdered compound moistened with an inert liquid diluent. The tablets may be optionally be coated or scored and may be formulated so as to provide slow or controlled release of the active agent.

Other formulations suitable for oral administration include lozenges comprising the active agent in a flavoured base, usually sucrose and acacia or tragacanth; pastilles comprising the active agent in an inert base such as gelatin and glycerin, or sucrose and acacia; and mouthwashes comprising the active agent in a suitable liquid carrier.

Other forms of administration comprise solutions or emulsions which may be injected intravenously, intraarterially, intrathecally, subcutaneously, intradermally, intraperitoneally or intramuscularly, and which are prepared from sterile or sterilisable solutions. Injectable forms typically contain between 10 - 1000 mg, preferably between 10 - 250 mg, of active ingredient per dose.

The pharmaceutical compositions of the present invention may also be in form of suppositories, pessaries, suspensions, emulsions, lotions, ointments, creams, gels, sprays, solutions or dusting powders.

An alternative means of transdermal administration is by use of a skin patch. For example, the active ingredient can be incorporated into a cream consisting of an aqueous emulsion of polyethylene glycols or liquid paraffin. The active ingredient can

also be incorporated, at a concentration of between 1 and 10% by weight, into an ointment consisting of a white wax or white soft paraffin base together with such stabilisers and preservatives as may be required.

DOSAGE

A person of ordinary skill in the art can easily determine an appropriate dose of one of the instant compositions to administer to a subject without undue experimentation. Typically, a physician will determine the actual dosage which will be most suitable for an individual patient and it will depend on a variety of factors including the activity of the specific compound employed, the metabolic stability and length of action of that compound, the age, body weight, general health, sex, diet, mode and time of administration, rate of excretion, drug combination, the severity of the particular condition, and the individual undergoing therapy. The dosages disclosed herein are exemplary of the average case. There can of course be individual instances where higher or lower dosage ranges are merited, and such are within the scope of this invention.

In accordance with this invention, an effective amount of a compound of general formula (I) may be administered to inhibit the proteinase implicated with a particular condition or disease. Of course, this dosage amount will further be modified according to the type of administration of the compound. For example, to achieve an "effective amount" for acute therapy, parenteral administration of a compound of general formula (I) is preferred. An intravenous infusion of the compound in 5% dextrose in water or normal saline, or a similar formulation with suitable excipients, is most effective, although an intramuscular bolus injection is also useful. Typically, the parenteral dose will be about 0.01 to about 100 mg/kg; preferably between 0.1 and 20 mg/kg, in a manner to maintain the concentration of drug in the plasma at a concentration effective to inhibit a cysteine proteinase. The compounds may be administered one to four times daily at a level to achieve a total daily dose of about 0.4 to about 400 mg/kg/day. The precise amount of an inventive compound which is therapeutically effective, and the route by which such compound is best administered, is readily determined by one of

ordinary skill in the art by comparing the blood level of the agent to the concentration required to have a therapeutic effect. Prodrugs of compounds of the present invention may be prepared by any suitable method. For those compounds in which the prodrug moiety is a ketone functionality, specifically ketals and/or hemiketals, the conversion may be effected in accordance with conventional methods.

The compounds of this invention may also be administered orally to the patient, in a manner such that the concentration of drug is sufficient to inhibit bone resorption or to achieve any other therapeutic indication as disclosed herein. Typically, a pharmaceutical composition containing the compound is administered at an oral dose of between about 0.1 to about 50 mg/kg in a manner consistent with the condition of the patient. Preferably the oral dose would be about 0.5 to about 20 mg/kg.

No unacceptable toxicological effects are expected when compounds of the present invention are administered in accordance with the present invention. The compounds of this invention, which may have good bioavailability, may be tested in one of several biological assays to determine the concentration of a compound which is required to have a given pharmacological effect.

COMBINATIONS

In a particularly preferred embodiment, the one or more compounds of the invention are administered in combination with one or more other active agents, for example, existing drugs available on the market. In such cases, the compounds of the invention may be administered consecutively, simultaneously or sequentially with the one or more other active agents.

Drugs in general are more effective when used in combination. In particular, combination therapy is desirable in order to avoid an overlap of major toxicities, mechanism of action and resistance mechanism(s). Furthermore, it is also desirable to administer most drugs at their maximum tolerated doses with minimum time intervals between such doses. The major advantages of combining chemotherapeutic drugs are

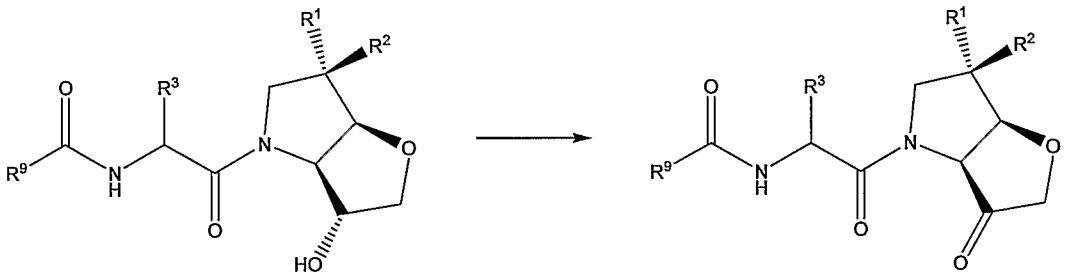
that it may promote additive or possible synergistic effects through biochemical interactions and also may decrease the emergence of resistance.

Beneficial combinations may be suggested by studying the inhibitory activity of the test compounds with agents known or suspected of being valuable in the treatment of a particular disorder. This procedure can also be used to determine the order of administration of the agents, i.e. before, simultaneously, or after delivery. Such scheduling may be a feature of all the active agents identified herein.

SYNTHESIS

Synthesis of 5,5-Bicyclic Core

One aspect of the invention relates to a process of preparing a compound of formula (I) as defined above, said process comprising oxidation of a compound of formula (II).



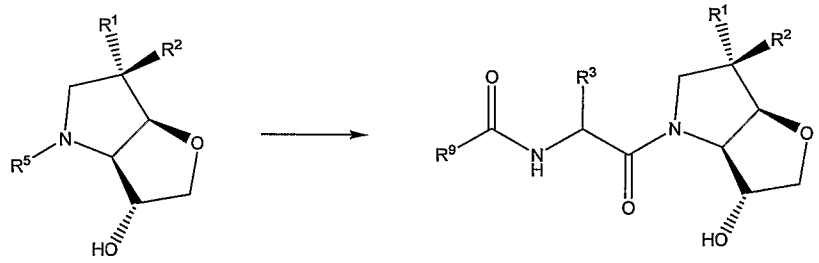
(II) (I)

Any suitable oxidising agent may be used to convert the secondary alcohol group of (II) into the corresponding ketone (I). Suitable oxidising agents will be familiar to the skilled artisan. By way of example, the oxidation may be carried out via a Dess-Martin periodinane reaction [Dess, D.B. *et al*, J. Org. Chem. 1983, 48, 4155; Dess, D.B. *et al*, J. Am. Chem. Soc. 1991, 113, 7277], or via a Swern oxidation [Mancuso, A. J. *et al*, J. Org. Chem. 1978, 43, 2480]. Alternatively, the oxidation can be carried out using SO_3/pyridine/Et_3N/DMSO [Parith, J. R. *et al*, J. Am. Chem. Soc. 1967, 5505; US 3,444,216, Parith, J. R. *et al*,], P_2O_5/DMSO or P_2O_5/Ac_2O [Christensen, S. M. *et al*, Organic Process Research and Development, 2004, 8, 777]. Other alternative oxidation

reagents include activated dimethyl sulphoxide [Mancuso, A. J., Swern, D. J., Synthesis, 1981, 165], pyridinium chlorochromate [Pianeatelli, G. *et al*, Sythesis, 1982, 245] and Jones' reagent [Vogel, A, I., Textbook of Organic Chemistry, 6th Edition].

More preferably, the process comprises treating a compound of formula (II) with Dess-Martin periodinane. Preferably, the reaction is carried out using dichloromethane as solvent.

In one preferred embodiment, the process of the invention comprises the step of converting a compound of formula (III) into a compound of formula (II) through standard amide bond formation between $R^9CONHCH(R^3)COOH$ and the compound of formula (III; R^5 = H) with a suitable carboxylic acid activating agent.



(III) (II)

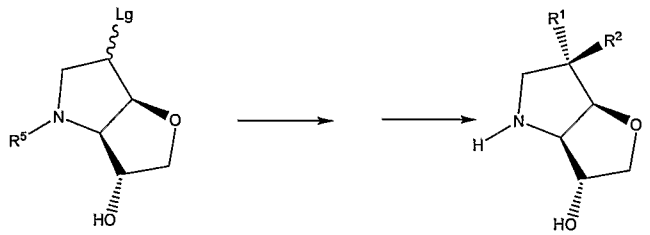
where R^5 is a protecting group or hydrogen.

In one preferred embodiment, protecting group R^5 is selected from benzyloxycarbonyl, *tert*-butoxycarbonyl, fluoren-9-ylmethoxycarbonyl, 1-(biphenyl-4-yl)-1-methylethoxycarbonyl, α,α-dimethyl-3,5-dimethoxylbenzyloxycarbonyl, *p*-methoxybenzyloxycarbonyl, *p*-nitrobenzyloxycarbonyl, allyloxycarbonyl and trichloroethoxycarbonyl.

More preferably, R^5 is benzyloxycarbonyl, *tert*-butoxycarbonyl (Boc) or flouren-9-ylmethoxycarbonyl (Fmoc).

In another preferred embodiment R^5 is H.

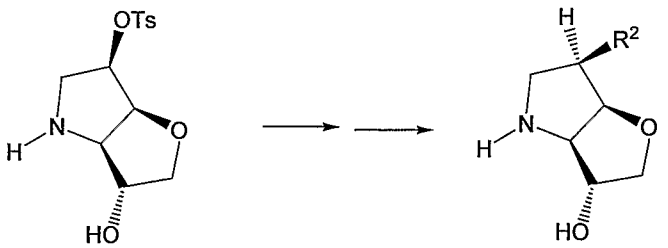
In a more preferred embodiment the process of the invention comprises the step of converting a compound of formula (IV) into a compound of formula (III; R^5 = H)



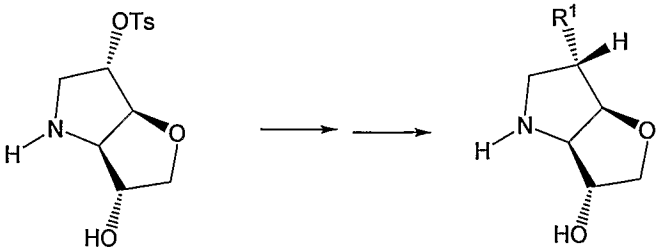
(IV) (III; R^5 = H)

where Lg is a leaving group such as tosylate, mesylate or bromide and R^5 is as previously defined.

In an even more preferred embodiment the process of the invention comprises the step of converting a compound of formula (IVa; R^5 = H) into a compound of formula (IIIa) or a compound of formula (IVb) into a compound of formula (IIIb)

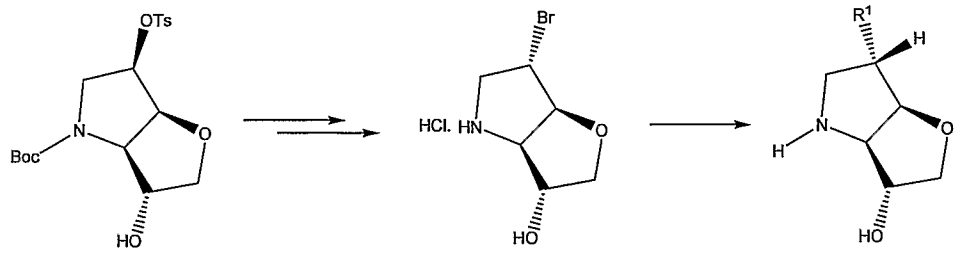


(IVa) (IIIa)



(IVb) (IIIb)

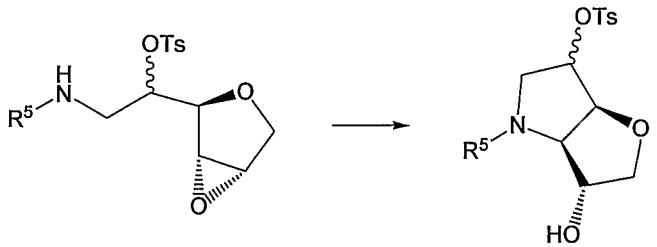
Alternatively, a compound of formula (IVc) may be converted into a compound of formula (IIIb) via the intermediate inverted bromide (IVd)



(IVc) (IVd) (IIIb)

For compounds of formulae (IIIa) and (IIIb) wherein R^1 or R^2 are methyl the displacement of tosylate or bromide is typically performed using an excess of a variety of suitable alkylmetal reagents e.g. a mixture of 2 eq. MeLi to 1 eq.Cu(I)Br that generates Li-Cu(Me)$_2$ as the active species. This displacement proceeds with retention of configuration. By analogy a similar displacement with alternative alkylmetal reagents may be performed to give for example R^1 or R^2 as ethyl, propyl, iso-propyl, *tert*-butyl and cyclopropyl.

In one preferred embodiment the process of the invention comprises the step of converting a compound of formula (V) into a compound of formula (IV)

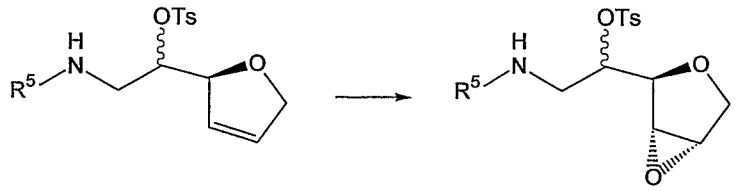


(V) (IV)

More preferably the intra-molecular cyclisation of compound (V) is induced by removal of the protecting group R^5. Preferably, for this embodiment, R^5 is

benzyloxycarbonyl (Cbz), and the process comprises hydrogenating a compound of formula (V) in the presence of a palladium catalyst.

In one preferred embodiment the process of the invention comprises the step of converting a compound of formula (VI) into a compound of formula (V)



(VI) (V) (anti)

In one preferred embodiment, the oxidising agent is mCPBA.

In another preferred embodiment, the oxidising agent is a dioxirane.

The use of dioxiranes as oxidising agents is well documented in the literature [see (a) Hodgson, D. M. *et al*, Synlett, 310 (2002); (b) Adam, W. *et al*, Acc. Chem. Res. 22, 205, (1989); (c) Yang, D. *et al*, J. Org. Chem., 60, 3887, (1995); (d) Mello, R. *et al*, J. Org. Chem., 53, 3890, (1988); (e) Curci, R. *et al*, Pure & Appl. Chem., 67(5), 811 (1995); (f) Emmons, W. D. *et al*, J. Amer. Chem. Soc. 89, (1955)].

Preferably, the dioxirane is generated *in situ* by the reaction of $KHSO_5$ with a ketone. However, the oxidation step can also be carried out using an isolated dioxirane, for example a stock solution of the dioxirane formed from acetone.

More preferably, the dioxirane is generated *in situ* using Oxone®, which is a commercially available oxidising agent containing $KHSO_5$ as the active ingredient.

Thus, in one preferred embodiment, the claimed process involves the *in situ* epoxidation of a compound of formula (VI) using Oxone® ($2KHSO_5 \cdot KHSO_4 \cdot K_2SO_4$) and a ketone co-reactant.

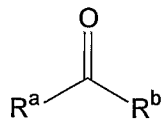
As mentioned above, the active ingredient of Oxone® is potassium peroxymonosulfate, $KHSO_5$ [CAS-RN *10058-23-8*], commonly known as potassium monopersulfate, which is present as a component of a triple salt with the formula $2KHSO_5 \cdot KHSO_4 \cdot K_2SO_4$ [potassium hydrogen peroxymonosulfate sulfate (5:3:2:2), CAS-RN *70693-62-8;* commercially available from DuPont]. The oxidation potential of Oxone® is derived from its peracid chemistry; it is the first neutralization salt of peroxymonosulfuric acid H_2SO_5 (also known as Caro's acid).

$K^+ \ ^-O\text{-}S(=O)_2(\text{-}OOH)$

Potassium Monopersulfate

Under slightly basic conditions (pH 7.5-8.0), persulfate reacts with the ketone co-reactant to form a three membered cyclic peroxide (a dioxirane) in which both oxygens are bonded to the carbonyl carbon of the ketone. The cyclic peroxide so formed then epoxidises the compound of formula VI by *syn* specific oxygen transfer to the alkene bond.

Preferably, the ketone is of formula (XIX)



(XIX)

wherein R^a and R^b are each independently alkyl, aryl, haloalkyl or haloaryl.

Where R^a and/or R^b are alkyl, the alkyl group may be a straight chain or branched alkyl group. Preferably, the alkyl group is a $C_{1\text{-}20}$ alkyl group, more preferably a $C_{1\text{-}15}$, more preferably still a $C_{1\text{-}12}$ alkyl group, more preferably still, a $C_{1\text{-}8}$ or $C_{1\text{-}6}$ alkyl group, more

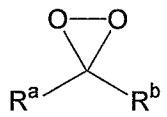
preferably a C_{1-4} alkyl group. Particularly preferred alkyl groups include, for example, methyl, ethyl, propyl, isopropyl, butyl, isobutyl, *tert*-butyl, pentyl and hexyl.

As used herein, the term "haloalkyl" refers to an alkyl group as described above in which one or more hydrogens are replaced by halo.

Where R^a and/or R^b are aryl, the aryl group is typically a C_{6-12} aromatic group. Preferred examples include phenyl and naphthyl etc.

As used herein, the term "haloaryl" refers to an aryl group as described above in which one or more hydrogens are replaced by halo.

By way of example, the reaction of $KHSO_5$ (Oxone®) with a ketone of formula XVI would form a dioxirane of formula:



wherein R^a and R^b are as defined above.

More preferably, R^a and R^b are each independently alkyl or haloalkyl.

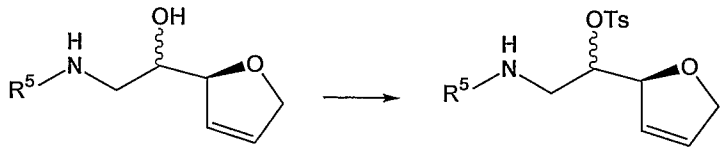
In a highly preferred embodiment, at least one of R^a and R^b is a haloalkyl, more preferably, CF_3 or CF_2CF_3.

In one preferred embodiment, R^a and R^b are each independently methyl or trifluoromethyl.

In one preferred embodiment of the invention, the ketone is selected from acetone and a 1,1,1-trifluoroalkyl ketone.

In a more preferred embodiment of the invention, the trifluoroalkyl ketone is 1,1,1-trifluoroacetone or 1,1,1-trifluoro-2-butanone, more preferably 1,1,1-trifluoro-2-butanone.

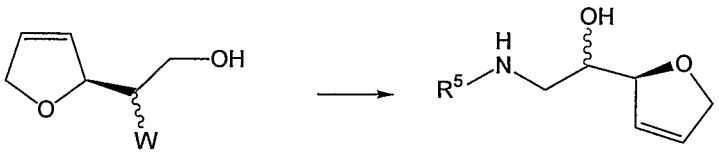
In one preferred embodiment the process of the invention comprises the step of converting a compound of formula (VII) into a compound of formula (VI)



(VII) (VI)

Preferably the process comprises treating a compound of formula (VII) with tosyl chloride in pyridine. Alternatively the process comprises treating a compound of formula (VII) with tosyl chloride in dichloromethane and triethylamine.

In one preferred embodiment the process of the invention comprises the step of converting a compound of formula (VIII) into a compound of formula (VII)



(VIII) (VII)

where W is halogen or tosyl.

Preferably, this step comprises the steps of:

(a) reacting a compound of formula (VIII), where W is halogen or OTs, with aqueous ammonia and alcohol; and

(b) converting the product formed in step (a) to a compound of formula (VII).

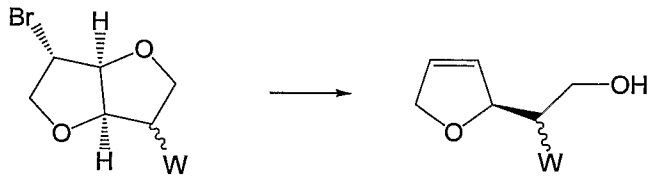
Preferably, steps (a) and (b) of the above process are a one-pot process.

In one particularly preferred embodiment, R^5 is benzyloxycarbonyl, and step (b) comprises treating the mixture formed in step (a) with benzyloxycarbonyl chloride.

Preferably, W is I, Br or OTs, more preferably, Br or OTs, even more preferably OTs.

Preferably, the alcohol is isopropyl alcohol or ethanol.

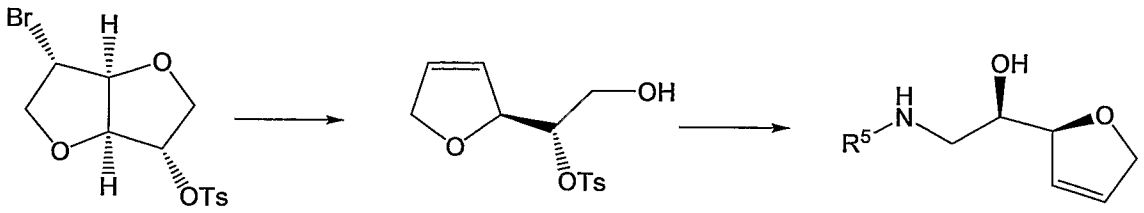
In one preferred embodiment of the invention, said compound of formula VIII is prepared from a compound of formula IX



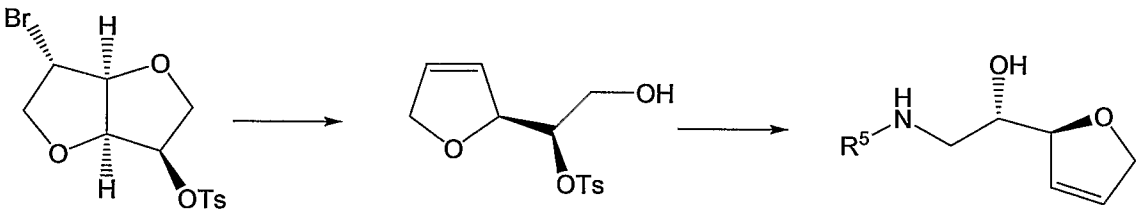
IX VIII

Preferably, the above process comprises treating said compound of formula IX with methyl lithium.

More preferably, compound of formula IX is compound 47 and compound of formula VIII is compound 14; or compound of formula IX is compound 46 and compound of formula VIII is compound 13. Treatment of monobromotosylates 46 or 47 with zinc dust at room temperature in organic / aqueous mixtures (most preferably an isopropanol, tetrahydrofuran, water, ammonium chloride mixture) provides alcohols 13 and 14 respectively in high yield. Additionally, completion of the one-pot conversion gives alcohols VIIa and VIIb with defined stereochemistry and in high yield.

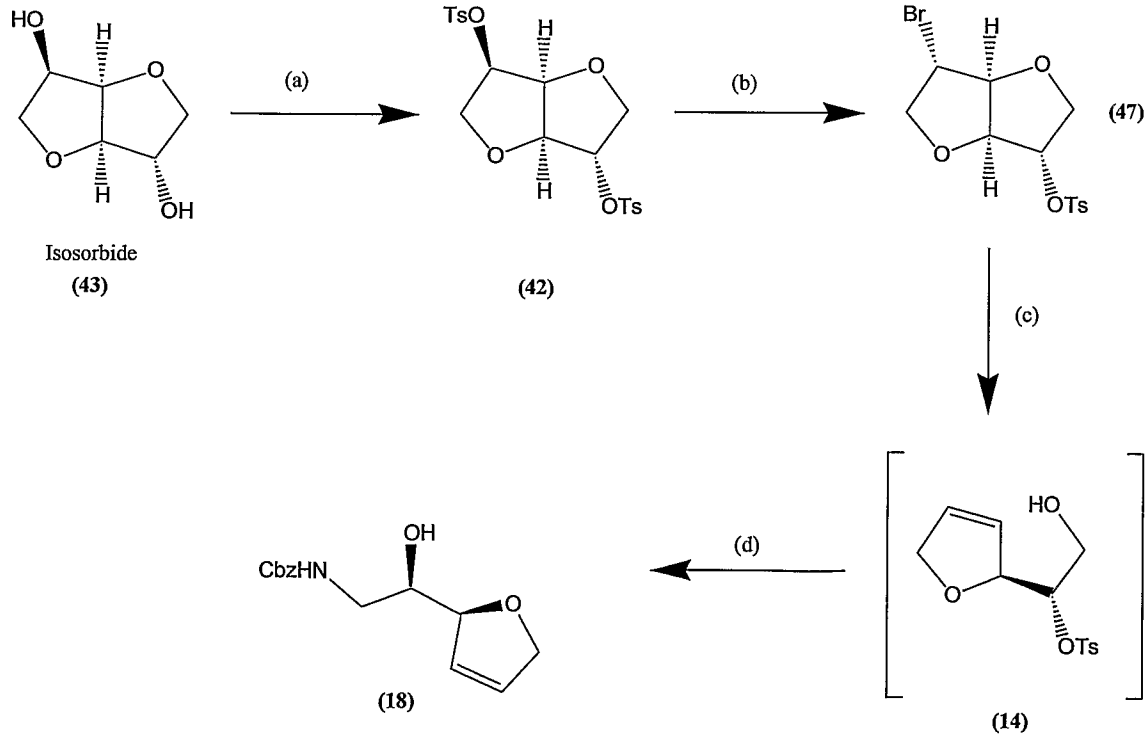


(47) (14) (VIIa)



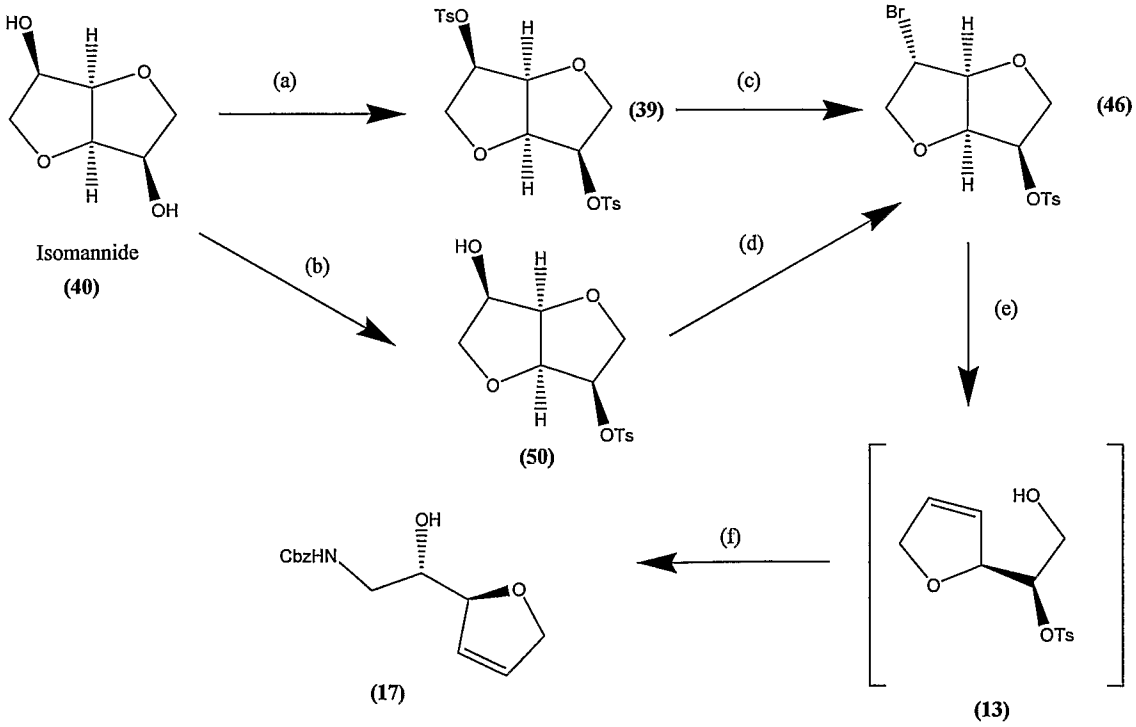
(46) (13) (VIIb)

Commencing from the commercially available sugars isomannide and isosorbide, the present invention also provides facile preparation of monobromotosylates 46 and 47 One highly preferred preparation is shown below in Scheme 15



Scheme 15: (a) TsCl, triethylamine, DCM, 25°C → 50°C, 20h under Ar; (b) LiBr, DMSO, 110°C→ 120°C, 10h under Ar; (c) Zn, ^{i}PrOH, THF, H_2O, NH_4Cl, RT, 16h; (d) (i) NH_4OH, NH_3 in ^{i}PrOH, 75°C, 16h; (ii) Cbz-Cl, Na_2CO_3, dioxan, water.

Isosorbide (43) is converted to the di-tosylate (42) which is obtained following recrystallisation from methanol in 97% yield. Mono-bromination is effected by 2.5eq lithium bromide in DMSO (or DMF) with temperature control 110°C→ 120°C. The product bromide is isolated following extractive work-up and purification either by column chromatography (74%) or attractive for large scale by recrystallisation from methanol giving a first crop of 55% plus mother liquors containing good quality material that may be pooled from batch runs and purified later. Thus, preparation of monobromotosylate (47) with defined stereochemistry by methods in Scheme 15 is attractive for large scale applications. Treatment of monobromotosylate (47) with zinc dust at room temperature in organic / aqueous mixtures (most preferably an isopropanol, tetrahydrofuran, water, ammonium chloride mixture) provides alcohol (14) which is derivatised as the Cbz compound (18) through one pot conversion.



Scheme 16: (a) 2.2eq TsCl, KOH(aq), DCM, CCl_4, 0°C, 24h under Ar; (b) (i) 0.5eq TsCl, KOH(aq), DCM, CCl_4, 0°C, 7h under Ar or (ii) 1.0eq TsCl, pyridine, 0°C→ RT, 1h; (c) LiBr, DMF, 100°C, 27h; (d) CBr_4, Ph_3P, pyridine, 65°C, 2h under Ar; (e) Zn, ^iPrOH, THF, H_2O, NH_4Cl, RT, 16h; (f) (i) NH_4OH, NH_3 in ^iPrOH, 75°C, 16h; (ii) Cbz-Cl, Na_2CO_3, dioxan, water.

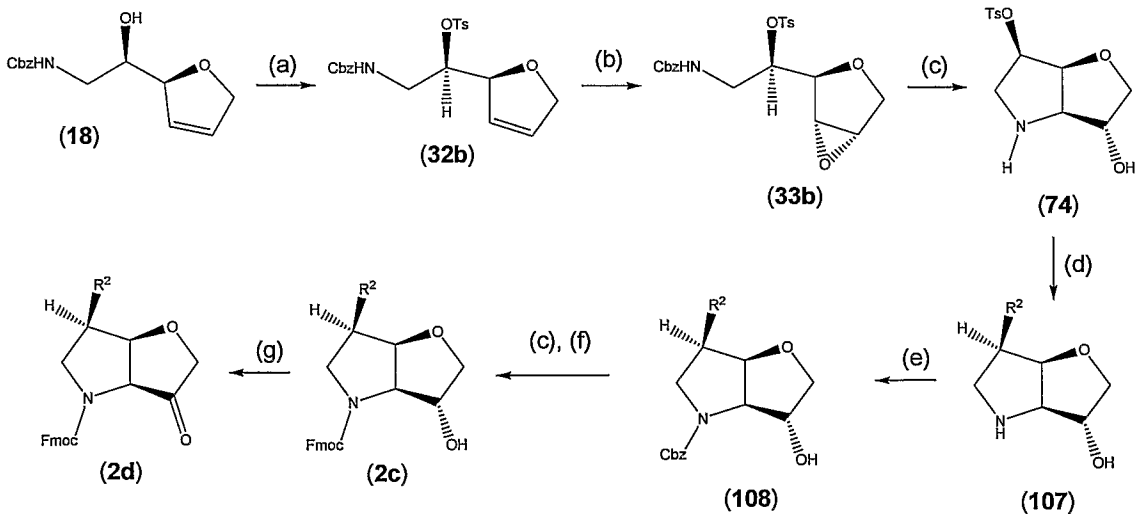
Treatment of isomannide (40) (Scheme 16) with tosylchloride (2.2eq) in a bi-phasic potassium hydroxide / dichloromethane / carbon tetrachloride mixture at 0°C gives ditosylate (39) in 48% yield following simple filtration and trituration with methanol. Alternatively, treatment of isomannide (40) with tosylchloride (0.5eq) in a bi-phasic potassium hydroxide / dichloromethane / carbon tetrachloride mixture at 0°C gives monotosylate in 38% yield following simple extraction and re-crystallisation from carbon tetrachloride (conditions as described in US 6,858,632). Although the monotosylate can be obtained in higher yield by treatment of isomannide (40) with tosylchloride in pyridine, purification currently requires column chromatography which may becomes undesirable at large scale. Monobromotosylate (46) may then be prepared by treatment of ditosylate (39) with lithium bromide in DMF (29% yield following chromatography) or by treatment of monotosylate under Mitsunobu conditions with carbon tetrabromide (63% yield following chromatography). Treatment of monobromotosylate (46) with zinc dust at room temperature in organic / aqueous mixtures (most preferably an isopropanol, tetrahydrofuran, water, ammonium chloride mixture) provides alcohol (13) which is derivatised as the Cbz compound (17) through one pot conversion.

In one highly preferred embodiment of the invention, the 6-alkyl-5,5-bicylic core is prepared in accordance with the steps set forth in Scheme 1 below:

The alcohol functionality of (18) may be derivatised as the *para*-toluene sulphonate (Ts) giving (*R*)-2-(benzyloxycarbonylamino)-1-((*S*)-2,5-dihydrofuran-2-yl)ethyl 4-methylbenzenesulfonate (32b) which proceeds through the *anti*-epoxide (*R*)-2-(benzyloxycarbonylamino)-1-((1*S*, 2*S*, 5*S*)-3,6-dioxabicyclo[3.1.0]hexan-2-yl)ethyl 4-methylbenzenesulphonate (33b). Hydrogenation of tosylate (33b) provides free amine

that undergoes intramolecular cyclisation to provide intermediate (74). Intermediate (74), either as the free base or hydrochloride salt, undergoes displacement with an excess of a variety of suitable alkylmetal reagents e.g. a mixture of 2 eq. MeLi to 1 eq.Cu(I)Br that generates Li-Cu(Me)$_2$ as the active species, to give the 6-alkyl analogues with retention of configuration. By analogy a similar displacement with alternative alkylmetal reagents may be performed to give for example R^1 or R^2 as ethyl, propyl, iso-propyl, *tert*-butyl and cyclopropyl. Urethane protection of the secondary amine of the bicyclic intermediate (107) followed by oxidation to ketone provides intermediate (2d) that is particularly useful for solid phase synthesis of compounds of general formula I.

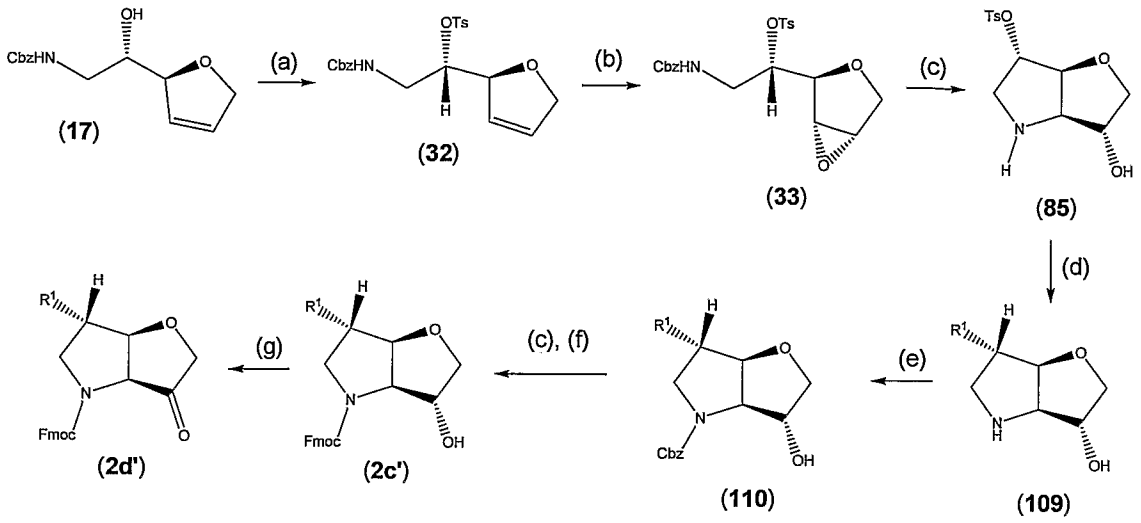
Advantageously, the epoxidation to give the desired *anti*-epoxide is directed by the presence of the tosylate group.



Scheme 1: (a) TsCl, pyridine: (b) (i) *m*CPBA, DCM or (ii) OXONE®, $NaHCO_3$, 1,1,1-trifluoroacetone, CH_3CN, H_2O, Na_2.EDTA 0 °C or (iii) 30% H_2O_2, CH_3CN, MeOH, $NaHCO_3$; (c) Pd-C, H_2, ethanol; (d) Alkyl-Li in Et_2O, Cu(I)Br, THF; or Alkyl-MgBr in Et_2O, Cu(I)Br, LiCl, THF; (e) Cbz-Cl, Na_2CO_3, dioxan, H_2O; (f) Fmoc-Cl, Na_2CO_3, dioxan, H_2O; (g) Dess-Martin periodinane, anhydrous DCM, RT.

An analogous reaction scheme can be applied to the enantiomer of (18), namely, benzyl (*S*)-2-((*S*)-2,5-dihydrofuran-2-yl)-2-hydroxyethyl carbamate (17), proceeding through

the analogous *anti*-epoxide (*S*)-2-(benzyloxycarbonylamino)-1-((1*S*, 2*S*, 5*S*)-3,6-dioxabicyclo[3.1.0] hexan-2-yl)ethyl 4-methylbenzenesulphonate (32) (Scheme 2).

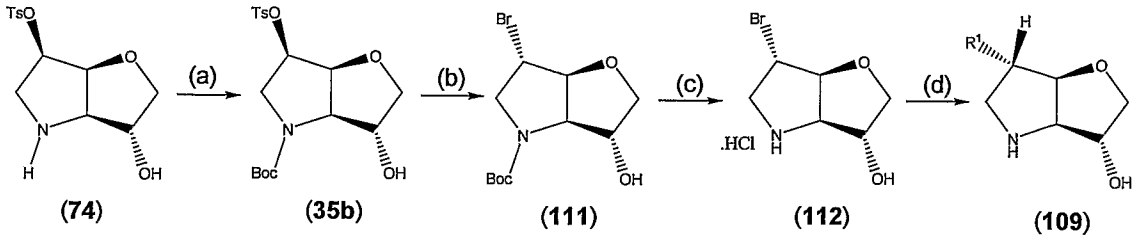


Scheme 2: (a) TsCl, pyridine: (b) (i) *m*CPBA, DCM or (ii) OXONE®, $NaHCO_3$, 1,1,1-trifluoroacetone, CH_3CN, H_2O, Na_2.EDTA 0 °C or (iii) 30% H_2O_2, CH_3CN, MeOH, $NaHCO_3$; (c) Pd-C, H_2, ethanol; (d) Alkyl-Li in Et_2O, Cu(I)Br, THF; or Alkyl-MgBr in Et_2O, Cu(I)Br, LiCl, THF; (e) Cbz-Cl, Na_2CO_3, dioxan, H_2O; (f) Fmoc-Cl, Na_2CO_3, dioxan, H_2O; (g) Dess-Martin periodinane, anhydrous DCM, RT.

The tosyl group of bicyclic intermediates (74) and (85) can act as a leaving group that undergoes displacement with an excess of a variety of suitable alkylmetal reagents e.g. a mixture of 2 eq. MeLi to 1 eq.Cu(I)Br that generates Li-$Cu(Me)_2$ as the active species, to give the 6-alkyl analogues with retention of configuration.

Alternatively, intermediate tosylate (74) may be Boc protected to give protected analogue (35b) that may undergo inversion to bromide (111) through treatment with LiBr in DMF at typically 130 °C (Scheme 4). Acidolytic removal of Boc provides intermediate bromide (112) that undergoes displacement with an excess of a variety of suitable alkylmetal reagents e.g. a mixture of 2 eq. MeLi to 1 eq.Cu(I)Br that generates

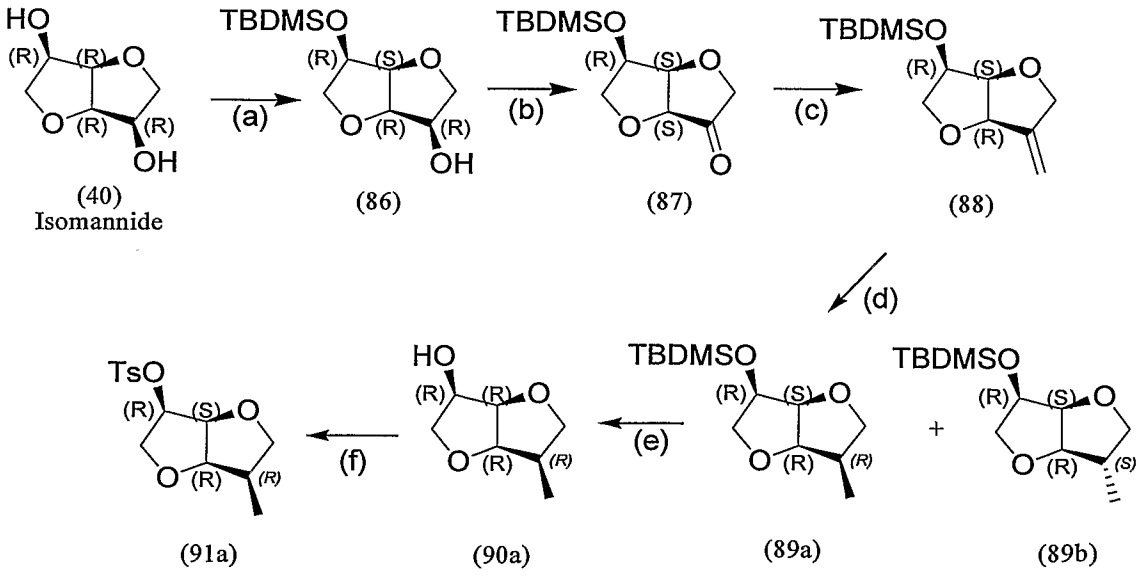
Li-Cu(Me)$_2$ as the active species, to give the 6-alkyl analogues with retention of configuration. e.g. (109; R^1 = Me).



Scheme 4: (a) Boc_2O, Na_2CO_3, dioxan, H_2O; (b) LiBr, DMF, 130°C; (c) 4N HCl in dioxan; (d) Alkyl-Li in Et_2O, Cu(I)Br, THF; or Alkyl-MgBr in Et_2O, Cu(I)Br, LiCl, THF.

<u>Alternative Preparation of 6-alkyltetrahydrofuro[3,2-*b*]pyrrol-3-one cores</u>

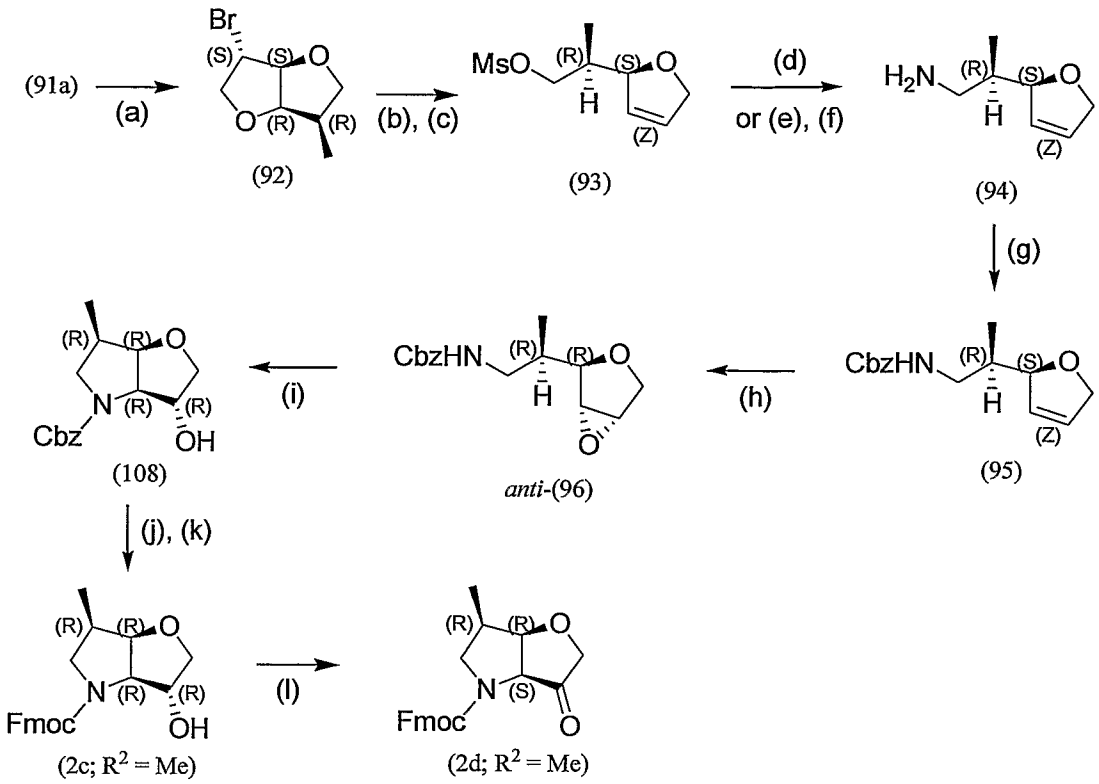
An alternative synthesis of 6-alkyl substituted bicyclic building blocks may be achieved through the chemistries described in Schemes 6, 7, 8 and 9.



Scheme 6. (a) TBDMS-Cl, imidazole, DMF; (b) Dess-Martin periodinane, DCM, 30-35 °C or Et_3N, oxalyl chloride, DMSO, DCM -70 °C; (c) *n*-BuLi, CH_3PPh_3Br, THF or

KO^tBu, CH_3PPh_3Br, THF; (d) Pd/C, H_2, EtOH or Pd/C, H_2, EtOAc; (e) TBAF, THF; (f) TsCl, pyridine.

Isomannide (40) is mono *tert*-butyldimethylsilyl (TBDMS) protected by treatment with *tert*-butyldimethylsilyl chloride and imidazole in DMF to give intermediate (86). Oxidation of alcohol (86) with Dess-Martin periodinane in DCM provides (3a*S*, 6*R*, 6a*S*)-6-(*tert*-butyldimethylsilyloxy)tetrahydrofuro[3,2-*b*]furan-3(2*H*)-one (87), an intermediate suitable for reaction with a variety of Wittig reagents. For example, reaction of ketone (87) with potassium *tert*-butoxide and methyltriphenylphosphonium bromide in THF provides exocyclic alkene (88) in 91% yield following chromatography. Hydrogenation of alkene (88) over Pd-C provides an ~ 9:1 mixture of methyl analogues (89a) and (89b) respectively that are not readily separated by silica column chromatography. Subsequent transformaions / purifications provide further enrichment of the major isomer derived from (89a). Removal of TBDMS protection from intermediate (89a) may be performed with TBAF in THF and subsequent treatment of alcohol (90a) with p-toluenesulphonyl chloride and pyridine in DCM gives tosyl intermediate (91a) in high yield.

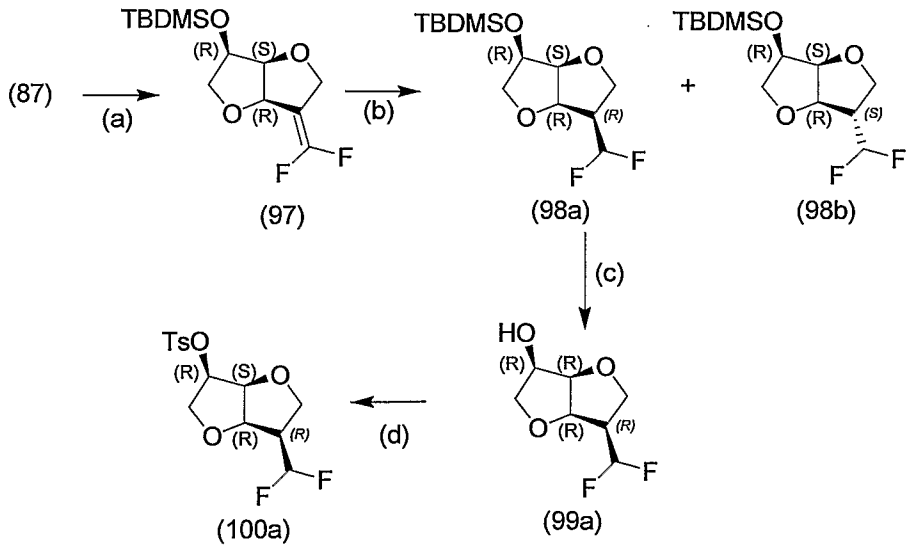


Scheme 7. (a) LiBr, DMF, 110-125°C; (b) Zn, THF, H_2O, NH_4Cl; (c) Et_3N, $MeSO_2Cl$, DCM; (d) NH_3, ^iPrOH, H_2O, 70 °C; (e) NaN_3, DMF, 60 °C; (f) Ph_3P, H_2O, RT→55 °C; (g) Cbz-Cl, Na_2CO_3, dioxan, H_2O; (h) OXONE®, $NaHCO_3$, 1,1,1-trifluoroacetone, CH_3CN, H_2O, Na2.EDTA, 0 °C; (i) NaH, anhydrous THF, 3h, RT. (j) Pd-C, H_2, methanol; (k) Fmoc-Cl, Na_2CO_3, dioxan, H_2O; (l) Dess-Martin periodinane, DCM.

Then following the general theme detailed previously in Scheme 16, tosylate (91a) may be converted to the monobromide (92) by treatment with lithium bromide in DMF. Treatment of bromide (92) with zinc dust in ammonium chloride and THF followed by extraction then treatment with triethylamine and methanesulphonyl chloride provides mesylate (93). Preparation of amine (94) may be achieved by direct treatment of mesylate (93) with ammonia in propan-2-ol or via the 2-step procedure of azide displacement of mesylate with sodium azide in DMF followed by reduction of azide to amine (94) through treatment with triphenylphosphine and water in DMF. Amine (94) may then be Cbz protected by treatment with Cbz-Cl and sodium carbonate in aqueous dioxan. Epoxidation of alkene (95) through use of 1,1,1-trifluoroacetone provides an ~

3.5:1 mixture of the desired *anti*-(96) and side-product *syn*-(96) respectively. Treatment of epoxide mixture (96) with sodium hydride in anhydrous THF provides a new slower eluting product on TLC that is the desired bicycle (3*R*, 3a*R*, 6*R*, 6a*R*)-benzyl 3-hydroxy-6-methyltetrahydro-2*H*-furo[3,2-*b*]pyrrole-4(5*H*)-carboxylate (2a). Hydrogenation, Fmoc protection and oxidation provides intermediate ketone (2d; R^2 = Me) that is particularly suited to solid phase synthesis of analogues of general formula I (R^2 = Me).

Alternatively, ketone (87) may be treated with triphenylphosphine and dibromodifluoromethane in N,N-dimethylacetamide to give *tert*-butyl((3*R*, 3a*S*, 6a*R*)-6-(difluoromethylene)hexahydrofuro[3,2-*b*]furan-3-yloxy)dimethylsilane (97) as detailed in Scheme 8.

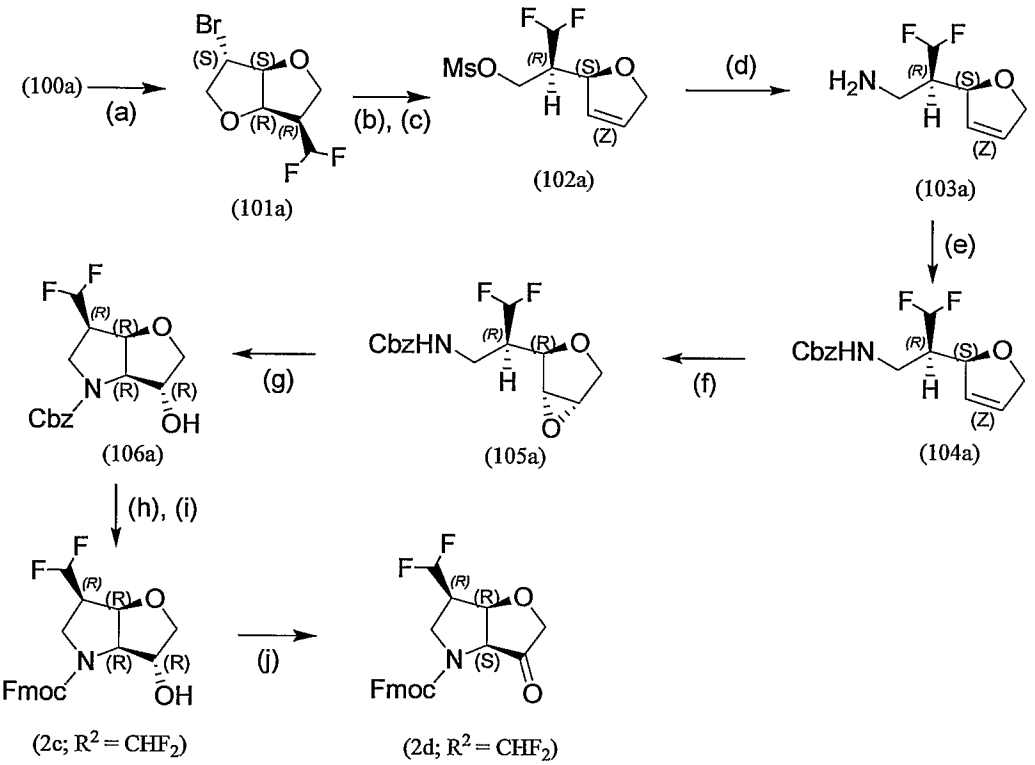


Scheme 8. (a) Br_2CF_2, PPh_3, Zn, DMA; (b) Pd/C, H_2, MeOH. (c) TBAF, THF; (d) TsCl, pyridine.

Subsequent hydrogenation of alkene (97) over Pd-C provides an ~ 9:2 mixture of the difluoromethyl analogues (98a) and (98b) respectively, that are readily separated by silica column chromatography. Removal of TBDMS protection from intermediate (98a) may be performed with TBAF in THF and subsequent treatment of alcohol (99a) with p-toluenesulphonyl chloride and pyridine in DCM gives tosyl intermediate (100a) in

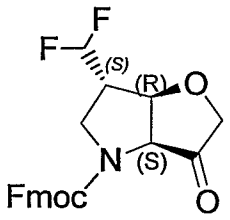
high yield. Analogous reactions may be performed on (98b) to give the opposite 6-difluoromethyl isomer (100b).

Then in an analogous manner to that described in Scheme 7, intermediate (100a) may be converted into (3a*S*, 6*R*, 6a*R*)-(9*H*-Fluoren-9-yl)methyl 6-(difluoromethyl)-3-oxotetrahydro-2*H*-furo[3,2-*b*]pyrrole-4(5*H*)-carboxylate (2d; R^2= CHF_2) (Scheme 9).



Scheme 9. (a) LiBr, DMF, 110-125°C; (b) Zn, THF, H_2O, NH_4Cl; (c) Et_3N, $MeSO_2Cl$, DCM; (d) NH_3, ^iPrOH, H_2O, 70 °C; (e) Cbz-Cl, Na_2CO_3, dioxan, H_2O; (f) OXONE®, $NaHCO_3$, 1,1,1-trifluoroacetone, CH_3CN, H_2O, Na_2.EDTA, 0 °C; (g) NaH, anhydrous THF, 3h, RT. (h) Pd-C, H_2, methanol; (i) Fmoc-Cl, Na_2CO_3, dioxan, H_2O; (j) Dess-Martin periodinane, DCM.

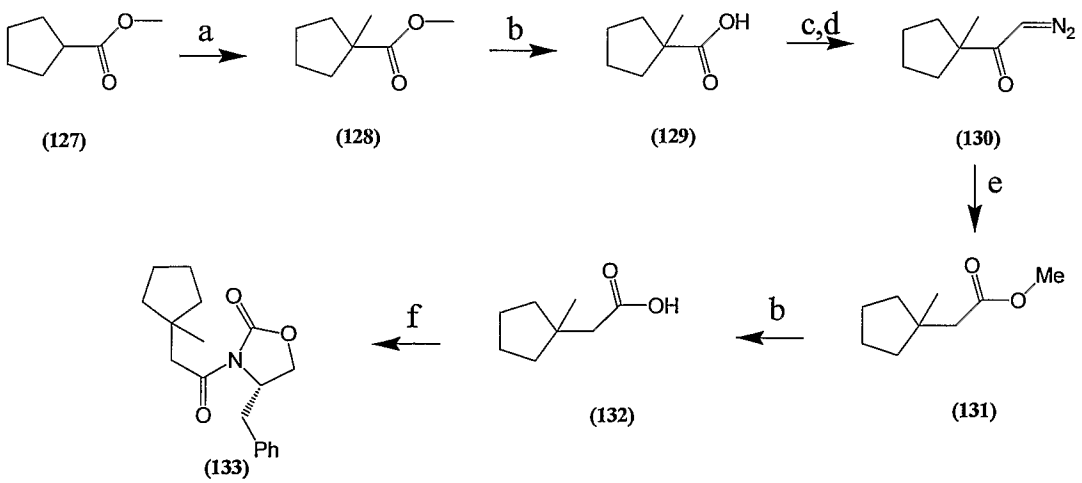
In an analogous manner, intermediate (100b) may be converted into (3a*S*, 6*S*, 6a*R*)-(9*H*-Fluoren-9-yl)methyl 6-(difluoromethyl)-3-oxotetrahydro-2*H*-furo[3,2-*b*]pyrrole-4(5*H*)-carboxylate (2d'; R^1= CHF_2).



(2d'; $R^1 = CHF_2$)

Preparation of Novel Aminoacids

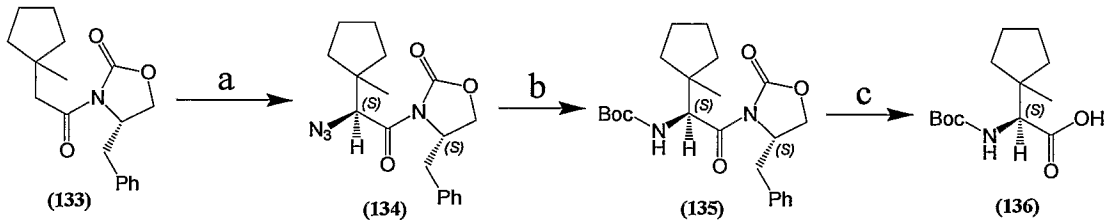
The novel aminoacid (*S*)-2-amino-2-(1-methylcyclopentyl)acetic acid that forms an intrinsic feature of a selection of compounds of formula I may be prepared following adaptation of a variety of known general literature syntheses of aminoacids. In one such method (Scheme 17), commercially available methyl cyclopentanecarboxylate (**127**) (CAS 4630-80-2) is converted to methyl 2-(1-methylcyclopentyl)acetate (**131**) as detailed in WO-A-06064286. Ester (**131**) is readily hydrolysed to 2-(1-methylcyclopentyl)acetic acid (**132**) using LiOH in methanol. Preparation of (*S*)-4-benzyl-3-(2-(1-methylcyclopentyl)acetyl)oxazolidin-2-one (**133**) is then completed using commercially available (*S*)-4-benzyl-2-oxazolidinone (CAS 90719-32-7) following the general methods detailed in WO98017626 (pg 49).



Scheme 17. (a) LDA, MeI, THF, -78°C; (b) LiOH, MeOH; (c) Oxalyl chloride, DCM, DMF: (d) Diazomethane, triethylamine, diethylether; (e) Silver benzoate, triethylamine,

MeOH; (f) (i) Pivaloyl chloride, THF, triethylamine; (ii) (S)-4-benzyl-2-oxazolidinone (CAS 90719-32-7), n-BuLi, hexanes;

Asymmetric addition of azide is then conducted by deprotonation of the chiral auxiliary (**133**) and reaction with trisyl azide. Reduction of azide (**134**) and concomitant Boc amino protection following the general methods detailed in US5128448 provides intermediate (**135**). Finally, hydrolysis of the auxiliary is conducted with hydrogen peroxide and lithium hydroxide following the general methods detailed in US5128448. The final product (*S*)-2-(tert-butoxycarbonylamino)-2-(1-methylcyclopentyl)acetic acid (**136**) is obtained following simple aqueous extraction (Scheme 18).



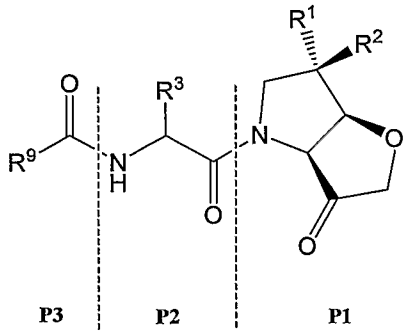
Scheme 18. (a) (i) KHMDS, THF, toluene, N_2, -78°C; (ii) Trisyl azide, THF; (b) Pd/C, H_2, DMF, Boc_2O; (c) 30% H_2O_2, LiOH, THF, H_2O.

Synthesis of Compounds of Formula (I)

To those skilled in the practices of organic chemistry, compounds of general formula (I) may be readily synthesised by a number of chemical strategies, performed either in solution or on the solid phase (see Atherton, E. and Sheppard, R. C. In '*Solid Phase Peptide Synthesis: A Practical Approach*', Oxford University Press, Oxford, U.K. 1989, for a general review of solid phase synthesis principles), or a combination thereof.

Compounds of general formula (I) may be conveniently considered as a combination of three building blocks (P1, P2 and P3) that respectively occupy the S1, S2 and S3 binding sites of the protease (see Berger, A and Schechter, I., *Philos. Trans. R. Soc. Lond. [Biol.],* 257, 249-264, 1970 for a description of the designation of enzyme S-

subsites and substrate P-subsites within enzyme-substrate or enzyme-inhibitor complexes). The notional concepts of P1, P2 and P3 are used herein for convenience only and the above-mentioned compounds are intended to be within the scope of the invention regardless of binding mode.



A suitably protected and/or activated building block may then be prepared and subsequently chemically bonded (coupled) together with other building blocks to provide compounds of general formula (I).

Compounds of formula (I) may be prepared: (1) by the stepwise addition of P3 and P2 to the bicyclic 6-alkyltetrahydrofuro[3,2-*b*]pyrrol-3-one core; or (2) by reaction of the bicyclic 6-alkyltetrahydrofuro[3,2-*b*]pyrrol-3-one core with a P3-P2 prescursor molecule; or (3) by introducing the P3-P2 group prior to formation of the bicyclic 6-alkyltetrahydrofuro[3,2-*b*]pyrrol-3-one core, i.e. prior to the oxidation step or prior to the intramolecular cyclisation step.

Thus, alternative orders of coupling of the building blocks are possible, for example P2 + P1 → P2-P1 then addition of P3 → P3-P2-P1 or P3 + P2 → P3-P2 then addition to P1 → P3-P2-P1. Within each of these combinations each of the P1, P2 or P3 building blocks may contain additional alternative functionalities that are further transformed following coupling to give the final compound. For example the ketone functionality of the P1 building block may be protected as a ketal during coupling of building blocks and transformed to the final ketone by hydrolysis following completion of the coupling reactions. Alternatively, the ketone functionality of the P1 building block may be initially introduced via a lower oxidation state such as the corresponding alcohol and

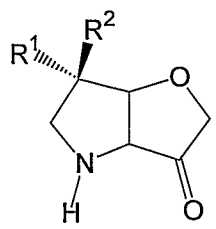
following completion of the coupling reactions be re-introduced by oxidation of the alcohol. Alternatively, the ketone functionality of the P1 building block may be protected through a semi-carbazone suitable for solid phase synthesis (e.g. see WO 02/057270 and references cited therein) and following completion of the coupling reactions released from the solid phase by acidolytic reaction.

The chemical bond formed by coupling of the building blocks is a secondary amide (P3-P2) or a tertiary amide (P2-P1) that are formed through reaction of an activated carboxylic acid with a primary and secondary amine respectively. Many methods are available for activation of a carboxylic acid prior to coupling to an amine and in principle, any of these methods may be used herein. Typical carboxylic acid activation methods are exemplified but not restricted to the azide method, mixed anhydride method (e.g. via isobutylchloroformate), carbodiimide methods (e.g. via dicyclohexylcarbodiimide, diisopropylcarbodiimide, 1-ethyl-3-(3'-dimethylamino propyl)carbodiimide), active ester method (e.g. via p-nitrophenyl ester, N-hydroxysuccinic imido ester, pentafluorophenyl ester), uronium method (e.g. via addition of HBTU, PyBop, BOP), carbonyldiimidazole method or via pre-formation of acyl fluorides or acyl chlorides. In some instances the coupling reaction may be enhanced by the addition of a further activation catalyst such as 1-hydroxybenzotriazole, or 4-dimethylaminopyridine. A general description of carboxylic acid activation techniques and the use of activation additives may be found in Bodanszky, M. 'Principles of Peptide Synthesis', 2nd rev. ed., Springer-Verlag, Berlin, 1993 and references cited therein.

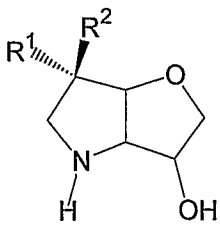
The α-amino group of the P2 aminoacid building block is usually protected during coupling reactions to the P1 building block to avoid the formation of undesired self-condensation products. The art of α-amino protection is well known in peptide chemistry (e.g. see Bodanszky, M. 'Principles of Peptide Synthesis', 2nd rev. ed., Springer-Verlag, Berlin, 1993 and references cited therein) and example protection groups include, but are not limited to, 9-fluorenylmethoxycarbonyl (Fmoc), *tert*-butoxycarbonyl (Boc), benzyloxycarbonyl (Cbz), allyloxycarbonyl (Alloc) and

trichloroethoxycarbonyl (Treoc). The Fmoc group is particularly well suited for solid phase syntheses (e.g. see Atherton, E.; Sheppard, R. C. in 'Solid Phase Peptide Synthesis A Practical Approach', IRL Press, Oxford, U.K., 1989) typically being removed by treatment with 20% v/v piperidine in dimethylformamide or 1% v/v 1,8-diazabicyclo[5.4.0]undec-7-ene in dimethylformamide. The Boc group is particularly well suited to solution phase syntheses typically being removed by treatment with trifluoroacetic acid based mixtures or HCl in dioxan or ethyl acetate. The Cbz group is also particularly well suited for solution phase syntheses typically being removed by catalytic hydrogenation with hydrogen and palladium catalysis or by treatment with HBr in acetic acid. Once the coupling sequence is complete, any protecting groups are removed in whatever manner is dictated by the choice of protecting groups (for a general description of protecting groups and their respective stabilities and methods of removal see Greene, T. W. and Wuts, P. G. M. 'Protective Groups in Organic Synthesis' John Wiley and Sons, New York, 1991 and references therein).

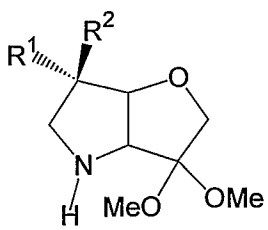
In the simplest example, the entire left hand portion of a compound of general formula (I) (i.e. P3-P2) as the carboxylic acid can be prepared in solution by traditional organic chemistry methods and coupled to ketone, alcohol or ketal intermediates such as compounds (IIb), (IIc) and (IId). Then oxidation of the alcohol intermediate (e.g. Dess-Martin periodinane in DCM) or acidolytic cleavage of the ketal intermediate provides compounds of general formula (I). The alcohol oxidation route is particularly useful when the compound of general formula (I) contains a substituent that is labile to trifluoroacetic acid, this being the final reagent used in each of the solid phase syntheses.



(IIb)



(IIc)



(IId)

Examples of these different coupling tactics have been detailed previously (see (i) Quibell, M. *et. al., Bioorg. Med. Chem.* 13, 609-625, 2005. (ii) Wang, Y. *et. al., Bioorg. Med. Chem Lett.* 15, 1327-1331, 2005) and the optimum synthetic route is dependant upon the specific substituent combinations of the target compound of general formula (I).

In more detail, one preferred strategy for the synthesis of compounds of general formula (I) comprises:-

(a) Preparation of an appropriately functionalised and protected bicyclic ketone or bicyclic alcohol building block in solution;

(b) Attachment of the building block (a) to the solid phase through a linker that is stable to the conditions of synthesis, but readily labile to cleavage at the end of a synthesis (see James, I. W., *Tetrahedron, 55(Report Nº 489)*, 4855-4946, 1999, for examples of the 'linker' function as applied to solid phase synthesis);

(c) Solid phase organic chemistry (see Brown, R. D. *J. Chem. Soc., Perkin Trans.1*, 19, 3293-3320, 1998), to construct the remainder of the molecule;

(d) Compound cleavage from the solid phase into solution; and

(e) Cleavage work-up and compound analysis.

A second strategy for the synthesis of compounds of general formula (I) comprises:-

(a) Preparation of an appropriately functionalised and protected bicyclic intermediate building block in solution. Preferred protecting groups for solution phase chemistry are the 9-fluorenylmethoxycarbonyl (Fmoc), Nα-*tert*-butoxycarbonyl (Boc), Nα-benzyloxycarbonyl (Cbz) and Nα-allyloxycarbonyl group (Alloc).

(b) Standard organic chemistry methods for the conversion of building block obtained in step (a) towards compounds of general formula (I).

As mentioned above, in one preferred embodiment of the invention, compounds of formula (I) may be prepared using conventional solution phase chemistry, for example,

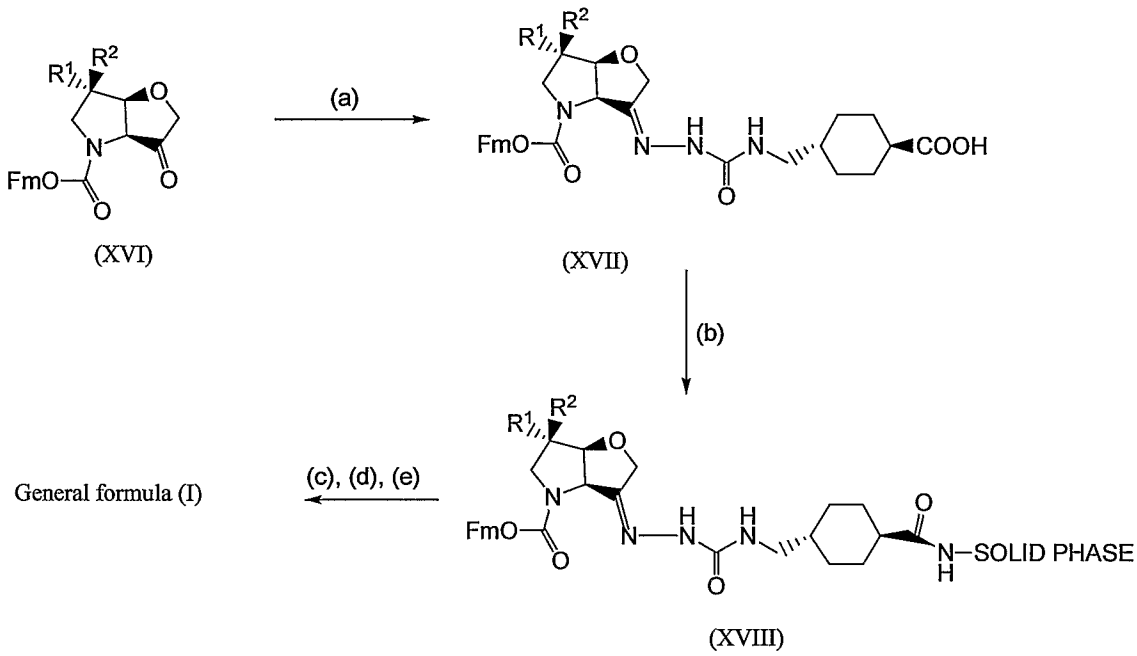
as described in Quibell, M *et al*, Bioorg. Med. Chem, 13, 609-625, 2005 (see in particular, Schemes 3 and 4). The solution phase strategy is attractive in being able to generate larger quantities of preferred analogues, typically on a multi-gram to multi-kilogram scale.

In an alternative preferred embodiment of the invention, compounds of formula (I) may be prepared using conventional solid phase chemistry, for example, as described in Quibell M, *et al* Bioorg. Med. Chem, 12, 5689-5710, 2004, see in particular, Scheme 3 and Section 3.2, and references cited therein; and Bioorg. Med. Chem, 13, 609-625, 2005, see Scheme 5 and Section 2.2, and references cited therein). The solid phase strategy is attractive in being able to generate many thousands of analogues, typically on a 5-100mg scale, through established parallel synthesis methodologies (e.g. see (a) Bastos, M.; Maeji, N. J.; Abeles, R. H. *Proc. Natl. Acad. Sci. USA,* 92, 6738-6742, 1995).

The synthetic strategy is based on reversible anchorage of the ketone functionality via a hydrazide linker bond using general multipin techniques previously described in the art (Watts J. *et al*, Bioorg. Med. Chem. 12(11), 2903, 2004; Quibell M., *et al*, Bioorg. Med. Chem. 5689-5710, 2004; Grabowksa U. *et al*, J. Comb. Chem. 2000, 2(5), 475).

Compounds of formula (III; R^5 = Fmoc) may be oxidised to the corresponding ketone (e.g. XVI, Scheme 3) and utilised in a solid phase synthesis of inhibitor molecules (I). The solid phase linkage of an aldehyde or ketone, has previously been described by a variety of methods (e.g. see (a) James, I. W., 1999, (b) Lee, A., Huang, L., Ellman, J. A., *J. Am. Chem. Soc,* 121(43), 9907-9914, 1999, (c) Murphy, A. M., *et al*, J. Am. Chem. Soc, 114, 3156-3157, 1992). A suitable method amenable to the reversible linkage of an alkyl ketone functionality is through a combination of the previously described chemistries. The semicarbazide, 4-[[(hydrazinocarbonyl)amino]methyl]cyclohexane carboxylic acid. trifluoroacetate (Murphy, A. M., *et al*, J. Am. Chem. Soc, 114, 3156-3157, 1992), may be utilised as

illustrated in Scheme 3, exemplified by linkage of the Fmoc protected 6-alkyltetrahydrofuro[3,2-*b*]pyrrol-3-one (XVI).



Scheme 3: (a) (XVI) in 90% EtOH / H_2O / 1.5eq NaOAc / 4-[[(hydrazinocarbonyl)-amino]methyl]- cyclohexane carboxylic acid.trifluoroacetate, 2hr reflux. (b) 3eq construct (XVII) / 3eq HBTU / 3eq HOBt / 6eq NMM, NH_2-SOLID PHASE, DMF, RT, o/n. (c) 20% piperidine / DMF, 30mins. (d) Range of chemistries to introduce P3-P2 (e) TFA / H_2O (95:5, v/v), RT, 2hr.

Construct (XVII) is prepared through reaction of the linker molecule and the 6-alkyltetrahydrofuro[3,2-*b*]pyrrol-3-one (XVI) by refluxing in aqueous ethanol/sodium acetate. Standard solid phase techniques (e.g. see Atherton, E. and Sheppard, R. C., 1989) are used to anchor the construct to an amino-functionalised solid phase through the free carboxylic acid functionality of (XVII), providing the loaded construct (XVIII). Loaded construct (XVIII) be reacted with a wide range of carboxylic acids available commercially or in the literature, to introduce the left-hand portion 'P3-P2'.

Preferred carboxylic acids for the introduction of the [R^9-CO] synthon are known in the literature with the following representative examples; 4-(5-(piperidin-1-ylmethyl)thiophen-2-yl)benzoic acid (CAS 860343-90-4), 4-(5-(morpholinomethyl)thiophen-2-yl)benzoic acid (CAS 860344-74-7), 4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzoic acid (CAS 294622-47-2), 4-(2-(4-(2-methoxyethyl)piperazin-1-yl)thiazol-4-yl)benzoic acid (CAS 860343-99-3), 4-(5-(1-morpholinoethyl)thiophen-2-yl)benzoic acid (CAS 860344-01-0), 4-(5-(1-morpholinoethyl)furan-2-yl)benzoic acid (CAS 860344-04-3), (*S*)-4-(2-(1-(dimethylamino)ethyl)thiazol-4-yl)benzoic acid (CAS 860344-10-1), (*S*)-4-(5-methyl-2-(1-(methylamino)ethyl)thiazol-4-yl)benzoic acid (CAS 860344-76-9), (*S*)-4-(2-(1-(dimethylamino)ethyl)-5-methylthiazol-4-yl)benzoic acid (CAS 860344-19-0), (*S*)-4-(2-(1-(methylamino)ethyl)thiazol-5-yl)benzoic acid (CAS 860344-78-1), (*S*)-4-(2-(1-(methylamino)ethyl)thiazol-4-yl)benzoic acid (CAS 860344-79-2), 4-(2-(4-fluoro-1-methylpyrrolidin-2-yl)thiazol-4-yl)benzoic acid (CAS 860344-38-3), 4-(3-methyl-5-(morpholinomethyl)thiophen-2-yl)benzoic acid (CAS 860344-81-6), 3-methyl-4-(5-(morpholinomethyl)furan-2-yl)benzoic acid (CAS 860344-82-7), 4-(5-methyl-2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzoic acid (CAS 860344-50-9), 4-(2-morpholinothiazol-4-yl)benzoic acid (CAS 860344-51-0), 4-(2-(piperidin-1-yl)thiazol-4-yl)benzoic acid (CAS 860344-52-1), 4-(2-(dimethylamino)thiazol-4-yl)benzoic acid (CAS 849682-29-7), 4-(2-(isopropyl(methyl)amino)-5-methylthiazol-4-yl)benzoic acid (CAS 860344-56-5), 4-(2-(methylamino)thiazol-4-yl)benzoic acid (CAS 860344-57-6), 4-(2-(4,4-difluoropiperidin-1-yl)thiazol-4-yl)benzoic acid (CAS 860344-58-7), 4-(2-(isopropylamino)thiazol-4-yl)benzoic acid (CAS 860344-59-8), 4-(2-(piperidin-4-yl)thiazol-4-yl)benzoic acid (CAS 860344-62-3), 4-(2-(1-methylpiperidin-4-yl)thiazol-4-yl)benzoic acid (CAS 860344-63-4), 4-(2-(pyridin-3-ylamino)thiazol-4-yl)benzoic acid (CAS 294622-46-1), 4-(2-(pyridin-2-ylamino)thiazol-4-yl)benzoic acid (CAS 860344-64-5), 4-(2-(cyclopentylamino)thiazol-4-yl)benzoic acid (CAS 860344-65-6), 4-(2-(cyclopropylamino)thiazol-4-yl)benzoic acid (CAS 860344-66-7), 4-(2-(cyclopropyl(methyl)amino)thiazol-4-yl)benzoic acid (CAS 860344-67-8), 4-(2-(1-methylpyrrolidin-3-yl)thiazol-4-yl)benzoic acid (CAS 860344-80-5), 4-(6-(4-methylpiperazin-1-yl)pyridin-2-yl)benzoic acid (CAS 860344-69-0), 4-(6-

morpholinopyridin-2-yl)benzoic acid (CAS 860344-70-3). Typical preparations for these general types of carboxylic acids are extensively detailed in Palmer, J. T. *et al*, J. Med. Chem, 2005, 48(24), 7520-34 and WO05066180. General methods for the preparation of 4-(4-alkylpiperazin-1-yl)benzoic acids and 4-(1-alkylylpiperidin-4-yl)benzoic acids are given in WO0158886.

The present invention is further described by way of example.

EXAMPLES

General procedures

Solvents were purchased from ROMIL Ltd, U.K. at SpS or Hi-Dry grade unless otherwise stated. ^{1}H NMR and ^{13}C NMR were obtained on a Bruker DPX400 (400 MHz ^{1}H frequency and 100 MHz ^{13}C frequency; QXI probe) or Bruker Avance 500MHz (TXI probe with ATM) in the solvents indicated. Chemical shifts are expressed in parts per million (δ) and are referenced to residual signals of the solvent. Coupling constants (*J*) are expressed in Hz. All analytical HPLC were obtained on Phenomenex Jupiter C_4, 5 μ, 300 Å, 250 × 4.6 mm, using mixtures of solvent A (0.1% aq trifluoroacetic acid (TFA)) and solvent B (90% acetonitrile / 10% solvent A) on automated Agilent systems with 215 and / or 254 nm UV detection. Unless otherwise stated a gradient of 10 to 90% B in A over 25 min at 1.5 mL / min was performed for full analytical HPLC. HPLC-MS analysis was performed on an Agilent 1100 series LC/MSD, using automated Agilent HPLC systems, with a gradient of 10 to 90% B in A over 10 min on Phenomenex Luna C_8, 5μ, 300 Å, 50 × 2.0 mm at 0.6 mL / min. Semi-preparative HPLC purification was performed on Phenomenex Jupiter C_4, 5μ, 300 Å, 250 × 10 mm, using a gradient of 10 to 90% B in A over 25 min at 4 mL / min on automated Agilent systems with 215 and / or 254 nm UV detection. Flash column purification was performed on silica gel 60 (Merck 9385) or using isolute SPE flash silica columns (Biotage, Hengoed, UK).

Preparation of benzyl (*S*)-2-((*S*)-2,5-dihydrofuran-2-yl)-2-hydroxyethyl carbamate (17). (i) Preparation of (3*R*, 3a*S*, 6*R*, 6a*S*)-hexahydrofuro[3,2-*b*]furan-3,6-diyl bis(4-methylbenzenesulfonate) (39). Isomannide (40) (50 g, 342.5 mmol) and *p*-toluenesulphonyl chloride (143.6 g, 753.2 mmol) were dissolved in a mixture of carbon tetrachloride (300 mL), dichloromethane (30 mL) and water (250 mL). The flask was cooled to 0 °C and a solution of potassium hydroxide (42.0 g, 750.0 mmol) in water (42 mL) added dropwise over 2 hours with stirring under argon. The resulting biphasic mixture was stirred vigorously at 0 °C for 24 hours. The resulting off-white precipitate, comprising a mixture of mono- and bistosylates (approximately 1 : 1), was collected by filtration *in vacuo*. The filter cake was washed with water then triturated with methanol (500 mL). The solid was isolated by filtration *in vacuo* to obtain ditosylate (39) as an off-white powder (75 g, 48%). $[\alpha]_D^{18}$ +96.7° (c = 10.5, $CHCl_3$).

(ii) Preparation of (3*R*, 3a*S*, 6*S*, 6a*S*)-6-bromohexahydrofuro[3,2-*b*]furan-3-yl 4-methylbenzenesulfonate (46). A stirred mixture of ditosylate (39) (16.9 g, 37.22 mmol) and lithium bromide (4.85 g, 55.84 mmol) in *N*,*N*-dimethylformamide (100 mL) was heated at 100 °C for 27 hours. The mixture was allowed to cool then water (150 mL) added before extracting with *tert*-butyl methyl ether (1 x 100 mL then 5 x 50 mL). The organic phase was dried ($MgSO_4$), filtered and reduced *in vacuo* to give a colourless oil which solidified on standing. Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 0 : 100 to 80 : 20 gave bromotosylate (46) as a white solid (2.86 g, 29 %). TLC (R_f = 0.45 diethyl ether : heptane, 1:1), analytical HPLC: R_f = 16.768 min; HPLC-MS: 363.1 / 365.0 $[M+H]^+$, 380.1 / 382.1, 749.0 / 751.0 $[2M+Na]^+$; $[\alpha]_D^{18}$ +64.7° (c = 8.5, $CHCl_3$); δ_H (500 MHz, $CDCl_3$) 2.45 (3H, s, C*H*$_3$), 3.74 (1H, dd, *J* = 9.60 and 7.05 Hz, C*H*$_2$), 3.95 (1H, dd, *J* = 9.60 and 6.47 Hz, C*H*$_2$), 4.14-4.22 (2H, m, C*H*$_2$), 4.29 (1H, d, *J* = 3.03 Hz, C*H*Br), 4.68 (1H, d, *J* = 4.03 Hz, C*H*CH), 4.76 (1H, t, *J* = 4.48 Hz, C*H*OTs), 4.87 (1H, m, CHC*H*), 7.36 (2H, brd, *J* = 7.97 Hz, aromatic CH_3CCH), 7.83 (2H, brd, *J* = 8.33 Hz, aromatic OSO_2CCH). δ_C (125 MHz, $CDCl_3$) 21.69 (*C*H$_3$), 50.06 (*C*HBr), 70.26 (*C*H$_2$CHOTs), 76.54 (*C*H$_2$CHBr), 78.27 (*C*HOTs), 80.17 and 88.80 (*CHC*HCHOTs), 127.98 and 129.94 (aromatic *C*H), 133.01 ($CHOSO_2C$ quaternary), 145.28 (CH_3C quaternary).

(iii) Preparation of (3*R*, 3a*S*, 6*R*, 6a*R*)-6-hydroxyhexahydrofuro[3,2-*b*]furan-3-yl 4-methylbenzenesulfonate (50). Isomannide (40) (10 g, 68.49 mmol) and *p*-toluenesulphonyl chloride (6.53 g, 34.25 mmol) were dissolved in a mixture of carbon tetrachloride (50 mL), dichloromethane (5 mL) and water (40 mL). The flask was cooled to 0 °C and a solution of potassium hydroxide (1.92 g, 34.25 mmol) in water (5 mL) added dropwise over 30 minutes with stirring. The resulting biphasic mixture was stirred at 0 °C for 7 hours. Then off-white precipitate was collected by filtration *in vacuo* then partitioned between dichloromethane (30 mL) and water (10 mL). The organic phase was washed with brine (2 x 10 mL) then dried (Na_2SO_4), filtered and reduced *in vacuo* to leave a colourless solid. Recrystallisation from carbon tetrachloride gave monotosylate (50) as colourless granules (3.92 g, 38%). TLC (R_f = 0.11, EtOAc : heptane 1 : 1); analytical HPLC main peak, R_t = 10.692 min; HPLC-MS 318.2, 323.1 $[M + Na]^+$, 623.2 $[2M + Na]^+$; $[\alpha]_D^{18}$+72.2° (c = 5.4, $CHCl_3$); δ_H (500 MHz, $CDCl_3$) 2.44 (3H, s, C*H*$_3$), 3.54 (1H, dd, *J* = 9.31 and 7.23 Hz, OC*H*$_2$CHOH), 3.78 (1H, dd, *J* = 9.18 and 7.59 Hz, OC*H*$_2$CHOTs), 3.95 (1H, dd, *J* = 9.36 and 6.45 Hz, OC*H*$_2$CHOH), 4.01 (1H, dd, *J* = 9.33 and 6.64 Hz, OC*H*$_2$CHOTs), 4.26 (1H, m, C*H*OH), 4.42 and 4.48 (each 1H, brt, *J* = 5.03 and 5.00 Hz respectively, CHC*H*CHOH and CHC*H*CHOTs), 4.90 (1H, dd, *J* = 12.15 and 6.84 Hz, C*H*OTs), 7.37 (2H, d, *J* = 8.13 Hz, aromatic CH_3CCH), 7.82 (2H, d, *J* = 8.20 Hz, aromatic OSO_2CCH); δ_C (125 MHz, $CDCl_3$) 21.69 (*C*H$_3$), 70.03 (*C*H$_2$CHOTs), 72.29 (*C*HOTs), 74.02 (*C*H$_2$CHOH), 80.00 (CH$_2$*C*HOH), 81.36 (*C*HCHOTs), 81.76 (*C*HCHOH), 128.00 and 129.89 (aromatic *C*H), 133.04 ($CHOSO_2C$ quaternary), 145.26 (CH_3C quaternary).

(iv) Alternative preparation of (3*R*, 3a*S*, 6*R*, 6a*R*)-6-hydroxyhexahydrofuro[3,2-*b*]furan-3-yl 4-methylbenzenesulfonate (50). A solution of *p*-toluenesulfonyl chloride (24.8 g, 130 mmol) in pyridine (150 mL) was added to a stirred solution of isomannide (40) (19.0 g, 130 mmol) in pyridine (150 mL) over 1 hour at 0 °C then stirred at ambient temperature for 1 hour. The mixture was poured onto iced-water (1 L) then extracted with dichloromethane (3 x 300 mL). The organic phase washed with brine (300 mL), dried ($MgSO_4$), filtered and reduced *in vacuo* to leave a residue. Flash

chromatography over silica, eluting with ethyl acetate : heptane mixtures 0 : 100 to 50 : 50 gave monotosylate (50) (23.4 g, 60%) as a white solid.

(v) Alternative preparation of (3*R*, 3a*S*, 6*S*, 6a*S*)-6-bromohexahydrofuro[3,2-*b*]furan-3-yl 4-methylbenzenesulfonate (46). A solution of carbon tetrabromide (18.12 g, 54.63 mmol) in pyridine (100 mL) was added to a solution of monotosylate (50) (14.9 g, 49.66 mmol) and triphenylphosphine (26.1 g, 99.32 mmol) in pyridine (150 mL) over 30 minutes, then the mixture heated at 65 °C for 1.5 hours under an atmosphere of argon. Water (200 mL) was added then the aqueous phase extracted with dichloromethane (5 x 100 mL). The organic phase was washed with brine (50 mL), then dried ($MgSO_4$), filtered and reduced *in vacuo* to leave a residue which was azeotroped with toluene (5 x 50 mL). Flash chromatography over silica, eluting with diethyl ether : heptane mixtures 0 : 100 to 100 : 0 gave bromotosylate (46) (7.70 g, 43%) as a white solid. $[\alpha]_D^{17}$ +68.6° (c = 0.51, $CHCl_3$).

(vi) Preparation of (*R*)-1-((*S*)-2,5-dihydrofuran-2-yl)-2-hydroxyethyl 4-methyl benzenesulfonate (13). A solution of ammonium chloride (100 mg, 1.87 mmol) in water (1.25 mL) then zinc dust (100 mg, 1.54 mmol) were added to a solution of bromotosylate (46) (0.5 g, 1.38 mmol) in tetrahydrofuran (5 mL) and propan-2-ol (2.5 mL) under argon. The mixture was stirred for 16 hours before filtering the suspension through celite *in vacuo*. The filter cake was washed with diethyl ether (20 mL). Hydrochloric acid (1M, 20 mL) was added to the filtrate then the organic phase separated. The aqueous layer was extracted with diethyl ether (20 mL) then the combined organic phase was washed with brine (20 mL), then dried ($MgSO_4$), filtered and reduced *in vacuo* to leave a residue. Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 20 : 80 to 50 : 50 gave alcohol (13) (292 mg, 75%) as a white solid. $[\alpha]_D^{15}$ -64.8° (c = 9.8, $CHCl_3$).

(vii) Preparation of benzyl (*S*)-2-((*S*)-2,5-dihydrofuran-2-yl)-2-hydroxyethylcarbamate (17); Zinc and 'One-pot' procedure. A solution of ammonium chloride (560 mg, 10.5 mmol) in water (7 mL) was added to a solution of

bromotosylate (46) (2.86 g, 7.88 mmol) in propan-2-ol (14 mL) under argon. Zinc dust (560 mg, 8.67 mmol) was then added in portions over 4 minutes then the suspension stirred for 16 hours before filtering through celite *in vacuo*. The filter cake was washed with diethyl ether (60 mL). Hydrochloric acid (1M, 60 mL) was added to the filtrate then the organic phase separated. The aqueous layer was extracted with diethyl ether (60 mL) then the combined organic phase was washed with brine (60 mL), then dried ($MgSO_4$), filtered and reduced *in vacuo*. The residue was dissolved in ammonium hydroxide (18 mL) and a solution of ammonia in propan-2-ol (12 mL, 2.0M, 24 mmol) then divided into three equal portions and heated in sealed tubes at 75 °C for 16 hours. The mixtures were combined using methanol then the solvents were removed *in vacuo*. The residue was azeotroped with diethyl ether (3 x 10 mL) to obtain (*S*)-2-amino-1-((*S*)-2,5-dihydrofuran-2-yl)ethanol which was used without further purification.

A solution of sodium carbonate (1.75 g, 16.6 mmol) in water (16 mL) was added whilst stirring to a solution of (*S*)-2-amino-1-((*S*)-2,5-dihydrofuran-2-yl)ethanol (assumed to be 7.88 mmol) in 1,4-dioxan (20 mL). The mixture was cooled to 0 °C then benzylchloroformate (1.69 mL, 11.82 mmol) was added dropwise over 10 minutes. The mixture was stirred at 0 °C for 85 minutes, then dichloromethane (75 mL) and water (100 mL) added. The organic phase was separated and the aqueous extracted with dichloromethane (2 x 50 mL). The organic layer was washed with brine (50 mL), then dried (Na_2SO_4), filtered and reduced *in vacuo* to leave a residue (3.1 g). Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 20 : 80 to 70 : 30 gave alcohol (17) (1.10 g, 53%). $[\alpha]_D^{18}$ -83.1° (c = 9.9, $CHCl_3$).

Preparation of Benzyl (*R*)-2-((*S*)-2,5-dihydrofuran-2-yl)-2-hydroxyethyl carbamate (18). (i) Preparation of (3*R*, 3a*S*, 6*S*, 6a*S*)-hexahydrofuro[3,2-*b*]furan-3,6-diyl bis(4-methylbenzenesulfonate) (42). A stirred solution of *p*-toluenesulfonyl chloride (57.4 g, 301 mmol) and isosorbide (43) (20 g, 137 mmol) in pyridine (315 mL) was heated at 95 °C for 4.5 hours under an atmosphere of argon then stood at ambient temperature for 16 hours before being poured onto iced-water (1 L). The aqueous was extracted with dichloromethane (2 x 500 mL), then the combined organic layers were

washed with water (2 x 500 mL), then dried (Na_2SO_4), filtered then reduced *in vacuo* to leave a viscous oil (65.22 g). The oil was crystallized from hot methanol (350 mL). The white solid was collected by filteration *in vacuo*, then washed with methanol (100 mL) and dried *in vacuo* to obtain ditosylate (42) as a white solid (45.87 g, 74%). TLC (R_f = 0.30, EtOAc : heptane 2 : 3), analytical HPLC single main peak, R_t = 20.219 min., HPLC-MS 455.1 $[M + H]^+$, 931.2 $[2M + Na]^+$, $[\alpha]_D^{20}$ +57.2° (c = 10.2, $CHCl_3$); δ_H (500 MHz, $CDCl_3$) 2.44 (6H, s, C*H*$_3$), 3.68 (1H, dd, *J* = 9.80 and 6.46 Hz, C*H*$_2$), 3.82-3.87 (2H, m, C*H*$_2$), 3.94 (1H, d, *J* = 11.28 Hz, C*H*$_2$), 4.46 (1H, d, *J* = 4.44 Hz, C*H*CHOTs), 4.58 (1H, t, *J* = 4.74 Hz, C*H*CHOTs), 4.82-4.86 (2H, m, C*H*OTs), 7.32-7.36 (4H, m, aromatic CH_3CC*H*), 7.74-7.80 (4H, m, aromatic OSO_2CC*H*).

(ii) Alternative preparation of (3*R*, 3a*S*, 6*S*, 6a*S*)-hexahydrofuro[3,2-*b*]furan-3,6-diyl bis(4-methylbenzenesulfonate) (42). Triethylamine (123.2 mL, 876 mmol) was added dropwise to a stirred solution of *p*-toluenesulfonyl chloride (156.6 g, 822 mmol) and isosorbide (43) (40 g, 274 mmol) in dichloromethane (600 mL) over 15 minutes. The mixture was stirred at 25 °C for 16 hours then at 50 °C for 4 hours before diluting with dichloromethane (1 L). The organic layer was washed with water (2 x 1 L), then dried (Na_2SO_4), filtered then reduced *in vacuo* to leave a viscous oil. The oil was crystallized from hot methanol (600 mL) to obtain ditosylate (42) as a white solid (120.1 g, 97%). $[\alpha]_D^{15}$ +56.3° (c = 11.2, $CHCl_3$).

(iii) Preparation of (3*S*, 3a*S*, 6*S*, 6a*S*)-6-bromohexahydrofuro[3,2-*b*]furan-3-yl 4-methylbenzenesulfonate (47). Lithium bromide (9.6 g, 110.1 mmol) was added to a stirred solution of ditosylate (42) (20.0 g, 44.05 mmol) in dimethylformamide (100 mL) under an atmosphere of argon. The mixture was heated at 110 °C for 5 hours then stood at ambient temperature for 3 days, then heated at 90 °C for 3.5 hours. The mixture was diluted with water (250 mL) extracted with *tert*-butyl methyl ether (4 x 125 mL) then the organic phase washed with water (3 x 125 mL), brine (125 mL), dried ($MgSO_4$), filtered and reduced *in vacuo* to leave a brown oil (16.8 g). Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 0 : 100 to 30 : 70 gave bromotosylate (47) (11.88 g, 74%) as a pale yellow solid. TLC (R_f = 0.20, EtOAc :

heptane 1 : 3); analytical HPLC main peak, R_t = 18.050 min; HPLC-MS 381.0 / 383.0 $[M + H_2O + H]^+$, 385.0 / 387.0 $[M + Na]^+$; $[\alpha]_D^{18}$ +51.0° (c = 5.0, $CHCl_3$); δ_H (500 MHz, $CDCl_3$) 2.45 (3H, s, C*H*$_3$), 3.84 (1H, dd, *J* = 11.19 and 3.51 Hz, C*H*$_2$), 4.05-4.15 (3H, m, C*H*$_2$), 4.28 (1H, d, *J* = 3.40 Hz, C*H*Br), 4.78 (1H, d, *J* = 3.37 Hz, C*H*CH), 4.84 (1H, d, *J* = 3.42 Hz, C*H*OTs), 4.90 (1H, d, *J* = 3.37 Hz, CHC*H*), 7.36 (2H, brd, *J* = 7.98 Hz, aromatic CH_3CC*H*), 7.79 (2H, brd, *J* = 8.32 Hz, aromatic OSO_2CC*H*).

(iv) Alternative preparation of (3*S*, 3a*S*, 6*S*, 6a*S*)-6-bromohexahydrofuro[3,2-*b*]furan-3-yl 4-methylbenzenesulfonate (47). Lithium bromide (19.2 g, 220.2 mmol) was added to a stirred solution of ditosylate (42) (40.0 g, 88.1 mmol) in dimethyl sulfoxide (200 mL) under an atmosphere of argon. The mixture was heated at 110 °C for 8 hours then at 120 °C for 1.75 hours. The mixture was diluted with water (500 mL) then extracted with *tert*-butyl methyl ether (4 x 250 mL). The organic phase was washed with water (3 x 250 mL) then brine (250 mL), dried ($MgSO_4$), filtered and reduced *in vacuo* to leave an orange solid. Recrystallisation from methanol (100 mL) gave bromotosylate (47) (17.47 g, 55%) as a pale yellow solid. $[\alpha]_D^{15}$ +49.5° (c = 11.7, $CHCl_3$).

(v) Preparation of (*S*)-1-((*S*)-2,5-dihydrofuran-2-yl)-2-hydroxyethyl 4-methyl benzenesulfonate (14). Ammonium chloride (20 mg, 0.37 mmol) then zinc dust (20 mg, 0.31 mmol) were added to a solution of bromotosylate (47) (100 mg, 0.28 mmol) in ethanol (1.5 mL) under argon. The mixture was stirred for 16 hours before filtering the suspension through celite *in vacuo*. The filter cake was washed with ethanol (20 mL) then the filtrate reduced *in vacuo* to leave a residue (111 mg). Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 20 : 80 to 40 : 60 gave alcohol (14) (53 mg, 68%) as a white solid. TLC (R_f = 0.15, EtOAc : heptane 1 : 2); analytical HPLC main peak, R_t = 12.543 min; HPLC-MS 285.1 $[M + H]^+$, 302.1, 591.2 $[2M + Na]^+$; $[\alpha]_D^{15}$ -86.8° (c = 5.3, $CHCl_3$); δ_H (500 MHz, $CDCl_3$) 2.12 (1H, brs, O*H*), 2.44 (3H, s, aryl-C*H*$_3$), 3.77 (2H, d, *J* = 4.85 Hz, C*H*$_2$OH), 4.54-4.58 (3H, m, C*H*$_2$OC*H*), 4.94-4.98 (1H, m, C*H*OTs), 5.64-5.67 and 5.97-6.00 (2H total, m, CH_2CH=C*H*), 7.33 (2H, brd, *J* = 8.23 Hz, aromatic CH_3CC*H*), 7.79 (2H, brd, *J* = 8.31

Hz, aromatic OSO_2CCH); δ_C (125 MHz, $CDCl_3$) 21.660 (CH_3), 62.303 (CH_2OH), 75.940 ($OCH_2CH=CH$), 82.720 and 85.221 (OCHCHOTs), 124.792, 127.977, 129.479 and 129.749 ($OCH_2CH=CH$ and aromatic CH), 133.496 ($CHOSO_2C$ quaternary), 144.973 (CH_3C quaternary).

(vi) Alternative preparation of (*S*)-1-((*S*)-2,5-dihydrofuran-2-yl)-2-hydroxyethyl 4-methyl benzenesulfonate (14). A solution of ammonium chloride (200 mg, 3.7 mmol) in water (2.5 mL) then zinc dust (200 mg, 3.1 mmol) were added to a solution of bromotosylate (47) (1 g, 2.75 mmol) in tetrahydrofuran (10 mL) and propan-2-ol (5 mL) under argon. The mixture was stirred for 16 hours before filtering the suspension through celite *in vacuo*. The filter cake was washed with diethyl ether (20 mL). Hydrochloric acid (1M, 20 mL) was added to the filtrate then the organic phase separated. The aqueous layer was extracted with diethyl ether (20 mL) then the combined organic phase was washed with brine (20 mL), then dried ($MgSO_4$), filtered and reduced *in vacuo* to leave a residue (1.06 g). Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 20 : 80 to 50 : 50 gave alcohol (14) (528 mg, 68%) as a white solid. $[\alpha]_D^{16}$ -82.7° (c = 11.3, $CHCl_3$).

(vii) Preparation of benzyl (*R*)-2-((*S*)-2,5-dihydrofuran-2-yl)-2-hydroxyethylcarbamate (18). Zinc and 'One-pot' procedure. A solution of ammonium chloride (600 mg, 11.2 mmol) in water (7.5 mL) was added to a solution of bromotosylate (47) (3.0 g, 8.26 mmol) in propan-2-ol (15 mL) under argon. Zinc dust (600 mg, 9.2 mmol) was then added in portions over 4 minutes and the mixture was stirred for 16 hours before filtering the suspension through celite *in vacuo*. The filter cake was washed with diethyl ether (60 mL). Hydrochloric acid (1M, 60 mL) was added to the filtrate then the organic phase separated. The aqueous layer was extracted with diethyl ether (60 mL) then the combined organic phase was washed with brine (60 mL), then dried ($MgSO_4$), filtered and reduced *in vacuo*. The residue was dissolved in ammonium hydroxide (18 mL) and a solution of ammonia in propan-2-ol (12 mL, 2.0M, 24 mmol), then divided into two equal portions and heated in sealed tubes at 75 °C for 16 hours. The mixtures were combined using methanol then the solvents were

removed *in vacuo*. The residue was azeotroped with diethyl ether (3 x 10 mL) to obtain (*R*)-2-amino-1-((*S*)-2,5-dihydrofuran-2-yl)ethanol which was used without further purification.

A solution of sodium carbonate (1.84 g, 17.4 mmol) in water (16 mL) was added whilst stirring to a suspension of (*R*)-2-amino-1-((*S*)-2,5-dihydrofuran-2-yl)ethanol (assumed to be 8.26 mmol) in 1,4-dioxan (20 mL). The mixture was cooled to 0 °C then benzylchloroformate (1.77 mL, 12.4 mmol) was added dropwise over 5 minutes. The mixture was stirred at 0 °C for 55 minutes then dichloromethane (75 mL) and water (100 mL) added. The organic phase was separated and the aqueous extracted with dichloromethane (2 x 50 mL). The organic phase was washed with brine (50 mL), then dried (Na_2SO_4), filtered and reduced *in vacuo* to leave a residue (3.7 g). Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 20 : 80 to 70 : 30 gave alcohol (18) (1.26 g, 58%). $[\alpha]_D^{16}$ -62.0° (c = 5.0, $CHCl_3$).

Preparation of (*S*)-2-(Benzyloxycarbonylamino)-1-((*S*)-2,5-dihydrofuran-2-yl)ethyl 4-methylbenzenesulfonate (32) A solution of *p*-toluenesulfonyl chloride (252 mg, 1.32 mmol) in pyridine (7.0 mL), alcohol (17) (290 mg, 1.10 mmol) was stirred at 24 °C for 2 days then diluted with water (15 mL). The product was extracted into *tert*-butyl methyl ether (3 x 20 mL) then dried ($MgSO_4$), filtered and reduced *in vacuo*. Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 7 : 93 to 20 : 80 gave tosylate (32) (282 mg, 61%) as a colourless oil. TLC (R_f = 0.35, EtOAc : heptane 1 : 1), analytical HPLC single main peak, R_t = 19.02 min., HPLC-MS 418.2 [M + H]$^+$, 857.3 [2M + Na]$^+$; $[\alpha]_D^{11}$ -86.1° (c = 1.103, $CHCl_3$; δ_H (500 MHz, $CDCl_3$) 2.37 (3H, s, aryl-C*H*$_3$), 3.29-3.37 and 3.50-3.56 (2H total, m, C*H*$_2$NH), 4.53-4.56 (2H total, m, OC*H*$_2$CH=CH), 4.62-4.66 (1H, m, OC*H*CH=CH), 4.85-4.90 (1H, m, C*H*OTs), 5.02-5.08 (2H, m, OC*H*$_2$Ph), 5.02 (1H, brs, N*H*), 5.65-5.70 and 5.94-5.98 (2H total, m, CH$_2$C*H*=C*H*), 7.27 (2H, d, *J* = 8.12 Hz, aromatic CH$_3$CC*H*), 7.29-7.37 (5H, m, phenyl C*H*), 7.76 (2H, d, *J* = 8.23 Hz, aromatic OSO$_2$CC*H*); δ_C (125 MHz, $CDCl_3$) 21.609 (aryl-*C*H$_3$), 41.749 (*C*H$_2$NHCbz), 66.833 (*C*H$_2$Ph), 75.939 (O*C*H$_2$CH=CH), 81.235 (*C*HOTs), 85.203 (O*C*HCH=CH), 124.702, 127.887, 128.026, 128.128, 128.504,

129.687 and 129.757 ($OCH_2CH{=}CH$ and aromatic *C*H), 133.591 ($CHOSO_2C$ quaternary), 136.368 (Cbz quaternary), 144.906 (CH_3C quaternary), 156.271 (Cbz *C*=O).

Alternative preparation of (*S*)-2-(benzyloxycarbonylamino)-1-((*S*)-2,5-dihydro furan-2-yl)ethyl 4-methylbenzenesulfonate (32). A solution of *p*-toluenesulfonyl chloride (760 mg, 3.99 mmol) in pyridine (10.0 mL), alcohol (17) (600 mg, 2.28 mmol) was stirred at 40 °C for a total of 6 hours and stood at 24 °C for 16 hours then diluted with water (20 mL). The product was extracted into *tert*-butyl methyl ether (2 x 50 mL) then dried ($MgSO_4$), filtered and reduced *in vacuo*. Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 10 : 90 to 30 : 70 gave tosylate (32) (789 mg, 83%) as a white solid.

Preparation of (*R*)-2-(benzyloxycarbonylamino)-1-((*S*)-2,5-dihydrofuran-2-yl) ethyl 4-methyl benzenesulfonate (32b). A solution of *p*-toluenesulfonyl chloride (368 mg, 2.03 mmol) in pyridine (1.5 mL) was added to alcohol (18) (333 mg, 1.27 mmol). The mixture was stirred at 14 °C for 16 hours and at 24 °C for 3.5 hours then diluted with *tert*-butyl methyl ether (35 mL). The organic layer was washed with water (15 mL), brine (15 mL), then dried ($MgSO_4$), filtered and reduced *in vacuo* to leave a pale yellow oil (0.712 g). Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 15 : 85 to 30 : 70 gave tosylate (32b) (429 mg, 81%) as a white solid. TLC (R_f = 0.75, EtOAc : heptane 3 : 1), analytical HPLC single main peak, R_t = 18.93 min., HPLC-MS 374.2, 418.2 $[M + H]^+$, 857.3 $[2M + Na]^+$; $[\alpha]_D^{18.5}$ -30.2° (c = 1.326, $CHCl_3$); δ_H (500 MHz, $CDCl_3$) 2.39 (3H, s, aryl-CH_3), 3.29-3.37 and 3.53-3.62 (2H total, m, CH_2NH), 4.44-4.50 and 4.52-4.57 (2H total, m, $OCH_2CH{=}CH$), 4.59-4.65 (1H, m, OC*H*CH=CH), 4.87-4.92 (1H, m, C*H*OTs), 5.05 (2H, m, OCH_2Ph), 5.03 (1H, brs, N*H*), 5.69-5.73 and 5.94-5.98 (2H total, m, $CH_2CH{=}CH$), 7.28 (2H, d, J = 8.10 Hz, aromatic CH_3CCH), 7.29-7.37 (5H, phenyl C*H*), 7.77 (2H, d, J = 8.10 Hz, aromatic OSO_2CCH); δ_C (125 MHz, $CDCl_3$) 21.627 (aryl-CH_3), 41.119 (CH_2NHCbz), 66.856 (CH_2Ph), 75.987 ($OCH_2CH{=}CH$), 82.352 (*C*HOTs), 85.622 (OCHCH=CH), 124.792, 127.825, 128.027, 128.126, 128.504, 129.357 and 129.537 ($OCH_2CH{=}CH$ and

aromatic *C*H), 133.674 ($CHOSO_2C$ quaternary), 136.348 (Cbz quaternary), 144.941 (CH_3C quaternary), 156.273 (Cbz *C*=O).

Epoxidation studies with (*R*)-2-(benzyloxycarbonylamino)-1-((*S*)-2,5-dihydro furan-2-yl)ethyl 4-methylbenzenesulfonate (32b).

(a) 3-Chloroperbenzoic acid (97 mg, ≤ 77%, 0.43 mmol) was added to a stirred solution of alkene (32b) (36 mg, 0.086 mmol) in dichloromethane (1.5 mL). The mixture was stirred for 20 hours at ambient temperature then 3-chloroperbenzoic acid (97 mg, ≤ 77%, 0.43 mmol) was added and stirring continued for 1 day at 24 °C then diluted with dichloromethane (15 mL). The organic phase was washed with aqueous sodium hydroxide solution (5%, 10 mL), water (10 mL), then dried (Na_2SO_4), filtered and reduced *in vacuo* to leave a residue (0.038 mg). Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 10 : 90 to 50 : 50 gave (in order of elution) *anti*-(33b) (16 mg, 43%) as a colourless viscous oil and *syn*-epoxide (9 mg, 24%) as a white solid. Data for *anti*-(33b); TLC (R_f = 0.50, EtOAc : heptane 1 : 1), analytical HPLC single main peak, R_t = 17.999 min., HPLC-MS 434.1 $[M + H]^+$, 456.1 $[M + Na]^+$, 889.2 $[2M + Na]^+$; $[\alpha]_D^{17}$ +25.6° (c = 2.54, $CHCl_3$); δ_H (500 MHz, $CDCl_3$) 2.41 (3H, s, aryl-CH_3), 3.31-3.38 and 3.60-3.66 (2H total, m, CH_2NH), 3.67 (1H, d, J = 10.46 Hz, OCH_2CH), 3.75 and 3.81 (each 1H, d, J = 2.50 and 2.75 Hz respectively, OCH_2CHCH), 3.94 (1H, d, J = 10.57 Hz, OCH_2CH), 4.07 (1H, d, J = 6.90 Hz, OCHCHOTs), 4.60-4.64 (1H, m, CHOTs), 4.97-5.01 (1H brt, NH), 5.08 (2H, brs, CH_2Ph), 7.29-7.37 (7H, aromatic CH_3CCH and phenyl CH), 7.78 (2H, d, J = 8.18 Hz, aromatic OSO_2CCH); δ_C (125 MHz, $CDCl_3$) 21.665 (aryl-CH_3), 42.054 (CH_2NHCbz), 56.175 and 57.048 (OCH_2CHCH), 67.031 (CH_2Ph), 67.672 (OCH_2CH), 76.732 (OCHCHOTs), 79.388 (CHOTs), 127.776, 128.108, 128.222, 128.544 and 130.043 (aromatic CH), 133.249 ($CHOSO_2C$ quaternary), 136.192 (Cbz quaternary), 145.487 (CH_3C quaternary), 156.224 (Cbz *C*=O).

(b) To a solution of alkene (32b) (262 mg, 0.63 mmol) in acetonitrile (4 mL) and aqueous Na_2.EDTA (4 mL, 0.4 mmol solution) at 0 °C was added 1,1,1-trifluoroacetone (0.67 mL, 7.54 mmol) *via* a pre-cooled syringe. To this solution was

added in portions a mixture of sodium bicarbonate (0.44 g, 5.28 mmol) and OXONE® (1.20 g, 1.95 mmol) over a period of 55 minutes. The mixture was stirred for 2.5 hours then diluted with water (25 mL) and the product extracted into dichloromethane (2 x 25 mL). The combined organic layers were washed with brine (12.5 mL) then dried (Na_2SO_4), filtered and reduced *in vacuo* to leave a residue (310 mg). Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 15 : 85 to 50 : 50 gave *anti*-(33b) as a viscous white oil (216 mg, 79%).

Epoxidation of (*S*)-2-(benzyloxycarbonylamino)-1-((*S*)-2,5-dihydro furan-2-yl)ethyl 4-methylbenzenesulfonate (32).

(a) To a solution of alkene (32) (765 mg, 1.83 mmol) in acetonitrile (10 mL) and aqueous Na_2.EDTA (10 mL, 0.4 mmol solution) at 0 °C was added 1,1,1-trifluoroacetone (1.98 mL, 22.0 mmol). To this solution was added in portions a mixture of sodium bicarbonate (1.29 g, 15.4 mmol) and OXONE® (3.49 g, 5.68 mmol) over a period of 1.5 hours. The mixture was stirred for 1.5 hours then diluted with water (30 mL) and the product extracted into dichloromethane (3 x 30 mL). The combined organic layers were washed with brine (50 mL) then dried ($MgSO_4$), filtered and reduced *in vacuo*. Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 10 : 90 to 30 : 70 gave (in order of elution) *anti*-(33) as a white solid (597 mg, 75%) and *syn*-epoxide (35 mg, 4%) as a white solid. Data for *anti*-(33); TLC (R_f = 0.50, EtOAc : heptane 1 : 1), analytical HPLC single main peak, R_t = 17.989 min., HPLC-MS 434.2 $[M + H]^+$, 889.3 $[2M + Na]^+$; $[\alpha]_D^{11.5}$ -49.08° (c = 1.630, $CHCl_3$); δ_H (500 MHz, $CDCl_3$) 2.38 (3H, s, aryl-C*H*$_3$), 3.30-3.37 and 3.44-3.50 (2H, m, *CH*$_2$NH), 3.73 and 2.74 (2H, each d, J = 2.78 and 2.73 Hz respectively, OCH$_2$C*HCH*), 3.81 (1H, d, J = 10.08 Hz, OC*H*$_2$CH), 3.91 (1H, d, J = 10.12 Hz, OC*H*$_2$CH), 4.13 (1H, d, J = 2.04 Hz, OC*H*CHOTs), 4.83-4.86 (1H, m, C*H*OTs), 4.89-5.00 (1H brt, J = 5.39 Hz, N*H*), 5.02-5.09 (2H, m, C*H*$_2$Ph), 7.28 (2H, d, J = 8.10 Hz, aromatic CH$_3$CC*H*), 7.31-7.38 (5H, phenyl C*H*), 7.76 (2H, d, J = 8.22 Hz, aromatic OSO$_2$CC*H*); δ_C (125 MHz, $CDCl_3$) 21.636 (aryl-*C*H$_3$), 42.085 (*C*H$_2$NHCbz), 56.414 and 57.217 (OCH$_2$*C*HCH), 66.977 (*C*H$_2$Ph), 68.582 (OC*H*$_2$CH), 76.846 (OCHCHOTs), 79.979 (*C*HOTs), 127.668, 128.073, 128.241, 128.551 and 130.001 (aromatic *C*H), 133.489 (CHOSO$_2$*C*

quaternary), 136.172 (Cbz quaternary), 145.322 (CH_3C quaternary), 156.247 (Cbz C=O).

Preparation of (3*R*, 3a*R*, 6*R*, 6a*S*)-3-hydroxyhexahydro-2*H*-furo[3,2-*b*]pyrrol-6-yl 4-methylbenzenesulfonate (74). Ethanol (1.5 mL) was added dropwise to a mixture of 10% palladium on charcoal (20 mg) and *anti*-(33b) (100 mg, 0.25 mmol) under an atmosphere of argon. The argon was replaced by hydrogen then the suspension was stirred for 4.5 hours before filtering the mixture through celite *in vacuo*. The filter cake was washed with ethanol (10 mL) then the solvents removed *in vacuo* from the filtrate. The residue was azeotroped with toluene (2 x 3 mL) to obtain (3*R*, 3a*R*, 6*R*, 6a*S*)-3-hydroxyhexahydro-2*H*-furo[3,2-*b*]pyrrol-6-yl 4-methylbenzenesulfonate (74) which was used without further purification.

Preparation of (3*R*, 3a*R*, 6*R*, 6a*S*)- *tert*-butyl 3-hydroxy-6-(tosyloxy)tetrahydro-2*H*-furo[3,2-*b*]pyrrole-4(5*H*)-carboxylate (35b).

A solution of sodium carbonate (56 mg, 0.275 mmol) in water (0.75 mL) was added whilst stirring to a solution of (3*R*, 3a*R*, 6*R*, 6a*S*)-3-hydroxyhexahydro-2*H*-furo[3,2-*b*]pyrrol-6-yl 4-methylbenzenesulfonate (74) in 1,4-dioxan (0.75 mL). A solution of di-*tert*-butyl dicarbonate (60 mg, 0.275 mmol) in 1,4-dioxan (0.5 mL) was added dropwise over 5 minutes then the mixture stirred for 1 hour before adding an additional aliquot of di-*tert*-butyl dicarbonate (40 mg, 0.184 mmol) in 1,4-dioxan (0.25 mL) dropwise over 1 minute. The mixture was stirred for 70 minutes then water (5 mL) was added and the product extracted into dichloromethane (3 x 5 mL). The organic layer was washed with brine (5 mL), then dried (Na_2SO_4), filtered and reduced *in vacuo* to leave a residue (132 mg). Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 15 : 85 to 45 : 55 gave bicyclic alcohol (35b) (58.9 mg, 60%) as a white solid. TLC (R_f = 0.30, EtOAc : heptane 1 : 1), analytical HPLC single main peak, R_t = 16.54 min., HPLC-MS 344.1 $[M + 2H - {}^tBu]^+$, 821.3 $[2M + Na]^+$; $[\alpha]_D^{18.5}$ -30.3° (c = 6.10, $CHCl_3$); δ_H (500 MHz, $CDCl_3$) mixture of rotamers major : minor 2 : 1; 1.44 (6H, brs, $(CH_3)_3C$, major), 1.46 (3H, brs, $(CH_3)_3C$, minor), 1.98 (0.33H, d, J = 4.00 Hz, O*H* minor), 2.44 (3H, s, aryl-CH_3), 2.69 (0.66H, d, J = 2.88 Hz, O*H* major), 3.08-3.15

(0.33H, m, BocNCH_2 minor), 3.26-3.32 (0.66H, m, BocNCH_2 major), 3.75-3.87 (2H, m, 1 x OCH_2CHOH and 1 x BocNCH_2), 3.94-4.02 (1H, m, OCH_2CHOH), 4.07 (1H, brs, BocNC*H*), 4.35 (0.33H, brs, OCH_2CHOH minor), 4.41 (0.66H, brs, OCH_2CHOH major), 4.52 (0.66H, t, J = 4.75 Hz, TsOCHC*H* major), 4.65 (0.33H, t, J = 3.95 Hz, TsOCHC*H* minor), 4.72-4.78 (1H, m, TsOC*H*CH), 7.34 (2H, brd, J = 7.82 Hz, aromatic CH_3CCH), 7.82 (2H, brd, J = 8.01 Hz, aromatic OSO_2CCH); δ_C (125 MHz, $CDCl_3$) 21.681 (aryl-CH_3), 28.294 / 28.386 ($(CH_3)_3C$), 46.810 / 48.177 ($BocNCH_2$), 68.153 / 68.484 (BocNCH), 75.484 / 75.697 (OCH_2CHOH), 76.228 / 76.980 (OCH_2CHOH), 76.269 / 76.585 (TsOCHCH), 79.391 / 80.233 (TsOCHCH), 81.079 / 81.139 ($(CH_3)_3C$ quaternary), 127.973, 129.911, 129.966 and 130.125 (aromatic CH), 133.144 ($CHOSO_2C$ quaternary), 145.247 (CH_3C quaternary), 153.161 / 154.244 (Boc C=O).

Preparation of (3*R*, 3a*R*, 6*R*, 6a*S*)-3-hydroxyhexahydro-2*H*-furo[3,2-*b*]pyrrol-6-yl 4-methylbenzenesulfonate. hydrochloride (74).

Boc alcohol (35b) (11.0g, 27.6 mmol) was dissolved in 4N HCl in dioxan (100 mL, 400 mmol) and the mixture stirred at ambient temperature for 1 hour. The mixture was then concentrated *in vacuo* and azeotroped three times from toluene to give a pale brown solid (Yield 9.25 g). HPLC-MS 3001 $[M + H]^+$; δ_H (500 MHz, d_6-DMSO) 2.44 (3H, s, CH_3-aryl), 3.13 (1H, dd, J = 7.8 Hz, NHCH_2), 3.38 (1H, dd, J = 6.7 Hz, NHCH_2), 3.68 (1H, dd, J = 2.0, 9.9 Hz, CHOCH_2), 3.93 (1H, d, J = 5.3 Hz, NHC*H*CH), 3.98(1H, dd, J = 4.3, 9.9 Hz, CHOCH_2), 4.50 (1H, m, NHCHC*H*), 4.57 (1H, t, J = 4.9 Hz, TsOCHC*H*), 5.03 (1H, m, TsOC*H*CH), 5.71 (1H, b, N*H*), 7.52 (2H, d, J = 8.0Hz, aryl), 7.84 (2H, d, J = 8.0 Hz, aryl), 9.92 (2H, b, O*H* + *H*Cl); δ_C (125 MHz, d_6-DMSO) 21.25 (aryl-CH_3), 45.99 ($NHCH_2$), 67.60 (NHCH), 72.63 (OCH_2CHOH), 75.94 (OCH_2CHOH), 77.18 (TsOCHCH), 79.15 (TsOCHCH), 127.84 and 130.40 (aromatic CH), 132.28 ($CHOSO_2C$ quaternary), 145.65 (CH_3C quaternary).

Preparation of (3*R*, 3a*R*, 6*R*, 6aR)-Benzyl 3-hydroxy-6-methyltetrahydro-2*H*-furo[3,2-*b*]pyrrole-4(5*H*)-carboxylate (108). A solution of methyllithium (1.6M in diethyl ether, 74.4 mL, 119 mmol) was added dropwise over 13 minutes to a stirred

suspension of copper(I) bromide (8.55 g, 59.6 mmol) in tetrahydrofuran (75 mL) at 0 °C. The mixture was stirred for 20 minutes then (3*R*, 3a*R*, 6*R*, 6a*S*)-3-hydroxyhexahydro-2*H*-furo[3,2-*b*]pyrrol-6-yl methylbenzenesulfonate hydrochloride (74) (5.0 g, 14.9 mmol) was added in portions over 8 minutes. The mixture was stirred for 30 minutes at 0 °C then at ambient temperature for 2.5 hours. A solution of sodium carbonate (4 g, 37.7 mmol) in water (60 mL) was added dropwise over 10 minutes. The mixture was stirred for 15 minutes then benzyl chloroformate (4.75 mL, 33.3 mmol) was added over 5 minutes. The mixture was stirred for 1.75 hours then water (500 mL) was added and the mixture extracted with dichloromethane (3 x 250 mL). The combined organic layers were washed with brine (250 mL), dried (Na_2SO_4), filtered and reduced *in vacuo* to leave a brown oil (6.22 g). Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 10 : 90 to 60 : 40 gave (3*R*, 3a*R*, 6*R*, 6aR)-benzyl 3-hydroxy-6-methyltetrahydro-2*H*-furo[3,2-*b*]pyrrole-4(5*H*)-carboxylate (108) (2.57 g, 62%) as a brown oil. TLC (R_f = 0.40, EtOAc : heptane 2 : 1), analytical HPLC single main peak, R_t = 10.87 min., HPLC-MS 278.1 $[M + H]^+$, 300.1 $[M + Na]^+$, 577.2 $[2M + Na]^+$;

Preparation (3*R*, 3a*R*, 6*S*, 6a*S*)- 3-hydroxyhexahydro-2*H*-furo[3,2-*b*]pyrrol-6-yl 4-methylbenzenesulfonate (85). Ethanol (20 mL) was added dropwise to a mixture of 10% palladium on charcoal (50 mg) and *anti*-(33) (578 mg, 1.33 mmol) under an atmosphere of argon. The argon was replaced by hydrogen then the suspension was stirred for 1.5 hours before filtering the mixture through celite *in vacuo*. The filter cake was washed with ethanol then the solvents removed *in vacuo* from the filtrate to obtain (3*R*, 3a*R*, 6*S*, 6a*S*)-3-hydroxyhexahydro-2*H*-furo[3,2-*b*]pyrrol-6-yl 4-methylbenzenesulfonate (85) which was used without further purification.

Preparation of (3*R*, 3a*R*, 6*S*, 6aR)-Benzyl 3-hydroxy-6-methyltetrahydro-2*H*-furo[3,2-*b*]pyrrole-4(5*H*)-carboxylate (110). A solution of methyllithium (1.6M in diethyl ether, 1.7 mL, 2.68 mmol) was added dropwise over 1 minute to a stirred suspension of copper(I) bromide (192 mg, 1.34 mmol) in tetrahydrofuran (1.7 mL) at 0 °C. The mixture was stirred for 20 minutes then a solution of (3*R*, 3a*R*, 6*S*, 6a*S*)-3-

hydroxyhexahydro-2*H*-furo[3,2-*b*]pyrrol-6-yl methylbenzenesulfonate (85) (100 mg, 0.33 mmol) in tetrahydrofuran (2.0 mL) was added *via* cannula. The mixture was stirred for 1 hour at 0 °C then at ambient temperature for 70 minutes. A solution of sodium carbonate (89 mg, 0.84 mmol) in water (1.5 mL) was added dropwise over 2 minutes. The mixture was stirred for 10 minutes then benzyl chloroformate (0.105 mL, 0.74 mmol) was added. The mixture stirred for 70 minutes then water (15 mL) was added and the mixture extracted with dichloromethane (10 mL). The aqueous layer was reextracted with dichloromethane (2 x 5 mL) then the combined organic layers were washed with brine (5 mL), dried (Na_2SO_4), filtered and reduced *in vacuo* to leave a pale yellow oil (140 mg). Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 10 : 90 to 45 : 55 gave (3*R*, 3a*R*, 6*S*, 6aR)-benzyl 3-hydroxy-6-methyltetrahydro-2*H*-furo[3,2-*b*]pyrrole-4(5*H*)-carboxylate (110) (66 mg, 73%) as a colourless oil. TLC (R_f = 0.30, EtOAc : heptane 2 : 1), analytical HPLC main peak, R_t = 9.890 min., HPLC-MS 278.1 $[M + H]^+$, 577.2 $[2M + Na]^+$.

Preparation of (3*R*, 3a*R*, 6*S*, 6a*R*)-(9*H*-fluoren-9-yl)methyl 3-hydroxy-6-methyltetrahydro-2*H*-furo[3,2-*b*]pyrrole-4(5*H*)-carboxylate (2c'; R^1 = Me).

Methanol (2.0 mL) was added dropwise to a mixture of 10% palladium on charcoal (20 mg) and bicyclic alcohol (110) (45 mg, 0.162 mmol) under an atmosphere of argon. The argon was replaced by hydrogen then the suspension was stirred for 1 hour then filtered through celite *in vacuo*. The filter cake was washed with ethanol (10 mL) then the solvents removed *in vacuo* from the filtrate. The residue was azeotroped with diethyl ether (3 x 3 mL) to obtain the crude (3*R*, 3a*R*, 6*S*, 6a*R*)-6-methylhexahydro-2*H*-furo[3,2-*b*]pyrrol-3-ol (109) which was used without further purification.

A solution of sodium carbonate (37.8 mg, 0.36 mmol) in water (1.0 mL) was added whilst stirring to a suspension of (3*R*, 3a*R*, 6*S*, 6a*R*)-6-methylhexahydro-2*H*-furo[3,2-*b*]pyrrol-3-ol (109) (assumed to be 0.162 mmol) in 1,4-dioxan (1.0 mL). A solution of 9-fluorenylmethoxycarbonyl chloride (47.5 mg, 0.178 mmol) in 1,4-dioxan (1.0 mL) was added then the mixture stirred for 2 hours then dichloromethane (10 mL) was added and the mixture washed with water (10 mL). The aqueous layer was re-extracted

with dichloromethane (2 x 5 mL) then the combined organic layers dried (Na_2SO_4), filtered and reduced *in vacuo* to leave a colourless oil (59 mg). Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 10 : 90 to 35 : 65 gave alcohol (2c'; R^1 = Me) (48.1 mg, 81.3%) as a white solid. TLC (R_f = 0.30, EtOAc : heptane 1 : 1), analytical HPLC single main peak, R_t = 14.54 min., HPLC-MS 366.2 $[M + H]^+$, 388.2 $[M + Na]^+$, 753.3 $[2M + Na]^+$; $[\alpha]_D^{22}$ -46.8° (c = 4.81, $CHCl_3$); δ_C (125 MHz, $CDCl_3$) mixture of approximately 1 : 1 rotamers, 16.67 / 16.97 ($CHCH_3$), 37.04 / 37.99 ($CHCH_3$), 47.31 / 47.55 (Fmoc *C*H), 51.49 / 51.74 ($FmocNCH_2$), 65.41 / 67.00 (Fmoc CH_2), 68.38 / 69.16 (FmocNCH), 73.81 / 74.04 (OCH_2CHOH), 76.26 (OCH_2CHOH), 87.23 / 87.82 ($OCHCHCH_3$), 119.84, 119.93, 124.39, 124.42, 124.87, 126.94, 127.36, 127.68, 127.80 and 127.83 (Fmoc aromatic *C*H), 141.21, 141.30, 141.38, 143.67, 143.80, 143.90 and 143.94 (Fmoc quaternary), 154.40 / 155.34 (Fmoc *C*=O).

Preparation of (3a*S*, 6*S*, 6a*R*)-(9*H*-fluoren-9-yl)methyl 6-methyl-3-oxotetrahydro-2*H*-furo[3,2-*b*]pyrrole-4(5*H*)-carboxylate (2d'; R^1 = Me).

Dess-Martin periodinane (99.2 mg, 0.234 mmol) was added to a stirred solution of alcohol (2c'; R^1 = Me) (42.7 mg, 0.117 mmol) in dichloromethane (2 mL) under an atmosphere of argon. The mixture was stirred for 2 hours then diluted with dichloromethane (15 mL). The organic phase was washed with a mixture of saturated aqueous sodium bicarbonate and 0.25M sodium thiosulphate solution (1 : 1, 10 mL), then saturated aqueous sodium bicarbonate (10 mL), then brine (10 mL), then dried (Na_2SO_4), filtered and reduced *in vacuo*. Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 10 : 90 to 30 : 70 gave ketone (2d'; R^1 = Me) (36.1 mg, 84.9%) as a white solid. TLC (R_f = 0.35, EtOAc : heptane 1 : 1), analytical HPLC broad main peak, R_t = 14.2-16.2 min., HPLC-MS 364.2 $[M + H]^+$, 386.2 $[M + Na]^+$, 404.1 $[M + H_2O + Na]^+$, 749.2 $[2M + Na]^+$; $[\alpha]_D^{22}$ -127.0° (c = 3.11, $CHCl_3$); δ_C (125 MHz, $CDCl_3$); 16.10 (CH_3CH), 38.0 (CH_3CH), 48.0 (Fmoc-*C*H), 52.5 ($FmocNCH_2$), 61.5 (FmocNCH), 68.0 (Fmoc-CH_2), 70.3 (OCH_2C=O), 87.3 ($OCHCHCH_3$), 120.0, 125.2, 126.5, 127.5 (Fmoc aromatic *C*H), 141.0, 141.5, 143.5, 144.0 and 144.512 (Fmoc quaternary), 154.8 (Fmoc *C*=O), 208.5 (ketone *C*=O).

Alternative preparation of (3*R*, 3a*R*, 6*S*, 6aR)-benzyl 3-hydroxy-6-methyltetrahydro-2*H*-furo[3,2-*b*]pyrrole-4(5*H*)-carboxylate (110).

(i) Preparation of (3*R*,3a*R*,6*S*,6a*S*)-*tert*-butyl 6-bromo-3-hydroxytetrahydro-2*H*-furo[3,2-*b*]pyrrole-4(5*H*)-carboxylate (111). Lithium bromide (11.51 g, 132 mmol) was added to a stirred solution of tosylate (35b) (5.28 g, 13.2 mmol) in anhydrous DMF (75 mL) and the mixture heated at 130 °C for 4 hours. The black solution was left to cool to ambient temperature then reduced *in vacuo*. The residue was taken into DCM (100mL) and washed with H_2O (100 mL). The organic layer was dried (Na_2SO_4), filtered and reduced *in vacuo* to leave a black tar (Yield 3.3 g). Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 5 : 95 to 30 : 70 gave bromide (111) (2.14g, 52.6%) as a pale green solid. TLC (R_f = 0.4, EtOAc : heptane 3 : 1), analytical HPLC main peak, R_t = 9.34 min., HPLC-MS 252.1 / 254.1 $[M + H - 56]^+$, 308.1 / 310.1 $[M + H]^+$; 330.0 / 332.0 $[M + Na]^+$; $[\alpha]_D^{22}$ -90.2° (c = 2.33, $CHCl_3$); δ_C (125 MHz, $CDCl_3$) 28.35 / 28.44 ($(CH_3)_3C$), 48.26 / 48.75 (BrCHCH), 53.48 / 54.14 (BocNCH_2), 67.78 / 68.29 (BocNCH), 75.48/ 75.63 (OCH_2CHOH), 75.24 / 76.08 (OCH_2CHOH), 80.78 / 81.07 ($(CH_3)_3C$ quarternary), 87.01 / 87.85 (BrCHCH), 153.83/ 154.61 (Boc C=O).

(ii) Preparation of (3*R*,3a*R*,6*S*,6a*S*)-6-bromohexahydro-2*H*-furo[3,2-*b*]pyrrol-3-ol hydrochloride (112). Bromide (111) (2.14g, 6.95 mmol) was dissolved in 4N HCl / dioxan (30 mL) with stirring at ambient temperature. The purple solution was stirred for 1hour then reduced *in vacuo* and evaporated three times from diethyl ether to give a purple crystalline solid crude (3*R*,3a*R*,6*S*,6a*S*)-6-bromohexahydro-2*H*-furo[3,2-*b*]pyrrol-3-ol hydrochloride (112) (Yield 1730 mg) which was used without further purification. HPLC-MS 208.0 / 210.0 $[M + H]^+$.

(iii) A solution of methyllithium (1.6M in diethyl ether, 29.25 mL, 46.8 mmol) was added dropwise over 15 minutes to a stirred suspension of copper(I) bromide (3.36 g, 23.4 mmol) in tetrahydrofuran (30 mL) at 0 °C. The mixture was stirred for 20 minutes then hydrochloride (112) (1.32 g, 5.40 mmol) was added in portions over 8 minutes followed by a suspension of hydrochloride (112) (110 mg, 0.45 mmol) in

tetrahydrofuran (10 mL) *via* cannula. The mixture was stirred for 1 hour 55 minutes then a solution of sodium carbonate (1.57 g, 14.8 mmol) in water (25 mL) was added dropwise over 3 minutes. The mixture was stirred for 15 minutes then benzyl chloroformate (1.9 mL, 13.3 mmol) was added over 2 minutes. The mixture stirred for 45 minutes then water (200 mL) was added and the mixture extracted with dichloromethane (3 x 50 mL). The combined organic layers were mixed with brine (50 mL) then filtered through celite. The filter pad was washed with dichloromethane then the organic layer separated, dried (Na_2SO_4), filtered and reduced *in vacuo* to leave a brown oil (2.78 g). Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 10 : 90 to 55 : 45 gave (3*R*, 3a*R*, 6*S*, 6aR)-benzyl 3-hydroxy-6-methyltetrahydro-2*H*-furo[3,2-*b*]pyrrole-4(5*H*)-carboxylate (110) (1.218 g, 75%) as a pale brown oil. TLC (R_f = 0.30, EtOAc : heptane 2 : 1), analytical HPLC main peak, R_t = 9.890 min., HPLC-MS 278.1 $[M + H]^+$, 577.2 $[2M + Na]^+$; $[\alpha]_D^{22}$ -67.9° (c = 5.08, $CHCl_3$); δ_H (500 MHz, $CDCl_3$) mixture of rotamers major : minor 2 : 1; 0.94 (3H, d, *J* = 7.30 Hz, C*H*$_3$CH), 2.28-2.36 (1H, m, CH$_3$C*H*), 2.39-2.44 (0.33H, m, O*H* minor), 3.26 (0.66H, brs, O*H* major), 3.28-3.48 (2H, m, CbzNC*H*$_2$), 3.68-3.75 (1H, m, 1 x OC*H*$_2$CHOH), 3.90 (0.33H, dd, *J* = 9.99 and 4.27 Hz, 1 x OC*H*$_2$CHOH minor), 3.98 (0.66H, dd, *J* = 9.74 and 4.85 Hz, 1 x OC*H*$_2$CHOH major), 4.15 (1H, m, CbzNC*H*), 4.32-4.37 (1.33H, m, OCH$_2$C*H*OH minor and CH$_3$CHC*H*), 4.43-4.46 (0.66H, m, OCH$_2$C*H*OH major), 5.09-5.24 (2H, m, C*H*$_2$Ph), 7.29-7.40 (5H, m, Cbz C*H*); δ_C (125 MHz, $CDCl_3$) 17.055 (*C*H$_3$CH), 37.510 / 38.042 (CH$_3$*C*H), 51.928 / 52.011 (CbzN*C*H$_2$), 67.158 / 67.287 (*C*H$_2$Ph), 68.192 / 69.273 (CbzNCH), 74.233 (O*C*H$_2$CHOH), 76.087 (OCH$_2$*C*HOH), 87.331 / 88.229 (CH$_3$CH*C*H), 127.764, 127.898, 128.100, 128.261, 128.372, 128.521, 128.597 and 128.702 (aromatic *C*H), 136.373 / 136.426 (Cbz quaternary), 154.649 / 155.529 (Cbz *C*=O).

Preparation of (3a*S*, 6*R*, 6a*R*)-(9*H*-fluoren-9-yl)methyl 6-methyl-3-oxotetrahydro-2*H*-furo[3,2-*b*]pyrrole-4(5*H*)-carboxylate (2d; R^2 = Me). Following schemes 6 and 7.

(i) Preparation of (3*R*, 3a*R*, 6*R*, 6a*S*)-6-(*tert* butyldimethylsilyloxy)hexahydrofuro [3,2-*b*]furan-3-ol (86). *tert*-Butyldimethylsilyl chloride (22.7 g, 151 mmol) was added

to a stirred solution of isomannide (40) (20.0 g, 137 mmol) and imidazole (21.0 g, 308 mmol) in dimethylformamide (150 mL). The mixture was stirred for 1.25 hours then the majority of solvents were removed *in vacuo*. The residue was partitioned between dichloromethane (400 mL) and water (250 mL). The aqueous phase was reextracted with dichloromethane (100 mL) then the combined organic layers washed with a mixture of water and brine (2.5 : 1 respectively, 2 x 350 mL). The organic phase was dried (Na_2SO_4), filtered and reduced *in vacuo* to leave a yellow oil (27.9 g). Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 5 : 95 to 40 : 60 gave alcohol (86) as an oily white solid (14.1 g, 39%). TLC (R_f = 0.30, EtOAc : heptane 1 : 2), HPLC-MS 261.2 $[M + H]^+$, $[\alpha]_D^{20}$ +62.0° (c = 3.065, $CHCl_3$); δ_H (500 MHz, $CDCl_3$) 0.09 and 0.10 (6H total, each s, $Si(CH_3)_2$), 0.89 (9H, s, $SiC(CH_3)_3$), 3.14 (1H, brs, O*H*), 3.70-3.75 (2H, m, 1 x CH_2CHOH and 1 x CH_2CHOTBDMS), 3.90-3.96 (2H, m, 1 x CH_2CHOH and 1 x CH_2CHOTBDMS), 4.17 (1H, brs, C*H*OH), 4.24 (1H, q, J = 5.5 Hz, C*H*OTBDMS), 4.39 (2H total, each t, J = 5.5 Hz, $CH_2OCHCHOCH_2$); δ_C (125 MHz, $CDCl_3$) -5.159 / -4.807 ($Si(CH_3)_2$), 18.337 ($SiC(CH_3)_3$), 25.774 ($SiC(CH_3)_3$), 71.753 (*C*HOH), 73.392 (*C*HOTBDMS), 74.208 and 75.749 (OCH_2CHOH and OCH_2CHOTBDMS), 81.523 and 82.039 (OCHCHO).

(ii) Preparation of (3a*S*, 6*R*, 6a*S*)-6-(*tert*-butyldimethylsilyloxy)tetrahydrofuro[3,2-*b*]furan-3(2*H*)-one (87). Dess-Martin periodinane (31.18 g, 73.5 mmol) was added to a stirred solution of alcohol (86) (9.56 g, 36.8 mmol) in dichloromethane (110 mL) under an atmosphere of argon. The mixture was stirred at 30-35 °C for 5 hours, at ambient temperature for 16 hours, at 30-35 °C for 8 hours and at ambient temperature for 20 hours before adding isolute® HM-N then removing the solvents *in vacuo*. Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 5 : 95 to 40 : 60 gave ketone (87) as a pale yellow oil (8.62 g, 91%).

(iii) Alternative preparation of (3a*S*, 6*R*, 6a*S*)-6-(*tert*-butyldimethylsilyloxy) tetrahydrofuro[3,2-*b*]furan-3(2*H*)-one (87). A solution of dimethyl sulfoxide (0.65 mL, 9.23 mmol) in dichloromethane (2 mL) was added dropwise to a stirred solution of oxalyl chloride (0.38 mL, 4.39 mmol) in dichloromethane (10 mL) at ≤ -60 °C over 15

minutes. The mixture was stirred for 10 minutes then a solution of alcohol (86) (1.0 g, 3.85 mmol) in dichloromethane (10 mL) was added dropwise over 15 minutes. The mixture was stirred for 15 minutes then triethylamine (2.68 mL, 19.23 mmol) was added dropwise over 5 minutes. The cooling bath was removed then the mixture allowed to warm to ambient temperature. Aqueous saturated ammonium chloride solution (15 mL) was added then the product extracted into diethyl ether (2 x 25 mL). The combined organic layers were washed with water (2 x 20 mL), dried ($MgSO_4$), filtered and reduced *in vacuo* to leave a pale yellow oil (964 mg). Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 5 : 95 to 35 : 65 gave ketone (87) as a colourless oil (869 mg, 88%). TLC (R_f = 0.60, EtOAc : heptane 1 : 1), HPLC-MS 259.2 $[M + H]^+$, $[\alpha]_D^{19.5}$ +87.1° (c = 2.01, $CHCl_3$).

(iv) Preparation of *tert*-butyldimethyl((3*R*, 3a*S*, 6a*R*)-6-methylenehexahydrofuro [3,2-*b*]furan-3-yloxy)silane (88). A solution of *n*-butyl lithium (2.5M in hexanes, 0.46 mL, 1.16 mmol) was added to a stirred suspension of methyltriphenylphosphonium bromide (415 mg, 1.16 mmol) in tetrahydrofuran (4 mL) at 0 °C under an atmosphere of argon over 2 minutes. The mixture was stirred at ambient temperature for 3 hours then a solution of ketone (87) (200 mg, 0.78 mmol) in tetrahydrofuran (2.5 mL) added. The mixture was heated at reflux for 1.25 hours then allowed to cool to ambient temperature. Water (10 mL) was added and the product extracted into diethyl ether (1 x 25 mL then 1 x 10 mL). The combined organic layers were washed with water (10 mL), then brine (10 mL), dried ($MgSO_4$), filtered and reduced *in vacuo* to leave a brown oil (296 mg). Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 0 : 100 to 20 : 80 gave alkene (88) as a colourless oil (96 mg, 48%). TLC (R_f = 0.80, EtOAc : heptane 1 : 2), analytical HPLC single main peak, R_t = 16.502 min.; HPLC-MS 257.2 $[M + H]^+$, $[\alpha]_D^{21}$ +142.2° (c = 1.547, $CHCl_3$); δ_H (500 MHz, $CDCl_3$) 0.09 and 0.10 (6H total, each s, $Si(CH_3)_2$), 0.89 (9H, s, $SiC(CH_3)_3$), 3.59 (1H, t, J = 8.22 Hz, 1 x $CH_2CHOTBDMS$), 3.82 (1H, dd, J = 8.39 and 6.30 Hz, 1 x $CH_2CHOTBDMS$), 4.22-4.26 (1H, m, $CHOTBDMS$), 4.31 (1H, d, J = 12.99 Hz, 1 x $CH_2C{=}CH_2$), 4.37 (1H, t, J = 4.82 Hz, $CHCHOTBDMS$), 4.53 (1H, d, J = 12.99 Hz, 1 x $CH_2C{=}CH_2$), 4.73 (1H, dd, J = 4.76 and 1.15 Hz, $CHC{=}CH_2$), 5.11-5.13 and 5.28-

5.30 (2H total, m, C=CH_2); δ_C (125 MHz, $CDCl_3$) -5.008 / -4.801 (Si(CH_3)$_2$), 18.386 (SiC(CH$_3$)$_3$), 25.866 (SiC(CH_3)$_3$), 71.043 and 72.181 (CH_2CHOTBDMS and OCH_2C=CH_2), 74.073 (*C*HOTBDMS), 82.377 and 83.053 (CH_2O*C*H*C*HOCH_2), 109.497 (C=CH_2), 148.610 (*C*=CH_2).

(v) Alternative preparation of *tert*-butyldimethyl((3*R*, 3a*S*, 6a*R*)-6-methylene hexahydrofuro[3,2-*b*]furan-3-yloxy)silane (88). A stirred suspension of methyltriphenylphosphonium bromide (1.84 g, 5.16 mmol) and potassium *tert*-butoxide (578 mg, 5.16 mmol) in tetrahydrofuran (15 mL) was heated at reflux under an atmosphere of argon for 3 hours then allowed to cool to ambient temperature. A solution of ketone (87) (888 mg, 3.44 mmol) in tetrahydrofuran (7.5 mL) was added then heating at reflux continued for 2.25 hours. The mixture was diluted with water (30 mL) then the product extracted into diethyl ether (2 x 30 mL). The combined organic layers were washed with brine (25 mL), dried ($MgSO_4$), filtered and reduced *in vacuo* to leave residue (2.07 g). Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 0 : 100 to 15 : 85 gave alkene (88) as a colourless oil (799 mg, 91%).

(vi) Preparation of *tert*-butyldimethyl((3*R*, 3a*S*, 6*R*, 6a*R*)-6-methylhexahydrofuro [3,2-*b*]furan-3-yloxy)silane (89a). Ethanol (1.5 mL) was added dropwise to a mixture of 10% palladium on charcoal (20 mg) and alkene (88) (69 mg, 0.27 mmol) under an atmosphere of argon. The argon was replaced by hydrogen then the suspension was stirred for 1.75 hours. The hydrogen was replaced by argon then mixture was filtered through celite *in vacuo*. The filter cake was washed with ethanol (10 mL) then the solvents removed *in vacuo* from the filtrate to leave a residue (69 mg). Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 0 : 100 to 25 : 75 gave a mixture of *tert*-butyldimethyl((3*R*, 3a*S*, 6*R*, 6a*R*)-6-methylhexahydrofuro[3,2-*b*]furan-3-yloxy)silane (89a) and *tert*-butyldimethyl((3*R*, 3a*S*, 6*S*, 6a*R*)-6-methylhexahydrofuro[3,2-*b*]furan-3-yloxy)silane (89b) (9 : 1 respectively) as a colourless oil (51 mg, 74%). Data for (89a): TLC (R_f = 0.80, EtOAc : heptane 1 : 2.5), HPLC-MS 259.2 $[M + H]^+$, $[\alpha]_D^{21}$ +86.8° (c = 2.651, $CHCl_3$); δ_H (500 MHz, $CDCl_3$) 0.07 and 0.09 (6H total, each s, Si(CH_3)$_2$), 0.88 (9H, s, SiC(CH_3)$_3$), 1.03

(3H, d, J = 6.84 Hz, CH_3CH), 2.16-2.23 (1H, m, CH_3CH), 3.36 (1H, dd, J = 11.14 and 8.13 Hz, 1 x CH_2CHCH$_3$), 3.48 (1H, dd, J = 8.42 and 7.34 Hz, 1 x CH_2CHOTBDMS), 3.76 (1H, dd, J = 8.52 and 6.19 Hz, 1 x CH_2CHOTBDMS), 3.95 (1H, t, J = 7.88 Hz, 1 x CH_2CHCH$_3$), 4.23-4.27 (1H, m, C*H*OTBDMS), 4.32 and 4.35 (2H total, each t, J = 4.50 Hz and t, J = 4.55 Hz respectively, $CH_2OCHCHOCH_2$); δ_C (125 MHz, $CDCl_3$) -5.039 / -4.768 (Si(CH_3)$_2$), 9.084 (CH_3CH), 18.396 (SiC(CH$_3$)$_3$), 25.876 (SiC(CH_3)$_3$), 39.892 (CH_3CH), 72.918 and 75.084 (CH_2CHOTBDMS and OCH_2CHCH_3), 74.488 (CHOTBDMS), 83.196 and 84.697 ($CH_2OCHCHOCH_2$).

(vii) Alternative preparation of *tert*-butyldimethyl((3*R*, 3a*S*, 6*R*, 6a*R*)-6-methylhexahydrofuro[3,2-*b*]furan-3-yloxy)silane (89a). Ethyl acetate (5 mL) was added dropwise to a mixture of 10% palladium on charcoal (50 mg) and (89a) (799 mg, 3.12 mmol) under an atmosphere of argon. The argon was replaced by hydrogen then the suspension was stirred for 1 hour 25 minutes before replacing the hydrogen with argon, adding water (2 mL) then filtering the mixture through celite *in vacuo*. The filter cake was washed with ethyl acetate (40 mL) then the solvents removed *in vacuo* from the filtrate to leave a colourless oil (795 mg). Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 0 : 100 to 20 : 80 gave a mixture of *tert*-butyldimethyl((3*R*, 3a*S*, 6*R*, 6a*R*)-6-methylhexahydrofuro[3,2-*b*]furan-3-yloxy)silane (89a) and *tert*-butyldimethyl((3*R*, 3a*S*, 6*S*, 6a*R*)-6-methylhexahydrofuro[3,2-*b*]furan-3-yloxy)silane (89b) (12 : 1 respectively) as a colourless oil (769 mg, 96%).

(viii) Preparation of (3*R*, 3a*R*, 6*R*, 6a*R*)-6-methylhexahydrofuro[3,2-*b*]furan-3-ol (90a). Tetrabutylammonium fluoride solution (1.0M in tetrahydrofuran, 2.65 mL, 2.65 mmol) was added to a stirred solution of (89a) and (89b) (9 : 1 respectively, 342 mg, 1.33 mmol) in tetrahydrofuran (2.5 mL). The solution was stirred for 50 minutes then water (20 mL) added. The product was extracted into dichloromethane (2 x 10 mL) then the combined organic phases washed with brine (10 mL), dried (Na_2SO_4), filtered and reduced *in vacuo* to leave residue (158 mg). Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 20 : 80 to 50 : 50 gave a mixture of alcohol (90a) and (3*R*, 3a*R*, 6*S*, 6a*R*)-6-methylhexahydrofuro[3,2-*b*]furan-3-ol (90b)

(11 : 1 respectively) as a colourless oil (66 mg, 35%). Data for (3*R*, 3a*R*, 6*R*, 6a*R*)-6-methylhexahydrofuro[3,2-*b*]furan-3-ol (90a): TLC (R_f = 0.35, EtOAc : heptane 1 : 1), HPLC-MS 145.1 $[M + H]^+$, 167.1 $[M + Na]^+$, 311.1 $[2M + Na]^+$, $[\alpha]_D^{21.5}$ +65.9° (c = 2.58, $CHCl_3$); δ_H (500 MHz, $CDCl_3$) 1.08 (3H, d, *J* = 6.83 Hz, C*H*$_3$CH), 2.25-2.35 (1H, m, CH_3CH), 2.77 (1H, brs, O*H*), 3.36 (1H, dd, *J* = 11.40 and 8.03 Hz, 1 x C*H*$_2$CHCH$_3$), 3.58 (1H, dd, *J* = 9.56 and 5.26 Hz, 1 x C*H*$_2$CHOH), 3.81 (1H, dd, *J* = 9.56 and 5.70 Hz, 1 x C*H*$_2$CHOH), 4.03 (1H, t, *J* = 7.86 Hz, 1 x C*H*$_2$CHCH$_3$), 4.25 (1H, dd, *J* = 11.09 and 5.56 Hz, C*H*OH), 4.33 and 4.51 (2H total, t, *J* = 4.49 Hz and dd, *J* = 5.64 and 4.39 Hz respectively, $CH_2OCHCHOCH_2$); δ_C (125 MHz, $CDCl_3$) 8.948 (*C*H$_3$CH), 39.976 (CH_3CH), 72.459 (*C*HOH), 74.564 and 74.921 (*C*H$_2$CHOH) and O*C*H$_2$CHCH$_3$), 83.095 and 84.958 ($CH_2OCHCHOCH_2$).

(ix) Preparation of (3*R*, 3a*S*, 6*R*, 6a*R*)-6-methylhexahydrofuro[3,2-*b*]furan-3-yl 4-methylbenzenesulfonate (91a). Tetrabutylammonium fluoride solution (1.0M in tetrahydrofuran, 18.5 mL, 18.5 mmol) was added to a stirred solution of alcohols (90a) and (90b) (7 : 1 respectively, 4.345 g, 16.84 mmol) in tetrahydrofuran (20 mL). The solution was stirred for 1 hour 25 minutes then dichloromethane (200 mL) was added. The solution was dried (Na_2SO_4), filtered and the majority of solvents removed *in vacuo*. Pyridine (30 mL) was added followed by *p*-toluenesulfonyl chloride (12.8 g, 67.4 mmol). The mixture was stirred under an atmosphere of argon for 20 hours then diluted with water (300 mL). The product was extracted into *tert*-butyl methyl ether (2 x 200 mL) then dried ($MgSO_4$), filtered and reduced *in vacuo* to leave a residue. Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 0 : 100 to 35 : 65 gave a mixture of tosylates (91a) and (91b) (approximately 7 : 1 respectively) as a pale yellow oil (4.47 g, 89%). Data for (91a); TLC (R_f = 0.20, EtOAc : heptane 1 : 3), HPLC-MS 299.1 $[M + H]^+$, 316.2, 619.2 $[2M + Na]^+$, $[\alpha]_D^{22}$ +84.8° (c = 3.065, $CHCl_3$); δ_H (500 MHz, $CDCl_3$) 1.03 (3H, d, *J* = 6.84 Hz, C*H*$_3$CH), 2.18-2.27 (1H, m, CH_3CH), 2.43 (3H, s, aryl-C*H*$_3$), 3.34 (1H, dd, *J* = 11.28 and 8.31 Hz, 1 x C*H*$_2$CHCH$_3$), 3.70 (1H, dd, *J* = 9.61 and 6.62 Hz, 1 x C*H*$_2$CHOTs), 3.84 (1H, dd, *J* = 9.61 and 6.24 Hz, 1 x C*H*$_2$CHOTs), 3.95 (1H, t, *J* = 8.01 Hz, 1 x C*H*$_2$CHCH$_3$), 4.32 and 4.50 (2H total, t, *J* = 4.54 Hz and t, *J* = 4.74 Hz respectively, $CH_2OCHCHOCH_2$), 4.88 (1H, dd, *J* = 11.6

and 6.42 Hz, C*H*OTs), 7.33 (2H, brd, J = 8.01 Hz, aromatic CH_3CCH), 7.82 (2H, brd, J = 8.34 Hz, aromatic OSO_2CCH); δ_C (125 MHz, $CDCl_3$) 8.841 (CH_3CH), 21.669 (aryl-CH_3), 39.786 (CH_3CH), 70.301 and 75.096 (CH_2CHOTs and CH_2CHCH_3), 79.422 (*C*HOTs), 81.409 and 84.859 ($CH_2OCHCHOCH_2$), 127.976 and 129.806 (aromatic *C*H), 133.392 / 133.426 ($CHOSO_2C$ quaternary), 144.966 (CH_3C quaternary).

(x) Preparation of (3*S*, 3a*S*, 6*R*, 6a*R*)-3-bromo-6-methylhexahydrofuro[3,2-*b*]furan (92). A stirred mixture of lithium bromide (596 mg, 6.85 mmol) and tosylate (91a) (0.68 g, 2.28 mmol) in dimethylformamide (5 mL) was heated at 110 °C for 1 hour, then at 125 °C for 1.5 hours, then at 130 °C for 2 hours under an atmosphere of argon then diluted with water (20 mL). The product was extracted into diethyl ether (4 x 10 mL) then the combined organic layers washed with water (3 x 10 mL), brine (10 mL), dried ($MgSO_4$), filtered and reduced *in vacuo* to leave an orange oil. Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 0 : 100 to 35 : 65 gave bromide (92) as a colourless oil (292 mg, 62%). TLC (R_f = 0.80, EtOAc : heptane 1 : 2), $[\alpha]_D^{20.5}$ +75.2° (c = 1.13, $CHCl_3$); δ_H (500 MHz, $CDCl_3$) 1.10 (3H, d, J = 6.80 Hz, C*H*$_3$CH), 2.24-2.33 (1H, m, CH_3CH), 3.30 (1H, dd, J = 11.23 and 8.20 Hz, 1 x CH_2CHCH_3), 4.13 (2H, m, C*H*$_2$CHBr), 4.20 (1H, t, J = 7.99 Hz, 1 x CH_2CHCH_3), 4.28-4.30 (1H, m, C*H*Br), 4.68 and 4.74 (2H total, t, J = 3.87 Hz and dd, J = 3.55 and 0.92 Hz respectively, BrCHC*H*C*H*O); δ_C (125 MHz, $CDCl_3$) 9.842 (CH_3CH), 39.904 (CH_3CH), 51.616 (*C*HBr), 74.993 and 76.118 (CH_2CHBr and CH_2CHCH_3), 84.708 and 89.891 (BrCH*C*H*C*HO).

(xi) Preparation of (*R*)-2-((*S*)-2,5-dihydrofuran-2-yl)propyl methanesulfonate (93). A solution of ammonium chloride (94 mg, 1.76 mmol) in water (1.1 mL) then zinc dust (176 mg, 2.71 mmol) were added consecutively to a solution of bromide (92) (280 mg, 1.35 mmol) in tetrahydrofuran (4.5 mL). The mixture was stirred for 2 hours 10 minutes before filtering the suspension through celite *in vacuo*. The filter cake was washed with diethyl ether (10 mL) then the filtrate washed with hydrochloric acid (1M, 10 mL). The aqueous layer was reextracted with diethyl ether (10 mL) then the combined organic layers were washed with brine (10 mL), then dried ($MgSO_4$), filtered

and the majority of solvents removed *in vacuo* to leave a residue. Triethylamine (0.292 mL, 2.10 mmol) then methanesulfonyl chloride (0.167 mL, 2.16 mmol) were added to the residue then the suspension stirred for 1.5 hours before adding triethylamine (0.097 mL, 0.89 mmol) and methanesulfonyl chloride (0.056 mL, 0.72 mmol). The suspension was stirred for 40 minutes then diluted with dichloromethane (15 mL), washed with water (10 mL), brine (10 mL), dried (Na_2SO_4), filtered and reduced *in vacuo* to leave a residue (225 mg). Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 0 : 100 to 40 : 60 gave mesylate (93) as a colourless oil (111 mg, 40%). TLC (R_f = 0.60, EtOAc : heptane 1 : 1), analytical HPLC single main peak, R_t = 7.028 min; HPLC-MS 207.1 $[M + H]^+$, 224.1, 435.1 $[2M + Na]^+$; δ_H (500 MHz, $CDCl_3$) 1.03 (3H, d, J = 6.93 Hz, CH_3CH), 1.97-2.06 (1H, m, CH_3CH), 3.00 (3H, s, OSO_2CH_3), 4.17 (1H, dd, J = 9.61 and 6.39 Hz, 1 x CH_2OMs), 4.28 (1H, dd, J = 9.61 and 4.52 Hz, 1 x CH_2OMs), 4.60-4.64 (2H, m, OCH_2CH=CH), 4.69-4.74 (1H, m, OC*H*CH=CH), 5.82-5.85 and 5.94-5.98 (2H total, m, C*H*=C*H*); δ_C (125 MHz, $CDCl_3$) 13.088 (CH_3CH), 37.062 (OSO_2CH_3), 38.829 (CH_3CH), 71.933 (CH_2OMs), 75.361 (OCH_2CH=CH), 86.908 (OCHCH=CH), 127.345 and 127.877 (CH=CH).

(xii) Alternative preparation of (*R*)-2-((*S*)-2,5-dihydrofuran-2-yl)propyl methanesulfonate (93). A stirred mixture of lithium bromide (773 mg, 8.89 mmol) and tosylate (91) (662 mg, 2.22 mmol) in dimethylformamide (4.5 mL) was heated at 125 °C for 3 hours under an atmosphere of argon then diluted with water (15 mL). The product was extracted into *tert*-butyl methyl ether (4 x 5 mL) then the organic phase washed with water (3 x 5 mL), brine (5 mL), dried ($MgSO_4$), filtered and reduced *in vacuo* to leave bromide (92)as a brown oil (411 mg) which was used without further purification.

A solution of ammonium chloride (154 mg, 2.89 mmol) in water (1.5 mL) then zinc dust (289 mg, 4.44 mmol) were added consecutively to a solution of bromide (92) (prepared as above, assumed to be 2.22 mmol) in tetrahydrofuran (6 mL). The mixture was stirred for 19 hours before filtering the suspension through celite *in vacuo*. The filter cake was washed with diethyl ether (15 mL). A mixture of brine and 1M

hydrochloric acid (1 : 1, 15 mL) was added to the filtrate then the organic phase separated. The aqueous layer was reextracted with diethyl ether (15 mL) then the combined organic layers were washed with brine (10 mL), then dried ($MgSO_4$), filtered and the majority of solvents removed *in vacuo* to leave a residue. Dichloromethane (2 mL) was added to the residue followed by triethylamine (0.618 mL, 4.44 mmol) then methanesulfonyl chloride (0.334 mL, 4.44 mmol). The suspension was stirred for 2.25 hours then triethylamine (0.309 mL, 2.22 mmol) and methanesulfonyl chloride (0.172 mL, 2.22 mmol) added. The suspension was stirred for 2.75 hours then triethylamine (0.155 mL, 1.11 mmol) and methanesulfonyl chloride (0.86 mL, 1.11 mmol) added. The suspension was stirred for 50 minutes then diluted with dichloromethane (25 mL), washed with water (10 mL), brine (10 mL), dried (Na_2SO_4), filtered and reduced *in vacuo* to leave a pale yellow oil (724 mg). Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 0 : 100 to 30 : 70 gave mesylate (93) as a colourless oil (260 mg, 57%).

(xiii) Preparation of Benzyl (*R*)-2-((*S*)-2,5-dihydrofuran-2-yl)propyl carbamate (95). A stirred mixture of mesylate (93) (68 mg, 0.33 mmol), ammonium hydroxide (0.8 mL) and ammonia in propan-2-ol (2M, 0.4 mL, 0.8 mmol) was heated at 70 °C in a sealed tube for 2 hours. The mixture was stirred at ambient temperature for 18 hours then the majority of the solvents were removed *in vacuo*. The residue was azeotroped with diethyl ether (3 x 3 mL) to obtain amine (94) which was used without further purification.

1,4-Dioxan (0.7 mL) then a solution of sodium carbonate (87 mg, 0.83 mmol) in water (0.6 mL) was added whilst stirring to the crude amine (94) amine (assumed to be 0.33 mmol) followed by benzylchloroformate (0.11 mL, 0.73 mmol). The mixture was stirred for 50 minutes before adding dichloromethane (5 mL) and water (10 mL). The organic phase was separated and the aqueous reextracted with dichloromethane (2 x 5 mL). The combined organic layers were washed with brine (5 mL), then dried (Na_2SO_4), filtered and reduced *in vacuo* to leave a residue. Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 0 : 100 to 25 : 75 gave benzyl (*R*)-2-

((*S*)-2,5-dihydrofuran-2-yl)propyl carbamate (95) as a colourless oil (31 mg, 36%). TLC (R_f = 0.45, EtOAc : heptane 2 : 3), analytical HPLC single main peak, R_t = 13.127 min; HPLC-MS 262.1 $[M + H]^+$, 545.2 $[2M + Na]^+$, $[\alpha]_D^{23}$ -58.7° (c = 2.81, $CHCl_3$); δ_H (500 MHz, $CDCl_3$) 0.93 (3H, d, J = 6.93 Hz, C*H*$_3$CH), 1.73-1.81 (1H, m, CH$_3$C*H*), 3.18-3.24 (2H, m, C*H*$_2$NH), 4.55-4.68 (3H, m, C*H*$_2$CH=CHC*H*), 5.08 (2H, brs, C*H*$_2$Ph), 5.38 (0.7H, brs, N*H*), 5.81-5.84 and 5.91-5.94 (2H total, m, C*H*=C*H*), 7.28-7.36 (5H, m, aromatic-C*H*); δ_C (125 MHz, $CDCl_3$) 14.404 (*C*H$_3$CH), 38.844 (CH$_3$*C*H), 44.727 (*C*H$_2$NH), 66.511 (*C*H$_2$Ph), 75.206 (O*C*H$_2$CH=CH), 90.150 (O*C*HCH=CH), 127.434, 128.017, 128.059, 128.097 and 128.468 and 127.877 (*C*H=*C*H and aromatic *C*H), 136.745 (Cbz quaternary), 156.509 (Cbz *C*=O).

(xiv) Alternative preparation of (*R*)-2-((*S*)-2,5-dihydrofuran-2-yl)propan-1-amine (94). Sodium azide (37 mg, 0.58 mmol) was added to a stirred solution of mesylate (93) (108 mg, 0.52 mmol) in dimethylformamide (1 mL) then the mixture heated at 60 °C under an atmosphere of argon for 6.25 hours. The mixture was stood at ambient temperature for 18 hours then sodium azide (5 mg, 0.08 mmol) was added. The mixture heated at 60 °C under an atmosphere of argon for 2.75 hours then water (0.1 mL) and triphenylphosphine (206 mg, 0.79 mmol) were added. The mixture stirred at 45-55 °C for 3.5 hours. HPLC-MS indicated the appearance of a new peak corresponding to amine (94) together with other products.

(xv) Preparation of benzyl (*R*)-2-((1*R*, 2*R*, 5*S*)-3,6-dioxabicyclo[3.1.0]hexan-2-yl)propylcarbamate (96). To a solution of benzyl (*R*)-2-((*S*)-2,5-dihydrofuran-2-yl)propyl carbamate (95) (215 mg, 0.82 mmol) in acetonitrile (6 mL) and aqueous Na_2.EDTA (0.4 mmol solution, 6 mL) at 0 °C was added 1,1,1-trifluoroacetone (1.34 mL, 9.89 mmol). To this solution was added in portions a mixture of sodium bicarbonate (0.58 g, 6.92 mmol) and OXONE® (1.57 g, 2.55 mmol) over a period of 1 hour. The mixture was stirred for 40 minutes then diluted with water (25 mL) and the product extracted into dichloromethane (2 x 15 mL). The combined organic layers were washed consecutively with water (10 mL), aqueous sodium hydrogen sulphite solution (5%, 10 mL) and water (10 mL), then dried (Na_2SO_4), filtered and reduced *in vacuo* to

leave a colourless oil (218 mg). Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 0 : 100 to 50 : 50 gave *anti*-(96), *syn*-(96) and *anti*-(96b), (approximately 3.5 : 1 : 0.5 respectively) as a colourless oil (100 mg, 44%). Data for *anti*-(96); TLC (R_f = 0.45, EtOAc : heptane 55 : 45), analytical HPLC main peak, R_t = 10.381 min., HPLC-MS 278.1 $[M + H]^+$, 300.1 $[M + Na]^+$, 577.2 $[2M + Na]^+$; δ_H (500 MHz, $CDCl_3$) 0.97 (3H, d, J = 6.81 Hz, CH_3CH), 1.68-1.73 (1H, m, CH_3CH), 3.20-3.27 (2H, m, CH_2NH), 3.63-3.75, 3.83 and 3.96 (3H, 1H and 1H respectively, m, d, J = 8.96 Hz and d, J = 10.53 Hz respectively, $OCH_2CHCHCH$), 5.08 (2H, brs, CH_2Ph), 5.23 (1H brs, NH), 7.28-7.36 (5H, m, aromatic CH); δ_C (125 MHz, $CDCl_3$) 14.523 (CH_3CH), 34.893 (CH_3CH), 44.771 (CH_2NHCbz), 56.132 and 58.001 (OCH_2CHCH), 66.623 (CH_2Ph), 67.623 (OCH_2CH), 81.732 ($OCHCHCH_3$), 128.103, 128.458 and 128.503 (aromatic CH), 136.576 (Cbz quaternary), 156.526 (Cbz C=O).

(xvi) Preparation of (3*R*, 3a*R*, 6*R*, 6a*R*)-benzyl 3-hydroxy-6-methyltetrahydro-2*H*-furo[3,2-*b*]pyrrole-4(5*H*)-carboxylate (108). To a solution of epoxide mixture (96) (90 mg, assuming 0.32 mmol) in anhydrous THF (3 mL) was added sodium hydride (1.3 eq, 60% dispersion in paraffin oil, 0.42 mmol, 17.0 mg) and the mixture stirred at ambient temperature under argon. After 2 hour a further aliquot of sodium hydride (0.3 eq, 4 mg) was added and stirring continued for 30 mins. The reaction mixture was diluted with DCM (25 mL), washed with saturated brine (25 mL), dried (Na_2SO_4), filtered and reduced *in vacuo* to a tan gum (110 mg). Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 20 : 80 to 50 : 50 gave bicyclic alcohol (108) as a clear gum (53.0 mg, 59.7%). TLC (R_f = 0.40, EtOAc : heptane 2 : 1), analytical HPLC single main peak, R_t = 10.87 min., HPLC-MS 278.1 $[M + H]^+$, 300.1 $[M + Na]^+$, 577.2 $[2M + Na]^+$; $[\alpha]_D^{22}$ -44.6° (c = 3.7, $CHCl_3$); δ_H (500 MHz, $CDCl_3$) mixture of rotamers major : minor 2 : 1; 1.08 (2H, d, J = 6.85 Hz, CH_3CH major), 1.10 (1H, d, J = 6.93 Hz, CH_3CH minor), 2.10-2.21 (1H, m, CH_3CH), 2.68 (1H, brs, OH), 2.85 (1H, dd, J = 21.67 and 10.77 Hz, 1 x $CbzNCH_2$), 3.71 (0.66H, dd, J = 10.50 and 8.02 Hz, 1 x $CbzNCH_2$ major), 3.71-3.76 (1H, m, 1 x OCH_2CHOH), 3.80 (0.33H, dd, J = 10.62 and 8.10 Hz, 1 x $CbzNCH_2$ minor), 3.85 (0.33H, dd, J = 9.98 and 4.13 Hz, OCH_2CHOH minor), 3.93 (0.66H, dd, J = 9.82 and 4.69 Hz, 1 x OCH_2CHOH major),

4.18 (1H, d, J = 4.42 Hz, CbzNC*H*), 4.32-4.37 (0.33H, m, OCH_2CHOH minor), 4.43 (0.66H, brt, J = 3.52 Hz, OCH_2CHOH major), 4.49-4.53 (1H, m, CH_3CHCH), 5.06-5.21 (2H, m, CH_2Ph), 7.29-7.38 (5H, m, Cbz C*H*); δ_C (125 MHz, $CDCl_3$) 11.136 / 11.155 (CH_3CH), 37.394 / 37.707 (CH_3CH), 51.255 / 51.522 ($CbzNCH_2$), 67.123 / 67.180 (CH_2Ph), 69.977 / 71.069 (CbzNCH), 74.503 / 74.637 (OCH_2CHOH), 76.302 / 77.222 (OCH_2CHOH), 83.713 / 84.583 (CH_3CHCH), 127.900, 127.945, 128.117, 128.221, 128.518, 128.661 and 128.696 (aromatic *C*H), 136.385 / 136.483 (Cbz quaternary), 154.079 / 154.828 (Cbz *C*=O).

(xvii) Preparation of (3*R*, 3a*R*, 6*R*, 6a*R*)-(9*H*-fluoren-9-yl)methyl 3-hydroxy-6-methyltetrahydro-2*H*-furo[3,2-*b*]pyrrole-4(5*H*)-carboxylate (2c; R^2 = Me).

Methanol (1.25 mL) was added dropwise to a mixture of 10% palladium on charcoal (20 mg) and bicyclic alcohol (108) (49 mg, 0.177 mmol) under an atmosphere of argon. The argon was replaced by hydrogen then the suspension was stirred for 1 hour then filtered through celite *in vacuo*. The filter cake was washed with ethanol (10 mL) then the solvents removed *in vacuo* from the filtrate. The residue was azeotroped with diethyl ether (3 x 3 mL) to obtain the crude (3*R*, 3a*R*, 6*R*, 6a*R*)-6-methylhexahydro-2*H*-furo[3,2-*b*]pyrrol-3-ol (107) which was used without further purification.

A solution of sodium carbonate (41 mg, 0.389 mmol) in water (0.5 mL) was added whilst stirring to a suspension of (3*R*, 3a*R*, 6*R*, 6a*R*)-6-methylhexahydro-2*H*-furo[3,2-*b*]pyrrol-3-ol (107) (assumed to be 0.177 mmol) in 1,4-dioxan (0.4 mL). A solution of 9-fluorenylmethoxycarbonyl chloride (50 mg, 0.195 mmol) in 1,4-dioxan (0.6 mL) was added then the mixture stirred for 19.5 hours then dichloromethane (10 mL) was added and the mixture washed with water (10 mL). The aqueous layer was re-extracted with dichloromethane (2 x 5 mL) then the combined organic layers dried (Na_2SO_4), filtered and reduced *in vacuo* to leave a colourless oil (80 mg). Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 10 : 90 to 40 : 60 gave alcohol (2c; R^2 = Me) (55.35 mg, 85%) as a white solid. TLC (R_f = 0.33, EtOAc : heptane 1 : 1), analytical HPLC single main peak, R_t = 14.961 min., HPLC-MS 366.2 $[M + H]^+$, 388.1 $[M + Na]^+$, 753.3 $[2M + Na]^+$; $[\alpha]_D^{22}$ -34.6° (c = 4.92, $CHCl_3$); δ_H (500 MHz, $CDCl_3$)

mixture of rotamers major : minor 55 : 45; 0.96 (0.55H, d, J = 3.66 Hz, O*H* major), 1.00 (1.65H, d, J = 6.82 Hz, C*H*$_3$CH major), 1.12 (1.35H, d, J = 6.82 Hz, C*H*$_3$CH minor), 1.92-2.01 (0.55H, m, CH$_3$C*H* major), 2.15-2.24 (0.45H, m, CH$_3$C*H* minor), 2.46 (0.45H, d, J = 3.52 Hz, O*H* minor), 2.67 (0.55H, t, J = 11.10 Hz, 1 x FmocNC*H*$_2$ major), 2.86 (0.45H, t, J = 10.84 Hz, 1 x FmocNC*H*$_2$ minor), 3.43 (0.55H, d, J = 4.44 Hz, FmocNC*H* major), 3.45-3.52 (1.10H, m, OCH$_2$C*H*OH major and 1 x OC*H*$_2$CHOH major), 3.58-3.69 (1.55H, m, 1 x FmocNC*H*$_2$ and 1 x OC*H*$_2$CHOH major), 3.72 (0.45H, dd, J = 9.80 and 3.46 Hz, 1 x OC*H*$_2$CHOH minor), 3.93 (0.45H, dd, J = 9.75 and 4.85 Hz, 1 x OC*H*$_2$CHOH minor), 4.16 (0.45H, brd, J = 4.68 Hz, FmocNC*H* minor), 4.20-4.24 (1H, m, Fmoc C*H*), 4.26 (0.55H, t, J = 3.78 Hz, OC*H*CHCH$_3$ major), 4.36-4.47 (1.35H, m, Fmoc C*H*$_2$ minor and OCH$_2$C*H*OH minor), 4.50 (0.45H, t, J = 4.38 Hz, OC*H*CHCH$_3$ minor), 4.74 (0.55H, dd, J = 10.85 and 3.84 Hz, 1 x Fmoc C*H*$_2$ major), 4.79 (0.55H, dd, J = 10.85 and 4.14 Hz, 1 x Fmoc C*H*$_2$ major), 7.29-7.80 (8H, Fmoc aromatic C*H*); δ_C (125 MHz, $CDCl_3$) 11.039 / 11.159 (CH*C*H$_3$), 37.080 / 37.663 (*C*HCH$_3$), 47.315 / 47.450 (Fmoc *C*H), 51.051 / 51.109 (FmocN*C*H$_2$), 65.517 / 67.255 (Fmoc *C*H$_2$), 70.319 / 71.071 (FmocN*C*H), 74.235 / 74.296 (O*C*H$_2$CHOH), 76.628 / 76.913 (OCH$_2$*C*HOH), 83.679 / 84.293 (O*C*HCHCH$_3$), 119.880, 119.903, 119.998, 124.431, 124.957, 124.991, 127.026, 127.408, 127.432, 127.739, 127.748, 127.839 and 127.889 (Fmoc aromatic *C*H), 141.243, 141.327, 141.349, 141.428, 143.765, 143.915, 143.982 and 144.047 (Fmoc quaternary), 153.854 / 154.783 (Fmoc *C*=O).

(xviii) Preparation of (3a*S*, 6*R*, 6a*R*)-(9*H*-fluoren-9-yl)methyl 6-methyl-3-oxotetrahydro-2*H*-furo[3,2-*b*]pyrrole-4(5*H*)-carboxylate (2d; R^2 = Me). Dess-Martin periodinane (114 mg, 0.269 mmol) was added to a stirred solution of alcohol (2c; R^2 = Me) (49 mg, 0.134 mmol) in dichloromethane (1.25 mL) under an atmosphere of argon. The mixture was stirred for 22 hours then diluted with dichloromethane (15 mL). The organic phase was washed with a mixture of saturated aqueous sodium bicarbonate and 0.25M sodium thiosulphate solution (1 : 1, 5 mL), then saturated aqueous sodium bicarbonate (5 mL), then brine (5 mL), then dried (Na_2SO_4), filtered and reduced *in vacuo*. Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 15 : 85 to 40 : 60 gave ketone (2d; R^2 = Me) (42 mg, 87%) as a white

solid. TLC (R_f = 0.35, EtOAc : heptane 1 : 1), analytical HPLC broad main peak, R_t = 14.720 min., HPLC-MS 364.2 $[M + H]^+$, 386.2 $[M + Na]^+$, 404.2 $[M + H_2O + Na]^+$, 749.3 $[2M + Na]^+$; $[\alpha]_D^{22}$ -135.2° (c = 3.55, $CHCl_3$); δ_H (500 MHz, $CDCl_3$) mixture of rotamers 1 : 1; 1.18 (3H, d, *J* = 6.81 Hz, C*H*$_3$CH), 2.23-2.33 (1H, m, CH$_3$C*H*), 3.08 (1H, t, *J* = 10.90 Hz, 1 x FmocNC*H*$_2$), 3.79 (0.5H, brt, *J* = 9.01 Hz, 0.5 x FmocNC*H*$_2$), 3.93-4.01 (1.5 H, m, 0.5 x FmocNC*H*$_2$ and 1 x OC*H*$_2$C=O), 4.14-4.59 (5H, m, 1 x OC*H*$_2$C=O, FmocNC*H*, Fmoc-C*H*$_2$ and Fmoc-C*H*), 4.64 (1H, brs, 0.5 x OC*H*CHCH$_3$), 4.69 (1H, brs, 0.5 x OC*H*CHCH$_3$), 7.29-7.79 (8H, Fmoc aromatic C*H*); δ_C (125 MHz, $CDCl_3$); 10.070 / 10.136 (*C*H$_3$CH), 37.729 / 38.240 (CH$_3$*C*H), 47.192 / 47.268 (Fmoc-*C*H), 51.013 / 51.318 (FmocN*C*H$_2$), 62.596 / 63.082 (FmocN*C*H), 67.623 / 68.209 (Fmoc-*C*H$_2$), 70.425 / 71.006 (O*C*H$_2$C=O), 83.680 / 84.582 (OCHCHCH$_3$), 119.883 / 119.954 / 124.989 / 125.166 / 125.501 / 127.056 / 127.634 and 127.694 (Fmoc aromatic *C*H), 141.239, 141.320, 143.655, 143.774, 143.983 and 144.512 (Fmoc quaternary), 154.753 / 154.813 (Fmoc *C*=O), 208.738 / 208.858 (ketone *C*=O).

Preparation of (3a*S*, 6*R*, 6a*R*)-(9*H*-fluoren-9-yl)methyl 6-(difluoromethyl)-3-oxotetrahydro-2*H*-furo[3,2-*b*]pyrrole-4(5*H*)-carboxylate (2d; R^2 = CHF_2). Following schemes 8 and 9.

(i) Preparation of *tert*-butyl((3*R*, 3a*S*, 6a*R*)-6-(difluoromethylene)hexahydrofuro [3,2-*b*]furan-3-yloxy)dimethylsilane (97) A solution of triphenylphosphine (13.30 g, 50.8 mmol) in *N*, *N*-dimethylacetamide (35 mL) was added to a stirred suspension of ketone (87) (6.55 g, 25.4 mmol) and dibromodifluoromethane (4.64 mL, 50.8 mmol) in *N*, *N*-dimethylacetamide (40 mL) at 0 °C under an atmosphere of argon dropwise over 1.25 hours. The mixture was stirred at ambient temperature for 1.25 hours then zinc dust (3.30 g, 50.8 mmol) was added over 5 minutes. The mixture was stirred at ambient temperature for 20 minutes then heated at 70 °C for 4 hours then stirred at ambient temperature for 18 hours. The mixture was diluted with diethyl ether (200 mL) then filtered through celite. The filter cake was washed with diethyl ether (200 mL) then water (400 mL) was added to the filtrate. The mixture was separated then the aqueous re-extracted with diethyl ether (250 mL). The combined organic layers were washed with brine (250 mL), dried (Na_2SO_4), filtered and reduced *in vacuo* to leave an orange-

brown solid (15.8 g). Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 0 : 100 to 10 : 90 gave alkene (97) as a colourless oil (4.84 g, 65%). TLC (R_f = 0.75, EtOAc : heptane 1 : 4), HPLC-MS 156.1, 293.1 $[M + H]^+$, $[\alpha]_D^{22}$ +135.6° (c = 2.175, $CHCl_3$); δ_H (500 MHz, $CDCl_3$) 0.09 and 0.10 (6H total, each s, $Si(CH_3)_2$), 0.90 (9H, s, $SiC(CH_3)_3$), 3.61 (1H, dd, J = 8.59 and 7.63 Hz, 1 x $CH_2CHOTBDMS$), 3.84 (1H, dd, J = 8.72 and 6.05 Hz, 1 x $CH_2CHOTBDMS$), 4.23 (1H, dt, J = 7.48 and 5.63 Hz, $CHOTBDMS$), 4.41-4.46 (2H, m, 1 x $CH_2C{=}CF_2$ and $CHCHOTBDMS$), 4.54-4.59 (1H, ddd, J = 12.29, 4.19 and 0.74 Hz, 1 x $CH_2C{=}CF_2$), 5.11 (1H, brdt, J = 5.05 and 1.28 Hz, $CHC{=}CF_2$); δ_C (125 MHz, $CDCl_3$) -5.064 / -4.811 ($Si(CH_3)_2$), 18.342 ($SiC(CH_3)_3$), 25.817 ($SiC(CH_3)_3$), 67.479 / 67.491 / 67.501 and 67.513 ($CH_2C{=}CF_2$), 71.680 ($CH_2CHOTBDMS$), 73.257 ($CHOTBDMS$), 79.668 / 79.692 / 79.718 and 79.741 ($CHC{=}CF_2$), 83.104 ($CHCHOTBDMS$), 91.167 / 91.334 and 91.501 ($C{=}CF_2$), 148.892 / 151.193 and 153.492 ($C{=}CF_2$).

(ii) Preparation of *tert*-Butyl((3*R*, 3a*S*, 6*R*, 6a*R*)-6-(difluoromethyl) hexahydrofuro[3,2-*b*]furan-3-yloxy)dimethylsilane (98a) and *tert*-butyl((3*R*, 3a*S*, 6*S*, 6a*R*)-6-(difluoromethyl)hexahydrofuro[3,2-*b*]furan-3-yloxy) dimethylsilane (98b). Methanol (5 mL) was added dropwise to 10% palladium on charcoal (450 mg) followed by a solution of alkene (97) (4.84 g, 16.6 mmol) in methanol (20 mL) under an atmosphere of argon at 0 °C. The argon was replaced by hydrogen then the suspension was stirred at ambient temperature for 3 hours 50 minutes. The hydrogen was replaced by argon then mixture was filtered through celite *in vacuo*. The filter cake was washed with ethanol (100 mL) then the solvents removed *in vacuo* from the filtrate to leave a residue. NMR analysis of the residue indicated a mixture of *tert*-butyl((3*R*, 3a*S*, 6*R*, 6a*R*)-6-(difluoromethyl)hexahydrofuro[3,2-*b*]furan-3-yloxy)dimethylsilane (98a) and *tert*-butyl((3*R*, 3a*S*, 6*S*, 6a*R*)-6-(difluoromethyl)hexahydrofuro[3,2-*b*]furan-3-yloxy)dimethylsilane (98b) (approximately 4.5 : 1 respectively) to be present. Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 0 : 100 to 10 : 90 gave (in order of elution) *tert*-butyl((3*R*, 3a*S*, 6*R*, 6a*R*)-6-(difluoromethyl)hexahydrofuro[3,2-*b*]furan-3-yloxy)dimethylsilane (98a) as a colourless oil (3.55 g, 73%), and *tert*-butyl((3*R*, 3a*S*, 6*S*, 6a*R*)-6-

(difluoromethyl)hexahydrofuro[3,2-*b*]furan-3-yloxy)dimethylsilane (98b) as a colourless oil (446 mg, 9%). Data for (98a); TLC (R_f = 0.50, EtOAc : heptane 1 : 4), HPLC-MS 156.1, 295.1 $[M + H]^+$, $[\alpha]_D^{22}$ +67.7° (c = 2.068, $CHCl_3$); δ_H (500 MHz, $CDCl_3$) 0.09 and 0.10 (6H total, each s, $Si(CH_3)_2$), 0.90 (9H, s, $SiC(CH_3)_3$), 2.61-2.71 (1H, m, $CHCHF_2$), 3.64 (1H, dd, J = 8.86 and 6.16 Hz, 1 x $CH_2CHOTBDMS$), 3.76 (1H, dd, J = 8.86 and 5.75 Hz, 1 x $CH_2CHOTBDMS$), 3.84 (1H, brt, J = 9.87 Hz, 1 x CH_2CHCHF_2), 4.03 (1H, t, J = 8.47 Hz, 1 x CH_2CHCHF_2), 4.28 (1H, dd, J = 10.90 and 5.90 Hz, $CHOTBDMS$), 4.45 (1H, t, J = 4.69 Hz, $CHCHOTBDMS$), 4.59 (1H, t, J = 4.83 Hz, $CHCHCHF_2$), 5.99 (1H, ddd, J = 56.95, 55.33 and 7.44 Hz, CHF_2); δ_C (125 MHz, $CDCl_3$) -5.107 / -4.796 ($Si(CH_3)_2$), 18.364 ($SiC(CH_3)_3$), 25.748 / 25.830 ($SiC(CH_3)_3$), 49.277 / 49.451 and 49.625 ($CHCHF_2$), 68.618 / 68.693 ($CH_2CHOTBDMS$), 73.573 (CH_2CHCHF_2), 73.777 ($CHOTBDMS$), 81.807 / 81.879 ($CHCHCHF_2$), 84.018 ($CHCHOTBDMS$), 114.408 / 116.289 / 116.318 and 118.198 (CHF_2). Data for (98b); TLC (R_f = 0.46, EtOAc : heptane 1 : 4), HPLC-MS 156.1, 295.1 $[M + H]^+$, $[\alpha]_D^{22}$ +70.9° (c = 1.833, $CHCl_3$); δ_H (500 MHz, $CDCl_3$) 0.10 and 0.11 (6H total, each s, $Si(CH_3)_2$), 0.90 (9H, s, $SiC(CH_3)_3$), 2.64-2.75 (1H, m, $CHCHF_2$), 3.64 (1H, dd, J = 8.97 and 6.15 Hz, 1 x $CH_2CHOTBDMS$), 3.75 (1H, dd, J = 8.97 and 5.57 Hz, 1 x $CH_2CHOTBDMS$), 3.95 (1H, dd, J = 9.49 and 4.01 Hz, 1 x CH_2CHCHF_2), 4.03 (1H, brt, J = 8.19 Hz, 1 x CH_2CHCHF_2), 4.23 (1H, dd, J = 11.37 and 5.58 Hz, $CHOTBDMS$), 4.39 (1H, t, J = 5.20 Hz, $CHCHOTBDMS$), 4.60 (1H, dd, J = 5.16 and 1.47 Hz, $CHCHCHF_2$), 5.78 (1H, ddd, J = 56.17, 56.06 and 4.82 Hz, CHF_2); δ_C (125 MHz, $CDCl_3$) -5.182 / -4.845 ($Si(CH_3)_2$), 18.362 / 18.410 ($SiC(CH_3)_3$), 25.793 / 25.826 ($SiC(CH_3)_3$), 51.512 / 51.670 and 51.829 ($CHCHF_2$), 68.275 / 68.314 ($CH_2CHOTBDMS$), 72.588 (CH_2CHCHF_2), 73.741 ($CHOTBDMS$), 82.441 / 82.483 / 82.523 and 82.585 ($CHCHCHOTBDMS$), 113.622 / 115.547 and 117.471 (CHF_2).

(iii) Preparation of (3*R*, 3a*S*, 6*R*, 6a*R*)-6-(difluoromethyl)hexahydrofuro[3,2-*b*]furan-3-yl 4-methylbenzenesulfonate (100a). Tetrabutylammonium fluoride solution (1.0M in tetrahydrofuran, 1.38 mL, 1.38 mmol) was added to a stirred solution of (98a) (369 mg, 1.26 mmol) in tetrahydrofuran (1.5 mL). The solution was stirred for 40 minutes then dichloromethane (15 mL) was added. The solution was dried

(Na_2SO_4), filtered and the majority of solvents removed *in vacuo* to leave alcohol (99a) which was used without further purification. HPLC-MS 181.0 $[M + H]^+$.

Pyridine (2.25 mL) then *p*-toluenesulfonyl chloride (956 mg, 5.02 mmol) were added to alcohol (99a) (prepared as above, assumed to be 1.26 mmol). The mixture was stirred under an atmosphere of argon for 20 hours then diluted with water (25 mL). The product was extracted into *tert*-butyl methyl ether (2 x 15 mL) then dried (Na_2SO_4), filtered and reduced *in vacuo* to leave an orange oil (524 mg). Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 0 : 100 to 30 : 70 gave tosylate (100a) as a white solid (306 mg, 73%). TLC (R_f = 0.45, EtOAc : heptane 2 : 3), analytical HPLC main peak, R_t = 13.987 min; HPLC-MS 335.1 $[M + H]^+$, 352.1, 357.1 $[M + Na]^+$, 691.1 $[2M + Na]^+$, $[\alpha]_D^{22}$ +90.7° (c = 2.15, $CHCl_3$); δ_H (500 MHz, $CDCl_3$) 2.44 (3H, s, aryl-C*H*$_3$), 2.63-2.74 (1H, m, C*H*CHF$_2$), 3.78 (1H, brt, *J* = 10.02 Hz, 1 x C*H*$_2$CHCHF$_2$), 3.85 (2H, d, *J* = 5.81 Hz, C*H*$_2$CHOTs), 4.02 (1H, t, *J* = 8.57 Hz, 1 x C*H*$_2$CHCHF$_2$), 4.57 (1H, t, *J* = 4.64 Hz, C*H*CHCHF$_2$), 4.60 (1H, t, *J* = 4.79 Hz C*H*CHOTs), 4.91 (1H, dd, *J* = 10.99 and 5.71 Hz, C*H*OTs), 5.95 (1H, ddd, *J* = 55.92, 55.23 and 7.32 Hz, C*H*F$_2$), 7.34 (2H, brdd, *J* = 8.56 and 0.60 Hz, aromatic CH$_3$CC*H*), 7.82 (2H, brd, *J* = 8.33 Hz, aromatic OSO$_2$CC*H*); δ_C (125 MHz, $CDCl_3$) 21.680 (aryl-*C*H$_3$), 49.136 / 49.315 and 49.493 (*C*HCHF$_2$), 68.625 / 68.698 (*C*H$_2$CHCHF$_2$), 70.936 (*C*H$_2$CHOTs), 78.612 (*C*HOTs), 81.999 / 82.072 (*C*HCHCHF$_2$), 82.301 (*C*HCHOTs), 113.808 / 115.693 / 115.721 and 117.605 (*C*HF$_2$), 127.952 and 129.882 (aromatic *C*H), 133.192 (CHOSO$_2$*C* quaternary), 145.209 (CH$_3$*C* quaternary).

(iv) Preparation of (*R*)-2-((*S*)-2,5-dihydrofuran-2-yl)-3,3-difluoropropyl methanesulfonate (102a). A stirred mixture of lithium bromide (3.17 g, 36.41 mmol) and tosylate (100a) (3.04 g, 9.10 mmol) in dimethylformamide (25 mL) was heated at 120 °C for 3.5 hours under an atmosphere of argon then diluted with water (300 mL). The product was extracted into *tert*-butyl methyl ether (2 x 250 mL) then the combined organic layers washed with water (5 x 200 mL), brine (200 mL), dried (Na_2SO_4), filtered and partially reduced *in vacuo* to leave bromide (101a) as a brown oil (2.08 g) which was used without further purification.

A solution of ammonium chloride (595 mg, 11.13 mmol) in water (7.5 mL) was added to a stirred solution of bromide (101a) (prepared as above, assumed to be 8.56 mmol) in tetrahydrofuran (30 mL) followed by zinc dust (1.11 g, 17.12 mmol). The mixture was stirred for 17.75 hours then filtered through celite *in vacuo*. The filter cake was washed with diethyl ether (250 mL) then the filtrate washed with a mixture of brine : 1M hydrochloric acid (1 : 1, 150 mL). The aqueous layer was re-extracted with diethyl ether (150 mL) then the combined organic layers were washed with brine (100 mL), then dried ($MgSO_4$), filtered and the majority of solvents removed *in vacuo* to leave a yellow oil which was dissolved in dichloromethane (22.5 mL) then cooled to 0 °C.

Triethylamine (4.17 mL, 30.0 mmol) then methanesulfonyl chloride (2.32 mL, 30.0 mmol) were added then the suspension stirred for 40 minutes at 0 °C, then at ambient temperature for 35 minutes. Dichloromethane (200 mL) was added then the mixture washed with water (75 mL), brine (75 mL), dried (Na_2SO_4), filtered and reduced *in vacuo* to leave a residue (2.92 g). Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 0 : 100 to 35 : 65 gave mesylate (102a) as a pale brown oil (1.674 g, 76%). TLC (R_f = 0.32, EtOAc : heptane 2 : 3); HPLC-MS 243.0 $[M + H]^+$, 265.0 $[M + Na]^+$; $[\alpha]_D^{22}$ -40.00° (c = 2.00, $CHCl_3$); δ_H (500 MHz, $CDCl_3$) 2.35-2.45 (1H, m, C*H*CHF_2), 3.01 (3H, s, OSO_2CH_3), 4.39 (2H, d, J = 5.22 CH_2OMs), 4.59-4.69 (2H, m, OCH_2CH=CH), 5.06-5.11 (1H, m, OC*H*CH=CH), 5.83-5.87 and 6.02-6.05 (2H total, m, C*H*=C*H*), 5.97 (1H, dt, J = 55.54 and 4.65 Hz, CHF_2); δ_C (125 MHz, $CDCl_3$) 37.217 (OSO_2CH_3), 47.589 / 47.740 and 47.890 ($CHCHF_2$), 64.770 / 64.818 and 64.858 (CH_2OMs), 75.679 (OCH_2CH=CH), 81.545 / 81.582 and 81.618 (OCHCH=CH), 113.674 / 115.606 and 117.538 (CHF_2), 126.730 and 128.685 (CH=CH).

(v) Preparation of benzyl (*R*)-2-((*S*)-2,5-dihydrofuran-2-yl)-3,3-difluoropropyl carbamate (104a). A stirred mixture of mesylate (102a) (1.67 g, 6.90 mmol), ammonium hydroxide (10 mL) and ammonia in propan-2-ol (2M, 5 mL, 10 mmol) was heated at 70 °C in a sealed tube for 6 hours then stirred at ambient temperature for 16

hours, then heated at 70 °C for 8 hours. The majority of the solvents were removed *in vacuo* then the residue was azeotroped with diethyl ether (3 x 10 mL) to obtain amine (103a) which was used without further purification.

1,4-Dioxan (7.5 mL) then a solution of sodium carbonate (1.83 g, 17.25 mmol) in water (6.5 mL) was added whilst stirring to the crude amine (103a) (prepared as above, assumed to be 6.90 mmol) followed by benzylchloroformate (2.17 mL, 15.18 mmol) over 5 minutes. The mixture was stirred for 65 minutes before adding dichloromethane (30 mL) and water (40 mL). The organic phase was separated and the aqueous re-extracted with dichloromethane (2 x 15 mL). The combined organic layers were washed with brine (20 mL), then dried (Na_2SO_4), filtered and reduced *in vacuo* to leave a brown oil (2.82 g). Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 0 : 100 to 30 : 70 gave benzyl (*R*)-2-((*S*)-2,5-dihydrofuran-2-yl)-3,3-difluoropropylcarbamate (104a) as a colourless oil that contained other components (1.83 g, approximately 85% purity, 76%). TLC (R_f = 0.45, EtOAc : heptane 2 : 3), analytical HPLC main peak, R_t = 13.020 min; HPLC-MS 298.1 $[M + H]^+$, 320.1 $[M + Na]^+$, 617.2 $[2M + Na]^+$, $[\alpha]_D^{22}$ -45.1° (c = 2.108, $CHCl_3$); δ_H (500 MHz, $CDCl_3$) 2.13-2.26 (1H, m, C*H*CHF_2), 3.29-3.36 and 3.49 -3.57 (2H total, m, CH_2NH), 4.58-4.67 (2H, m, CH_2CH=CH), 4.69 (1H, d, *J* = 5.95 Hz, C*H*CH=CH), 5.03-5.17 (3H, m, N*H* and CH_2Ph), 5.82-6.04 (2H total, m, C*H*=C*H*), 5.91 (1H, dt, *J* = 55.89 and 4.84 Hz, C*H*F_2), 7.28-7.37 (5H, m, aromatic-C*H*); δ_C (125 MHz, $CDCl_3$) 36.545 / 36.584 and 36.621 (*C*H_2NH), 47.678 / 47.819 and 47.958 (*C*HCHF_2), 66.799 (*C*H_2Ph), 75.658 (O*C*H_2CH=CH), 83.362 / 83.402 and 83.442 (O*C*HCH=CH), 115.273 / 117.202 and 119.131 (*C*HF_2), 126.964, 127.193, 128.122, 128.157, 128.235, 128.518 and 128.544 (*C*H=*C*H and aromatic *C*H), 136.403 (Cbz quaternary), 156.321 (Cbz *C*=O).

(vi) Preparation of benzyl (*R*)-2-((1*R*, 2*R*, 5*S*)-3,6-dioxabicyclo[3.1.0]hexan-2-yl)-3,3-difluoropropylcarbamate (105a). To a solution of benzyl (*R*)-2-((*S*)-2,5-dihydrofuran-2-yl)-3,3-difluoropropylcarbamate (104a) (1.79 g, 6.03 mmol) in acetonitrile (36 mL) and aqueous Na_2.EDTA (0.4 mmol solution, 36 mL) at 0 °C was added 1,1,1-trifluoroacetone (6.47 mL, 72.3 mmol). To this solution was added in

portions a mixture of sodium bicarbonate (4.25 g, 50.6 mmol) and OXONE® (11.49 g, 18.7 mmol) over a period of 1 hour. The mixture was stirred for 25 minutes then diluted with water (250 mL) and the product extracted into dichloromethane (2 x 150 mL). The combined organic layers were washed consecutively with water (150 mL), aqueous sodium hydrogen sulphite solution (5%, 150 mL) and water (100 mL), then dried (Na_2SO_4), filtered and reduced *in vacuo* to leave a colourless oil (1.62 g). Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 0 : 100 to 40 : 60 gave a mixture of *anti*-(105a) and *syn*-(105a) (approximately 4 : 1 respectively) as a colourless oil (1.11 g, 59%). Data for *anti*-(105a); TLC (R_f = 0.30, EtOAc : heptane 40 : 60), analytical HPLC main peak, R_t = 10.940 min., HPLC-MS 314.1 $[M + H]^+$, 336.1 $[M + Na]^+$, 649.2 $[2M + Na]^+$; δ_H (500 MHz, $CDCl_3$) 2.13-2.27 (1H, m, C*H*CHF_2), 3.30 (1H, dt, J = 14.49 and 6.05 Hz, 1 x CH_2NH), 3.50-3.61 (1H, m, 1 x CH_2NH), 3.73 (1H, d, J = 10.54 Hz, 1 x OCH_2CH), 3.79-3.83 and 3.85-3.89 (2H total, m, OCH_2CHCH), 3.99 (1H, d, J = 10.59 Hz, 1 x OCH_2CH), 4.25 (1H, d, J = 7.38 Hz, OC*H*$CHCHF_2$), 5.05-5.13 (2H, m, CH_2Ph), 5.13 (1H brs, N*H*), 5.91 (1H, dt, J = 55.58 and 3.93 Hz, C*H*F_2), 7.30-7.38 (5H, m, aromatic C*H*); δ_C (125 MHz, $CDCl_3$) 37.341 / 37.383 and 37.423 (CH_2NHCbz), 45.038 / 45.183 and 45.328 ($CHCHF_2$), 56.416 and 58.186 (OCH_2CHCH), 66.982 (CH_2Ph), 67.278 (OCH_2CH), 75.000 / 75.032 and 75.063 ($OCHCHCHF_2$), 114.827 / 116.760 and 118.693 (CHF_2), 128.122, 128.270, 128.414, 128.440, 128.506 and 128.565 (aromatic *C*H), 136.193 (Cbz quaternary), 156.435 (Cbz *C*=O).

(vii) Preparation of (3*R*, 3a*R*, 6*R*, 6a*R*)-benzyl 6-(difluoromethyl)-3-hydroxy tetrahydro-2*H*-furo[3,2-*b*]pyrrole-4(5*H*)-carboxylate (106a). Sodium hydride (60% dispersion in oil, 169 mg, 4.23 mmol) was added over 2 minutes to a solution of a mixture of epoxides (105a) (1.06 g, 3.39 mmol) in tetrahydrofuran (12 mL) at 0 °C. The mixture was stirred for 30 minutes at 0 °C then at ambient temperature for 45 minutes. Dichloromethane (200 mL) was added then the solution was washed with brine (100 mL) dried (Na_2SO_4), filtered and reduced *in vacuo* to leave a pale brown residue (1.16 g). Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 20 : 80 to 50 : 50 gave bicyclic alcohol (106a) as a colourless oil (0.57 g,

54%). TLC (R_f = 0.34, EtOAc : heptane 1 : 1), analytical HPLC single main peak, R_t = 11.545 min., HPLC-MS 314.1 $[M + H]^+$, 336.1 $[M + Na]^+$, 649.2 $[2M + Na]^+$, $[\alpha]_D^{22}$ - 48.5° (c = 2.474, $CHCl_3$); δ_H (500 MHz, $CDCl_3$) mixture of rotamers major : minor 2 : 1; 2.55-2.66 (1H, m, C*H*CHF_2), 3.18-3.27 (1H, m, 1 x CbzNC*H*$_2$), 3.76-3.83 (1.66H, m, 1 x CbzNC*H*$_2$ major and 1 x OC*H*$_2$CHOH), 3.88-3.94 (0.66H, m, 1 x CbzNC*H*$_2$ minor and 1 x OC*H*$_2$CHOH minor), 3.95-4.01 (0.66H, m, 1 x OC*H*$_2$CHOH major), 4.24 (0.66H, brs, CbzNC*H* major), 4.25 (0.33H, brs, CbzNC*H* minor), 4.38 (0.33H, brs, OCH_2CHOH minor), 4.49 (0.66H, brs, OCH_2CHOH major), 4.74 (0.66H, brt, J = 4.28 Hz, C*H*$CHCHF_2$ major), 4.77 (0.33H, brt, J = 4.17 Hz, C*H*$CHCHF_2$ minor), 5.08-5.22 (2H, m, C*H*$_2$Ph), 5.82-6.08 (1H, m, C*H*F_2), 7.31-7.39 (5H, m, aromatic C*H*); δ_C (125 MHz, $CDCl_3$) 45.023 / 45.103 and 45.381 / 45.463 ($CbzNCH_2$), 46.412 / 46.593 and 46.794 / 46.975 / 47.155 (*C*$HCHF_2$), 67.543 (*C*H_2Ph), 70.112 / 71.220 (CbzNCH), 75.039 / 75.138 (OCH_2CHOH), 75.494 / 76.488 (OCH_2CHOH), 80.219 / 80.290 and 81.190 / 81.262 (*C*$HCHCHF_2$), 114.347 / 116.240 / 118.145 and 114.408 / 116.305 / 118.203 (*C*HF_2), 128.052, 128.262, 128.343, 128.413, 128.508, 128.603 and 128.727 (aromatic *C*H), 135.931 / 136.113 (Cbz quaternary), 154.006 / 154.709 (Cbz *C*=O).

(viii) Preparation of (3*R*, 3a*R*, 6*R*, 6a*R*)-(9*H*-fluoren-9-yl)methyl 6-(difluoromethyl)-3-hydroxytetrahydro-2*H*-furo[3,2-*b*]pyrrole-4(5*H*)-carboxylate (2c; $R^2 = CHF_2$). Methanol (4 mL) was added dropwise to a mixture of 10% palladium on charcoal (30 mg) and bicyclic alcohol (106a) (250 mg, 0.80 mmol) under an atmosphere of argon at 0 °C. The argon was replaced by hydrogen then the suspension was stirred at ambient temperature for 50 minutes then filtered through celite *in vacuo*. The filter cake was washed with ethanol (30 mL) then the solvents removed *in vacuo* from the filtrate. The residue was azeotroped with diethyl ether (3 x 10 mL) to obtain the crude (3*R*, 3a*R*, 6*R*, 6a*R*)-6-(difluoromethyl)hexahydro-2*H*-furo[3,2-*b*]pyrrol-3-ol which was used without further purification.

A solution of sodium carbonate (186 mg, 1.76 mmol) in water (1.5 mL) was added whilst stirring to a solution of (3*R*, 3a*R*, 6*R*, 6a*R*)-6-(difluoromethyl)hexahydro-2*H*-furo[3,2-*b*]pyrrol-3-ol (prepared as above, assumed to be 0.80 mmol) in 1,4-dioxan (1.5

mL). A solution of 9-fluorenylmethoxycarbonyl chloride (227 mg, 0.88 mmol) in 1,4-dioxan (1.5 mL) was added then the mixture stirred for 65 minutes then dichloromethane (20 mL) was added and the mixture washed with water (20 mL). The aqueous layer was re-extracted with dichloromethane (2 x 10 mL) then the combined organic layers dried (Na_2SO_4), filtered and reduced *in vacuo* to leave a colourless oil (530 mg). Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 15 : 85 to 50 : 50 gave alcohol (2c: $R^2 = CHF_2$) (296 mg, 93%) as a white solid. TLC (R_f = 0.35, EtOAc : heptane 1 : 1), analytical HPLC single main peak, R_t = 15.861 min., HPLC-MS 402.2 $[M + H]^+$, 424.1 $[M + Na]^+$; $[\alpha]_D^{22}$ -31.1° (c = 1.93, $CHCl_3$); δ_H (500 MHz, $CDCl_3$) mixture of rotamers major : minor 3 : 2; 1.08 (0.6H, d, J = 3.97 Hz, O*H* major), 2.34-2.44 (0.6H, m, C*H*CHF_2 major), 2.52-2.64 (0.4H, m, 2.59 C*H*CHF_2 minor), 2.94 (0.4H, d, J = 3.45 Hz, O*H* minor), 3.01 (0.6H, brt, J = 11.19 Hz, 1 x FmocNCH_2 major), 3.16 (0.4H, brt, J = 11.03 Hz, 1 x FmocNCH_2 minor), 3.45 (0.6H, d, J = 4.44 Hz, FmocNC*H* major), 3.45-3.49 (0.6H, m, OCH_2CHOH major), 3.51 (0.6H, dd, J = 10.06 and 2.36 Hz, 1 x OCH_2CHOH major), 3.65-3.73 (1.6H, m, 1 x FmocNCH_2 and 1 x OCH_2CHOH major), 3.78 (0.4H, dd, J = 9.90 and 2.70 Hz, 1 x OCH_2CHOH minor), 3.93 (0.4H, dd, J = 9.89 and 4.59 Hz, 1 x OCH_2CHOH minor), 4.18-4.24 (1.4H, m, FmocNC*H* minor and Fmoc C*H*), 4.39-4.42 (0.4H, m, OCH_2CHOH minor), 4.42-4.50 (1.4H, m, Fmoc CH_2 minor and OC*H*$CHCHF_2$ major), 4.72 (0.4H, t, J = 4.22 Hz, OC*H*$CHCHF_2$ minor), 4.77 (0.6H, dd, J = 10.83 and 3.68 Hz, 1 x Fmoc CH_2 major), 4.83 (0.6H, dd, J = 10.84 and 3.95 Hz, 1 x Fmoc CH_2 major), 5.67-6.08 (1H, m, C*H*F_2), 7.29-7.81 (8H, Fmoc aromatic C*H*); δ_C (125 MHz, $CDCl_3$) 44.831 / 44.903 and 44.980 (FmocNCH_2), 46.145 / 46.323 / 46.507 and 46.961 (*C*HCHF_2), 47.260 / 47.371 (Fmoc *C*H), 65.802 / 67.564 (Fmoc *C*H_2), 70.444 / 71.146 (FmocN*C*H), 74.723 / 74.965 (OCH_2CHOH), 75.539 / 76.096 (OCH_2CHOH), 80.147 / 80.218 and 80.813 / 80.885 ($OCHCHCHF_2$), 114.312 / 116.210 and 118.110 (*C*HF_2), 119.870, 119.904, 120.055, 124.418, 124.439, 124.851, 124.877, 127.089, 127.485, 127.514, 127.855, 127.945 and 127.953 (Fmoc aromatic *C*H), 141.221, 141.352, 141.371, 141.451, 143.548, 143.657, 143.882 and 143.888 (Fmoc quaternary), 153.765 / 154.652 (Fmoc *C*=O).

(ix) Preparation of (3a*S*, 6*R*, 6a*R*)-(9*H*-fluoren-9-yl)methyl 6-(difluoromethyl)-3-oxotetrahydro-2*H*-furo[3,2-*b*]pyrrole-4(5*H*)-carboxylate (2d: R^2 = CHF_2). Dess-Martin periodinane (539 mg, 1.27 mmol) was added to a stirred solution of alcohol (2c: R^2 = CHF_2) (255 mg, 0.64 mmol) in dichloromethane (5 mL) under an atmosphere of argon. The mixture was stirred for 22 hours then diluted with dichloromethane (20 mL). The organic phase was washed with a mixture of saturated aqueous sodium bicarbonate and 0.25M sodium thiosulphate solution (1 : 1, 10 mL), then saturated aqueous sodium bicarbonate (10 mL), then brine (10 mL), then dried (Na_2SO_4), filtered and reduced *in vacuo*. Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 15 : 85 to 35 : 65 gave ketone (2d: R^2 = CHF_2) (230 mg, 91%) as a white solid. TLC (R_f = 0.38, EtOAc : heptane 1 : 1), analytical HPLC broad main peak, R_t = 15.245 min., HPLC-MS 400.1 $[M + H]^+$, 422.1 $[M + Na]^+$, 440.1 $[M + H_2O + Na]^+$, 821.2 $[2M + Na]^+$; $[\alpha]_D^{22}$ -108.1° (c = 1.988, $CHCl_3$); δ_C (125 MHz, $CDCl_3$); 45.024 / 45.472 ($FmocNCH_2$), 46.719 / 46.904 / 47.132 / 47.229 / 47.427 and 47.607 (Fmoc-*C*H and *C*HCHF_2), 62.336 / 62.822 (FmocNCH), 67.881 / 68.447 (Fmoc-CH_2), 70.718 (OCH_2C=O), 80.453 / 80.523 and 81.449 (O*C*HCHCHF_2), 113.339 / 115.233 and 117.128 (*C*HF_2), 120.013 / 120.165 / 120.294 / 124.321 / 124.894 / 125.091 / 125.364 / 127.065 / 127.118 / 127.234 / 127.796 / 127.872 and 128.042 (Fmoc aromatic *C*H), 141.269, 141.338, 143.498, 143.752 and 144.278 (Fmoc quaternary), 154.580 (Fmoc *C*=O), 206.629 / 206.708 (ketone *C*=O).

Preparation of (3a*S*, 6*S*, 6a*R*)-(9*H*-fluoren-9-yl)methyl 6-(difluoromethyl)-3-oxotetrahydro-2*H*-furo[3,2-*b*]pyrrole-4(5*H*)-carboxylate (2d'; R^1 = CHF_2). Following general schemes 8 and 9.

(i) Preparation of (3*R*, 3a*S*, 6*S*, 6a*R*)-6-(difluoromethyl)hexahydrofuro[3,2-*b*]furan-3-yl 4-methylbenzenesulfonate (100b). Tetrabutylammonium fluoride solution (1.0M in tetrahydrofuran, 2.5 mL, 2.5 mmol) was added to a stirred solution of *tert*-butyl((3*R*, 3a*S*, 6*S*, 6a*R*)-6-(difluoromethyl)hexahydrofuro[3,2-*b*]furan-3-yloxy)dimethylsilane (98b) (666 mg, 2.26 mmol) in tetrahydrofuran (2.5 mL). The solution was stirred for 45 minutes then dichloromethane (25 mL) was added. The solution was dried (Na_2SO_4), filtered and the majority of solvents removed *in vacuo* to

leave alcohol (99b) which was used without further purification. HPLC-MS 181.0 $[M + H]^+$.

Pyridine (5.0 mL) then *p*-toluenesulfonyl chloride (1720 mg, 9.04 mmol) were added to alcohol (99b) (prepared as above, assumed to be 2.26 mmol). The mixture was stirred under an atmosphere of argon for 20 hours then diluted with water (75 mL). The product was extracted into *tert*-butyl methyl ether (3 x 50 mL) then dried (Na_2SO_4), filtered and reduced *in vacuo* to leave an orange oil (680 mg). Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 0 : 100 to 25 : 75 gave tosylate (100b) as a white solid (548 mg, 72.6%). TLC (R_f = 0.55, EtOAc : heptane 1 : 1), analytical HPLC main peak, R_t = 13.16 min; HPLC-MS 335.1 $[M + H]^+$, 352.1, $[M + Na]^+$, 691.0 $[2M + Na]^+$, $[\alpha]_D^{22}$ +66.25° (c = 3.4, $CHCl_3$); δ_H (500 MHz, $CDCl_3$) 2.44 (3H, s, aryl-C*H*$_3$), 2.67-2.77 (1H, m, C*H*CHF$_2$), 3.82-3.85 (2H, m, C*H*$_2$CHOTs), 3.95-3.98 (1H, m, 1 x C*H*$_2$CHCHF$_2$), 4.02-4.08 (1H, m, 1 x C*H*$_2$CHCHF$_2$), 4.53 (1H, t, J = 5.20 Hz, C*H*CHCHF$_2$), 4.61 (1H, b, C*H*CHOTs), 4.84 (1H, dd, J = 11.20 and 5.70 Hz, C*H*OTs), 5.64/5.76/5.87 (0.25, 0.5, 0.25H, ddd, C*H*F$_2$), 7.34 (2H, d, J = 8.00, aromatic CH$_3$CC*H*), 7.82 (2H, d, J = 8.00 Hz, aromatic OSO$_2$CC*H*); δ_C (125 MHz, $CDCl_3$) 21.68 (aryl-*C*H$_3$), 51.17 / 51.33 and 51.49 (*C*HCHF$_2$), 68.57/68.61/68.65 (*C*H$_2$CHCHF$_2$), 69.96 (*C*H$_2$CHOTs), 78.30 (*C*HOTs), 81.07 (*C*HCHOTs), 82.56/82.60/82.64 (*C*HCHCHF$_2$), 113.11 / 115.693 / 115.04/116.97 (*C*HF$_2$), 127.95 /133.19 (aromatic *C*H), 133.192 (CHOSO$_2$*C* quaternary), 145.17 (CH$_3$*C* quaternary).

(ii) Preparation of (*S*)-2-((*S*)-2,5-dihydrofuran-2-yl)-3,3-difluoropropyl methane sulfonate (102b). A stirred mixture of lithium bromide (554 mg, 6.38 mmol) and tosylate (100a) (533 mg, 1.59 mmol) in dimethylformamide (4 mL) was heated at 115 - 120 °C for 6 hours under an atmosphere of argon then reduced in vacuo to leave a tan solid (~ 2.8 g). The residue was partially dissolved in TBME (10 mL) and extracted with water (5 mL). The organic layer was dried (Na_2SO_4), filtered and reduced *in vacuo* to give a mobile tan oil bromide (101b) (384 mg, assuming 1.59 mmol) which was used without further purification.

A solution of ammonium chloride (111 mg, 2.07 mmol) in water (1.5 mL) was added to a stirred solution of bromide (101b) (prepared as above, assumed to be 1.59 mmol) in tetrahydrofuran (6 mL) followed by zinc dust (207 mg, 3.18 mmol). The mixture was stirred for 20 hours then filtered through celite *in vacuo*. The filter cake was washed with diethyl ether (2 x 15 mL mL) then the filtrate washed with a mixture of brine : 1M hydrochloric acid (1 : 1, 15 mL). The combined organic were washed with brine (15 mL), then dried ($MgSO_4$), filtered and the majority of solvents removed *in vacuo* to leave a tan oil (~ 300mg) which was dissolved in dichloromethane (5 mL) then cooled to 0 °C.

Triethylamine (0.78 mL, 5.57 mmol) then methanesulfonyl chloride (0.43 mL, 5.57 mmol) were added then the suspension stirred for 40 minutes at 0 °C, then at ambient temperature for 35 minutes. Dichloromethane (20 mL) was added then the mixture washed with water (10 mL), brine (10 mL), dried (Na_2SO_4), filtered and reduced *in vacuo* to leave a residue (0.6 g). Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 0 : 100 to 20 : 80 gave mesylate (102b) as a clear oil (239 mg, 62%). TLC (R_f = 0.45, EtOAc : heptane 1: 1); HPLC-MS 243.1 $[M + H]^+$, 265.0 $[M + Na]^+$; $[\alpha]_D^{22}$ -62.5° (c = 1.76, $CHCl_3$); δ_C (125 MHz, $CDCl_3$) 37.29 (OSO_2CH_3), 47.28 / 47.43 and 47.57 ($CHCHF_2$), 64.38 / 64.41 / 64.43 and 64.46 (CH_2OMs), 75.44 ($OCH_2CH=CH$), 81.88 / 81.91 / 81.92 and 81.95 ($OCHCH=CH$), 113.40 / 115.33 and 117.27 (CHF_2), 126.22 / 126.33 and 128.95 ($CH=CH$).

(iii) Preparation of benzyl (*S*)-2-((*S*)-2,5-dihydrofuran-2-yl)-3,3-difluoropropyl carbamate (104b). A stirred mixture of mesylate (102b) (239 mg, 0.99 mmol), ammonium hydroxide (2 mL) and ammonia in propan-2-ol (2M, 1 mL, 2 mmol) was heated at 70 °C in a sealed tube for 6 hours then stirred at ambient temperature for 16 hours and this cycle repeated for 4 days. The majority of the solvents were removed *in vacuo* then the residue was azeotroped with diethyl ether (3 x 5 mL) to obtain amine (103b) which was used without further purification.

1,4-Dioxan (1 mL) then a solution of sodium carbonate (264 mg, 2.5 mmol) in water (1 mL) was added whilst stirring to the crude amine (103b) (prepared as above, assumed to be 0.99 mmol) followed by benzylchloroformate (0.313 mL, 2.2 mmol) in 1,4-dioxan (1 mL) over 5 minutes. The mixture was stirred for 1 hour before adding dichloromethane (10 mL) and water (10 mL). The organic phase was separated and the aqueous re-extracted with dichloromethane (10 mL). The combined organic layers were washed with brine (10 mL), then dried (Na_2SO_4), filtered and reduced *in vacuo* to leave a tan oil (0.6 g). Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 0 : 100 to 7.5 : 92.5 gave benzyl (*S*)-2-((*S*)-2,5-dihydrofuran-2-yl)-3,3-difluoropropylcarbamate (104b) as a colourless oil that contained other components (151 mg, approximately 85% purity, 50%). TLC (R_f = 0.56, EtOAc : heptane 1 : 1), analytical HPLC main peak, R_t = 13.38 min; HPLC-MS 298.1 $[M + H]^+$, 320.1 $[M + Na]^+$, 617.2 $[2M + Na]^+$, $[\alpha]_D^{22}$ -63.7° (c = 1.57, $CHCl_3$); δ_C (125 MHz, $CDCl_3$) 36.70 / 36.74 and 36.78 (CH_2NH), 47.44 / 47.58 and 47.72 ($CHCHF_2$), 66.82 (CH_2Ph), 75.36 ($OCH_2CH=CH$), 83.41 / 83.44 / 83.46 and 83.49 ($OCHCH=CH$), 114.98 / 116.91 and 118.83 (CHF_2), 126.97, 128.03, 128.11, 128.16, 128.35, 128.47 and 128.52 ($CH=CH$ and aromatic CH), 136.39 (Cbz quaternary), 156.34 (Cbz $C=O$).

(iv) Preparation of benzyl (*S*)-2-((1*R*, 2*R*, 5*S*)-3,6-dioxabicyclo[3.1.0]hexan-2-yl)-3,3-difluoropropylcarbamate (105b). To a solution of alkene (104b) (147 mg, 0.49 mmol) in acetonitrile (3.6 mL) and aqueous Na_2.EDTA (0.04 mmol solution, 3.6 mL) at 0 °C was added 1,1,1-trifluoroacetone (0.53 mL, 5.9 mmol). To this solution was added in portions a mixture of sodium carbonate (0.352 g, 4.2 mmol) and OXONE® (0.942 g, 1.53 mmol) over a period of 1 hour. The mixture was stirred for 25 minutes then diluted with water (25 mL) and the product extracted into dichloromethane (3 x 25 mL). The combined organic layers were washed consecutively with water (150 mL), aqueous sodium hydrogen sulphite solution (5%, 25 mL) and brine (25 mL), then dried (Na_2SO_4), filtered and reduced *in vacuo* to leave a colourless oil (0.19 g), used without further purification. HPLC-MS 314.1 $[M + H]^+$, 336.1 $[M + Na]^+$.

(v) Preparation of (3*R*, 3a*R*, 6*S*, 6a*R*)-benzyl 6-(difluoromethyl)-3-hydroxy tetrahydro-2*H*-furo[3,2-*b*]pyrrole-4(5*H*)-carboxylate (106b). Sodium hydride (60% dispersion in oil, 26 mg, 0.64 mmol) was added over 2 minutes to a solution of a mixture of epoxides (105b) (190 mg, ~0.49 mmol) in tetrahydrofuran (3 mL) at 0 °C. The mixture was stirred for 10 minutes at 0 °C then at ambient temperature for 3 hour. Dichloromethane (25 mL) was added then the solution was washed with brine (25 mL) dried (Na_2SO_4), filtered and reduced *in vacuo* to leave a yellow oil (0.18 g). Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 5 : 95 to 30 : 70 gave bicyclic alcohol (106b) as an opaque gum (74.2 mg, 48%). TLC (R_f = 0.48, EtOAc : heptane 2 : 1), analytical HPLC single main peak, R_t = 10.81 min., HPLC-MS 314.1 $[M + H]^+$, 336.1 $[M + Na]^+$, 649.2 $[2M + Na]^+$, $[\alpha]_D^{22}$ -37.1° (c = 7.42, $CHCl_3$); δ_C (125 MHz, $CDCl_3$) 44.79 / 45.23 ($CbzNCH_2$), 47.12 / 47.27 / 47.86 / 48.02 and 48.18 ($CHCHF_2$), 67.45 / 67.60 / 67.89 (CH_2Ph), 69.63 / 70.57 (CbzNCH), 73.95 (OCH_2CHOH), 76.63 / 76.73 (OCH_2CHOH), 80.88 / 81.79 ($CHCHCHF_2$), 113.28 / 115.21 / 115.31 and 117.15 (CHF_2), 127.89, 127.93, 128.25, 128.32, 128.43, 128.53, 128.58, 128.71 and 128.78 (aromatic CH), 136.08 (Cbz quaternary), 154.11 / 154.97 (Cbz C=O).

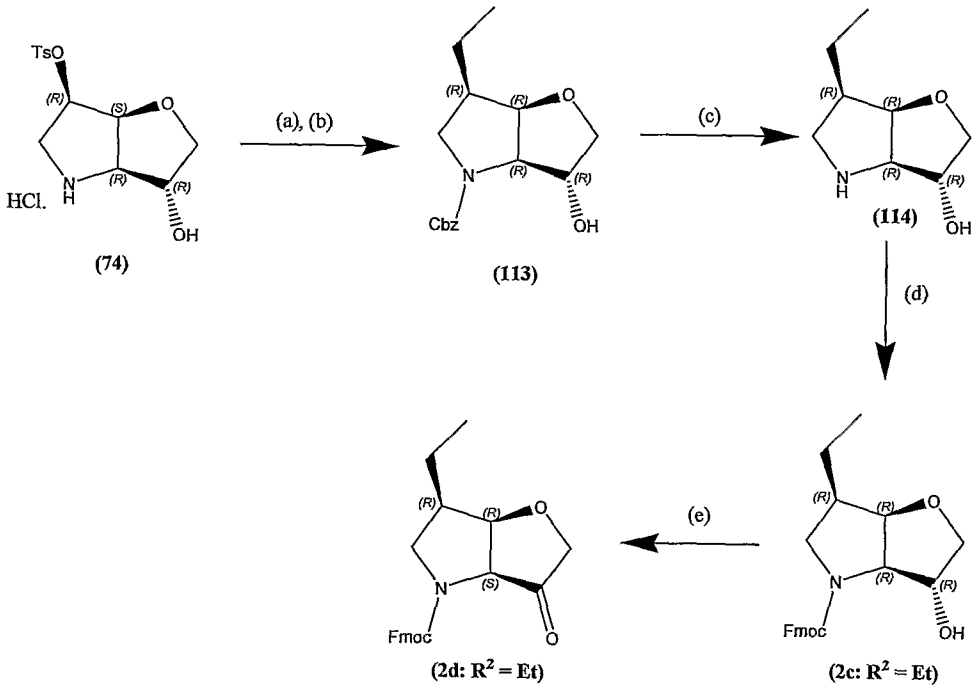
(vi) Preparation of (3*R*, 3a*R*, 6*S*, 6a*R*)-(9*H*-fluoren-9-yl)methyl 6-(difluoromethyl)-3-hydroxytetrahydro-2*H*-furo[3,2-*b*]pyrrole-4(5*H*)-carboxylate (2c'; R^1 = CHF_2). Methanol (2 mL) was added dropwise to a mixture of 10% palladium on charcoal (25 mg) and alcohol (106b) (69 mg, 0.22 mmol) under an atmosphere of argon at 0 °C. The argon was replaced by hydrogen then the suspension was stirred at ambient temperature for 1 hour then filtered through celite *in vacuo*. The filter cake was washed with ethanol (3 x 10 mL) then the solvents removed *in vacuo* from the filtrate. The residue was azeotroped with diethyl ether (3 x 10 mL) to obtain the crude (3*R*, 3a*R*, 6*S*, 6a*R*)-6-(difluoromethyl)hexahydro-2*H*-furo[3,2-*b*]pyrrol-3-ol which was used without further purification.

A solution of sodium carbonate (40 mg, 0.46 mmol) in water (2 mL) was added whilst stirring to a solution of (3*R*, 3a*R*, 6*S*, 6a*R*)-6-(difluoromethyl)hexahydro-2*H*-furo[3,2-*b*]pyrrol-3-ol (prepared as above, assumed to be 0.22 mmol) in 1,4-dioxan (2 mL). A

solution of 9-fluorenylmethoxycarbonyl chloride (62 mg, 0.23 mmol) in 1,4-dioxan (1 mL) was added then the mixture stirred for 10 minutes and stirred at ambient temperature for 1 hour. Dichloromethane (25 mL) was added and the mixture washed with brine / pH 5.5 HCl (1 : 1, 20 mL). The aqueous layer was re-extracted with dichloromethane (2 x 15 mL) then the combined organic layers dried (Na_2SO_4), filtered and reduced *in vacuo* to leave a colourless gum (110 mg). Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 10 : 90 to 30 : 70 gave alcohol (2c'; $R^1 = CHF_2$) (65.2 mg, 74.2%) as a white solid. TLC (R_f = 0.40, EtOAc : heptane 2 : 1), analytical HPLC single main peak, R_t = 15.31 min., HPLC-MS 402.2 $[M + H]^+$, 424.2 $[M + Na]^+$; $[\alpha]_D^{22}$ -36.4° (c = 5.9, $CHCl_3$); δ_C (125 MHz, $CDCl_3$) 44.57 / 44.78 ($FmocNCH_2$), 46.88 / 47.04 / 47.20 / 47.29 / 47.50 / 48.02 ($CHCHF_2$ and Fmoc *C*H), 65.65 / 67.33 (Fmoc CH_2), 69.63 / 70.38 (FmocNCH), 73.64 / 73.93 (OCH_2CHOH), 76.54 / 76.73 (OCH_2CHOH), 80.82 / 81.41 and 81.45 ($OCHCHCHF_2$), 113.20, 115.14, 117.07 (CHF_2), 119.89, 119.92, 120.02, 124.41, 124.48, 124.89, 127.07, 127.47, 127.53, 127.80 and 127.95 (Fmoc aromatic *C*H), 141.19, 141.35, 141.42, 143.53, 143.72, 143.79 and 143.84 (Fmoc quaternary), 153.91 / 154.78 (Fmoc *C*=O).

(vii) Preparation of (3a*S*, 6*S*, 6a*R*)-(9*H*-fluoren-9-yl)methyl 6-(difluoromethyl)-3-oxotetrahydro-2*H*-furo[3,2-*b*]pyrrole-4(5*H*)-carboxylate (2d'; $R^1 = CHF_2$). Dess-Martin periodinane (125 mg, 0.294 mmol) was added to a stirred solution of alcohol (2c'; $R^1 = CHF_2$) (59 mg, 0.147 mmol) in dichloromethane (3 mL) under an atmosphere of argon. The mixture was stirred for 20 hours then diluted with dichloromethane (20 mL). The organic phase was washed with a mixture of saturated aqueous sodium bicarbonate and 0.25M sodium thiosulphate solution (1 : 1, 20 mL), then saturated aqueous sodium bicarbonate (20 mL), then brine (20 mL), then dried (Na_2SO_4), filtered and reduced *in vacuo*. Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 10 : 90 to 25 : 75 gave ketone (2d'; $R^1 = CHF_2$) (44 mg, 75%) as a white solid. TLC (R_f = 0.45, EtOAc : heptane 1 : 1), analytical HPLC broad main peak, R_t = 14.7-17.1 min., HPLC-MS 222.1, 400.1 $[M + H]^+$, 422.1 $[M + Na]^+$, 821.2 $[2M + Na]^+$; $[\alpha]_D^{22}$ -125.6° (c = 3.9, $CHCl_3$); δ_C (125 MHz, $CDCl_3$); 44.80 / 45.34 ($FmocNCH_2$), 47.18 / and 48.26 (Fmoc-*C*H and $CHCHF_2$), 61.54 / 61.87 (FmocNCH),

67.69 / 68.07 / 68.36 (Fmoc-CH_2), 70.05 (OCH_2C=O), 80.41 / 81.27 ($OCHCHCHF_2$), 102.76 ($C(OH)_2$, hydrate), 114.20 / 115.10 and 117.10 (CHF_2), 119.94 / 120.08 / 124.89 / 125.15 / 125.28 / 127.07 / 127.10 / 127.71 / 127.74 and 127.90 (Fmoc aromatic *C*H), 141.33 / 143.57 (Fmoc quaternary), 154.68 (Fmoc *C*=O), 207.83 (ketone *C*=O).



Scheme 10 (a) EtMgBr in Et_2O, Cu(I)Br, LiCl, THF; (b) Cbz-Cl, Na_2CO_3, dioxan, H_2O; (c) Pd-C, H_2, methanol; (d) Fmoc-Cl, Na_2CO_3, dioxan, H_2O; (e) Dess-Martin periodinane, DCM.

Preparation of (3*R*, 3a*R*, 6*R*, 6a*R*)-Benzyl 3-hydroxy-6-ethyltetrahydro-2*H*-furo [3,2-*b*]pyrrole-4(5*H*)-carboxylate (113)

A solution of ethylmagnesium bromide (3M in diethyl ether, 2 mL, 6 mmol) was added dropwise over 2 minutes to a stirred suspension of copper(I) bromide (428 mg, 2.98 mmol) and lithium chloride (253 mg, 5.96 mmol) in tetrahydrofuran (3 mL) at -50 °C. The mixture was stirred for 1.5 hours at ≤ -45 °C then (3*R*, 3a*R*, 6*R*, 6a*S*)-3-hydroxyhexahydro-2*H*-furo[3,2-*b*]pyrrol-6-yl 4-methylbenzenesulfonate hydrochloride (74) (250 mg, 0.745 mmol) was added. The mixture was allowed to warm to 10 °C

over 3.75 hours then water (5 mL) followed by a solution of sodium carbonate (223 mg, 2.10 mmol) in water (2.5 mL) were added. The mixture was stirred for 20 minutes then benzyl chloroformate (0.262 mL, 1.84 mmol) was added. The mixture was stirred for 50 minutes at 10 °C then water (25 mL) and dichloromethane (20 mL) were added. The mixture was filtered through celite then the filter cake washed with water (5 mL) and dichloromethane (10 mL). The organic layer was separated then the aqueous layer extracted with dichloromethane (2 x 10 mL). The combined organic layers were washed with brine (10 mL), dried (Na_2SO_4), filtered and reduced *in vacuo* to leave a red-brown oil (323 mg). Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 10 : 90 to 60 : 40 gave alcohol (113) (117 mg, 54%) as a pale brown oil. TLC (R_f = 0.30, EtOAc : heptane 2 : 1), analytical HPLC main peak, R_t = 15.172 min., HPLC-MS 292.2 $[M + H]^+$, 605.3 $[2M + Na]^+$; $[\alpha]_D^{23}$ -44.0° (c = 1.136, $CHCl_3$); δ_H (500 MHz, $CDCl_3$) mixture of rotamers major : minor 3 : 2; 0.96 (1.8H, t, J = 7.46 Hz, CH_3CH_2 major), 0.97 (1.2H, t, J = 7.45 Hz, CH_3CH_2 minor), 1.41-1.67 (2H, m, CH_3CH_2), 1.93-2.03 (1H, m, CH_3CH_2CH), 2.20 (0.4H, brs, OH minor), 2.83-2.91 (1H, m, 1 x $CbzNCH_2$), 2.99 (0.6H, brs, OH major), 3.68-3.89 (2.4H, m, 1 x $CbzNCH_2$ and 1.4 x OCH_2CHOH), 3.92 (0.6H, dd, J = 9.82 and 4.74 Hz, 1 x OCH_2CHOH major), 4.16-4.19 (1H, m, CbzNCH), 4.32 (0.4H, brs, OCH_2CHOH minor), 4.44 (0.6H, m, OCH_2CHOH major), 4.57-4.62 (1H, m, CH_3CH_2CHCH), 5.07-5.21 (2H, m, CH_2Ph), 7.29-7.39 (5H, m, Cbz CH); δ_C (125 MHz, $CDCl_3$) 12.408 (CH_3CH_2), 19.958 / 20.007 (CH_3CH_2), 44.750 / 45.077 (CH_3CH_2CH), 50.095 / 50.405 ($CbzNCH_2$), 67.113 / 67.216 (CH_2Ph), 69.996 / 71.055 (CbzNCH), 74.393 / 74.561 (OCH_2CHOH), 76.339 (OCH_2CHOH), 82.119 / 83.046 (CH_3CH_2CHCH), 127.941, 127.965, 128.125, 128.249, 128.524 and 128.679 (aromatic CH), 136.418 (Cbz quaternary), 154.887 (Cbz C=O).

Preparation of (3*R*,3*aR*,6*R*,6*aR*)-6-ethylhexahydro-2*H*-furo[3,2-*b*]pyrrol-3-ol (114)

Methanol (2.0 mL) was added dropwise to a mixture of 10% palladium on charcoal (10 mg) and alcohol (113) (105 mg, 0.36 mmol) under an atmosphere of argon. The argon was replaced by hydrogen then the suspension was stirred for 75 mins before filtering the mixture through celite *in vacuo*. The filter cake was washed with ethanol (3 x 10 mL) then the solvents removed *in vacuo* from the filtrate. The residue was azeotroped with toluene (2 x 3 mL) to obtain free base which was used without further purification.

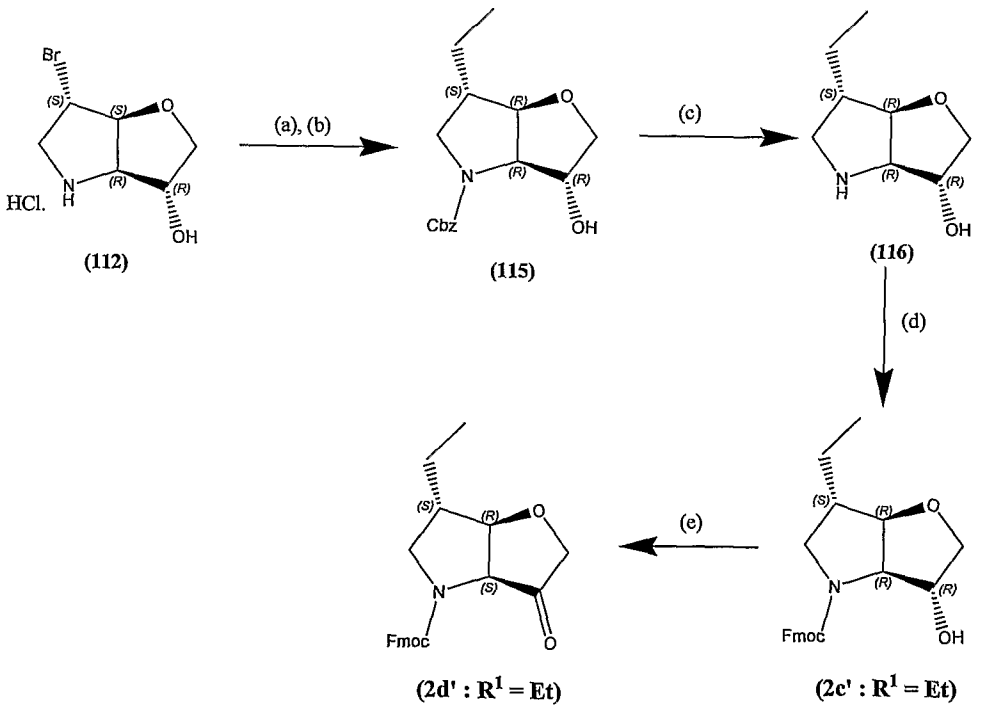
Preparation of (3*R*,3*aR*,6*R*,6*aR*)-(9*H*-fluoren-9-yl)methyl 6-ethyl-3-hydroxytetrahydro-2*H*-furo[3,2-*b*]pyrrole-4(5*H*)-carboxylate (2c: R^2 = Et)

A solution of sodium carbonate (80.1 mg, 0.756 mmol) in water (2.0 mL) was added to an ice-cooled and stirred solution of aminoalcohol (114) (assuming 0.36 mmol) in 1,4-dioxan (2.0 mL). A solution of 9-fluorenylmethoxycarbonyl chloride (101 mg, 0.378 mmol) in 1,4-dioxan (1.0 mL) was added over 10 mins then the mixture stirred for 1 hour at ambient temperature. The mixture was diluted with dichloromethane (20 mL) and washed with 0.1N HCl (20 mL) then brine (20 mL). The organic layer was dried (Na_2SO_4), filtered and reduced *in vacuo* to leave a yellow oil (237 mg). Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 5 : 95 to 40 : 60 gave desired alcohol (2c: R^2 = Et) as a clear gum (Yield 120.0 mg, 0.316 mmol, 87.8 %). TLC (R_f = 0.35, EtOAc : heptane 1 : 1), analytical HPLC single main peak, R_t = 18.96 min., HPLC-MS 380.2 $[M + H]^+$, 402.2 $[M + Na]^+$; $[\alpha]_D^{22}$ -30.7° (c = 5.7, $CHCl_3$); δ_C (125 MHz, $CDCl_3$) mixture of approximately 1 : 1 rotamers, 12.33 / 12.41 (CH_2CH_3), 19.90 / 19.94 / 22.67 (CH_2CH_3), 44.48 / 45.06 ($CHCH_2CH_3$), 47.32 / 47.45 (Fmoc *C*H), 49.95 / 49.98 (FmocNCH_2), 65.57 / 67.28 (Fmoc CH_2), 70.24 / 71.03 (FmocN*C*H), 74.22 / 74.35 (OCH_2CHOH), 76.37 (OCH_2CHOH), 82.06 / 82.74 ($OCHCHCH_3$), 119.87, 119.90, 119.99, 124.44, 124.47, 124.95, 124.97, 127.02, 127.04, 127.42, 127.74, 127.75, 127.83 and 127.88 (Fmoc aromatic *C*H), 141.25, 141.34, 141.36, 141.43, 143.77, 143.89, 143.98 and 144.05 (Fmoc quaternary), 153.95 / 154.85 (Fmoc *C*=O).

Preparation of (3*R*,3*aR*,6*R*,6*aR*)-(9*H*-fluoren-9-yl)methyl 6-ethyl-3-oxytetrahydro-2*H*-furo[3,2-*b*]pyrrole-4(5*H*)-carboxylate (2d: R^2 = Et)

Dess-Martin periodinane (257 mg, 0.606 mmol) was added to a stirred solution of alcohol (2c: R^2 = Et) (115 mg, 0.303 mmol) in dichloromethane (5 mL) under an atmosphere of argon. The mixture was stirred for 4 hours then diluted with dichloromethane (20 mL). The organic phase was washed with a mixture of saturated aqueous sodium bicarbonate and 0.25M sodium thiosulphate solution (1 : 1, 20 mL), then a mixture of saturated aqueous sodium bicarbonate and brine (1 : 1, 20 mL), then dried (Na_2SO_4), filtered and reduced *in vacuo*. Flash chromatography over silica,

eluting with ethyl acetate : heptane mixtures 10 : 90 to 40 : 60 gave ketone (2d: R^2 = Et) (108.4 mg, 0.287 mmol, 94.8%) as a white solid. TLC (R_f = 0.40, EtOAc : heptane 1 : 1), analytical HPLC broad main peak, R_t = 18.50-21.09 min., HPLC-MS 378.2 $[M + H]^+$, 400.2 $[M + Na]^+$, 418.2 $[M + H_2O + Na]^+$, 777.2 $[2M + Na]^+$; $[\alpha]_D^{22}$ -130.0° (c = 1.0, $CHCl_3$); δ_H (500 MHz, $CDCl_3$) mixture of rotamers 1 : 1; 1.01 (3H, t, J = 7.45 Hz, CH_3CH_2), 1.50-1.70 (2H, b, CH_3CH_2), 2.09 (1H, m, CH_3CH_2CH), 3.08 (1H, q, J = 11.20 Hz, 1 x FmocNCH_2), 3.77 (0.5H, brt, 0.5 x FmocNCH_2), 3.90-4.00 (1.5 H, m, 0.5 x FmocNCH_2 and 1 x OCH_2C=O), 4.15-4.58 (5H, m, 1 x OCH_2C=O, FmocNCH, Fmoc-CH_2 and Fmoc-CH), 4.72 / 4.77 (1H, brs, 2 x 0.5 OCHCHCH$_2$CH$_3$), 7.30-7.79 (8H, Fmoc aromatic CH); δ_C (125 MHz, $CDCl_3$); 12.40 (CH_3CH_2), 18.87 (CH_3CH_2), 45.12 / 45.61 (CH_3CH_2CH), 47.19 / 47.29 (Fmoc-CH), 49.91 / 50.24 (FmocNCH$_2$), 62.59 / 63.05 (FmocNCH), 67..57 / 68.23 (Fmoc-CH_2), 70.96 (OCH$_2$C=O), 82.21 / 83.20 (OCHCHCH$_2$CH$_3$), 119.88 / 119.94 / 120.04 / 124.98 / 125.16 / 125.49 / 127.05 / 127.69 and 127.77 (Fmoc aromatic CH), 141.24, 141.32, 143.66, 143.76, 144.01 and 144.50 (Fmoc quaternary), 154.85 (Fmoc C=O), 208.69 / 208.82 (ketone C=O).



Scheme 11 (a) EtMgBr in Et_2O, Cu(I)Br, LiCl, THF; (b) Cbz-Cl, Na_2CO_3, dioxan, H_2O; (c) Pd-C, H_2, methanol; (d) Fmoc-Cl, Na_2CO_3, dioxan, H_2O; (e) Dess-Martin periodinane, DCM.

Preparation of (3*R*, 3a*R*, 6*S*, 6a*R*)-Benzyl 6-ethyl-3-hydroxytetrahydro-2*H*-furo[3,2-*b*]pyrrole-4(5*H*)-carboxylate (115)

A solution of ethylmagnesium bromide (3M in diethyl ether, 1.51 mL, 4.52 mmol) was added dropwise over 4 minutes to a stirred suspension of copper(I) bromide (324 mg, 2.26 mmol) and lithium chloride (191 mg, 4.52 mmol) in tetrahydrofuran (2.25 mL) at -50 °C. The mixture was stirred for 1.5 hours at ≤ -45 °C then (3*R*, 3a*R*, 6*S*, 6a*S*)-6-bromohexahydro-2*H*-furo[3,2-*b*]pyrrol-3-ol hydrochloride (112) (138 mg, 0.564 mmol) was added. The mixture was allowed to warm to 0 °C over 2.75 hours then a solution of sodium carbonate (169 mg, 1.59 mmol) in water (3.75 mL) was added. The mixture was stirred for 20 minutes then benzyl chloroformate (0.198 mL, 1.39 mmol) was added. The mixture was stirred for 1.25 hours at ≤ 10 °C then water (20 mL) and dichloromethane (15 mL) were added. The mixture was filtered through celite then the filter cake washed with dichloromethane (15 mL). The organic layer was separated then the aqueous layer extracted with dichloromethane (2 x 10 mL). The combined organic layers were washed with brine (10 mL), dried (Na_2SO_4), filtered and reduced *in vacuo* to leave an oily residue (289 mg). Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 10 : 90 to 40 : 60 gave alcohol (115) (62 mg, 38%) as a colourless oil. TLC (R_f = 0.30, EtOAc : heptane 2 : 1), analytical HPLC main peak, R_t = 14.752 min., HPLC-MS 292.2 $[M + H]^+$, 605.3 $[2M + Na]^+$; $[\alpha]_D^{23}$ -49.5° (c = 0.707, $CHCl_3$); δ_H (500 MHz, $CDCl_3$) mixture of rotamers major : minor 2 : 1; 0.91-0.96 (3H, m, C*H*$_3$CH$_2$), 1.15-1.39 (2H, m, CH$_3$C*H*$_2$), 2.05 (0.33H, d, *J* = 4.02 Hz, O*H* minor), 2.07-2.14 (1H, m, CH$_3$CH$_2$C*H*), 2.98 (0.66H, d, *J* = 2.99 Hz, O*H* major), 3.34-3.95 (4H, m, CbzNC*H*$_2$ and OC*H*$_2$CHOH), 3.98-4.04 (1H, m, CbzNC*H*), 4.30-4.34 (0.33H, m, OCH$_2$C*H*OH minor), 4.40-4.45 (1.66H, m, CH$_3$CH$_2$CHC*H* and OCH$_2$C*H*OH major), 5.08-5.25 (2H, m, C*H*$_2$Ph), 7.30-7.38 (5H, m, Cbz C*H*); δ_C (125 MHz, $CDCl_3$) 11.972 (*C*H$_3$CH$_2$), 24.415 / 24.473 (CH$_3$*C*H$_2$), 44.784 / 45.425 (CH$_3$CH$_2$*C*H), 50.076 (CbzNCH$_2$), 67.135 / 67.334 (*C*H$_2$Ph), 68.554 / 69.637 (CbzNCH), 73.971 (OCH$_2$CHOH), 76.524 / 77.198 (OCH$_2$*C*HOH), 86.110 / 87.015 (CH$_3$CH$_2$*C*HCH),

127.766, 127.944, 128.104, 128.316, 128.530 and 128.734 (aromatic *C*H), 136.370 / 136.418 (Cbz quaternary), 154.552 / 155.520 (Cbz *C*=O).

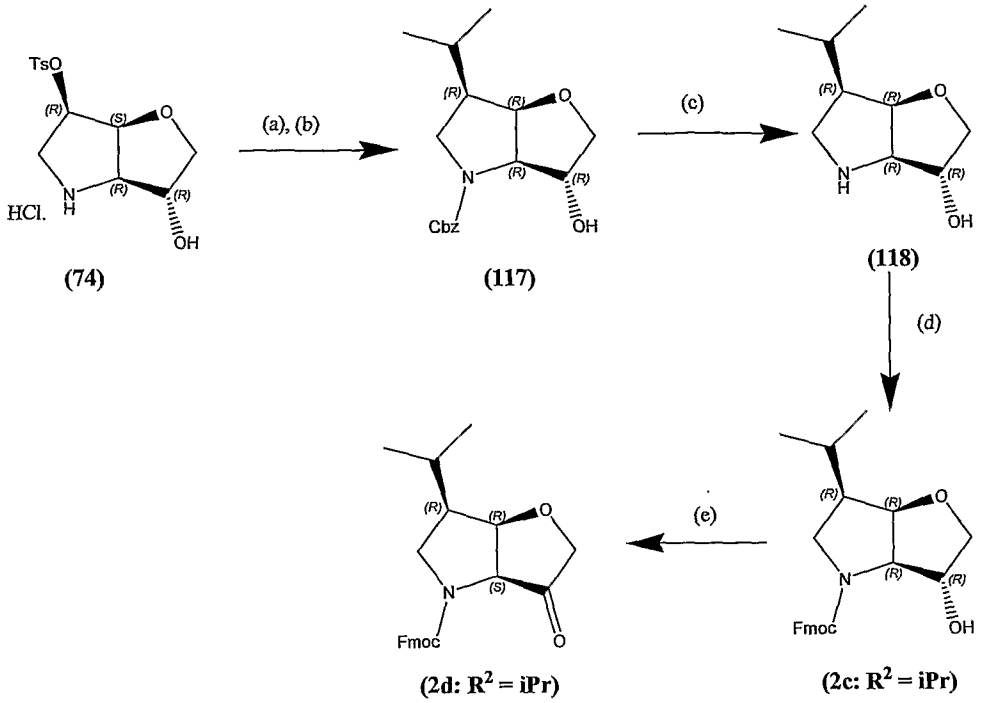
Preparation of (3*R*, 3a*R*, 6*S*, 6a*R*)-(9*H*-Fluoren-9-yl)methyl 6-ethyl-3-hydroxytetrahydro-2*H*-furo[3,2-*b*]pyrrole-4(5*H*)-carboxylate (2c': R^1 = Et)

Methanol (0.6 mL) was added dropwise to a mixture of 10% palladium on charcoal (26 mg) and alcohol (115) (55 mg, 0.189 mmol) under an atmosphere of argon. The argon was replaced by hydrogen then the suspension was stirred for 1.5 hours then filtered through celite *in vacuo*. The filter cake was washed with ethanol (8 mL) then the solvents removed *in vacuo* from the filtrate. The residue was azeotroped with diethyl ether (3 x 2 mL) to obtain the crude aminoalcohol (116) which was used without further purification.

A solution of sodium carbonate (42 mg, 0.397 mmol) in water (0.5 mL) was added whilst stirring to a solution of aminoalcohol (116) (assumed to be 0.189 mmol) in 1,4-dioxan (0.2 mL). A solution of 9-fluorenylmethoxycarbonyl chloride (51 mg, 0.199 mmol) in 1,4-dioxan (0.3 mL) was added then the mixture stirred for 50 miutes then dichloromethane (10 mL) was added and the mixture washed with water (10 mL). The aqueous layer was reextracted with dichloromethane (2 x 5 mL) then the combined organic layers dried (Na_2SO_4), filtered and reduced *in vacuo* to leave a pale yellow oil (107 mg). Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 10 : 90 to 50 : 50 gave alcohol (2c': R^1 = Et) (60 mg, 84%) as a colourless oil. TLC (R_f = 0.38, EtOAc : heptane 2 : 1), analytical HPLC single main peak, R_t = 18.651 min., HPLC-MS 380.2 $[M + H]^+$, 402.2 $[M + Na]^+$, 781.3 $[2M + Na]^+$; $[\alpha]_D^{22}$ -23.9° (c = 0.628, $CHCl_3$); δ_C (125 MHz, $CDCl_3$) 11.843 / 11.991 (CH_2CH_3), 24.143 / 24.396 (CH_2CH_3), 44.409 / 45.428 ($CHCH_2CH_3$), 47.318 / 47.596 (Fmoc *C*H), 49.564 / 49.787 (FmocNCH_2), 65.452 / 67.096 (Fmoc CH_2), 68.641 / 69.452 (FmocN*C*H), 73.657 / 73.958 (OCH_2CHOH), 76.469 / 76.746 (OCH_2CHOH), 86.056 / 86.593 ($OCHCHCH_2CH_3$), 119.897, 119.916, 120.002, 124.437, 124.491, 124.923, 126.997, 127.010, 127.406, 127.431, 127.731, 127.747, 127.851 and 127.896 (Fmoc aromatic

*C*H), 141.253, 141.354, 141.378, 141.424, 143.752, 143.804, 143.925 and 143.997 (Fmoc quaternary), 154.405 / 155.366 (Fmoc *C*=O).

Preparation of (3*R*,3*aR*,6*S*,6*aR*)-(9*H*-fluoren-9-yl)methyl 6-ethyl-3-oxytetrahydro-2*H*-furo[3,2-*b*]pyrrole-4(5*H*)-carboxylate (2d': R^1 = Et). Dess-Martin periodinane (120 mg, 0.284 mmol) was added to a stirred solution of alcohol (2c': R^1 = Et) (54 mg, 0.142 mmol) in dichloromethane (4 mL) under an atmosphere of argon. The mixture was stirred for 2 hours then diluted with dichloromethane (20 mL). The organic phase was washed with a mixture of saturated aqueous sodium bicarbonate and 0.25M sodium thiosulphate solution (1 : 1, 20 mL), then a mixture of saturated aqueous sodium bicarbonate and brine (1 : 1, 20 mL), then dried (Na_2SO_4), filtered and reduced *in vacuo*. Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 10 : 90 to 40 : 60 gave ketone (2d': R^1 = Et) (44.2 mg, 0.117 mmol, 82.4%) as a clear gum. TLC (R_f = 0.35, EtOAc : heptane 1 : 1), analytical HPLC broad main peak, R_t = 18.20-20.65 min., HPLC-MS 378.2 $[M + H]^+$, 400.2 $[M + Na]^+$, 777.2 $[2M + Na]^+$; $[\alpha]_D^{22}$ -127.5° (c = 1.0, $CHCl_3$); δ_H (500 MHz, $CDCl_3$) mixture of rotamers 1 : 1; 0.90-1.02 (3H, bm, C*H*$_3$CH$_2$), 1.51-1.70 (2H, b, CH$_3$C*H*$_2$), 2.15-2.21 (1H, m, CH$_3$CH$_2$C*H*), 3.35-3.40 / 3.48-3.61 (1.5H, 1.5 x FmocNC*H*$_2$), 3.93-3.99 (1H, t, OC*H*$_2$C=O), 4.11-4.32 (3.5H, m, 1 x OC*H*$_2$C=O, 0.5 x FmocNC*H*$_2$ and 2 x Fmoc-C*H*$_2$), 4.42-4.62 (3H, m, Fmoc-C*H*, OC*H*CHCH$_2$CH$_3$ and FmocNC*H*), 7.28-7.78 (8H, Fmoc aromatic C*H*); δ_C (125 MHz, $CDCl_3$); 11.85 / 11.95 (*C*H$_3$CH$_2$), 23.72 (CH$_3$*C*H$_2$), 44.66 / 45.44 (CH$_3$CH$_2$*C*H), 47.27 (Fmoc-*C*H), 49.81 / 50.20 (FmocNCH$_2$), 61.02 / 61.39 (FmocN*C*H), 67.39 / 68.04 (Fmoc-*C*H$_2$), 70.05 / 70.24 (O*C*H$_2$C=O), 85.59 / 86.44 (O*C*HCHCH$_2$CH$_3$), 119.95 / 124.91 / 125.18 / 125.39 / 127.02 / 127.04 / 127.68 and 127.82 (Fmoc aromatic *C*H), 141.33 / 143.69 and 143.98 (Fmoc quaternary), 154.20 (Fmoc *C*=O), 208.69 / 209.28 (ketone *C*=O).



Scheme 12 (a) ^{i}PrMgCl in Et_2O, Cu(I)Br, LiCl, THF; (b) Cbz-Cl, Na_2CO_3, dioxan, H_2O; (c) Pd-C, H_2, methanol; (d) Fmoc-Cl, Na_2CO_3, dioxan, H_2O; (e) Dess-Martin periodinane, DCM.

Preparation of (3*R*, 3a*R*, 6*R*, 6a*R*)-Benzyl 3-hydroxy-6-isopropyltetrahydro-2*H*-furo[3,2-*b*]pyrrole-4(5*H*)-carboxylate (117)

A solution of isopropylmagnesium bromide (2M in diethyl ether, 2.4 mL, 4.77 mmol) was added dropwise over 2 minutes to a stirred suspension of copper(I) bromide (342 mg, 2.38 mmol) and lithium chloride (202 mg, 4.77 mmol) in tetrahydrofuran (2.5 mL) at -50 °C. The mixture was stirred for 1.5 hours at ≤ -45 °C then (3*R*, 3a*R*, 6*R*, 6a*S*)-3-hydroxyhexahydro-2*H*-furo[3,2-*b*]pyrrol-6-yl 4-methylbenzenesulfonate hydrochloride (74) (200 mg, 0.596 mmol) was added. The mixture was allowed to warm to 8 °C over 3.25 hours then a solution of sodium carbonate (178 mg, 1.68 mmol) in water (6 mL) was added. The mixture was stirred for 20 minutes then benzyl chloroformate (0.21 mL, 1.47 mmol) was added over 1 minute. The mixture was stirred for 65 minutes at 10 °C then water (20 mL) and dichloromethane (15 mL) were added. The mixture was filtered through celite then the filter cake washed with dichloromethane (10 mL). The organic layer was separated then the aqueous layer extracted with dichloromethane (2 x

5 mL). The combined organic layers were washed with brine (5 mL), dried (Na_2SO_4), filtered and reduced *in vacuo* to leave a pale pink oil (227 mg). Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 10 : 90 to 55 : 45 gave alcohol (117) (36 mg, 20%) as a pale brown oil. TLC (R_f = 0.45, EtOAc : heptane 2 : 1), analytical HPLC main peak, R_t = 16.651 min., HPLC-MS 306.2 $[M + H]^+$, 633.3 $[2M + Na]^+$; $[\alpha]_D^{23}$ -22.2° (c = 0.9, $CHCl_3$); δ_H (500 MHz, $CDCl_3$) mixture of rotamers major : minor 3 : 2; 0.87 (1.8H, d, *J* = 6.69 Hz, C*H*$_3$CH major), 0.90 (1.2H, d, *J* = 6.71 Hz, C*H*$_3$CH minor), 1.13 (1.2H, d, *J* = 6.53 Hz, C*H*$_3$CH minor), 1.14 (1.8H, d, *J* = 6.51 Hz, C*H*$_3$CH major), 1.66 (1H, m, $(CH_3)_2CHCH$), 1.78-1.88 (1H, m, $(CH_3)_2CH$), 2.06 (0.4H, brs, O*H* minor), 2.86 (0.6H, brs, O*H* major), 2.92 (0.4H, t, *J* = 11.09 Hz, 1 x CbzNC*H*$_2$ minor), 2.94 (0.6H, t, *J* = 11.09 Hz, 1 x CbzNC*H*$_2$ major), 3.68-3.75 (1.6H, m, 1 x CbzNC*H*$_2$ major and 1 x OC*H*$_2$CHOH), 3.82-3.88 (0.8H, m, 1 x CbzNC*H*$_2$ minor and 1 x OC*H*$_2$CHOH minor), 3.93 (0.6H, dd, *J* = 9.83 and 4.79 Hz, 1 x OC*H*$_2$CHOH major), 4.16 (1H, brt, *J* = 3.61 Hz, CbzNC*H*), 4.32 (0.4H, brs, OCH$_2$C*H*OH minor), 4.44 (0.6H, brt, *J* = 3.64 Hz, OCH$_2$C*H*OH major), 4.41-4.46 (1H, m, $(CH_3)_2CHCHCH$), 5.08-5.21 (2H, m, C*H*$_2$Ph), 7.30-7.38 (5H, m, Cbz C*H*); δ_C (125 MHz, $CDCl_3$) 21.043 / 21.073 and 21.632 / 21.668 ($(CH_3)_2CH$), 28.806 ($(CH_3)_2CH$), 49.494 / 49.893 ($CbzNCH_2$), 50.708 / 51.009 ($(CH_3)_2CHCH$), 67.118 / 67.239 (CH_2Ph), 70.184 / 71.253 (CbzNCH), 74.301 / 74.493 (OCH_2CHOH), 76.349 / 77.246 (OCH_2CHOH), 81.734 / 82.581 ($(CH_3)_2CHCHCH$), 127.990, 128.138, 128.265, 128.532, 128.601 and 128.687 (aromatic CH), 136.439 / 136.453 (Cbz quaternary), 154.196 / 154.928 (Cbz C=O).

Preparation of (3*R*, 3a*R*, 6*R*, 6a*R*)-(9*H*-Fluoren-9-yl)methyl 3-hydroxy-6-isopropyl tetrahydro-2*H*-furo[3,2-*b*]pyrrole-4(5*H*)-carboxylate (2c: R^2 = iPr).

Methanol (0.5 mL) was added dropwise to a mixture of 10% palladium on charcoal (30 mg) and alcohol (117) (36 mg, 0.118 mmol) under an atmosphere of argon. The argon was replaced by hydrogen then the suspension was stirred for 1 hour then filtered through celite *in vacuo*. The filter cake was washed with ethanol (7 mL) then the solvents removed *in vacuo* from the filtrate. The residue was azeotroped with diethyl

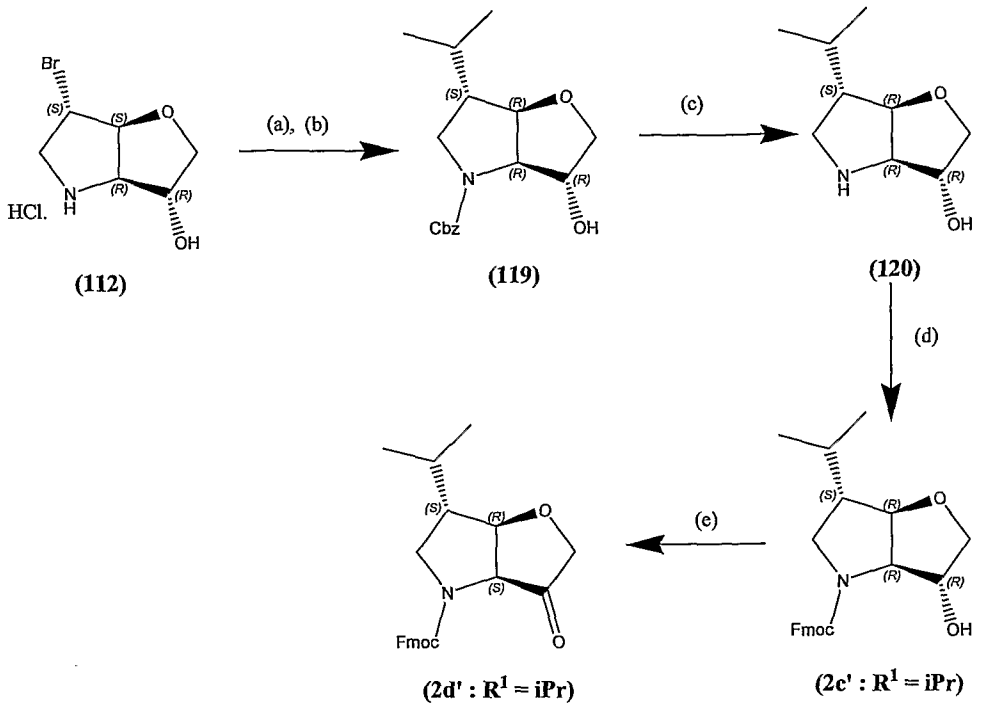
ether (3 x 2 mL) to obtain the crude aminoalcohol (118) which was used without further purification.

A solution of sodium carbonate (26.3 mg, 0.248 mmol) in water (0.5 mL) was added whilst stirring to a solution of aminoalcohol (118) (assumed to be 0.118 mmol) in 1,4-dioxan (0.2 mL). A solution of 9-fluorenylmethoxycarbonyl chloride (32.0 mg, 0.124 mmol) in 1,4-dioxan (0.3 mL) was added then the mixture stirred for 40 minutes then dichloromethane (10 mL) was added and the mixture washed with water (10 mL). The aqueous layer was reextracted with dichloromethane (2 x 5 mL) then the combined organic layers dried (Na_2SO_4), filtered and reduced *in vacuo* to leave a residue (51 mg). Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 10 : 90 to 45 : 55 gave alcohol (2c: R^2 = iPr). (31 mg, 67%) as a white solid. TLC (R_f = 0.52, EtOAc : heptane 2 : 1), analytical HPLC single main peak, R_t = 20.046 min., HPLC-MS 394.2 $[M + H]^+$; $[\alpha]_D^{23}$ -28.7° (c = 1.22, $CHCl_3$); δ_C (125 MHz, $CDCl_3$) 20.956 / 21.060 and 21.556 / 21.653 ($CH(CH_3)_2$), 26.687 / 26.783 ($CH(CH_3)_2$), 47.329 / 47.444 (Fmoc *C*H), 49.432 / 49.460 (FmocNCH_2), 50.467 / 51.011 ($CHCH(CH_3)_2$), 65.624 / 67.243 (Fmoc CH_2), 70.384 / 71.110 (FmocN*C*H), 74.206 / 74.362 (OCH_2CHOH), 76.183 / 76.723 (OCH_2CHOH), 81.673 / 82.254 ($OCHCH(CH_3)_2$), 119.864, 119.891, 119.981, 124.448, 124.490, 124.951, 127.019, 127.405, 127.414, 127.735, 127.752, 127.832 and 127.879 (Fmoc aromatic *C*H), 141.250, 141.362, 141.376, 141.420, 143.798, 143.866, 143.983 and 144.048 (Fmoc quaternary), 154.024 / 154.860 (Fmoc *C*=O).

Preparation of (3*aS*,6*R*,6*aR*)-(9*H*-fluoren-9-yl)methyl 6-isopropyl-3-oxotetrahydro -2*H*-furo[3,2-*b*]pyrrole-4(5*H*)-carboxylate (2d: R^2 = iPr).

Dess-Martin periodinane (91 mg, 0.214 mmol) was added to a stirred solution of alcohol (2c: R^2 = iPr). (42 mg, 0.107 mmol) in dichloromethane (3 mL) under an atmosphere of argon. The mixture was stirred for 2 hours then diluted with dichloromethane (20 mL). The organic phase was washed with a mixture of saturated aqueous sodium bicarbonate and 0.25M sodium thiosulphate solution (1 : 1, 20 mL), then a mixture of saturated aqueous sodium bicarbonate and brine (1 : 1, 20 mL), then

dried (Na_2SO_4), filtered and reduced *in vacuo*. Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 10 : 90 to 40 : 60 gave ketone (2d: R^2 = iPr). (40.4 mg, 0.103 mmol, 96.5%) as a clear gum. TLC (R_f = 0.45, EtOAc : heptane 1 : 1), analytical HPLC broad main peak, R_t = 19.51-22.01 min., HPLC-MS 392.2 $[M + H]^+$, 414.2 $[M + Na]^+$, 805.3 $[2M + Na]^+$; $[\alpha]_D^{22}$ -137.5° (c = 1.0, $CHCl_3$); δ_H (500 MHz, $CDCl_3$) mixture of rotamers 1 : 1; 0.95 (3H, t, $(CH_3)_2CH$), 1.07 (3H, t, J = 6.50 Hz, $(CH_3)_2CH$), 1.71-1.84 (1H, bm, $(CH_3)_2CHCH$), 1.91-2.20 (1H, m, $(CH_3)_2CHCH$), 3.07-3.19 (1H, bm, FmocNCH_2), 3.70-3.77 (0.5H, bm, 0.5 x FmocNCH_2), 3.90-4.03 ((1.5H, bm, 0.5 x FmocNCH_2 + 1 x OCH_2C=O), 4.12-4.58 (5H, bm, 2 x Fmoc-CH_2 + Fmoc-CH + OCH_2C=O + FmocNCH), 4.73 / 4.81 (2 x 0.5H, bs, OCHCHCH$(CH_3)_2$), 7.30-7.78 (8H, Fmoc aromatic CH); δ_C (125 MHz, $CDCl_3$); 21.01 / 21.71 ($(CH_3)_2CH$), 25.78 ($(CH_3)_2CH$),47.18 / 47.30 (Fmoc-CH), 49.41 / 49.81 (FmocNCH_2), 51.09/ 51.19 / 51.53 ($(CH_3)_2CHCH$),62.83 / 63.26 (FmocNCH), 67.50 / 68.25 (Fmoc-CH_2), 70.93 (OCH_2C=O), 81.91 / 82.84 (OCHCHCH$(CH_3)_2$), 119.88 / 124.98 / 125.16 / 125.50 / 126.99 / 127.05 / 127.63 / 127.69 and 127.81 (Fmoc aromatic CH), 141.23 / 141.33 / 143.66 / 143.73 / 144.05 and 144.52 (Fmoc quaternary), 154.89 (Fmoc C=O), 208.63 / 208.76 (ketone C=O).



Scheme 13 (a) ^{i}PrMgCl in Et_2O, Cu(I)Br, LiCl, THF; (b) Cbz-Cl, Na_2CO_3, dioxan, H_2O; (c) Pd-C, H_2, methanol; (d) Fmoc-Cl, Na_2CO_3, dioxan, H_2O; (e) Dess-Martin periodinane, DCM.

Preparation of (3*R*, 3a*R*, 6*S*, 6a*R*)-Benzyl 3-hydroxy-6-isopropyltetrahydro-2*H*-furo[3,2-*b*]pyrrole-4(5*H*)-carboxylate (119)

A solution of isopropylmagnesium bromide (2M in diethyl ether, 4.9 mL, 9.8 mmol) was added dropwise over 7 minutes to a stirred suspension of copper(I) bromide (704 mg, 4.9 mmol) and lithium chloride (416 mg, 9.8 mmol) in tetrahydrofuran (5 mL) at -50 °C. The mixture was stirred for 1.5 hours at ≤ -45 °C then (3*R*, 3a*R*, 6*S*, 6a*S*)-6-bromohexahydro-2*H*-furo[3,2-*b*]pyrrol-3-ol hydrochloride (112) (300 mg, 1.23 mmol) was added. The mixture was allowed to warm to 0 °C over 2 hours 25 minutes then a solution of sodium carbonate (369 mg, 3.48 mmol) in water (8.5 mL) was added over 5 minutes. The mixture was stirred for 20 minutes then benzyl chloroformate (0.432 mL, 3.03 mmol) was added over 1 minute. The mixture was stirred for 1.5 hours at 0 °C then at ambient temperature for 40 minutes. Benzyl chloroformate (0.15 mL, 1.05 mmol) was added then the mixture was stirred for 15 minutes before adding water (30

mL) and dichloromethane (25 mL). The mixture was filtered through celite then the filter cake washed with dichloromethane (15 mL). The organic layer was separated then the aqueous layer extracted with dichloromethane (2 x 10 mL). The combined organic layers were washed with brine (15 mL), dried (Na_2SO_4), filtered and reduced *in vacuo* to leave a pale brown oil (755 mg). Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 10 : 90 to 40 : 60 gave alcohol (119) (130 mg, 35%) as a pale brown oil. TLC (R_f = 0.50, EtOAc : heptane 2 : 1), analytical HPLC main peak, R_t = 16.106 min., HPLC-MS 306.2 $[M + H]^+$, 633.3 $[2M + Na]^+$; $[\alpha]_D^{21}$ -36.1° (c = 0.693, $CHCl_3$); δ_C (125 MHz, $CDCl_3$) 20.187 / 20.332 and 20.444 ($(CH_3)_2CH$), 29.700 / 29.909 ($(CH_3)_2CH$), 49.133 / 49.355 (CbzNCH_2), 50.689 ($(CH_3)_2CHCH$), 67.187 / 67.408 (CH_2Ph), 69.553 / 70.601 (CbzNCH), 73.424 / 73.629 (OCH_2CHOH), 77.081 / 77.739 (OCH_2CHOH), 85.099 / 85.973 ($(CH_3)_2CHCHCH$), 127.830, 127.972, 128.145, 128.376, 128.551 and 128.766 (aromatic CH), 136.403 (Cbz quaternary), 155.541 (Cbz C=O).

Preparation of (3*R*, 3a*R*, 6*S*, 6a*R*)-(9*H*-Fluoren-9-yl)methyl 3-hydroxy-6-isopropyl tetrahydro-2*H*-furo[3,2-*b*]pyrrole-4(5*H*)-carboxylate (2c': R^1 = iPr)

Methanol (1.25 mL) was added dropwise to a mixture of 10% palladium on charcoal (40 mg) and alcohol (119) (123 mg, 0.403 mmol) under an atmosphere of argon at 0 °C. The argon was replaced by hydrogen then the suspension was stirred at ambient temperature for 1 hour then filtered through celite *in vacuo*. The filter cake was washed with ethanol (10 mL) then the solvents removed *in vacuo* from the filtrate. The residue was azeotroped with diethyl ether (3 x 2 mL) to obtain the crude aminoalcohol (120) which was used without further purification.

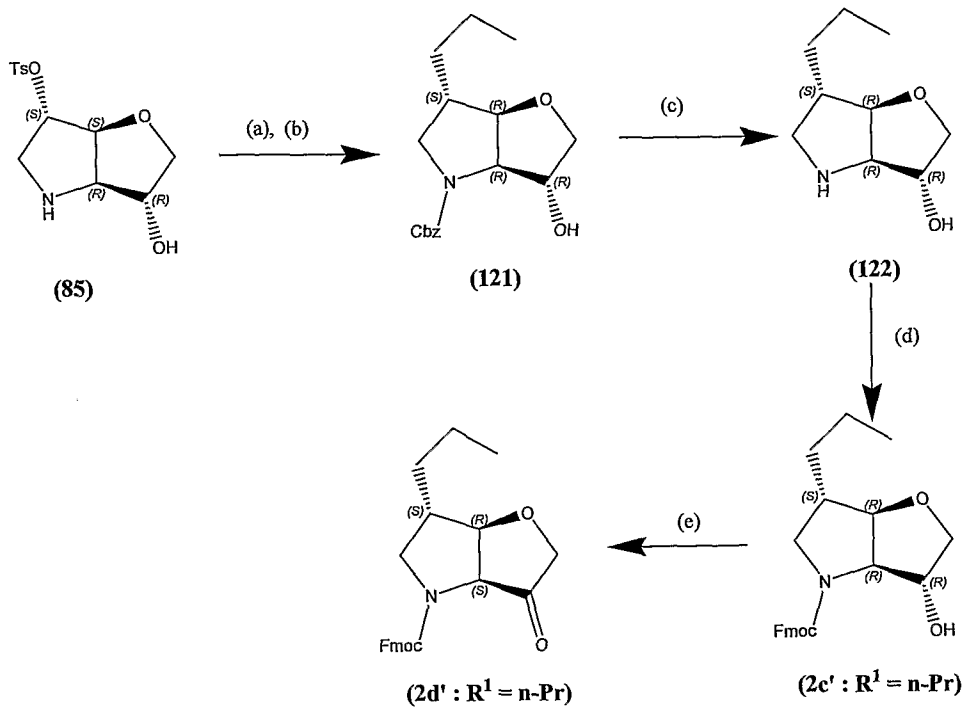
A solution of sodium carbonate (90 mg, 0.847 mmol) in water (1.0 mL) was added whilst stirring to a suspension of aminoalcohol (120) (assumed to be 0.403 mmol) in 1,4-dioxan (0.5 mL). A solution of 9-fluorenylmethoxycarbonyl chloride (109 mg, 0.423 mmol) in 1,4-dioxan (0.5 mL) was added then the mixture stirred for 40 minutes then dichloromethane (15 mL) was added and the mixture washed with water (15 mL). The organic layer was reextracted with dichloromethane (2 x 10 mL) then the

combined organic layers dried (Na_2SO_4), filtered and reduced *in vacuo* to leave a residue (221mg). Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 10 : 90 to 40 : 60 gave alcohol (2c': R^1 = iPr) (128 mg, 81%) as a white solid. TLC (R_f = 0.33, EtOAc : heptane 1 : 1), analytical HPLC main peak, R_t = 19.537 min., HPLC-MS 394.2 $[M + H]^+$, 416.2 $[M + Na]^+$, 809.3 $[2M + Na]^+$; $[\alpha]_D^{22}$ -27.3° (c = 0.732, $CHCl_3$); δ_C (125 MHz, $CDCl_3$) 20.027 / 20.228 / 20.259 and 20.425 ($CH(CH_3)_2$), 29.300 / 29.753 ($CH(CH_3)_2$), 47.323 / 47.633 (Fmoc *C*H), 48.447 / 49.072 (FmocNCH_2), 48.974 / 50.612 ($CHCH(CH_3)_2$), 65.377 / 67.182 (Fmoc CH_2), 69.599 / 70.383 (FmocN*C*H), 73.026 / 73.606 (OCH_2CHOH), 76.987 (OCH_2CHOH), 85.013 / 85.495 ($OCHCHCH(CH_3)_2$), 119.929, 119.983, 124.388, 124.426, 124.866, 124.944, 127.013, 127.045, 127.420, 127.755, 127.865 and 127.908 (Fmoc aromatic *C*H), 141.248, 141.385, 141.419, 143.760, 143.828 and 143.987 (Fmoc quaternary), 154.179 / 155.342 (Fmoc *C*=O).

Preparation of (3a*S*, 6*S*, 6a*R*)-(9*H*-Fluoren-9-yl)methyl 6-isopropyl-3-oxo tetrahydro-2*H*-furo[3,2-*b*]pyrrole-4(5*H*)-carboxylate (2d': R^1 = iPr)

Dess-Martin periodinane (259 mg, 0.611 mmol) was added to a stirred solution of alcohol (2c': R^1 = iPr) (120 mg, 0.305 mmol) in dichloromethane (4.5 mL) under an atmosphere of argon. The mixture was stirred for 2 hours 10 minutes then diluted with dichloromethane (20 mL). The organic phase was washed with a mixture of saturated aqueous sodium bicarbonate and 0.25M sodium thiosulphate solution (1 : 1, 20 mL), then saturated aqueous sodium bicarbonate (20 mL), then brine (20 mL), then dried (Na_2SO_4), filtered and reduced *in vacuo* to leave a colourless oil (220 mg). Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 10 : 90 to 40 : 60 gave ketone (2d': R^1 = iPr) (110 mg, 92%) as a colourless oil. TLC (R_f = 0.70, EtOAc : heptane 2 : 1), analytical HPLC broad main peak, R_t = 19.163-21.606 min., HPLC-MS 392.2 $[M + H]^+$, 414.2 $[M + Na]^+$, 432.2 $[M + H_2O + Na]^+$, 805.3 $[2M + Na]^+$; $[\alpha]_D^{21}$ -100.6° (c = 0.696, $CHCl_3$); δ_H (500 MHz, $CDCl_3$) 0.81-1.08 (6H, m, $(CH_3)_2CH$), 1.62-1.89 (1H, m, $(CH_3)_2CH$), 1.99-2.06 (1H, m, $(CH_3)_2CHCH$), 3.45-3.61 (1H, m, 1 x FmocNCH_2), 3.98 (8H, m, 1 x FmocNCH_2, OCH_2C=O, FmocNC*H*, Fmoc CH_2, Fmoc C*H* and $OCHCHCH(CH_3)_2$), 7.28-7.77 (8H, Fmoc aromatic C*H*); δ_C (125

MHz, $CDCl_3$); 20.484 ($(CH_3)_2CH$), 29.443 / 29.546 ($(CH_3)_2CH$), 47.270 (Fmoc *C*H), 48.828 / 49.288 (FmocN*C*H_2), 48.956 / 49.982 ($(CH_3)_2CHCH$), 61.620 / 61.967 (FmocNCH), 67.453 / 67.951 (Fmoc *C*H_2), 69.484 / 69.615 ($OCH_2C{=}O$), 83.997 / 84.697 ($OCHCHCH(CH_3)_2$), 119.922 / 119.983 / 124.898 / 125.177 / 125.299 / 127.036 / 127.179 / 127.677 and 127.829 (Fmoc aromatic *C*H), 141.331 and 143.694 (Fmoc quaternary), 155.075 (Fmoc *C*=O), 209.928 / 210.128 (ketone *C*=O).



Scheme 14 (a) n-PrMgCl in Et_2O, Cu(I)Br, LiCl, THF; (b) Cbz-Cl, Na_2CO_3, dioxan, H_2O; (c) Pd-C, H_2, methanol; (d) Fmoc-Cl, Na_2CO_3, dioxan, H_2O; (e) Dess-Martin periodinane, DCM.

Preparation of (3*R*, 3a*R*, 6*S*, 6a*R*)-Benzyl 3-hydroxy-6-propyltetrahydro-2*H*-furo[3,2-*b*]pyrrole-4(5*H*)-carboxylate (121).

A solution of n-propylmagnesium chloride (2M in diethyl ether, 5.35 mL, 10.7 mmol) was added dropwise over 2 minutes to a stirred suspension of copper(I) bromide (768 mg, 5.35 mmol) and lithium chloride (454 mg, 10.7 mmol) in tetrahydrofuran (5 mL) at ≤ -50 °C. The mixture was stirred for 1.5 hours at ≤ -45 °C then tosylate (85) (400 mg, 1.34 mmol) was added. The mixture was allowed to warm to 5 °C over 4 hours then a

solution of sodium carbonate (400 mg, 3.77 mmol) in water (10 mL) was added. The mixture was stirred for 15 minutes then benzyl chloroformate (0.47 mL, 3.29 mmol) was added over 1 minute. The mixture was stirred for 45 minutes at ≤ 10 °C then water (35 mL) and dichloromethane (25 mL) were added. The mixture was filtered through celite then the filter cake washed with dichloromethane (20 mL). The organic layer was separated then the aqueous layer extracted with dichloromethane (2 x 10 mL). The combined organic layers were washed with brine (10 mL), dried (Na_2SO_4), filtered and reduced *in vacuo* to leave an oily residue (720 mg). Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 10 : 90 to 40 : 60 gave alcohol (121) (295 mg, 72%) as a colourless oil. TLC (R_f = 0.30, EtOAc : heptane 2 : 1), analytical HPLC single main peak, R_t = 15.984 min., HPLC-MS 306.2 $[M + H]^+$, 633.3 $[2M + Na]^+$; $[\alpha]_D^{22}$ -54.6° (c = 1.557, $CHCl_3$); δ_H (500 MHz, $CDCl_3$) mixture of rotamers major : minor 3 : 2; 0.89 (3H, t, J = 7.18 Hz, CH_3CH_2), 1.10-1.40 (4H, m, $CH_3CH_2CH_2$), 1.82 (0.4H, brs, OH minor), 2.15-2.23 (1H, m, $CH_3CH_2CH_2CH$), 3.09 (0.6H, brs, OH major), 3.33-4.02 (4H, m, CbzNCH_2 and OCH_2CHOH), 4.10-4.14 (1H, m, CbzNCH), 4.33 (0.4H, brs, OCH_2CHOH minor), 4.40-4.45 (1.6H, m, $CH_3CH_2CH_2CHCH$ and OCH_2CHOH major), 5.08-5.25 (2H, m, CH_2Ph), 7.29-7.38 (5H, m, Cbz CH); δ_C (125 MHz, $CDCl_3$) 13.970 (CH_3CH_2), 20.592 (CH_3CH_2), 33.569 / 33.626 ($CH_3CH_2CH_2$), 42.777 / 43.424 ($CH_3CH_2CH_2CH$), 50.331 (CbzNCH_2), 67.130 / 67.331 (CH_2Ph), 68.476 / 69.547 (CbzNCH), 74.033 (OCH_2CHOH), 76.404 / 77.205 (OCH_2CHOH), 86.343 / 87.275 ($CH_3CH_2CH_2CHCH$), 127.759, 127.924, 128.097, 128.290, 128.524, and 128.727 (aromatic CH), 136.418 (Cbz quaternary), 154.575 / 155.512 (Cbz C=O).

Preparation of (3*R*, 3a*R*, 6*S*, 6a*R*)-(9*H*-Fluoren-9-yl)methyl 3-hydroxy-6-propyltetrahydro-2*H*-furo[3,2-*b*]pyrrole-4(5*H*)-carboxylate (2c': R^1 = iPr)

Methanol (4 mL) was added dropwise to a mixture of 10% palladium on charcoal (50 mg) and alcohol (121) (279 mg, 0.915 mmol) under an atmosphere of argon whilst chilling with iced water. The argon was replaced by hydrogen then the suspension was stirred for 1.25 hours. The hydrogen was replaced by argon then ethanol (4 mL) added before filtering through celite *in vacuo*. The filter cake was washed with ethanol (10 mL) then the solvents removed *in vacuo* from the filtrate. The residue was azeotroped

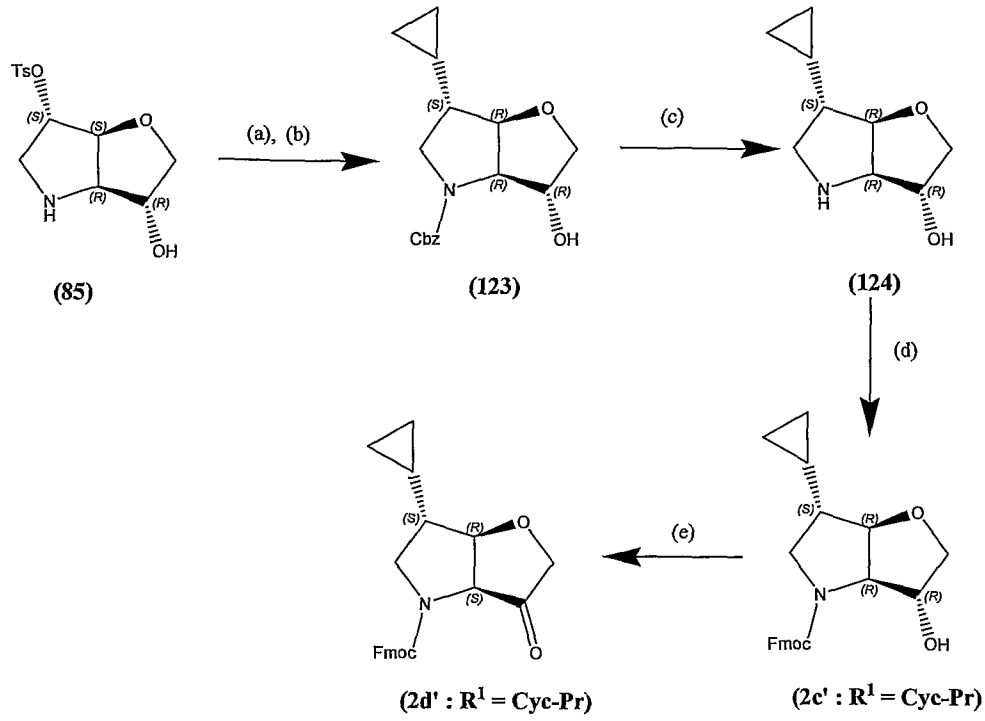
with diethyl ether (3 x 5 mL) to obtain the crude aminoalcohol (122) which was used without further purification.

A solution of sodium carbonate (204 mg, 1.92 mmol) in water (2.5 mL) was added whilst stirring to a solution of aminoalcohol (122) (assumed to be 0.915 mmol) in 1,4-dioxan (1.25 mL). A solution of 9-fluorenylmethoxycarbonyl chloride (248 mg, 0.961 mmol) in 1,4-dioxan (1.25 mL) was added over 10 minutes at 0 °C then the mixture stirred for 35 minutes then dichloromethane (25 mL) was added and the mixture washed with water (25 mL). The aqueous layer was re-extracted with dichloromethane (2 x 10 mL) then the combined organic layers dried (Na_2SO_4), filtered and reduced *in vacuo* to leave a colourless oil (559 mg). Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 10 : 90 to 40 : 60 gave alcohol (2c': R^1 = n-Pr) (375 mg, 104 %) as a colourless oil. TLC (R_f = 0.40, EtOAc : heptane 2 : 1), analytical HPLC single main peak, R_t = 19.257 min., HPLC-MS 394.2 $[M + H]^+$, 416.2 $[M + Na]^+$, 809.3 $[2M + Na]^+$; $[\alpha]_D^{22}$ -32.0° (c = 1.407, $CHCl_3$); δ_C (125 MHz, $CDCl_3$) 13.906 / 14.030 (CH_3CH_2), 20.473 / 20.611 (CH_3CH_2), 33.309 / 33.570 ($CH_3CH_2CH_2$), 42.396 / 43.436 ($CH_3CH_2CH_2CH$), 47.300 / 47.602 (Fmoc *C*H), 49.845 / 50.062 (FmocNCH_2), 65.486 / 67.103 (Fmoc CH_2), 68.597 / 69.368 (FmocNCH), 73.695 / 74.017 (OCH_2CHOH), 76.374 / 77.202 (OCH_2CHOH), 86.290 / 86.874 ($OCHCHCH_2CH_2CH_3$), 119.898, 119.923, 119.996, 124.455, 124.514, 124.907, 124.929, 126.996, 127.401, 127.427, 127.745, 127.866 and 127.891 (Fmoc aromatic *C*H), 141.264, 141.354, 141.376, 141.422, 143.756, 143.814, 143.929 and 144.011 (Fmoc quaternary), 154.420 / 155.348 (Fmoc *C*=O).

Preparation of (3a*S*, 6*S*, 6a*R*)-(9*H*-Fluoren-9-yl)methyl 6-isopropyl-3-oxo tetrahydro-2*H*-furo[3,2-*b*]pyrrole-4(5*H*)-carboxylate (2d': R^1 = iPr)

Dess-Martin periodinane (777 mg, 1.83 mmol) was added to a stirred solution of alcohol (2c': R^1 = n-Pr) (360 mg, 0.915 mmol) in dichloromethane (15 mL) under an atmosphere of argon. The mixture was stirred for 3 hours then diluted with dichloromethane (50 mL). The organic phase was washed with a mixture of saturated aqueous sodium bicarbonate and 0.2M sodium thiosulphate solution (1 : 1, 50 mL),

then saturated aqueous sodium bicarbonate (50 mL), then brine (50 mL), then dried (Na_2SO_4), filtered and reduced *in vacuo* to leave a residue (533 mg). Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 10 : 90 to 35 : 65 gave ketone (2d': R^1 = n-Pr) (342 mg, 96%) as a colourless oil. TLC (R_f = 0.70, EtOAc : heptane 2 : 1), analytical HPLC broad main peak, R_t = 18.840-21.089 min., HPLC-MS 392.2 $[M + H]^+$, 805.3 $[2M + Na]^+$; $[\alpha]_D^{22}$ -115.1° (c = 2.042, $CHCl_3$); δ_H (500 MHz, $CDCl_3$) mixture of rotamers approximately 1:1, 0.93 (3H, t, J = 7.22 Hz, $CH_2CH_2CH_3$), 1.07-1.48 (4H, m, $CH_2CH_2CH_3$), 2.25-2.32 (1H, m, $CHCH_2CH_2CH_3$), 3.34-3.40 (0.5H, m, 0.5 x FmocNCH_2), 3.48-3.60 (1.5H, m, 1.5 x FmocNCH_2), 3.93-4.02 (1H, m, 1 x OCH_2C=O), 4.10-4.34 (3.5H, m, FmocNC*H*, 0.5 x Fmoc CH_2, Fmoc C*H* and 1 x OCH_2C=O), 4.43-4.64 (2.5H, m, 1.5 x Fmoc CH_2 and OC*H*CHCH$_2$CH$_2$CH$_3$), 7.28-7.77 (8H, Fmoc aromatic C*H*); δ_C (125 MHz, $CDCl_3$); 13.978 ($CH_2CH_2CH_3$), 20.581 ($CH_2CH_2CH_3$), 32.831 ($CH_2CH_2CH_3$), 42.627 / 43.413 (OCHCHCH$_2$), 47.254 (Fmoc *C*H), 50.107 / 50.507 (FmocNCH$_2$), 61.017 / 61.383 (FmocN*C*H), 67.425 / 68.074 (Fmoc *C*H$_2$), 70.141 / 70.236 (O*C*H$_2$C=O), 85.814 / 86.699 (O*C*HCHCH$_2$), 119.892 / 119.952 / 120.052, 124.903 / 125.177 / 125.416 / 127.011 / 127.047 / 127.691 and 127.827 (Fmoc aromatic *C*H), 141.331 and 143.702 (Fmoc quaternary), 155.269 (Fmoc *C*=O), 209.098 / 209.290 (ketone *C*=O).



Scheme 15 (a) Cyclo-PrMgCl in Et_2O, Cu(I)Br, LiCl, THF; (b) Cbz-Cl, Na_2CO_3, dioxan, H_2O; (c) Pd-C, H_2, methanol; (d) Fmoc-Cl, Na_2CO_3, dioxan, H_2O; (e) Dess-Martin periodinane, DCM.

Preparation of (3*R*, 3a*R*, 6*S*, 6a*R*)-Benzyl 6-cyclopropyl-3-hydroxytetrahydro-2*H*-furo[3,2-*b*]pyrrole-4(5*H*)-carboxylate (123).

A solution of cyclo-propylmagnesium bromide (0.5M in tetrahydrofuran, 21.4 mL, 10.7 mmol) was added dropwise over 20 minutes to a stirred suspension of copper(I) bromide (768 mg, 5.35 mmol) and lithium chloride (454 mg, 10.7 mmol) in tetrahydrofuran (1 mL) at ≤ -50 °C. The mixture was stirred for 1.5 hours at ≤ -45 °C then tosylate (85) (400 mg, 1.34 mmol) was added. The mixture was allowed to warm to 10 °C over 4 hours then a solution of sodium carbonate (400 mg, 3.77 mmol) in water (10 mL) was added. The mixture was stirred for 15 minutes then benzyl chloroformate (0.47 mL, 3.29 mmol) was added over 1 minute. The mixture was stirred for 45 minutes at ≤ 13 °C then water (35 mL) and dichloromethane (25 mL) were added. The mixture was filtered through celite then the filter cake washed with dichloromethane (20 mL). The organic layer was separated then the aqueous layer extracted with dichloromethane (2 x 10 mL). The combined organic layers were

washed with brine (10 mL), dried (Na_2SO_4), filtered and reduced *in vacuo* to leave an oily residue (820 mg). Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 10 : 90 to 40 : 60 gave alcohol (123) (212 mg, 52%) as a pale yellow oil. TLC (R_f = 0.32, EtOAc : heptane 2 : 1), analytical HPLC single main peak, R_t = 14.884 min., HPLC-MS 304.2 $[M + H]^+$, 629.3 $[2M + Na]^+$; $[\alpha]_D^{22}$ -54.3° (c = 1.29, $CHCl_3$); δ_H (500 MHz, $CDCl_3$) mixture of rotamers major : minor 3 : 2; 0.09-0.17 (1H, m, 1 x cyclopropyl C*H*$_2$), 0.22-0.28 (1H, m, 1 x cyclopropyl C*H*$_2$), 0.43-0.50 (1H, m, 1 x cyclopropyl C*H*$_2$), 0.50-0.57 (3H, m, 2 x cyclopropyl C*H*$_2$ and cyclopropyl C*H*), 1.51-1.57 (1H, m, CbzNCH$_2$C*H*), 2.16 (0.4H, brs, O*H* minor), 3.02 (0.6H, brs, O*H* major), 3.37-4.00 (4H, m, CbzNC*H*$_2$ and OC*H*$_2$CHOH), 4.21-4.25 (1H, m, CbzNC*H*), 4.34 (0.4H, brs, OCH$_2$C*H*OH minor), 4.46 (0.6H, m, OCH$_2$C*H*OH major), 4.58-4.63 (1H, m, CbzNCH$_2$CHC*H*O), 5.10-5.26 (2H, m, C*H*$_2$Ph), 7.30-7.39 (5H, m, Cbz C*H*); δ_C (125 MHz, $CDCl_3$) 3.820, 3.870, 4.068 and 4.117 (cyclopropyl *C*H$_2$), 12.896 (cyclopropyl *C*H), 48.260 / 48.860 (CbzNCH$_2$*C*H), 50.538 (CbzN*C*H$_2$), 67.153 / 67.312 (*C*H$_2$Ph), 68.575 / 69.632 (CbzN*C*H), 74.087 / 74.124 (O*C*H$_2$CHOH), 76.334 / 77.190 (OCH$_2$*C*HOH), 86.256 / 87.190 (CbzNCH$_2$*C*HCHO), 127.780, 127.927, 128.097, 128.282, 128.524, and 128.714 (aromatic *C*H), 136.416 (Cbz quaternary), 154.486 / 155.410 (Cbz *C*=O).

Preparation of (3*R*, 3a*R*, 6*S*, 6a*R*)-(9*H*-Fluoren-9-yl)methyl 6-cyclopropyl-3-hydroxytetrahydro-2*H*-furo[3,2-*b*]pyrrole-4(5*H*)-carboxylate (2c': R^1 = Cyc-Pr)

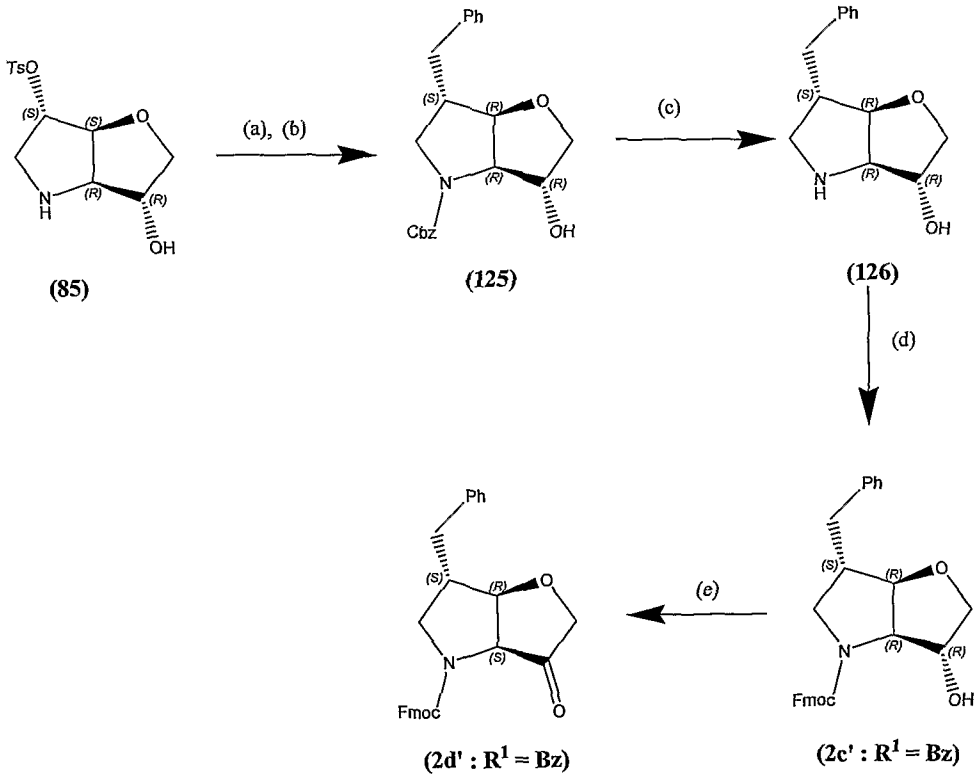
Methanol (2.5 mL) was added dropwise to a mixture of 10% palladium on charcoal (30 mg) and alcohol (123) (199 mg, 0.657 mmol) under an atmosphere of argon whilst chilling with iced water. The argon was replaced by hydrogen then the suspension was stirred for 1 hour. The hydrogen was replaced by argon then ethanol (2.5 mL) added before filtering through celite *in vacuo*. The filter cake was washed with ethanol (7.5 mL) then the solvents removed *in vacuo* from the filtrate. The residue was azeotroped with diethyl ether (3 x 3 mL) to obtain the crude aminoalcohol (124) which was used without further purification.

A solution of sodium carbonate (146 mg, 1.38 mmol) in water (2 mL) was added whilst stirring to a solution of aminoalcohol (124) (assumed to be 0.657 mmol) in 1,4-dioxan (1 mL). A solution of 9-fluorenylmethoxycarbonyl chloride (178 mg, 0.690 mmol) in 1,4-dioxan (1 mL) was added over 10 minutes at 0 °C then the mixture stirred for 65 minutes then dichloromethane (20 mL) was added and the mixture washed with water (20 mL). The aqueous layer was re-extracted with dichloromethane (2 x 5 mL) then the combined organic layers dried (Na_2SO_4), filtered and reduced *in vacuo* to leave a colourless oil (325 mg). Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 10 : 90 to 40 : 60 gave alcohol (2c': R^1 = Cyc-Pr) (207 mg, 81 %) as a white solid. TLC (R_f = 0.38, EtOAc : heptane 2 : 1), analytical HPLC single main peak, R_t = 18.609 min., HPLC-MS 392.2 $[M + H]^+$, 414.2 $[M + Na]^+$, 805.3 $[2M + Na]^+$; $[\alpha]_D^{21.5}$ -36.8° (c = 1.767, $CHCl_3$); δ_C (125 MHz, $CDCl_3$) 3.768, 3.955, 3.880 and 3.768 (cyclopropyl CH_2), 12.664 / 12.867 (cyclopropyl *C*H), 47.303 / 47.604 (Fmoc *C*H), 47.912 / 48.819 (FmocNCH$_2$CH), 50.118 / 50.334 (FmocNCH$_2$), 65.541 / 67.162 (Fmoc CH_2), 68.717 / 69.467 (FmocNCH), 73.838 / 74.108 (OCH$_2$CHOH), 76.251 / 76.654 (OCH$_2$CHOH), 86.165 / 86.807 (FmocNCH$_2$CHCHO), 119.895, 119.920, 120.003, 124.473, 124.528, 124.967, 124.929, 126.993, 127.015, 127.385, 127.427, 127.725, 127.750, 127.792 and 127.885 (Fmoc aromatic *C*H), 141.280, 141.349, 141.379, 141.440, 143.718, 143.852, 143.957 and 144.025 (Fmoc quaternary), 154.335 / 155.241 (Fmoc *C*=O).

Preparation of (3a*S*, 6*S*, 6a*R*)-(9*H*-Fluoren-9-yl)methyl 6-cyclopropyl-3-oxotetrahydro-2*H*-furo[3,2-*b*]pyrrole-4(5*H*)-carboxylate (2d': R^1 = Cyc-Pr)

Dess-Martin periodinane (412 mg, 0.972 mmol) was added to a stirred solution of alcohol (2c': R^1 = Cyc-Pr) (190 mg, 0.486 mmol) in dichloromethane (8 mL) under an atmosphere of argon. The mixture was stirred for 2.5 hours then diluted with dichloromethane (25 mL). The organic phase was washed with a mixture of saturated aqueous sodium bicarbonate and 0.2M sodium thiosulphate solution (1 : 1, 25 mL), then saturated aqueous sodium bicarbonate (25 mL), then brine (25 mL), then dried (Na_2SO_4), filtered and reduced *in vacuo* to leave a residue (306 mg). Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 10 : 90 to 40 :

60 gave ketone (2c': R^1 = Cyc-Pr) (170 mg, 90%) as a white solid. TLC (R_f = 0.70, EtOAc : heptane 2 : 1), analytical HPLC broad main peak, R_t = 18.02-20.23 min., HPLC-MS 390.2 $[M + H]^+$, 408.2 $[M + H_2O + H]^+$, 412.2 $[M + Na]^+$, 430.2 $[M + H_2O + Na]^+$, 801.3 $[2M + Na]^+$; $[\alpha]_D^{22}$ -95.0° (c = 1.00, $CHCl_3$); δ_C (125 MHz, $CDCl_3$); 3.80 / 3.99 (cyclohexyl CH_2), 12.04 / 12.09 (cyclohexyl CH), 47.26 (Fmoc CH), 48.18 / 48.94 (FmocNCH$_2$CH), 50.40 / 50.65 (FmocNCH$_2$), 61.08 / 61.52 (FmocNCH), 67.48 / 68.01 (Fmoc CH_2), 70.32 / 70.39 (OCH$_2$C=O), 85.97 / 86.88 (FmocNCH$_2$CHCHO), 119.86, 119.94, 124.94, 124.97, 125.17, 125.41, 127.01 and 127.66 (Fmoc aromatic CH), 141.23, 141.33, 143.61, 143.73, 143.93 and 144.47 (Fmoc quaternary), 155.08 / 155.16 (Fmoc C=O), 208.70 / 208.89 (ketone C=O).



Scheme 16 (a) $PhCH_2MgCl$ in Et_2O, Cu(I)Br, LiCl, THF; (b) Cbz-Cl, Na_2CO_3, dioxan, H_2O; (c) Pd-C, H_2, methanol; (d) Fmoc-Cl, Na_2CO_3, dioxan, H_2O; (e) Dess-Martin periodinane, DCM.

Preparation of (3*R*, 3a*R*, 6*S*, 6a*R*)-Benzyl 6-benzyl-3-hydroxytetrahydro-2*H*-furo[3,2-*b*]pyrrole-4(5*H*)-carboxylate (125).

A solution of benzylmagnesium chloride (1M in diethyl ether, 10.7 mL, 10.7 mmol) was added dropwise over 10 minutes to a stirred suspension of copper(I) bromide (768 mg, 5.35 mmol) and lithium chloride (454 mg, 10.7 mmol) in tetrahydrofuran (10 mL) at ≤ -50 °C. The mixture was stirred for 1.5 hours at ≤ -45 °C then tosylate (85) (400 mg, 1.34 mmol) was added. The mixture was allowed to warm to 8 °C over 4 hours then a solution of sodium carbonate (400 mg, 3.77 mmol) in water (10 mL) was added over 5 minutes. The mixture was stirred for 15 minutes then benzyl chloroformate (0.47 mL, 3.29 mmol) was added over 1 minute. The mixture was stirred for 75 minutes at ≤ 12 °C then water (35 mL) and dichloromethane (25 mL) were added. The mixture was filtered through celite then the filter cake washed with dichloromethane (20 mL). The organic layer was separated then the aqueous layer extracted with dichloromethane (2 x 10 mL). The combined organic layers were washed with brine (10 mL), dried (Na_2SO_4), filtered and reduced *in vacuo* to leave an oily residue (1.1 g). Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 15 : 85 to 45 : 55 gave alcohol (125) (336 mg, 71%) as a pale yellow oil. TLC (R_f = 0.30, EtOAc : heptane 2 : 1), analytical HPLC single main peak, R_t = 17.186 min., HPLC-MS 354.2 $[M + H]^+$, 729.3 $[2M + Na]^+$; $[\alpha]_D^{22}$ -32.1° (c = 2.18, $CHCl_3$); δ_H (500 MHz, $CDCl_3$) mixture of rotamers major : minor 2 : 1; 2.29 (0.33H, d, *J* = 3.31 Hz, O*H* minor), 2.36 (0.66H, dd, *J* = 13.57 and 9.43 Hz, 1 x CHC*H*$_2$Ph major), 2.44-2.62 (1.66H, m, CHC*H*$_2$Ph minor and CbzNCH$_2$C*H*), 2.64 (0.66, dd, *J* = 13.58 and 6.62 Hz, 1 x CHC*H*$_2$Ph major), 3.15 (0.66H, brs, O*H* major), 3.29-3.38 (1H, m, 1 x CbzNC*H*$_2$), 3.44 (0.66H, d, *J* = 11.19 Hz, 1 x CbzNC*H*$_2$ major), 3.57 (0.33H, d, *J* = 11.28 Hz, 1 x CbzNC*H*$_2$ minor), 3.67 (0.33H, dd, *J* = 9.93 and 2.34 Hz, 1 x OC*H*$_2$CHOH minor), 3.71 (0.66H, dd, *J* = 9.80 and 3.33 Hz, 1 x OC*H*$_2$CHOH major), 3.89 (0.33H, dd, *J* = 9.97 and 4.31 Hz, 1 x OC*H*$_2$CHOH minor), 3.96 (0.66H, dd, *J* = 9.80 and 4.81 Hz, 1 x OC*H*$_2$CHOH major), 4.13 (0.33H, d, *J* = 4.68 Hz, CbzNC*H* minor), 4.20 (0.66H, d, *J* = 4.80 Hz, CbzNC*H* major), 4.32 (0.33H, brs, OCH$_2$C*H*OH minor), 4.43 (0.66H, m, OCH$_2$C*H*OH major), 4.47 (1H, d, *J* = 4.74 Hz, CbzNCH$_2$CHC*H*), 5.05-5.25 (2H, m, C*H*$_2$Ph), 7.05-7.38 (10H, m, Cbz C*H*); δ_C (125 MHz, $CDCl_3$) 37.199 / 37.406 (*C*H$_2$Ph),

44.588 / 45.254 ($CbzNCH_2CH$), 49.193 / 49.707 ($CbzNCH_2$), 67.148 / 67.340 (CH_2Ph), 68.403 / 69.363 (CbzNCH), 74.163 / 74.215 (OCH_2CHOH), 76.299 / 77.194 (OCH_2CHOH), 85.457 / 86.287 ($CbzNCH_2CHCH$), 126.475, 127.855, 127.957, 128.146, 128.306, 128.525, 128.574, 128.715 and 128.856, (aromatic *C*H), 136.385 (Cbz aromatic quaternary) 138.726 / 138.826 (aromatic quaternary), 154.476 / 155.421 (Cbz *C*=O).

Preparation of (3*R*, 3a*R*, 6*S*, 6a*R*)-(9*H*-Fluoren-9-yl)methyl 6-benzyl-3-hydroxytetrahydro-2*H*-furo[3,2-*b*]pyrrole-4(5*H*)-carboxylate (2c': R^1 = Bz)

Methanol (4 mL) was added dropwise to a mixture of 10% palladium on charcoal (40 mg) and alcohol (125) (312 mg, 0.884 mmol) under an atmosphere of argon whilst chilling with iced water. The argon was replaced by hydrogen then the suspension was stirred for 2.25 hours. The hydrogen was replaced by argon then ethanol (4 mL) added before filtering through celite *in vacuo*. The filter cake was washed with ethanol (10 mL) then the solvents removed *in vacuo* from the filtrate. The residue was azeotroped with diethyl ether (3 x 5 mL) to obtain the crude aminoalcohol (126) which was used without further purification.

A solution of sodium carbonate (197 mg, 1.86 mmol) in water (2.5 mL) was added whilst stirring to a solution of aminoalcohol (126) (assumed to be 0.884 mmol) in 1,4-dioxan (1.25 mL). A solution of 9-fluorenylmethoxycarbonyl chloride (240 mg, 0.928 mmol) in 1,4-dioxan (1.25 mL) was added over 10 minutes at 0 °C then the mixture stirred for 50 minutes then dichloromethane (25 mL) was added and the mixture washed with water (25 mL). The aqueous layer was re-extracted with dichloromethane (2 x 10 mL) then the combined organic layers dried (Na_2SO_4), filtered and reduced *in vacuo* to leave a colourless oil (<620 mg). Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 10 : 90 to 50 : 50 gave alcohol (2c': R^1 = Bz) (365 mg, 94 %) as a white solid. TLC (R_f = 0.40, EtOAc : heptane 2 : 1), analytical HPLC single main peak, R_t = 20.099 min., HPLC-MS 442.2 $[M + H]^+$, 464.2 $[M + Na]^+$, 905.3 $[2M + Na]^+$; $[\alpha]_D^{22}$ -26.3° (c = 1.902, $CHCl_3$); δ_C (125 MHz, $CDCl_3$) 37.131 / 37.323 ($CHCH_2Ph$), 44.315 / 45.112 ($FmocNCH_2CH$), 47.296 / 47.647 (Fmoc *C*H), 49.141 /

49.368 (FmocNCH_2), 65.494 / 67.278 (Fmoc CH_2), 68.581 / 69.354 (FmocNCH), 73.813 / 74.082 (OCH_2CHOH), 76.319 / 76.699 (OCH_2CHOH), 85.411 / 85.943 (FmocNCH_2CHCH), 119.909, 119.932, 119.992, 120.001, 124.466, 124.574, 124.909, 124.961, 126.405, 126.529, 127.022, 127.434, 127.741, 127.898, 127.906, 128.501, 128.660, 128.795 and 128.841 (aromatic CH), 138.725 / 138.857 (phenyl quaternary), 141.313, 141.438, 143.717, 143.739, 143.943 and 144.034 (Fmoc quaternary), 154.308 / 155.377 (Fmoc C=O).

Preparation of (3a*S*, 6*S*, 6a*R*)-(9*H*-Fluoren-9-yl)methyl 6-benzyl-3-oxotetrahydro-2*H*-furo[3,2-*b*]pyrrole-4(5*H*)-carboxylate (2d': R^1 = Bz)

Dess-Martin periodinane (663 mg, 1.565 mmol) was added to a stirred solution of alcohol (2c': R^1 = Bz) (345 mg, 0.782 mmol) in dichloromethane (10 mL) under an atmosphere of argon. The mixture was stirred for 2 hours then diluted with dichloromethane (40 mL). The organic phase was washed with a mixture of saturated aqueous sodium bicarbonate and 0.2M sodium thiosulphate solution (1 : 1, 40 mL), then saturated aqueous sodium bicarbonate (40 mL), then brine (40 mL), then dried (Na_2SO_4), filtered and reduced *in vacuo* to leave a residue. Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 10 : 90 to 35 : 65 gave ketone (2d': R^1 = Bz) (318 mg, 93%) as a white solid. TLC (R_f = 0.65, EtOAc : heptane 2 : 1), analytical HPLC broad main peak, R_t = 19.697-21.766, HPLC-MS 440.2 $[M + H]^+$, 462.2 $[M + Na]^+$, 901.3 $[2M + Na]^+$; $[\alpha]_D^{22}$ -116.3° (c = 1.76, $CHCl_3$); δ_H (500 MHz, $CDCl_3$) mixture of rotamers approximately 6:5, 2.43-2.65 (3H, m, CHCH_2Ph), 3.46-3.53 (1.55H, m, 1 x FmocNCH_2 minor and 2 x FmocNCH_2 major), 3.70 (0.45H, dd, J = 8.97 and 1.78 Hz, 1 x FmocNCH_2 minor), 3.89-3.94 (1H, m, 1 x OCH_2C=O), 3.98-4.15 (1.45H, m, FmocNC*H* minor and 1 x OCH_2C=O), 4.19-4.24 (0.55H, m, Fmoc C*H* major), 4.25-4.35 (1H, m, FmocNC*H* major and Fmoc C*H* minor), 4.47-4.64 (3H, m, Fmoc CH_2 and FmocNCH$_2$CHC*H*), 7.08-7.77 (13H, aromatic C*H*); δ_C (125 MHz, $CDCl_3$); 36.690 (CH_2Ph), 44.733 / 45.276 (CHCH_2Ph), 47.30 (Fmoc CH), 49.69 / 49.87 (FmocNCH_2), 60.89 / 61.28 (FmocNCH), 67.54 / 67.97 (Fmoc CH_2), 70.28 / 70.36 (OCH_2C=O), 84.94 / 85.90 (FmocNCH$_2$CHCH), 119.88, 119.96, 124.94, 125.20, 125.40, 126.76, 127.05, 127.07, 127.70, 127.81, 128.71, 128.79 and 128.85 (aromatic

CH), 138.21 (phenyl quaternary), 141.31, 143.64, 143.93, and 144.43 (Fmoc quaternary), 155.02 / 155.27 (Fmoc *C*=O), 208.68 / 208.79 (ketone *C*=O).

Preparation of (*S*)-3-((*S*)-2-azido-2-(1-methylcyclopentyl)acetyl)-4-benzyl oxazolidin-2-one (134) A solution of potassium bis(trimethylsilyl)amide (0.5M in toluene, 34.4 mL, 17.2 mmol) was added over 8 minutes to a stirred solution of (*S*)-4-benzyl-3-(2-(1-methylcyclopentyl)acetyl)oxazolidin-2-one (2.39g, 7.92mmol) (**133**) in tetrahydrofuran (60 mL) at -70 °C under an atmosphere of argon. The solution was stirred at -70 °C for 20 minutes then a solution of trisyl azide (6.33 g, 20.5 mmol) in tetrahydrofuran (40 mL, precooled to -70 °C) was added *via* cannula over 15 minutes. The mixture was stirred at -70 °C for 1 hour, then stirred at 30 °C for 1h. A saturated aqueous solution of sodium hydrogen carbonate (100 mL) was added then the majority of solvents were removed *in vacuo*. The residue was partitioned between dichloromethane (300 mL) and brine (300 mL). The aqueous layer was re-extracted with dichloromethane (2 x 100 mL) then the combined organic layers were washed with saturated aqueous sodium hydrogen carbonate solution (100 mL), dried (Na_2SO_4), filtered and reduced *in vacuo* to leave a yellow oil (8.2 g). Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 0 : 100 to 15 : 85 gave desired intermediate (**134**) as a yellow oil, Yield 2.27g, 78%. TLC (R_f = 0.32, EtOAc : heptane 1 : 3), analytical HPLC, R_t = 23.56 min., HPLC-MS 315.2 $[M - N_2 + H]^+$, 365.1 $[M + Na]^+$.

Preparation of *tert*-butyl (*S*)-2-((S)-4-benzyl-2-oxooxazolidin-3-yl)-1-(1-methyl cyclopentyl)-2-oxoethylcarbamate (135). 10% Palladium on charcoal (450 mg) was added to azide (**134**) (2.23 g) followed by a solution of di-*tert*-butyl dicarbonate (4.36 g, 20.0 mmol,3.07eq.) in *N*,*N*-dimethylformamide (35 mL) under an atmosphere of argon. The argon was replaced by hydrogen then the mixture was stirred for 2 hours before filtering through celite *in vacuo*. The filter cake was washed with *N*,*N*-dimethylformamide (20 mL) then the solvents removed *in vacuo* from the filtrate (water bath temperature <50 °C). The residue was dissolved in ethyl acetate (400 mL) then washed with brine (3 x 100 mL), dried ($MgSO_4$), filtered and reduced *in vacuo* to

leave a dark oil (5.5 g). Flash chromatography over silica, eluting with ethyl acetate : heptane mixtures 0 : 100 to 20 : 80 gave desired Boc-protected intermediate (**135**) as a colourless gum (1.03 g, 38%). TLC (R_f = 0.38, EtOAc : heptane 1 : 3), analytical HPLC, R_t = 22.96 min., HPLC-MS 317.2 $[M - Boc + 2H]^+$, 361.2 $[M + 2H - {}^tBu]^+$, 855.4 $[2M + Na]^+$.

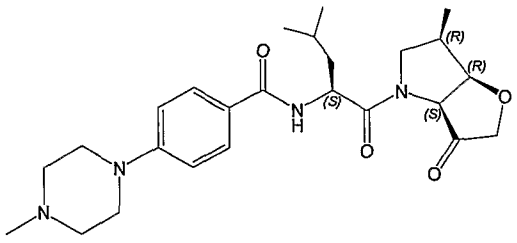
Preparation of (*S*)-2-(tert-butoxycarbonylamino)-2-(1-methylcyclopentyl)acetic acid (136). Aqueous hydrogen peroxide solution (30% 1.15 mL) was added to a stirred solution of Boc-protected intermediate (**135**) (1.02 g, 2.45 mmol) in a mixture of tetrahydrofuran (30 mL) and water (9 mL) at 0 °C. Lithium hydroxide monohydrate (128 mg, 3.04 mmol) was added then the mixture was stirred at 0 °C for 1h, then overnight at ambient temperature. A further aliquot of hydrogen peroxide solution (30% 0.575 mL) was added followed by lithium hydroxide monohydrate (64 mg and stirring continued at ambient temperature for 3h. A solution of sodium sulphite (1.87 g) in water (10 mL) was then added followed by aqueous sodium hydrogen carbonate solution (30 mL). The mixture was stirred for 5 minutes then the volume reduced by half *in vacuo* (≥ 25 mbar, external water bath 25 °C). Water (50 mL) was added then the pH adjusted to ≤ 2 using 5M hydrochloric acid. The aqueous phase was extracted with dichloromethane (4 x 50 mL), then the combined organic layers were dried (Na_2SO_4), filtered and reduced *in vacuo* to leave a pale yellow oil. The oil was partitioned between a solution of sodium carbonate (1.4 g) in water (50 mL) and diethyl ether (20 mL). The aqueous layer was re-extracted with diethyl ether (3 x 20 mL) then the pH adjusted to ≤ 2 using 5M hydrochloric acid. The acidified aqueous layer was then extracted with diethyl ether (3 x 20 mL) then the combined organic layers dried ($MgSO_4$), filtered and reduced *in vacuo* to leave acid (**136**) as a colourless gum (Yield 475mg, 76%). Analytical HPLC, R_t = 16.74 min., HPLC-MS 156.1 $[M - Boc + 2H]^+$, 220.1 $[M + 2H - {}^tBu]^+$, 537.3 $[2M + Na]^+$; $[\alpha]_D^{21}$ +27.2° (c = 2.576, $CHCl_3$). δ_H (500 MHz, $CDCl_3$) 0.90 (3H, s, CH_3C), 1.35-1.45 + 1.61-1.81 (8H, m, 4 x CH_2), 1.45 (9H, s, $(CH_3)_3C$), 4.18 (1H, d, J = 9.2, NC*H*), 5.12 (1H, d, J = 8.95, N*H*), 8.7-10.o (1H, b, COO*H*); δ_C (125 MHz, $CDCl_3$) 22.26/22.41/22.66 (CH_3C),

23.85/24.08/24.32/24.61/25.91 + 36.88/36.94 (4 x CH_2), 28.30 ($(CH_3)_3C$), 45.03/45.61 (CH_3C), 60.84 (NHCH), 79.98 ($(CH_3)_3C$), 155.76/156.46 (NHC=O), 177.04 (CHC=O).

Solid Phase Chemistry

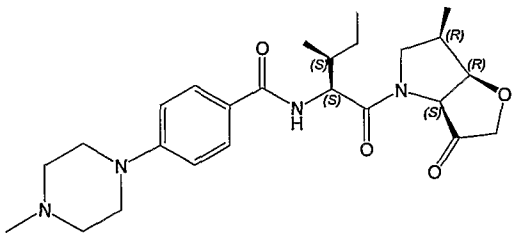
Fmoc-ketone building blocks (2c, 2c', 2d, 2d') may be utilised in a solid phase synthesis of example inhibitors (1-30 and 38-42) of general formula I. The methods used were directly analogous to those described in detail in WO02057270, utilising the 4-{[(Hydrazinocarbonyl)amino]methyl}cyclohexane carboxylic acid trifluoroacetate based linker, solid phase lanterns (ex Mimotopes), standard Fmoc chemistries or Boc chemistry with graduated acidolytic deprotection (see WO04007501, pg 309 (iv)) and acidolytic cleavage followed by semi-preparative HPLC purification (see WO02057270 pg 124-127 for full generic details). Alternative EXAMPLES of the invention can readily be prepared by the general methods detailed in WO02057270 through use of the appropriately derivatised R^9-COOH carboxylic acid and standard uronium activation techniques.

Example 1. *N*-((*S*)-4-methyl-1-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide



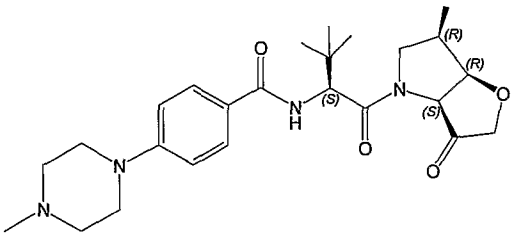
HPLC-MS R_t = 3.74 min, 457.3 $[M + H]^+$, 475.3 $[M + H + 18]^+$.

Example 2. *N*-((2*S*,3*S*)-3-methyl-1-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide



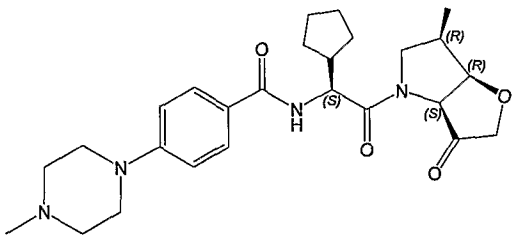
HPLC-MS R_t = 3.72 min, 457.2 $[M + H]^+$, 475.3 $[M + H + 18]^+$, 935.3 $[2M + H]^+$.

Example 3. *N*-((*S*)-3,3-dimethyl-1-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide



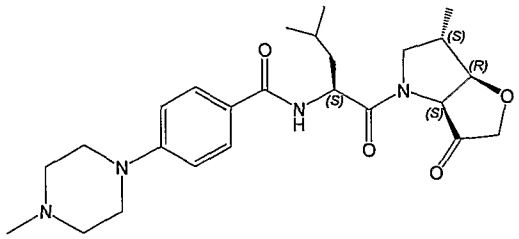
HPLC-MS R_t = 3.63 min, 457.2 $[M + H]^+$, 475.2 $[M + H + 18]^+$, 935.3 $[2M + H]^+$.

Example 4. *N*-((*S*)-1-cyclopentyl-2-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide



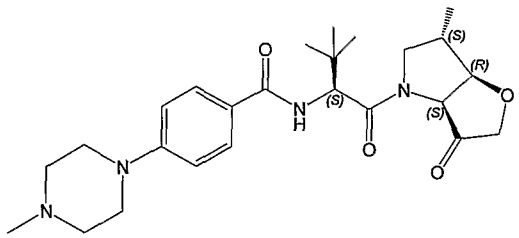
HPLC-MS R_t = 3.87 min, 469.3 $[M + H]^+$, 487.3 $[M + H + 18]^+$, 959.4 $[2M + Na]^+$.

Example 5. *N*-((*S*)-4-methyl-1-((3*aS*,6*S*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide



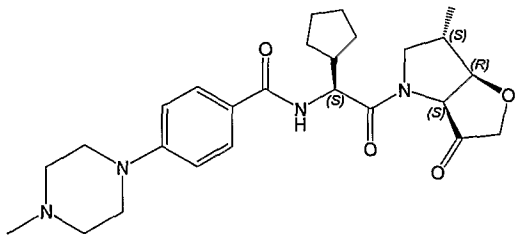
HPLC-MS R_t = 3.52 min, 457.2 $[M + H]^+$, 475.2 $[M + H + 18]^+$, 935.4 $[2M + H]^+$.

Example 6. *N*-((*S*)-3,3-dimethyl-1-((3*aS*,6*S*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide



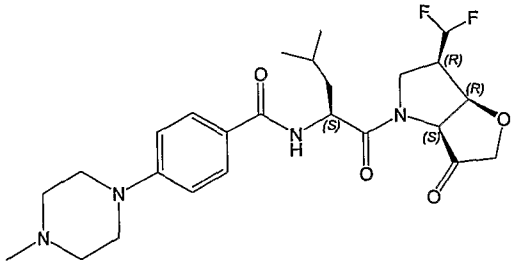
HPLC-MS R_t = 3.33 min, 457.2 $[M + H]^+$, 475.2 $[M + H + 18]^+$, 935.4 $[2M + H]^+$.

Example 7. *N*-((*S*)-1-cyclopentyl-2-((3*aS*,6*S*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide



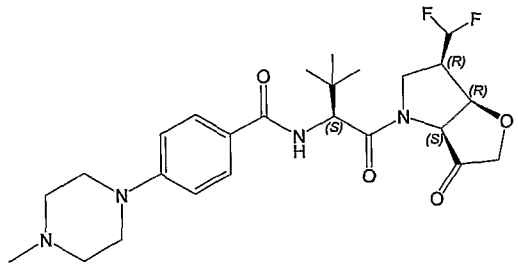
HPLC-MS R_t = 3.59 min, 469.2 $[M + H]^+$, 487.3 $[M + H + 18]^+$, 959.4 $[2M + Na]^+$.

Example 8. *N*-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide



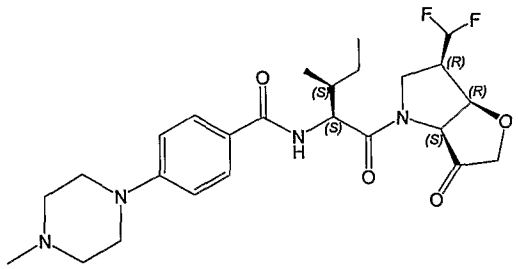
HPLC-MS R_t = 4.07 min, 493.2 $[M + H]^+$, 511.3 $[M + H + 18]^+$, 1007.3 $[2M + Na]^+$.

Example 9. *N*-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide



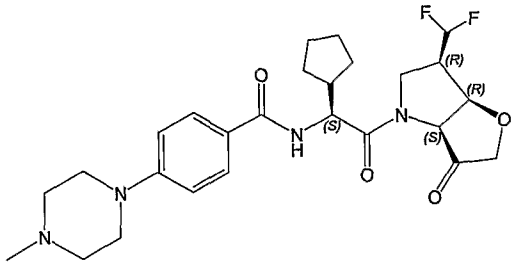
HPLC-MS R_t = 3.87 min, 493.2 $[M + H]^+$, 511.2 $[M + H + 18]^+$, 1007.3 $[2M + H]^+$.

Example 10. *N*-((2*S*,3*S*)-1-((3*aS*,6*R*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide



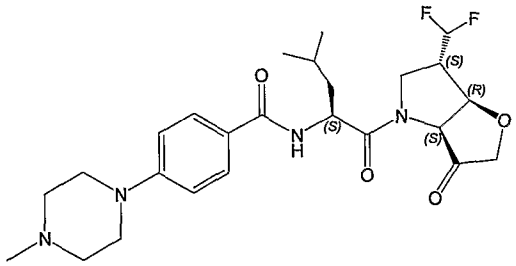
HPLC-MS R_t = 4.00 min, 493.2 $[M + H]^+$, 511.2 $[M + H + 18]^+$, 1007.3 $[2M + H]^+$.

Example 11. *N*-((*S*)-1-cyclopentyl-2-((3*aS*,6*R*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide



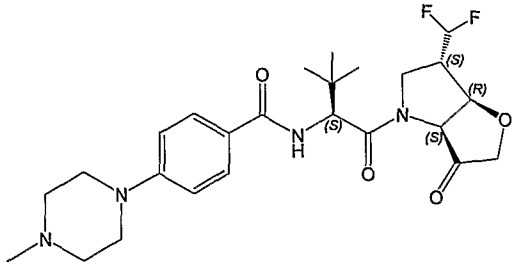
HPLC-MS R_t = 4.15 min, 505.2 $[M + H]^+$, 523.2 $[M + H + 18]^+$, 1031.3 $[2M + H]^+$.

Example 12. *N*-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide



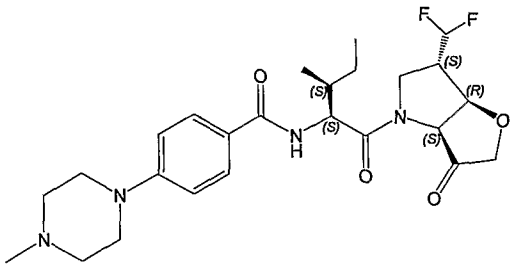
HPLC-MS R_t = 4.08 min, 493.2 $[M + H]^+$, 511.3 $[M + H + 18]^+$, 1007.3 $[2M + Na]^+$.

Example 13. *N*-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide



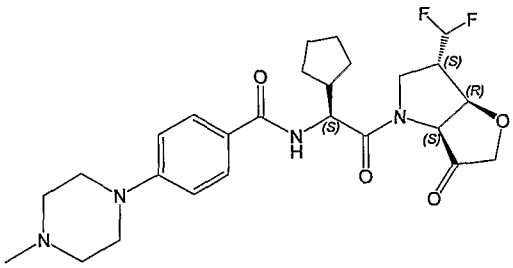
HPLC-MS R_t = 3.00 min, 493.2 $[M + H]^+$, 511.2 $[M + H + 18]^+$, 1007.3 $[2M + H]^+$.

Example 14. *N*-((2*S*,3*S*)-1-((3*aS*,6*S*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide



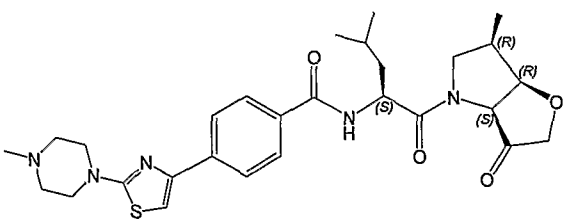
HPLC-MS R_t = 3.59 min, 493.2 $[M + H]^+$, 511.2 $[M + H + 18]^+$, 1007.3 $[2M + H]^+$.

Example 15. *N*-((*S*)-1-cyclopentyl-2-((3*aS*,6*S*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide



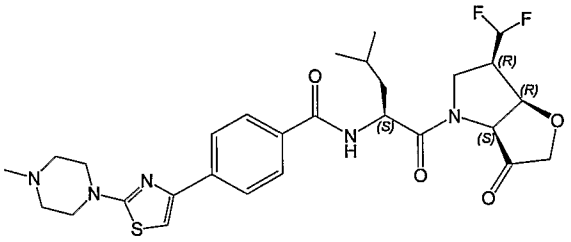
HPLC-MS R_t = 4.16 min, 505.2 $[M + H]^+$, 523.2 $[M + H + 18]^+$, 1031.3 $[2M + H]^+$.

Example 16. *N*-((*S*)-4-methyl-1-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide



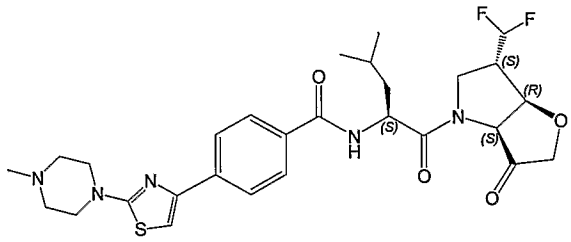
HPLC-MS R_t = 4.46 min, 270.7 $[M + 2H]^{2+}$, 540.3 $[M + H]^+$, 558.3 $[M + H + 18]^+$.

Example 17. *N*-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide



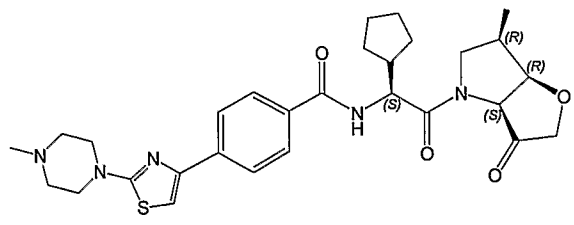
HPLC-MS R_t = 4.67 min, 576.2 $[M + H]^+$, 594.2 $[M + H + 18]^+$.

Example 18. *N*-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide



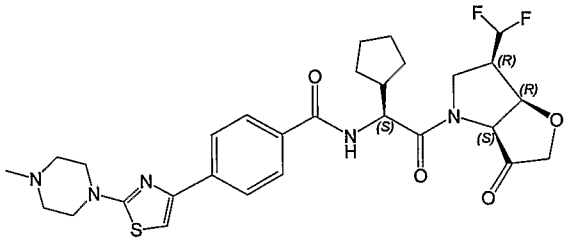
HPLC-MS R_t = 4.64 min, 286.6 $[M + 2H]^{2+}$, 576.2 $[M + H]^+$, 594.2 $[M + H + 18]^+$.

Example 19. *N*-((*S*)-1-cyclopentyl-2-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide



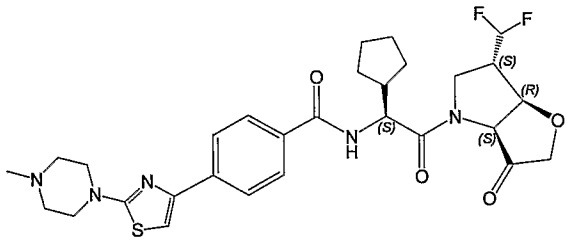
HPLC-MS R_t = 4.53 min, 276.2 $[M + 2H]^{2+}$, 552.2 $[M + H]^+$, 570.2 $[M + H + 18]^+$.

Example 20. *N*-((*S*)-1-cyclopentyl-2-((3*aS*,6*R*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide



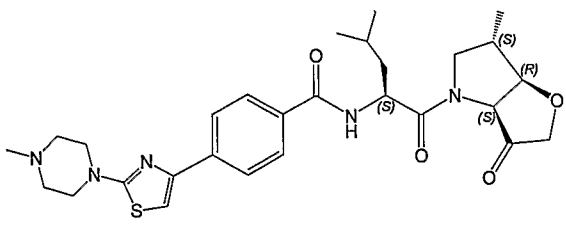
HPLC-MS R_t = 4.77 min, 294.7 $[M + 2H]^{2+}$, 588.2 $[M + H]^+$, 606.2 $[M + H + 18]^+$.

Example 21. *N*-((*S*)-1-cyclopentyl-2-((3*aS*,6*S*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide



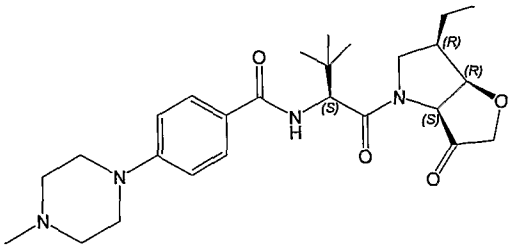
HPLC-MS R_t = 4.64 min, 294.6 $[M + 2H]^{2+}$, 588.2 $[M + H]^+$, 606.2 $[M + H + 18]^+$.

Example 22. *N*-((*S*)-4-methyl-1-((3*aS*,6*S*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide



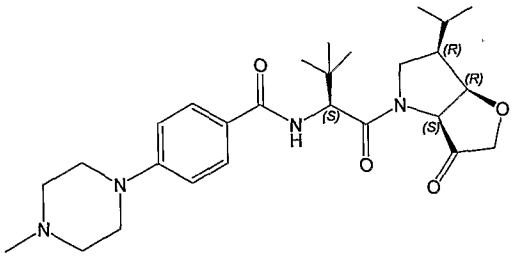
HPLC-MS R_t = 4.28 min, 270.7 $[M + 2H]^{2+}$, 540.2 $[M + H]^+$, 558.3 $[M + H + 18]^+$, 1101.3 $[2M + H]^+$.

Example 23. *N*-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxobutan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide



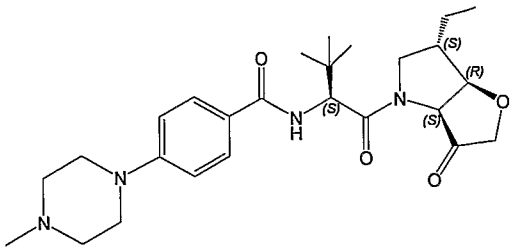
HPLC-MS R_t = 3.93 min, 471.3 $[M + H]^+$, 489.3 $[M + H + 18]^+$, 963.4 $[2M + H]^+$.

Example 24. *N*-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxobutan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide



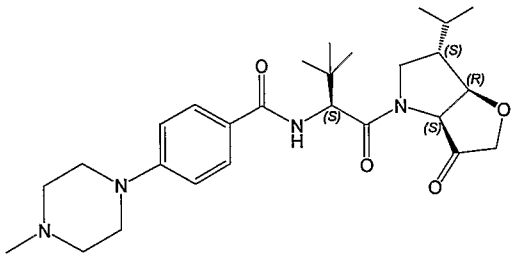
HPLC-MS R_t = 4.28 min, 485.3 $[M + H]^+$, 503.3 $[M + H + 18]^+$, 991.5 $[2M + H]^+$.

Example 25. *N*-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxobutan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide



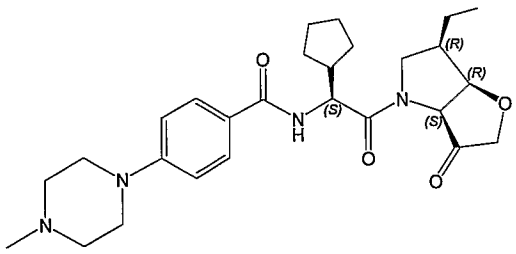
HPLC-MS R_t = 3.69 min, 471.3 $[M + H]^+$, 489.3 $[M + H + 18]^+$, 963.4 $[2M + H]^+$.

Example 26. *N*-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxobutan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide



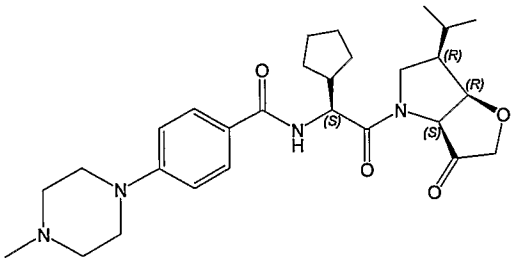
HPLC-MS R_t = 3.98 min, 485.3 $[M + H]^+$, 503.3 $[M + H + 18]^+$, 991.5 $[2M + H]^+$.

Example 27. *N*-((*S*)-1-cyclopentyl-2-((3*aS*,6*R*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide



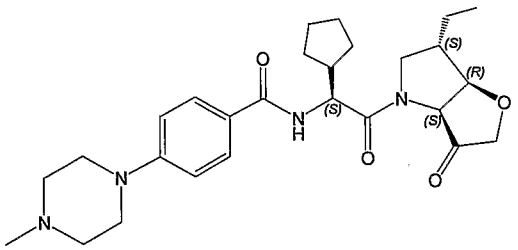
HPLC-MS R_t = 4.22 min, 483.3 $[M + H]^+$, 501.3 $[M + H + 18]^+$, 987.3 $[2M + Na]^+$.

Example 28. *N*-((*S*)-1-cyclopentyl-2-((3*aS*,6*R*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide



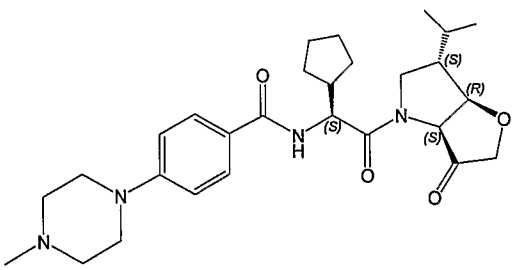
HPLC-MS R_t = 4.55 min, 497.3 $[M + H]^+$, 515.3 $[M + H + 18]^+$, 1015.4 $[2M + Na]^+$.

Example 29. *N*-((*S*)-1-cyclopentyl-2-((3*aS*,6*S*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide



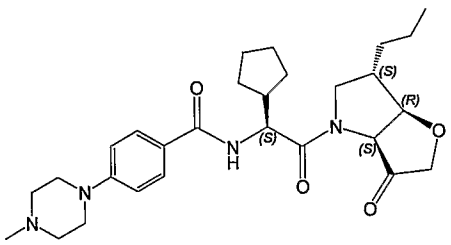
HPLC-MS R_t = 3.95 min, 483.3 $[M + H]^+$, 501.3 $[M + H + 18]^+$, 987.3 $[2M + Na]^+$.

Example 30. *N*-((*S*)-1-cyclopentyl-2-((3*aS*,6*S*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide



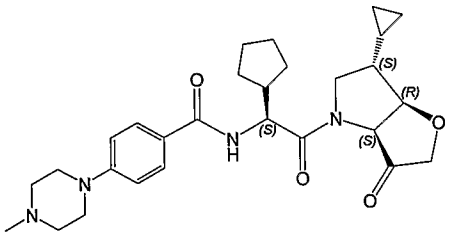
HPLC-MS R_t = 4.24 min, 497.3 $[M + H]^+$, 515.3 $[M + H + 18]^+$, 1015.4 $[2M + Na]^+$.

Example 38. *N*-((*S*)-1-cyclopentyl-2-oxo-2-((3*aS*,6*S*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)ethyl)-4-(4-methylpiperazin-1-yl)benzamide



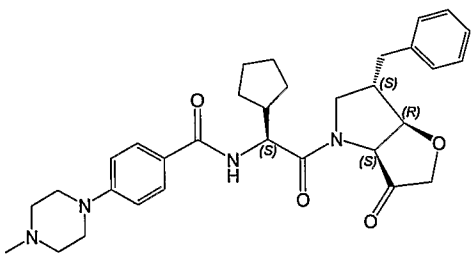
HPLC-MS R_t = 4.29 min, 497.3 $[M + H]^+$, 515.3 $[M + H + 18]^+$.

Example 39. *N*-((*S*)-1-cyclopentyl-2-((3*aS*,6*S*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide



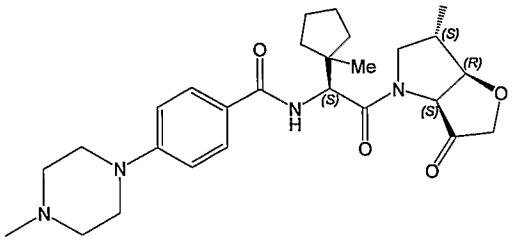
HPLC-MS R_t = 3.97 min, 495.3 $[M + H]^+$, 513.3 $[M + H + 18]^+$.

Example 40. *N*-((*S*)-2-((3*aS*,6*S*,6*aR*)-6-benzyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-cyclopentyl-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide



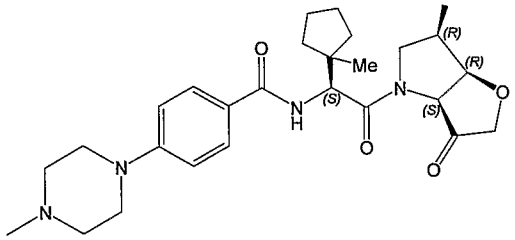
HPLC-MS R_t = 4.74 min, 545.3 $[M + H]^+$, 563.3 $[M + H + 18]^+$.

Example 41. *N*-((*S*)-2-((3*aS*,6*S*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-(1-methylcyclopentyl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide



HPLC-MS R_t = 4.09 min, 483.3 $[M + H]^+$, 501.3 $[M + H + 18]^+$, 987.4 $[2M + Na]^+$.

Example 42. *N*-((*S*)-2-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-(1-methylcyclopentyl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide



HPLC-MS R_t = 3.64 min, 483.4 $[M + H]^+$, 501.4 $[M + H + 18]^+$.

Solution Phase Syntheses.

Alternatively, EXAMPLES of the invention may be prepared by traditional solution phase organic chemistry techniques for example from building block (107) (3*R*,3*aR*,6*R*,6*aR*)-6-methylhexahydro-2*H*-furo[3,2-*b*]pyrrol-3-ol or building block (109) (3*R*,3*aR*,6*S*,6*aR*)-6-methylhexahydro-2*H*-furo[3,2-*b*]pyrrol-3-ol or the corresponding hydrochloride salt.

Alternative Preparation of. *N*-((*S*)-3,3-dimethyl-1-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide (EXAMPLE 3)

(i) Preparation of *tert*-butyl (*S*)-1-((3*R*,3*aR*,6*R*,6*aR*)-3-hydroxy-6-methyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3,3-dimethyl-1-oxobutan-2-ylcarbamate.

4-Methylmorpholine (1.062 mL, 9.7 mmol) was added to a suspension of 2-(1*H*-benzotriazole-1-yl)-1,1,3,3-tetramethyluronium hexafluorophosphate (HBTU, 1839 mg, 4.85 mmol), 1-hydroxybenzotriazole (654 mg, 4.85 mmol) and (*S*)-2-(*tert*-butoxycarbonylamino)-3,3-dimethylbutanoic acid (1.125 g, 4.85 mmol) in dimethylformamide (5 mL). The mixture was stirred for 5 minutes before adding to (3*R*,3*aR*,6*R*,6*aR*)-6-methylhexahydro-2*H*-furo[3,2-*b*]pyrrol-3-ol (107) (prepared as above with appropriate scaling of quantities, assume 4.62 mmol). The mixture was stirred for 16 hours then the solvents removed *in vacuo*. The crude product was dissolved in DCM (75 mL) then washed with (75 ML each) sat.$NaHCO_3$, 0.01N HCl, brine and the organic layer dried over Na_2SO_4. The mixture was filtered to leave a tan oil (2.20 g). Flash chromatography over silica, eluting with ethyl acetate : pentane mixtures 15 : 85 to 50 : 50 gave desired alcohol as a white solid (1.45 g, contaminated with tertamethylurea). Analytical HPLC main peak, R_t = 11.94 min., HPLC-MS 301.2 $[M + 2H - {}^tBu]^+$, 357.2 $[M + H]^+$, 379.2 $[M + Na]^+$, 735.5 $[2M + Na]^+$.

(ii) Preparation of (*S*)-2-amino-1-((3*R*,3*aR*,6*R*,6*aR*)-3-hydroxy-6-methyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethylbutan-1-one. hydrochloride.

A solution of 4N HCl in 1,4-dioxan (20 mL, 80 mmol) was added to *tert*-butyl (*S*)-1-((3*R*,3*aR*,6*R*,6*aR*)-3-hydroxy-6-methyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3,3-dimethyl-1-oxobutan-2-ylcarbamate (1.43 g, assuming 4.0 mmol). The solution was stirred for 90 minutes then the solvents were removed *in vacuo* and the residue azeotroped with TBME (3 x 25 mL) to leave (*S*)-2-amino-1-((3*R*,3*aR*,6*R*,6*aR*)-3-hydroxy-6-methyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethylbutan-1-one. hydrochloride as a purple crystalline solid which was used without further purification. HPLC-MS 257.2 $[M + H]^+$.

(iii) Preparation of (*N*-((*S*)-1-((3*R*,3*aR*,6*R*,6*aR*)-3-hydroxy-6-methyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxobutan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

4-Methylmorpholine (0.92 mL, 8.4 mmol) was added to a suspension of 2-(1*H*-benzotriazole-1-yl)-1,1,3,3-tetramethyluronium hexafluorophosphate (HBTU, 1.593 g, 4.2 mmol), 1-hydroxybenzotriazole (567mg, 4.2 mmol) and 4-(4-methylpiperazin-1-yl)benzoic acid (924 mg, 4.2 mmol) in DMF (5 mL). The suspension was sonicated for 1 minute then stirred for 5 minutes before adding to *S*)-2-amino-1-((3*R*,3*aR*,6*R*,6*aR*)-3-hydroxy-6-methyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethylbutan-1-one. hydrochloride (assume 4.0 mmol). The reaction was stirred for 6 hours then the majority of solvents removed *in vacuo*. The residue was dissolved in dichloromethane (75 mL) and washed with saturated sodium hydrogen carbonate solution (2 x 75 mL) The aqueous phase was extracted with dichloromethane (2 x 25 mL) then the combined organic layers washed with brine (75 mL), then dried (Na_2SO_4), filtered and reduced *in vacuo* to give a tan solid (Yield 1.70 g). Flash chromatography over silica, eluting with methanol : dichloromethane mixtures 1 : 99 to 10 : 90 gave desired alcohol as an off-white solid (1.53 g, 3.44 mmol, 88%). TLC (R_f = 0.18-0.29 double spot, MeOH : CH_2Cl_2 10 : 90), analytical HPLC main peak, R_t = 9.40 min., HPLC-MS 459.3 [M + H]$^+$, 939.4 [2M + Na]$^+$; $[\alpha]_D^{22.0}$ +25.0° (c = 2.0, $CHCl_3$);

(iv) Oxidation to EXAMPLE 3.

Dess-Martin periodinane (2.88 g, 6.8 mmol) was added to a stirred solution of (*N*-((*S*)-1-((3*R*,3*aR*,6*R*,6*aR*)-3-hydroxy-6-methyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxobutan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide (1.56 g, 3.40 mmol) in DCM (30 mL) under an atmosphere of argon. The mixture was stirred for 19 hours then diluted with dichloromethane (40 mL). The organic phase was washed with aqueous sodium hydroxide solution (1M, 40 mL) then the aqueous extracted with DCM (2 x 25 mL). The organic layer was washed with aqueous sodium hydroxide solution (1M, 40 mL) then 1 : 1 sat. $NaHCO_3$ / brine (40 mL), then dried (Na_2SO_4), filtered and reduced *in vacuo* to leave the desired ketone as a pale orange solid (1.54 g, 3.36 mmol,

99.1%). Analytical HPLC main peak, R_t = 9.17 min., HPLC-MS 457.2 $[M + H]^+$, 475.2 $[M + H_2O + H]^+$, 935.3 $[2M + Na]^+$.

(v) Preparation of Hydrochloride salt.

N-((*S*)-3,3-dimethyl-1-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-oxobutan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide (1.51 g, 3.33 mmol) was dissolved in acetonitrile (55 mL) and 0.1N HCl (43.3 mL, 4.33 mmol, 1.3 eq.) added. The mixture was spun-frozen then lyophilised to give an orange crystalline solid (Yield 2.88 g). $[\alpha]_D^{22.0}$ -12.0° (c = 1.04, $CHCl_3$); δ_C (125 MHz, d_6-DMSO); 10.13 (*C*H_3CH), 26.59 ((*C*H_3)C), 34.76 ((CH_3)*C*), 38.04 (CH_3*C*H), 41.95 (*C*H_3N), 44.52 / 44.54 (N*C*H_2), 51.86 / 52.39 (CH_3N*C*H_2*C*H_2N), 58.30 (NH*C*H), 62.09 (N*C*HCH), 70.74 (CHO*C*H_2CH), 82.25 (CH_3*C*HCH), 114.25 / 129.27 (*C*H-aryl), 124.27 / 151.17 (*C*-aryl), 166.49 (*C*ONH), 170.07 (*C*ON), 209.91 (*C*(O)CH_2).

Formation of EXAMPLE .hydrochloride salt.

EXAMPLE ketone (free base) (1 mmol) was dissolved in acetonitrile (16.7 mL) and standardised 0.1N HCl (1.3 eq, 13.0 mL) was added. The mixture was frozen and lyophilised to leave the EXAMPLE .hydrochloride salt as a solid.

EXAMPLE A. Assays for Cysteine Protease Activity

The compounds of this invention may be tested in one of a number of literature based biochemical assays that are designed to elucidate the characteristics of compound inhibition. The data from these types of assays enables compound potency and the rates of reaction to be measured and quantified. This information, either alone or in combination with other information, would allow the amount of compound required to produce a given pharmacological effect to be determined.

In vitro Cathepsin Ki Inhibition measurements

Stock solutions of substrate or inhibitor were made up to 10 mM in 100 % dimethylsulfoxide (DMSO) (Rathburns, Glasgow, U.K.) and diluted as appropriately

required. In all cases the DMSO concentration in the assays was maintained at less than 1 % (vol./vol.). The equilibrium inhibition constants (K_i^{ss}) for each compound were measured under steady-state conditions monitoring enzyme activity as a function of inhibitor concentration. The values were calculated on the assumption of pure competitive behaviour (Cornish-Bowden, A. *Fundamentals of enzyme kinetics* Portland Press; **1995**, 93-128.). Human recombinant cathepsin K (0.25 nM final; B. Turk, Josef, Stefan Institute, Ljubljana, Slovenia), was routinely assayed in 100 mM sodium acetate; pH 5.5 containing 1 mM EDTA, 10 mM L-cysteine and 1.8 μM Z-Leu-Arg-AMC ([S]=K_M).

Measurement of the apparent macroscopic binding (Michaelis) constants (K_M^{app}) for substrates

The apparent macroscopic binding constant (K_M^{app}) for each substrate was calculated, from the dependence of enzyme activity as a function of substrate concentration. The observed rates were plotted on the ordinate against the related substrate concentration on the abscissa and the data fitted by direct regression analysis (Prism v 3.02; GraphPad, San Diego, USA) using Equation 1 (Cornish-Bowden, A. *Fundamentals of enzyme kinetics* Portland Press; **1995**, 93-128.).

$$v_i = \frac{V_{max}^{app} \cdot [S_o]}{[S_o] + K_M^{app}} \qquad \textbf{(1)}$$

In Equation 1 '$\mathbf{v_i}$' is the observed initial rate, 'V_{max}^{app}' is the observed maximum activity at saturating substrate concentration, 'K_M^{app}' is the apparent macroscopic binding (Michaelis) constant for the substrate, '$\mathbf{[S_o]}$' is the initial substrate concentration.

Measurement of the inhibition constants

The apparent inhibition constant (K_i) for each compound was determined on the basis that inhibition was reversible and occurred by a pure-competitive mechanism. The K_i values were calculated, from the dependence of enzyme activity as a function of inhibitor concentration, by direct regression analysis (Prism v 3.02) using Equation 2 (Cornish-Bowden, A., 1995.).

$$v_i = \frac{V_{max}{}^{app}.[S]}{[S] + \{K_M{}^{app}.([I]/K_i)\}} \qquad (2)$$

In Equation 2 '$\mathbf{v_i}$' is the observed residual activity, '$V_{max}{}^{app}$' is the observed maximum activity (*i.e.* in the absence of inhibitor), '$K_M{}^{app}$' is the apparent macroscopic binding (Michaelis) constant for the substrate, '**[S]**' is the initial substrate concentration, 'K_i' is the apparent dissociation constant and '**[I]**' is the inhibitor concentration.

In situations where the apparent dissociation constant (K_i^{app}) approached the enzyme concentrations, the K_i^{app} values were calculated using a quadratic solution in the form described by Equation 3 (Morrison, J.F. *Trends Biochem. Sci.*, 7, 102-105, **1982**; Morrison, J.F. *Biochim. Biophys. Acta*, 185, 269-286, **1969**; Stone, S.R. and Hofsteenge, J. *Biochemistry*, 25, 4622-4628, **1986**).

$$v_i = \frac{F\{E_o - I_o - K_i^{app} + \sqrt{(E_o - I_o - K_i^{app})^2 + 4.K_i^{app}.E_o}\}}{2} \qquad (3)$$

$$K_i^{app} = K_i(1 + [S_o]/K_M{}^{app}) \qquad (4)$$

In Equation 3 '$\mathbf{v_i}$' is the observed residual activity, '**F**' is the difference between the maximum activity (*i.e.* in the absence of inhibitor) and minimum enzyme activity, '$\mathbf{E_o}$' is the total enzyme concentration, 'K_i^{app}' is the apparent dissociation constant and '$\mathbf{I_o}$' is the inhibitor concentration. Curves were fitted by non-linear regression analysis

(Prism) using a fixed value for the enzyme concentration. Equation 4 was used to account for the substrate kinetics, where 'K_i' is the inhibition constant, '$[S_o]$' is the initial substrate concentration and 'K_M^{app}' is the apparent macroscopic binding (Michaelis) constant for the substrate (Morrison, **1982**).

The second-order rate of reaction of inhibitor with enzyme

Where applicable, the concentration dependence of the observed rate of reaction (k_{obs}) of each compound with enzyme was analysed by determining the rate of enzyme inactivation under pseudo-first order conditions in the presence of substrate (Morrison, J.F., *TIBS*, 102-105, **1982**; Tian, W.X. and Tsou, C.L., *Biochemistry*, **21**, 1028-1032, **1982**; Morrison, J.F. and Walsh, C.T., from Meister (Ed.), *Advances in Enzymol.*, 61, 201-301, **1988**; Tsou, C.L., from Meister (Ed.), *Advances in Enzymol.*, 61, 381-436, **1988**;). Assays were carried out by addition of various concentrations of inhibitor to assay buffer containing substrate. Assays were initiated by the addition of enzyme to the reaction mixture and the change in fluorescence monitored over time. During the course of the assay less than 10% of the substrate was consumed.

$$F = v_s t + \frac{(v_o - v_s)\left[1 - e^{(k_{obs} \cdot t)}\right]}{k_{obs}} + D \qquad \textbf{(5)}$$

The activity fluorescence progress curves were fitted by non-linear regression analysis (Prism) using Eq. 5 (Morrison, 1969; Morrison, 1982); where '**F**' is the fluorescence response, '**t**' is time, 'v_o' is the initial velocity, 'v_s' is the equilibrium steady-state velocity, 'k_{obs}' is the observed pseudo first-order rate constant and '**D**' is the intercept at time zero (*i.e.* the ordinate displacement of the curve). The second order rate constant was obtained from the slope of the line of a plot of k_{obs} versus the inhibitor concentration (*i.e.* $k_{obs}/[I]$). To correct for substrate kinetics, Eq. 6 was used, where '$[S_o]$' is the iniitial substrate concentration and 'K_M^{app}' is the apparent macroscopic binding (Michaelis) constant for the substrate.

$$k_{inact} = \frac{k_{obs}\left(1 + [S_o]/K_M{}^{app}\right)}{[I]} \qquad \textbf{(6)}$$

Compounds of the invention when tested by the above described assays exhibit cathepsin K inhibitory activity with an *in vitro* Ki inhibitory constant of less than or equal to 100nM.

Liver Microsomal Incubations:

Human and rat liver microsomes were purchased from BD Gentest (Woburn, MA, USA) and β-nicotinamide adenine dinucleotide 2′-phosphate reduced tetrasodium salt (NADPH) was purchased from Sigma-Aldrich (Poole, Dorset, UK). All liver microsome incubations were carried out in 50 mM potassium phosphate buffer at pH 7.4, with a final microsomal protein concentration of 0.5 mg/mL. Compounds were taken from 5 mM DMSO stock solutions and diluted in incubation buffer to give a final concentration of 25 μM, with a final DMSO concentration of 0.5% v/v. In brief, compounds were added to the incubation buffer along with the liver microsomes and incubated at 37°C for 10 minutes. The reaction was then initiated by the addition of NADPH, previously dissolved in incubation buffer, to give a final concentration of 1 mM and re-incubated at 37°C. Aliquots were removed at 2 and 60 minutes and quenched with an equal volume of cold acetonitrile. After mixing vigorously, the precipitated protein matter was removed by filtration (Multiscreen Solvinert filter plates, Millipore, Bedford, MA, USA) and the filtrate analysed by reverse phase HPLC with mass spectrometric detection, using single ion monitoring of the $[M+H]^+$ species. Metabolic turnover was determined by comparison of peak areas from the ion chromatograms of the parent compound at 2 and 60 minutes and expressed as percent remaining at 1 hour.

Plasma Incubations:

Human and rat plasma were purchased from Innovative Research Inc. (Southfield. MI, USA). Compounds were taken from 5 mM DMSO stock solutions and added to plasma, which had previously been incubated at 37°C, to give a final concentration of 25 μM and re-incubated. Aliquots were removed at 2 and 60 minutes and quenched with an equal volume of cold acetonitrile. After mixing vigorously, the precipitated protein matter was removed by filtration (Multiscreen Solvinert filter plates, Millipore,

Bedford, MA, USA) and the filtrate analysed by reverse phase HPLC with mass spectrometric detection, using single ion monitoring of the $[M+H]^+$ species. Metabolic turnover was determined by comparison of peak areas from the ion chromatograms of the parent compound at 2 and 60 minutes and expressed as percent remaining at 1 hour.

LogD Determinations:

$LogD_{(PBS)}$ determinations were performed in 96 well microtitre plates using a miniaturised "shake-flask" method. In brief, compounds were taken from 10 mM DMSO stock solutions and added to wells containing equal volumes of phosphate buffered saline (10 mM; pH 7.4) (PBS) and 1-octanol (Sigma-Aldrich, Poole, Dorset, UK) to give a final concentration of 50 μM. The plates were then capped and mixed vigorously for 1 hour on a microtitre plate shaker, after which they were left to stand, allowing the PBS and octanol phases to separate. The PBS layer was analysed by reverse phase HPLC with mass spectrometric detection, using single ion monitoring of the $[M+H]^+$ species. $LogD_{(PBS)}$ was determined by comparison of the peak area from the ion chromatogram of the compound in the PBS phase with that of a 50 μM standard of the same compound dissolved in acetonitrile/water (50:50) and calculated using the following formula:

$$LogD = Log\left[\frac{AUCstd - AUCpbs}{AUCpbs}\right]$$

Where *AUCstd* and *AUCpbs* are the peak areas from the standard and test ion chromatograms respectively. $LogD_{(PBS)}$ determinations were also made using PBS at pH6.9 and 5.5 by adjusting the pH of the buffer prior to the start of the assay, with 0.1 M HCL.

Human Osteoclast Resorption Assay

Bone resorption was studied using a model where human osteoclast precursor cells were cultured on bovine bone slices for 9 days and allowed to differentiate into bone-resorbing osteoclasts. The formed mature osteoclasts were then allowed to resorb bone.

The assay was performed by Pharmatest Services Ltd, Itäinen Pitkakatu 4C, Turku, Finland. After the culture period, bone collagen degradation products were quantified from the culture medium as an index of bone resorption. Inhibitor compounds were added into the cell cultures after the differentiation period and their effects on the resorbing activity of mature osteoclasts were determined. The studies included a baseline group without added compounds and a positive control group where a potent cathepsin K inhibitor E-64 was added.

Human peripheral blood monocytes were suspended to culture medium and allowed to attach to bovine bone slices. The bone slices were transferred into 96-well tissue culture plates containing culture medium with appropriate amounts of important growth factors favouring osteoclast differentiation, including M-CSF, RANK-ligand and TGF-β. The cells were incubated in a CO_2 incubator in humidified atmosphere of 95% air and 5% carbon dioxide at 37°C. At day 7 when osteoclast differentiation was complete, the culture medium was replaced with culture medium containing conditions favouring osteoclast activity. The cell culture was continued for an additional 2 days, during which the formed mature osteoclasts were allowed to resorb bone in the presence of vehicle, control inhibitor (E64) or test compounds. At the end of the culture, bone collagen degradation products released into the culture medium were determined using a commercially available ELISA method (CrossLaps® for culture, Nordic Bioscience, Herlev, Denmark) as an index of bone resorption (see Bagger, Y. Z. et al, J. Bone. Miner. Res. 14 (suppl. 1), S370).

In this assay, selected EXAMPLES of the invention exhibit more than 75% inhibition of bone resorption at a concentration of 1000nM.

Rat Osteoclast Resorption Assay

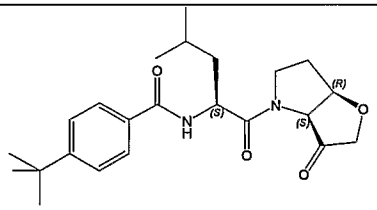
Bone resorption was studied using a model where mature osteoclasts derived from rat bone were cultured on bovine bone slices for 3 days and allowed to resorb bone in the presence of inhibitor, positive control (E-64) or vehicle. More specifically, tibia, femori and humeri were removed from 1 day old rat pups. The endosteal surfaces of the bones

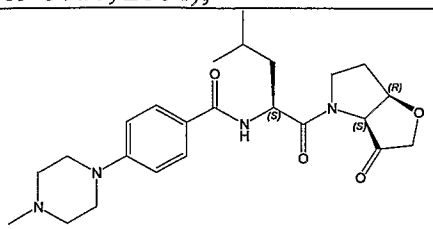
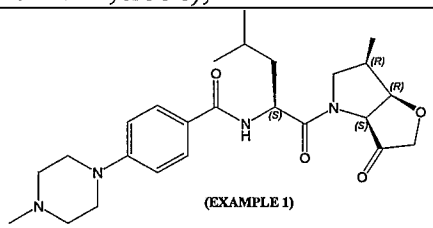
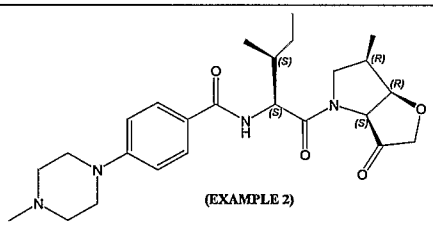
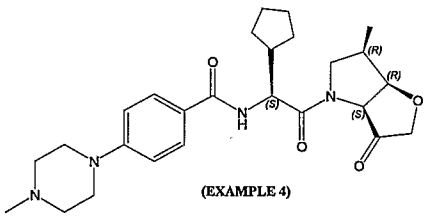
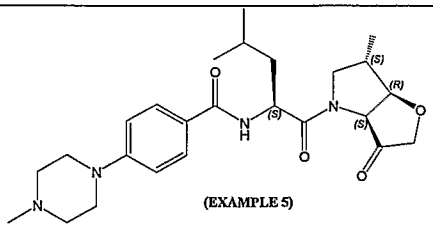
were scraped with a scapelto release osteoclasts into the culture medium and the osteoclasts were allowed to attach to bovine bone slices. After the culture period, bone collagen degradation products were quantified from the culture medium as an index of bone resorption. The assay was performed by Pharmatest Services Ltd, Itäinen Pitkakatu 4C, Turku, Finland.

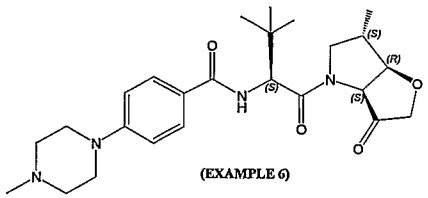
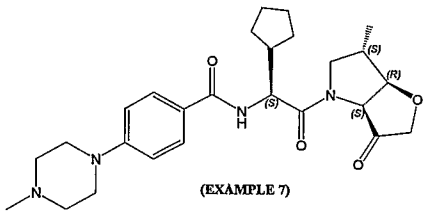
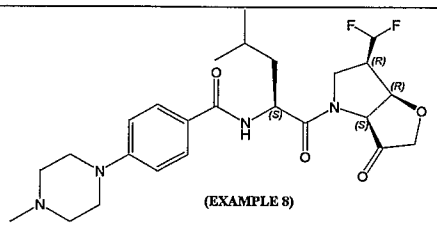
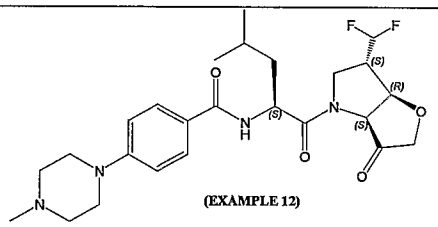
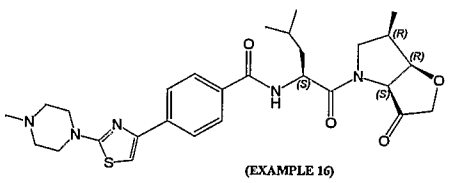
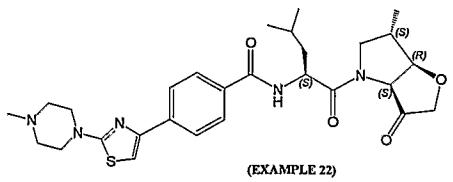
In this assay, selected EXAMPLES of the invention exhibit more than 75% inhibition of bone resorption at a concentration of 1000nM.

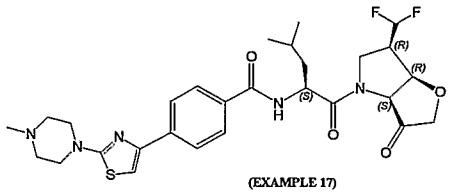
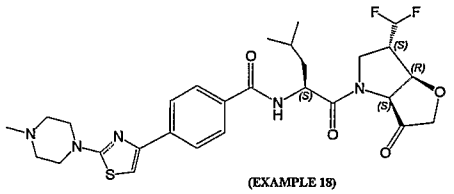
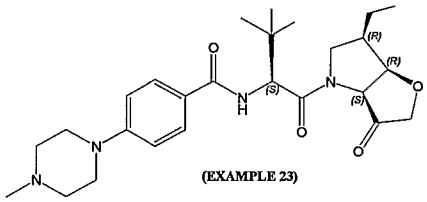
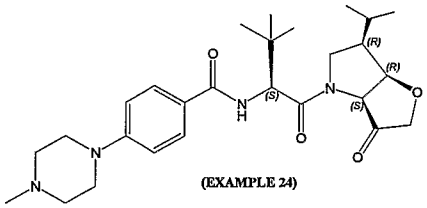
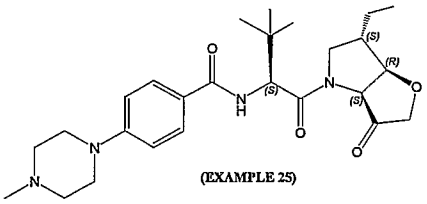
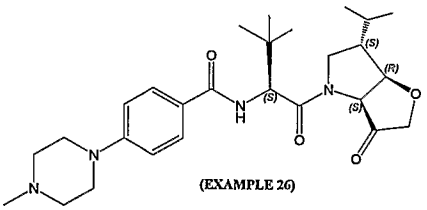
Various modifications and variations of the described aspects of the invention will be apparent to those skilled in the art without departing from the scope and spirit of the invention. Although the invention has been described in connection with specific preferred embodiments, it should be understood that the invention as claimed should not be unduly limited to such specific embodiments. Indeed, various modifications of the described modes of carrying out the invention which are obvious to those skilled in the relevant fields are intended to be within the scope of the following claims.

Table 1: Biological properties for EXAMPLE compounds and prior art compounds **(23)** and **(45)**.

EXAMPLE	*In vitro* Ki (nM) vs Cath K
	87.4
Prior art compound **23** (Quibell, M. *et. al. Bioorg. Med. Chem.*,13, 609-625, **2005**); Prior art compound **10** (Quibell, M. *et. al. Bioorg. Med. Chem.*, 12,	

5689-5710, **2004**);	
 Prior art compound **42** (Quibell, M. *et. al. Bioorg. Med. Chem.*, 13, 609-625, **2005**); Prior art compound **45a** (Quibell, M. *et. al. Bioorg. Med. Chem.*, 12, 5689-5710, **2004**);	8.7
 (EXAMPLE 1)	2.5
 (EXAMPLE 2)	1.5
 (EXAMPLE 4)	1.0
 (EXAMPLE 5)	0.75

 (EXAMPLE 6)	1.1
 (EXAMPLE 7)	0.35
 (EXAMPLE 8)	1.7
 (EXAMPLE 12)	0.8
 (EXAMPLE 16)	0.7
 (EXAMPLE 22)	0.6

 (EXAMPLE 17)	0.45
 (EXAMPLE 18)	0.7
 (EXAMPLE 23)	4.4
 (EXAMPLE 24)	3.2
 (EXAMPLE 25)	0.8
 (EXAMPLE 26)	0.8

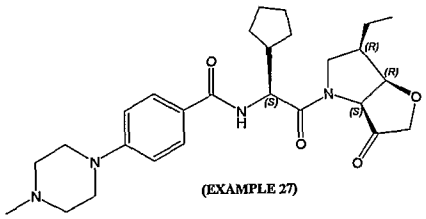
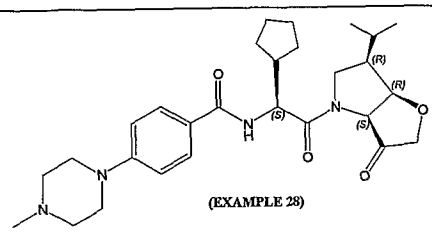
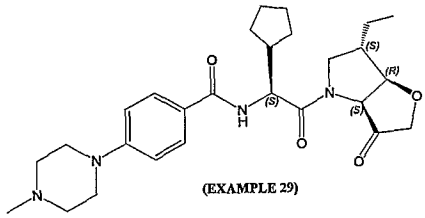
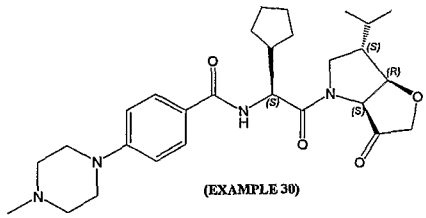
 (EXAMPLE 27)	1.2
 (EXAMPLE 28)	1.5
 (EXAMPLE 29)	0.4
 (EXAMPLE 30)	0.45

Table 2: Prior art WO-A-02057270 *in vitro* Ki against recombinant human cathepsin K. Selected compounds of the present invention are significantly more potent than those specifically detailed in prior art WO-A-02057270 when assayed *in vitro* against recombinant human cathepsin K (compare tables 1 and 2).

Example No (WO-A-02057270)	Ki (nM) vs Human Cathepsin K
1	>20000

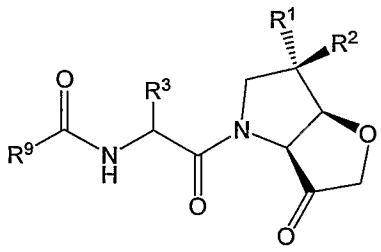
2	>50000
3	>4000
4	>100000
5	>100000
6	>20000
7	>15000
8	390
9	90
10	87
11	1300
12	170
13	560
14	300
15	60
16	110
17	235
18	130
19	530
20	390
21	210
22	450
23	>3000
24	>2000
25	620
26	>8000
27	>20000
28	>2500
29	>17000
30	>100000
31	>1500

32	>16000
33	>36000
34	>67000
35	>32000
36	570
37	>3500
38	>4000
39	>7500
40	>3500
41	>45000
42	>1500
43	>25000
44	>40000
45	>8500
46	>20000
47	830
48	>6500
49	>6000
50	>10000
51	>1500
52	>25000
53	200
54	>2000
55	>2000
56	>4000
57	390
58	>23000
59	>2000
60	>20000
61	>16000

62	**>10000**
63	**>250**
64	**>8000**
65	**100**
66	**>2500**
67	**>2000**
68	**>2500**
69	**>15000**
70	**>2500**
71	**>20000**
72	**>20000**
73	**>35000**
74	**>40000**
75	**>50000**
76	**>10000**
77	**>100000**
78	**>2000**
79	**>200**
80	**>150**
81	**>50000**
82	**>50000**

CLAIMS

1. A compound of formula (I), or a pharmaceutically acceptable salt, hydrate, complex or pro-drug thereof,



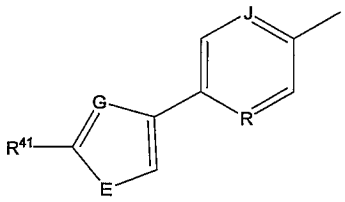
(I)

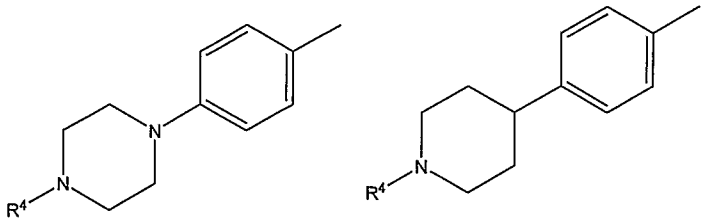
wherein:

one of R^1 and R^2 is H, and the other is selected from C_{1-8}-alkyl, C_{3-6}-cycloalkyl and C_{1-8}-alkyl-C_{5-10}-aryl;

R^3 is selected from *tert*-butylmethyl, *iso*-propylmethyl, *sec*-butyl, *tert*-butyl, cyclopentyl, cyclohexyl and 1-methylcyclopentyl;

R^9 is selected from the following:





wherein:

R^4 is selected from C_{1-8}-alkyl and C_{3-8}-cycloalkyl;

G is selected from:

$\rangle$CH, $\rangle$CMe and N;

E is selected from:

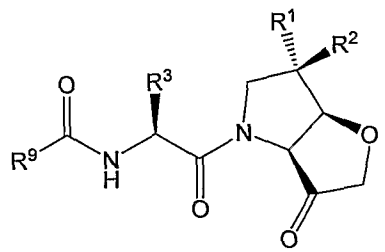
O, S, $\rangle SO_2$, $\rangle$NH, $\rangle$NMe and N-oxide ($\rangle N \rightarrow O$);

J and R are independently selected from:

$\rangle$CH, N and N-oxide ($\rangle N \rightarrow O$); and

R^{41} is selected from amino, methylamino, dimethylamino, isopropylamino, isopropyl(methyl)amino, cyclopropylamino, cyclopropyl(methyl)amino, cyclopentylamino, morpholino, piperidin-1-yl, piperidin-1-ylmethyl, morpholinomethyl, 4-methylpiperazin-1-yl, 4-(2-methoxyethyl)piperazin-1-yl, 1-morpholinoethyl, 1-(dimethylamino)ethyl, 1-(methylamino)ethyl, 4-fluoro-1-methylpyrrolidin-2-yl, 4,4-difluoropiperidin-1-yl, piperidin-4-yl, 1-methylpiperidin-4-yl, pyridin-3-ylamino, pyridin-2-ylamino, 1-methylpyrrolidin-3-yl, methyl, isopropyl;.

2. A compound according to claim 1 wherein said compound is of formula Ia



(Ia)

wherein R^1, R^2, R^3 and R^9 are as defined in claim 1.

3. A compound according to claim 1 or claim 2 wherein one of R^1 and R^2 is H, and the other is selected from methyl, ethyl, propyl, iso-propyl, *tert*-butyl, cyclopropyl,

cyclopropylmethyl, iso-propylmethyl, *tert*-butylmethyl, CH_2OH, CH_2OMe, CH_2OCH_2Ph, CH_2Ph, CH_2F and CHF_2.

4. A compound according to claim 1 or claim 2 wherein one of R^1 and R^2 is H, and the other is C_{1-8}-alkyl.

5. A compound according to any preceding claim wherein one of R^1 and R^2 is H, and the other is selected from methyl, ethyl, iso-propyl and CHF_2.

6. A compound according to any preceding claim wherein R^3 is selected from *tert*-butylmethyl, *iso*-propylmethyl, *sec*-butyl, *tert*-butyl, cyclopentyl and cyclohexyl.

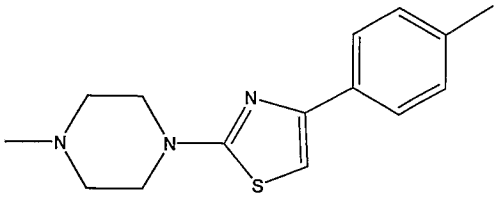
7. A compound according to any preceding claim wherein R^3 is cyclopentyl or *tert* -butyl.

8. A compound according to any preceding claim wherein with respect to the definition of R^9:
G is N;
E is selected from O, S and NH;
J and R are each independently selected from CH and N.

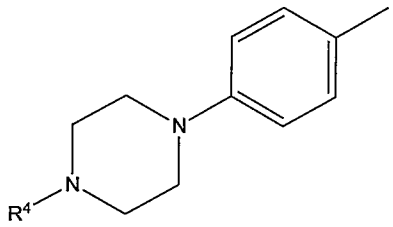
9. A compound according to any preceding claim wherein with respect to the definition of R^9:
G is N;
J and R are both CH;
E is S.

10. A compound according to any preceding claim wherein R^{41} is selected from 4-methylpiperazin-1-yl and 4-(2-methoxyethyl)piperazin-1-yl.

11. A compound according to any one of claims 1 to 10 wherein R^9 is:



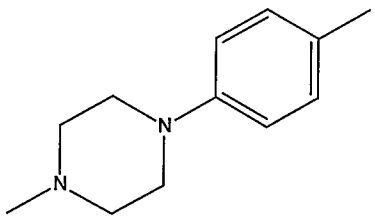
12. A compound according to any one of claims 1 to 7 wherein R^9 is:



and R^4 is C_{1-8}-alkyl

13. A compound according to claim 13 wherein R^4 is selected from methyl, ethyl and propyl.

14. A compound according to claim 13 wherein R^9 is:



15. A compound according to any preceding claim which is selected from the following:

N-((*S*)-4-methyl-1-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

4-(4-ethylpiperazin-1-yl)-*N*-((*S*)-4-methyl-1-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-oxopentan-2-yl)benzamide

N-((*S*)-4-methyl-1-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-4-methyl-1-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((S)-1-((3aS,6R,6aR)-6-ethyl-3-oxodihydro-2H-furo[3,2-b]pyrrol-4(5H,6H,6aH)-yl)-4-methyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-4-methyl-1-oxo-1-((3*aS*,6*R*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)pentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

4-(4-ethylpiperazin-1-yl)-*N*-((*S*)-4-methyl-1-oxo-1-((3*aS*,6*R*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)pentan-2-yl)benzamide

N-((*S*)-4-methyl-1-oxo-1-((3*aS*,6*R*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)pentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-4-methyl-1-oxo-1-((3*aS*,6*R*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)pentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-4,4-dimethyl-1-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-4,4-dimethyl-1-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-4,4-dimethyl-1-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-4,4-dimethyl-1-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-4,4-dimethyl-1-oxo-1-((3*aS*,6*R*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)pentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-4,4-dimethyl-1-oxo-1-((3*aS*,6*R*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)pentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-4,4-dimethyl-1-oxo-1-((3*aS*,6*R*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)pentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-4,4-dimethyl-1-oxo-1-((3*aS*,6*R*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)pentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

4-(4-ethylpiperazin-1-yl)-*N*-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((2*S*,3*S*)-3-methyl-1-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

4-(4-ethylpiperazin-1-yl)-*N*-((2*S*,3*S*)-3-methyl-1-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-oxopentan-2-yl)benzamide

N-((2*S*,3*S*)-3-methyl-1-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((2*S*,3*S*)-3-methyl-1-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*R*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*R*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*R*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*R*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((2*S*,3*S*)-3-methyl-1-oxo-1-((3*aS*,6*R*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)pentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

4-(4-ethylpiperazin-1-yl)-*N*-((2*S*,3*S*)-3-methyl-1-oxo-1-((3*aS*,6*R*,6*aR*)-3-oxo-6-propyldihydro-2H-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)pentan-2-yl)benzamide

N-((2*S*,3*S*)-3-methyl-1-oxo-1-((3*aS*,6*R*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)pentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((2*S*,3*S*)-3-methyl-1-oxo-1-((3*aS*,6*R*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)pentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*R*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

4-(4-ethylpiperazin-1-yl)-*N*-((2*S*,3*S*)-1-((3a*S*,6*R*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3-methyl-1-oxopentan-2-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*R*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*R*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*R*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((2*S*,3*S*))-1-((3*aS*,6*R*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((2*S*,3*S*))-1-((3*aS*,6*R*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((2*S*,3*S*))-1-((3*aS*,6*R*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*R*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*R*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*R*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*R*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*R*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*R*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*R*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*R*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-3,3-dimethyl-1-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-3,3-dimethyl-1-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-3,3-dimethyl-1-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-3,3-dimethyl-1-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-3,3-dimethyl-1-oxo-1-((3*aS*,6*R*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)pentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-3,3-dimethyl-1-oxo-1-((3*aS*,6*R*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)pentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-3,3-dimethyl-1-oxo-1-((3*aS*,6*R*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)pentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-3,3-dimethyl-1-oxo-1-((3*aS*,6*R*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)pentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

4-(4-ethylpiperazin-1-yl)-*N*-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*R*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*R*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*R*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*R*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-cyclopentyl-2-oxo-2-((3*aS*,6*R*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6aH)-yl)ethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-oxo-2-((3*aS*,6*R*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6aH)-yl)ethyl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-oxo-2-((3*aS*,6*R*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6aH)-yl)ethyl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-oxo-2-((3*aS*,6*R*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6aH)-yl)ethyl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*R*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*R*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*R*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*R*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-2-((3*aS*,6*R*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-cyclopentyl-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-2-((3*aS*,6*R*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-cyclopentyl-2-oxoethyl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-2-((3*aS*,6*R*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-cyclopentyl-2-oxoethyl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-2-((3*aS*,6*R*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-cyclopentyl-2-oxoethyl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*R*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*R*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*R*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*R*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*R*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*R*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*R*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*R*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*R*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*R*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*R*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*R*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-cyclohexyl-2-oxo-2-((3*aS*,6*R*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6aH)-yl)ethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-oxo-2-((3*aS*,6*R*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6aH)-yl)ethyl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-oxo-2-((3*aS*,6*R*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6aH)-yl)ethyl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-oxo-2-((3*aS*,6*R*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6aH)-yl)ethyl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*R*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*R*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*R*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*R*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-2-((3*aS*,6*R*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-cyclohexyl-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-2-((3*aS*,6*R*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-cyclohexyl-2-oxoethyl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-2-((3*aS*,6*R*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-cyclohexyl-2-oxoethyl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-2-((3*aS*,6*R*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-cyclohexyl-2-oxoethyl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*R*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*R*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*R*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*R*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*R*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*R*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*R*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*R*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-4-methyl-1-((3*aS*,6*S*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

4-(4-ethylpiperazin-1-yl)-*N*-((*S*)-4-methyl-1-((3*aS*,6*S*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-oxopentan-2-yl)benzamide

N-((*S*)-4-methyl-1-((3*aS*,6*S*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-4-methyl-1-((3*aS*,6*S*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-4-methyl-1-oxo-1-((3*aS*,6*S*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)pentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

4-(4-ethylpiperazin-1-yl)-*N*-((*S*)-4-methyl-1-oxo-1-((3*aS*,6*S*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)pentan-2-yl)benzamide

N-((*S*)-4-methyl-1-oxo-1-((3*aS*,6*S*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)pentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-4-methyl-1-oxo-1-((3*aS*,6*S*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)pentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,S6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-4,4-dimethyl-1-((3*aS*,6*S*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-4,4-dimethyl-1-((3*aS*,6*S*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-4,4-dimethyl-1-((3*aS*,6*S*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-4,4-dimethyl-1-((3*aS*,6*S*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-4,4-dimethyl-1-oxo-1-((3*aS*,6*S*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)pentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-4,4-dimethyl-1-oxo-1-((3*aS*,6*S*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)pentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-4,4-dimethyl-1-oxo-1-((3*aS*,6*S*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)pentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-4,4-dimethyl-1-oxo-1-((3*aS*,6*S*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)pentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

4-(4-ethylpiperazin-1-yl)-*N*-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4,4-dimethyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((2*S*,3*S*)-3-methyl-1-((3*aS*,6*S*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

4-(4-ethylpiperazin-1-yl)-*N*-((2*S*,3*S*)-3-methyl-1-((3*aS*,6*S*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-oxopentan-2-yl)benzamide

N-((2*S*,3*S*)-3-methyl-1-((3*aS*,6*S*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((2*S*,3*S*)-3-methyl-1-((3*aS*,6*S*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*S*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*S*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*S*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*S*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((2*S*,3*S*)-3-methyl-1-oxo-1-((3*aS*,6*S*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)pentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

4-(4-ethylpiperazin-1-yl)-*N*-((2*S*,3*S*)-3-methyl-1-oxo-1-((3*aS*,6*S*,6*aR*)-3-oxo-6-propyldihydro-2H-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)pentan-2-yl)benzamide

N-((2*S*,3*S*)-3-methyl-1-oxo-1-((3*aS*,6*S*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)pentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((2*S*,3*S*)-3-methyl-1-oxo-1-((3*aS*,6*S*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)pentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*S*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

4-(4-ethylpiperazin-1-yl)-*N*-((2*S*,3*S*)-1-((3a*S*,6*S*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3-methyl-1-oxopentan-2-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*S*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*S*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*S*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((2*S*,3*S*))-1-((3*aS*,6*S*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((2*S*,3*S*))-1-((3*aS*,6*S*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((2*S*,3*S*))-1-((3*aS*,6*S*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*S*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*S*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*S*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*S*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*S*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*S*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*S*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*S*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-3,3-dimethyl-1-((3*aS*,6*S*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-3,3-dimethyl-1-((3*aS*,6*S*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-3,3-dimethyl-1-((3*aS*,6*S*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-3,3-dimethyl-1-((3*aS*,6*S*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-3,3-dimethyl-1-oxo-1-((3*aS*,6*S*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)pentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-3,3-dimethyl-1-oxo-1-((3*aS*,6*S*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)pentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-3,3-dimethyl-1-oxo-1-((3*aS*,6*S*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)pentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-3,3-dimethyl-1-oxo-1-((3*aS*,6*S*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)pentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

4-(4-ethylpiperazin-1-yl)-*N*-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*S*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*S*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*S*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*S*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*S*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*S*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*S*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*S*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-cyclopentyl-2-oxo-2-((3*aS*,6*S*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6aH)-yl)ethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-oxo-2-((3*aS*,6*S*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6aH)-yl)ethyl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-oxo-2-((3*aS*,6*S*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6aH)-yl)ethyl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-oxo-2-((3*aS*,6*S*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6aH)-yl)ethyl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*S*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*S*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*S*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*S*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-2-((3*aS*,6*S*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-cyclopentyl-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-2-((3*aS*,6*S*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-cyclopentyl-2-oxoethyl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-2-((3*aS*,6*S*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-cyclopentyl-2-oxoethyl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-2-((3*aS*,6*S*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-cyclopentyl-2-oxoethyl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*S*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*S*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*S*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*S*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*S*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*S*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*S*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*S*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*S*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*S*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*S*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*S*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*S*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*S*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*S*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*S*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-cyclohexyl-2-oxo-2-((3*aS*,6*S*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6aH)-yl)ethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-oxo-2-((3*aS*,6*S*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6aH)-yl)ethyl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-oxo-2-((3*aS*,6*S*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6aH)-yl)ethyl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-oxo-2-((3*aS*,6*S*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6aH)-yl)ethyl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*S*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*S*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*S*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*S*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-2-((3*aS*,6*S*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-cyclohexyl-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-2-((3*aS*,6*S*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-cyclohexyl-2-oxoethyl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-2-((3*aS*,6*S*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-cyclohexyl-2-oxoethyl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-2-((3*aS*,6*S*,6*aR*)-6-*tert*-butyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-cyclohexyl-2-oxoethyl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*S*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*S*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*S*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*S*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*S*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*S*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-ethylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*S*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclohexyl-2-((3*aS*,6*S*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide.

16. A compound according to any preceding claim which is selected from the following:

N-((*S*)-4-methyl-1-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((2*S*,3*S*)-3-methyl-1-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-oxopentan-2-yl)-4-(4-propylpiperazin-1-yl)benzamide

N-((*S*)-3,3-dimethyl-1-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-4-methyl-1-((3*aS*,6*S*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-3,3-dimethyl-1-((3*aS*,6*S*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6a*H*)-yl)-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*S*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*R*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*R*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((2*S*,3*S*)-1-((3*aS*,6*S*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3-methyl-1-oxopentan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*S*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-4-methyl-1-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-4-methyl-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*R*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*S*,6*aR*)-6-(difluoromethyl)-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-4-methyl-1-((3*aS*,6*S*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-oxopentan-2-yl)-4-(2-(4-methylpiperazin-1-yl)thiazol-4-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxobutan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*R*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxobutan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxobutan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-((3*aS*,6*S*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-3,3-dimethyl-1-oxobutan-2-yl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*R*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*R*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*S*,6*aR*)-6-ethyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*S*,6*aR*)-6-isopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-oxo-2-((3*aS*,6*S*,6*aR*)-3-oxo-6-propyldihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)ethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-1-cyclopentyl-2-((3*aS*,6*S*,6*aR*)-6-cyclopropyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-2-((3*aS*,6*S*,6*aR*)-6-benzyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-cyclopentyl-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide

N-((*S*)-2-((3*aS*,6*S*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-(1-methylcyclopentyl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide and

N-((*S*)-2-((3*aS*,6*R*,6*aR*)-6-methyl-3-oxodihydro-2*H*-furo[3,2-*b*]pyrrol-4(5*H*,6*H*,6*aH*)-yl)-1-(1-methylcyclopentyl)-2-oxoethyl)-4-(4-methylpiperazin-1-yl)benzamide.

17. A pharmaceutical or veterinary composition comprising a compound according to any one of claims 1 to 16 and a pharmaceutically acceptable or veterinarily acceptable diluent, excipient and/or carrier.

18. A process for preparing a pharmaceutical or veterinary composition according to claim 17, said process comprising admixing a compound according to any one of claims 1 to 16 with a pharmaceutically acceptable or veterinarily acceptable diluent, excipient and/or carrier.

19. A compound according to any one of claims 1 to 16 for use in medicine.

20. Use of a compound according to any one of claims 1 to 16 in the preparation of a medicament for treating a disease selected from osteoporosis, Paget's disease, Chagas's disease, malaria, gingival diseases, hypercalaemia, metabolic bone disease, diseases involving matrix or cartilage degradation, and bone cancer disorders such as bone metastases and associated pain.

21. Use according to claim 20 wherein the gingival disease is gingivitis or periodontitis.

22. Use according to claim 20 wherein the disease involving matrix or cartilage degradation is selected from osteoporosis, osteoarthritis, rheumatoid arthritis and neoplastic diseases.

23. Use of a compound according to any one of claims 1 to 16 for inhibiting a cysteine proteinase.

24. Use according to claim 23 wherein the cysteine proteinase is a CAC1 cysteine proteinase.

25. Use according to claim 24 wherein the CAC1 cysteine proteinase is cathepsin K.

26. A method of inhibiting a cysteine proteinase in a cell, said method comprising contacting said cell with a compound according to any one of claims 1 to 16.

27. A method of inhibiting a cysteine proteinase in a subject, said method comprising administering to the subject a pharmacologically effective amount of a compound according to any one of claims 1 to 16.

28. A method of treating a disease selected from osteoporosis, Paget's disease, Chagas's disease, malaria, gingival diseases, hypercalaemia, metabolic bone disease, diseases involving matrix or cartilage degradation, and bone cancer disorders such as bone metastases and associated pain, in a subject, said method comprising administering to the subject a pharmacologically effective amount of a compound according to any one of claims 1 to 16.

29. Use of a compound according to any one of claims 1 to 16 in an assay for identifying further candidate compounds capable of inhibiting one or more cysteine proteinases.

30. Use according to claim 29 wherein said assay is a competitive binding assay.

31. Use according to claim 30 wherein said competitive binding assay comprises contacting a compound according to any one of claims 1 to 16 with a cysteine proteinase and detecting any change in the interaction between the compound according to any one of claims 1 to 17 and the cysteine proteinase.

32. A method of validating a known or putative cysteine proteinase as a therapeutic target, the method comprising:

(a) assessing the in vitro binding of a compound according to any one of claims 1 to 16 to an isolated or known putative cysteine proteinase, providing a measure of potency; and optionally, one or more of the steps of:

(b) assessing the binding of a compound according to any one of claims 1 to 16 to closely related homologous proteinases of the target and general housekeeping proteinases (e.g. trypsin) to provide a measure of selectivity;

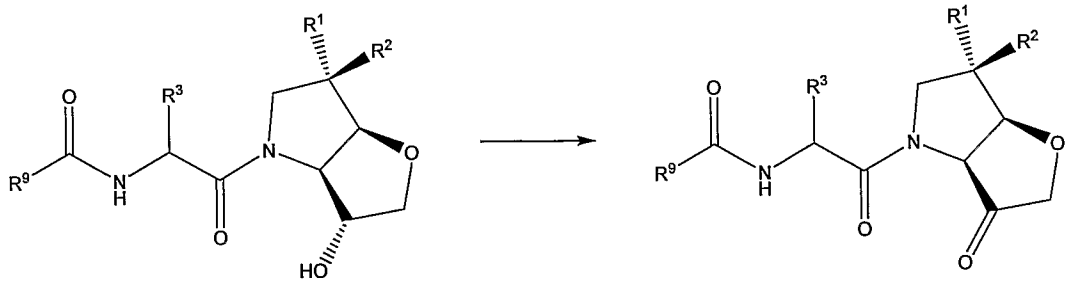
(c) monitoring a cell-based functional marker of a particular cysteine proteinase activity in the presence of a compound according to any one of claims 1 to 16; and

(d) monitoring an animal model-based functional marker of a particular cysteine proteinase activity in the presence of a compound according to any one of claims 1 to 16.

33. Use of a compound according to any one of claims 1 to 16 in the validation of a known or putative cysteine proteinase as a therapeutic target.

34. Use of a compound according to any one of claims 1 to 16 for treating a disease selected from osteoporosis, Paget's disease, Chagas's disease, malaria, gingival diseases, hypercalaemia, metabolic bone disease, diseases involving matrix or cartilage degradation, and bone cancer disorders such as bone metastases and associated pain.

35. A process of preparing a compound of formula (I) as defined in claim 1, said process comprising treating a compound of formula (II) with an oxidizing agent.

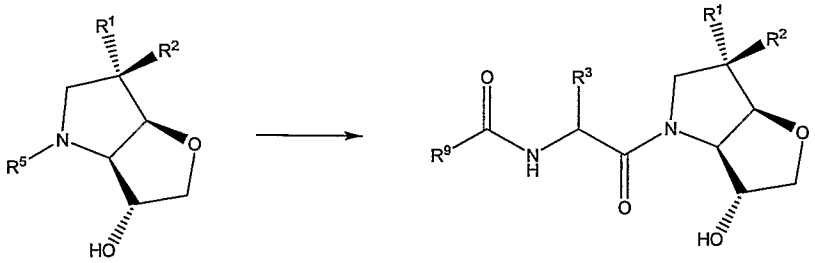


(II) (I)

36. A process according to claim 35 wherein the oxidizing agent is Dess-Martin periodinane.

37. A process according to claim 35 or claim 36 which comprises the step of converting a compound of formula (III), where R^5 is a protecting group or hydrogen,

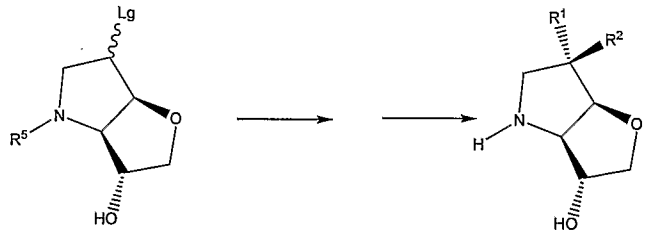
into a compound of formula (II), by treating a compound of formula IIIa (R^5 = H) with a compound of formula $R^9CONHCH(R^3)COOH$



(III) (II)

38. A process according to claim 37 wherein protecting group R^5 is selected from benzyloxycarbonyl, *tert*-butoxycarbonyl, fluoren-9-ylmethoxycarbonyl, 1-(biphenyl-4-yl)-1-methylethoxycarbonyl, α,α-dimethyl-3,5-dimethoxylbenzyloxycarbonyl, *p*-methoxybenzyloxycarbonyl, *p*-nitrobenzyloxycarbonyl, allyloxycarbonyl and trichloroethoxycarbonyl.

39. A process according to claim 37 which comprises the step of converting a compound of formula (IV) into a compound of formula (III; R^5 = H)

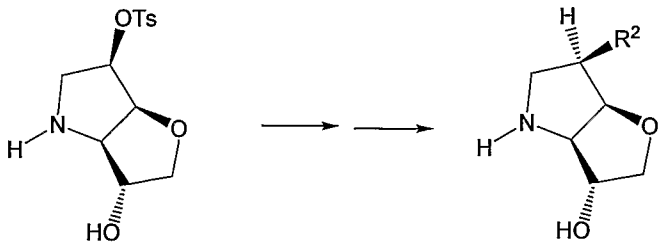


(IV) (III; R^5 = H)

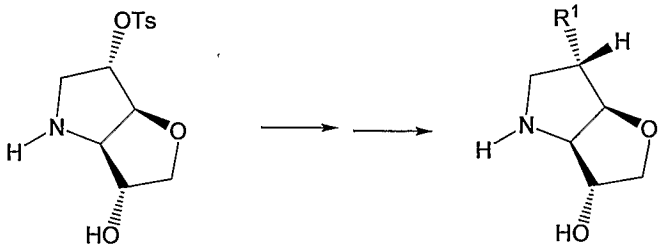
where Lg is a leaving group.

40. A process according to claim 39 where Lg is tosylate, mesylate or bromide.

41. A process according to claim 39 which comprises the step of converting a compound of formula (IVa; R^5 = H) into a compound of formula (IIIa) or a compound of formula (IVb) into a compound of formula (IIIb)

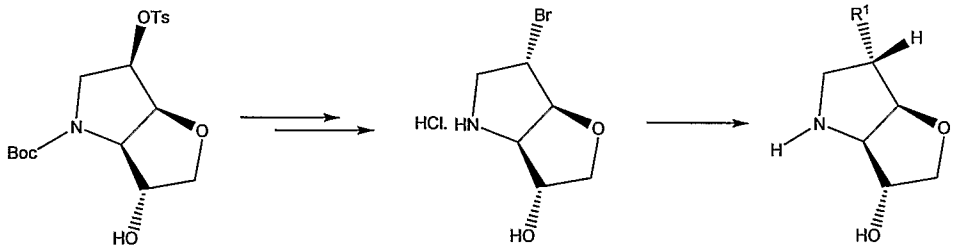


(IVa) (IIIa)



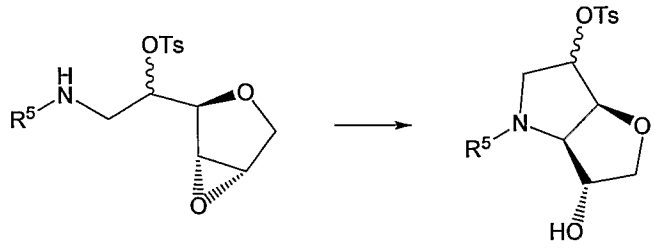
(IVb) (IIIb)

42. A process according to claim 39 which comprises the step of converting a compound of formula (IVc) into a compound of formula (IIIb) via the intermediate inverted bromide (IVd)



(IVc) (IVd) (IIIb)

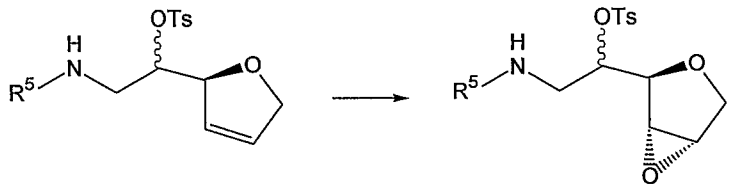
43. A process according to claim 41 or claim 42 which comprises the step of converting a compound of formula (V) into a compound of formula (IV)



(V) (IV)

44. A process according to claim 43 wherein R^5 is benzyloxycarbonyl (Cbz) and the process comprises the step of hydrogenating said compound of formula (V) in the presence of a palladium catalyst.

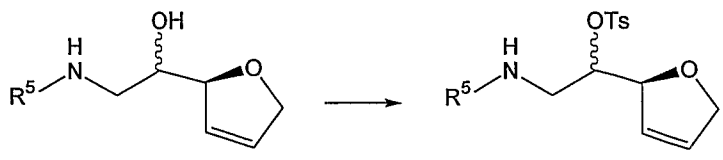
45. A process according to claim 43 which comprises the step of converting a compound of formula (VI) into a compound of formula (V) by treating said compound of formula (VI) with an oxidising agent.



(VI) (V) (anti)

46. A process according to claim 45 wherein the oxidising agent is mCPBA or a dioxirane.

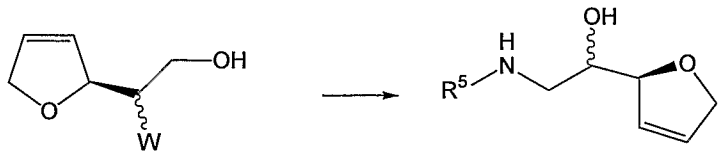
47. A process according to claim 45 which comprises the step of converting a compound of formula (VII) into a compound of formula (VI)



(VII) (VI)

48. A process according to claim 47 which comprises the step of treating a compound of formula (VII) with (a) tosyl chloride in pyridine, or (b) tosyl chloride in dichloromethane and triethylamine.

49. A process according to claim 47 which comprises the step of converting a compound of formula (VIII) into a compound of formula (VII)



(VIII) (VII)

where W is halogen or tosyl.

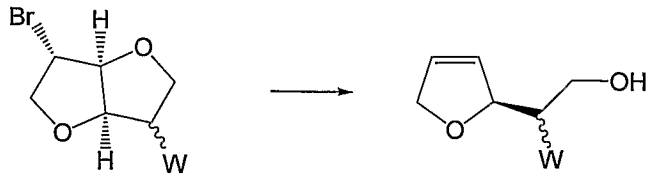
50. A process according to claim 49 which comprises the steps of:

(a) reacting a compound of formula (VIII), where W is halogen or OTs, with aqueous ammonia and alcohol; and

(b) converting the product formed in step (a) to a compound of formula (VII).

51. A process according to claim 50 wherein steps (a) and (b) are carried out in a one-pot process.

52. A process according to claim 49 which comprises preparing a compound of formula VIII from a compound of formula IX



IX VIII

53. A process according to claim 52 which comprises treating said compound of formula IX with methyl lithium.

54. A compound according to any one of claims 1 to 16 for treating a disease selected from osteoporosis, Paget's disease, Chagas's disease, malaria, gingival diseases, hypercalaemia, metabolic bone disease, diseases involving matrix or cartilage degradation, and bone cancer disorders such as bone metastases and associated pain.