

Dihydropyridine derivatives

The present invention describes the preparation of low molecular weight hormone mimetics that selectively have agonistic activity on the FSH receptor.

5 Gonadotropins serve important functions in a variety of bodily functions including metabolism, temperature regulation and the reproductive process. Gonadotropins act on specific gonadal cell types to initiate ovarian and testicular differentiation and steroidogenesis. The hypophyseal gonadotropin FSH (follicle stimulating hormone) for example plays a pivotal role in the stimulation of follicle development and maturation
10 whereas LH (luteinizing hormone) induces ovulation (Sharp, R.M. Clin Endocrinol. 33:787-807, 1990; Dorrington and Armstrong, Recent Prog. Horm. Res. 35:301-342,1979). Currently, FSH is applied clinically, in combination with LH, for ovarian stimulation i.e. ovarian hyperstimulation for in vitro fertilisation (IVF) and induction of ovulation in infertile anovulatory women (Insler, V., Int. J. Fertility 33:85-97, 1988,
15 Navot and Rosenwaks, J. Vitro Fert. Embryo Transfer 5:3-13, 1988), as well as for male hypogonadism and male infertility.

The gonadotropin FSH is released from the anterior pituitary under the influence of gonadotropin-releasing hormone and oestrogens, and from the placenta during pregnancy. In the female, FSH acts on the ovaries promoting development of follicles
20 and is the major hormone regulating secretion of oestrogens. In the male, FSH is responsible for the integrity of the seminiferous tubules and acts on Sertoli cells to support gametogenesis. Purified FSH is used clinically to treat infertility in females and for some types of failure of spermatogenesis in males. Gonadotropins destined for therapeutic purposes can be isolated from human urine sources and are of low purity
25 (Morse et al, Amer. J. Reproduct. Immunol. and Microbiology 17:143, 1988). Alternatively, they can be prepared as recombinant gonadotropins. Recombinant human FSH is available commercially and is being used in assisted reproduction (Olijve et al. Mol. Hum. Reprod. 2:371, 1996; Devroey et al. Lancet 339:1170, 1992).

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The actions of the FSH hormone are mediated by a specific plasma membrane receptor that is a member of the large family of G-protein coupled receptors. These receptors consist of a single polypeptide with seven transmembrane domains and are able to interact with the Gs protein, leading to the activation of adenylate cyclase

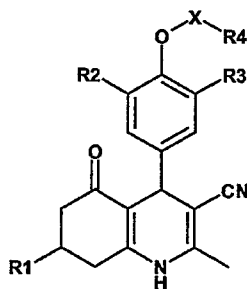
- 5 The FSH receptor is a highly specific target in the ovarian follicle growth process and is exclusively expressed in the ovary. Blocking of the receptor or inhibiting the signalling which is normally induced after FSH-mediated receptor activation will disturb follicle development and thus ovulation and fertility. Low molecular weight FSH antagonists could form the basis for new contraceptives, while low molecular weight FSH agonists can be used for the same clinical purposes as native FSH, i.e. for
10 the treatment of infertility and for ovarian hyperstimulation on behalf of in vitro fertilisation.

- Low molecular weight FSH mimetics with agonistic properties were disclosed in the International Application WO 2000/08015 (Applied Research Systems ARS Holding
15 N.V.) and in WO 2002/09706 (Affymax Research Institute).

Certain tetrahydroquinoline derivatives have recently been disclosed in the International Application WO2003/004028 (AKZO NOBEL N.V.) as FSH modulating substances, either having agonistic or antagonistic properties.

- 20 The present invention describes the preparation of low molecular weight hormone mimetics that selectively activate the FSH receptor.

Thus, it has now been found, that the following class of dihydropyridine compounds of formula I or pharmaceutically acceptable salts thereof, have FSH receptor agonistic activity:



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Formula I

wherein

R¹ is (1-6C)alkyl, (2-6C)alkenyl, (2-6C)alkynyl, phenyl or (1-5C)heteroaryl

R², R³ are independently (1-4C)alkyl, (2-4C)alkenyl, (2-4C)alkynyl, (1-4C)alkoxy, (2-4C)alkenyloxy, (3-4C)alkynyloxy, halogen

X is SO₂, CH₂, C(O) or X is a bond

R⁴ is (1-6C)alkyl, (2-6C)alkenyl, (2-6C)alkynyl, (3-6C)cycloalkyl, (3-6C)cycloalkenyl, (3-6C)cycloalkyl(1-4C)alkyl, (2-6C)heterocycloalkyl, (2-6C)heterocycloalkyl(1-4C)alkyl, (6-10C)aryl, (6-10C)aryl(1-4C)alkyl, (1-9C)heteroaryl or (1-9C)heteroaryl(1-4C)alkyl.

If X is CH₂, R⁴ may furthermore be R⁵-oxycarbonyl or R⁵-carbonyl.

If R⁴ is phenyl, phenyl may, in addition to the substituents for (6-10C)aryl groups as mentioned in the definitions, optionally be substituted with one or more substituents from the following groups:

(1-4C)alkylthio, (1-4C)alkylsulfonyl, R⁵-oxycarbonyl, R⁵-carbonyl or R⁵,R⁶-aminocarbonyl.

R⁵, R⁶ independently is H, (1-4C)alkyl, (2-4C)alkenyl, (2-4C)alkynyl, (3-6C)cycloalkyl, (3-6C)cycloalkyl(1-4C)alkyl, (2-6C)heterocycloalkyl, (2-6C)heterocycloalkyl(1-4C)alkyl, (1-4C)alkoxycarbonyl(1-4C)alkyl, (1-4C)(di)alkylaminocarbonyl(1-4C)alkyl, (6-10C)aryl, (1-9C)heteroaryl, (6-10C)aryl(1-4C)alkyl, (1-9C)heteroaryl(1-4C)alkyl, (6-10C)arylaminocarbonyl(1-4C)alkyl, (1-9C)heteroarylaminocarbonyl(1-4C)alkyl or R⁵,R⁶ may be joined in a (2-6C)heterocycloalkyl ring.

The compounds according to the present invention modulate the FSH receptor function and can be used for the same clinical purposes as native FSH since they behave like agonists, with the advantage that they may display altered stability properties and may be administered differently.

Thus, the FSH-receptor agonists of the present invention may be used for treating infertility. Preferably the compounds of the present invention are used to activate the FSH-receptor.

The term (1-4C)alkyl as used in the definition means a branched or unbranched alkyl group having 1-4 carbon atoms, being methyl, ethyl, propyl, isopropyl, butyl, sec-butyl and tert-butyl.

- 5 The term (1-6C)alkyl means a branched or unbranched alkyl group having 1-6 carbon atoms, for example methyl, ethyl, propyl, isopropyl, butyl, tert-butyl, n-pentyl and n-hexyl. (1-5C)Alkyl groups are preferred, (1-4C)alkyl being the most preferred.

The term (2-6C)alkenyl means a branched or unbranched alkenyl group having 2-6 carbon atoms, such as ethenyl, 2-butenyl, and n-pentenyl.

- 10 The term (2-4C)alkenyl means a branched or unbranched alkenyl group having 2-4 carbon atoms, such as ethenyl, n-propenyl and 2-butenyl.

The term (2-6C)alkynyl means a branched or unbranched alkynyl group having 2-6 carbon atoms, such as ethynyl, propynyl and n-pentynyl.

- 15 The term (2-4C)alkynyl means an alkynyl group having 2-4 carbon atoms, such as ethynyl and propynyl.

The term (3-6C)cycloalkyl means a cycloalkyl group having 3-6 carbon atoms, being cyclopropyl, cyclobutyl, cyclopentyl and cyclohexyl.

The term (3-6C)cycloalkenyl means a cycloalkenyl group having 3-6 carbon atoms, such as cyclopropenyl, cyclopentenyl and cyclohexenyl.

- 20 The term (3-6C)cycloalkyl(1-4C)alkyl means a cycloalkylalkyl group, the cycloalkyl group of which has 3-6 carbon atoms with the same meaning as previously defined and the alkyl group having 1-4 carbon atoms with the same meaning as previously defined.

- The term (2-6C)heterocycloalkyl means a heterocycloalkyl group having 2-6 carbon atoms, preferably 3-5 carbon atoms, and at least including one heteroatom selected
25 from N, O and/or S, which may be attached via a heteroatom if feasible, or a carbon atom. Preferred heteroatoms are N or O. Most preferred are piperidinyl, morpholinyl, pyrrolidinyl and piperazinyl.

The term (2-6C)heterocycloalkyl(1-4C)alkyl means a heterocycloalkylalkyl group, the heterocycloalkyl group of which has 2-6 carbon atoms with the same meaning as

previously defined and the alkyl group having 1-4 carbon atoms with the same meaning as previously defined.

The term (1-4C)alkoxy means an alkoxy group having 1-4 carbon atoms, the alkyl moiety having the same meaning as previously defined. (1-2C)Alkoxy groups are
5 preferred.

The term (1-4C)alkylthio means an alkylthio group having 1-4 carbon atoms, the alkyl moiety having the same meaning as previously defined.

The term (2-4C)alkenyloxy means an alkenyloxy group having 2-4 carbon atoms, the alkenyl moiety having the same meaning as previously defined.

10 The term (3-4C)alkynyloxy means an alkynyloxy group having 3-4 carbon atoms, the alkynyl moiety having the same meaning as previously defined.

The term (6-10C)aryl means an aromatic hydrocarbon group having 6-10 carbon atoms, such as phenyl, naphthyl, tetrahydronaphthyl or indenyl, which may optionally be substituted with one or more substituents selected from hydroxy, amino, halogen,
15 nitro, trifluoromethyl, cyano, (1-4C)alkyl, (2-4C)alkenyl, (2-4C)alkynyl, (1-4C)alkoxy, or (1-4C)(di)alkylamino, the alkyl moieties having the same meaning as previously defined. The preferred aromatic hydrocarbon group is phenyl.

The term (1-9C)heteroaryl means a substituted or unsubstituted aromatic group having 1-9 carbon atoms, at least including one heteroatom selected from N, O and/or S, like
20 tetrazolyl, imidazolyl, thiadiazolyl, pyridinyl, (benzo)thienyl, (benzo)furyl, (iso)quinolinyl, tetrahydro(iso)quinolinyl, coumarinyl, quinoxalinyl or indolyl. The substituents on the (1-9C)heteroaryl group may be selected from the group of substituents listed for the (6-10C)aryl group. (1-5C)heteroaryl is preferred. The (1-9C)heteroaryl group may be attached via a carbon atom or a heteroatom, if feasible.

25 The term (1-5C)heteroaryl means a substituted or unsubstituted aromatic group having 1-5 carbon atoms, at least including one heteroatom selected from N, O and/or S, like tetrazolyl, imidazolyl, thiadiazolyl, pyridinyl, thienyl or furyl, furyl being the most preferred. Preferred heteroaryl groups are thienyl, furyl and pyridinyl. The substituents on the (1-5C)heteroaryl group may be selected from the group of substituents listed for
30 the (6-10C)aryl group.

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The term (6-10C)aryl(1-4C)alkyl means an arylalkyl group, the aryl group of which contains 6-10 carbon atoms with the same meaning as previously defined and the alkyl group contains 1-4 carbon atoms with the same meaning as previously defined. Most preferred is benzyl.

- 5 The term (1-9C)heteroaryl(1-4C)alkyl means a heteroarylalkyl group, the heteroaryl group of which contains 1-9 carbon atoms with the same meaning as previously defined and the alkyl group contains 1-4 carbon atoms with the same meaning as previously defined.

The term (1-4C)alkylsulfonyl means an alkylsulfonyl group, the alkyl group of which
10 contains 1-4 carbon atoms with the same meaning as previously defined.

The term (1-4C)alkoxycarbonyl means an (1-4C)alkoxycarbonyl group, the alkoxy group of which contains 1-4 carbon atoms with the same meaning as previously defined. (1-2C)Alkoxycarbonyl groups are preferred

The term (1-4C)alkoxycarbonyl(1-4C)alkyl means an alkoxycarbonylalkyl group, the
15 alkyl groups of which contain 1-4 carbon atoms with the same meaning as previously defined.

The term (1-4C)(di)alkylaminocarbonyl(1-4C)alkyl means a (di)alkylaminocarbonylalkyl group, the alkyl groups of which contain 1-4 carbon atoms with the same meaning as previously defined.

- 20 The term halogen means fluorine, chlorine, bromine or iodine.

The term pharmaceutically acceptable salt represents those salts which are, within the scope of medical judgement, suitable for use in contact for the tissues of humans and lower animals without undue toxicity, irritation, allergic response and the like, and are commensurate with a reasonable benefit/risk ratio. Pharmaceutically acceptable salts
25 are well known in the art. They may be obtained during the final isolation and purification of the compounds of the invention, or separately by reacting the free base function with a suitable mineral acid such as hydrochloric acid, phosphoric acid, or sulfuric acid, or with an organic acid such as for example ascorbic acid, citric acid, tartaric acid, lactic acid, maleic acid, malonic acid, fumaric acid, glycolic acid, succinic
30 acid, propionic acid, acetic acid, methanesulfonic acid, and the like. The acid function

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can be reacted with an organic or a mineral base, like sodium hydroxide, potassium hydroxide or lithium hydroxide.

The invention also relates to compounds of formula I, wherein R^1 is (1-6C)alkyl, phenyl or (1-5C)heteroaryl, all optionally substituted with the substituents as mentioned in the definitions. More in particular, the invention relates to compounds
5 wherein R^1 is (1-4C)alkyl, phenyl or 4C-heteroaryl. The invention also concerns compounds wherein R^1 is n-propyl or furyl.

Another aspect of the invention are compounds according to formula I wherein R^2, R^3 is halogen and/or (1-4C)alkoxy.

10 In yet another aspect, the invention concerns compounds of formula I, wherein X is CH_2 .

Another aspect of the invention is a compound wherein R^4 is phenyl, optionally substituted with the substituents as mentioned in the definitions. In another aspect the invention relates to compounds wherein R^4 is phenyl which is substituted at the ortho
15 and/or meta positions. In yet another aspect, the invention concerns compounds of formula I wherein R^4 is phenyl, substituted with R^5, R^6 -aminocarbonyl, (1-4C)alkoxy and/or halogen. In yet another aspect, the invention relates to compounds wherein R^5, R^6 -in R^5, R^6 aminocarbonyl is (1-4C)(di)alkylamino, (1-4C)alkoxycarbonyl(1-4C)alkyl. or (1-9C)heteroaryl(1-4C)alkyl. In yet another aspect, at least one of R^5, R^6 -in
20 R^5, R^6 aminocarbonyl is H.

In another aspect the invention concerns compounds wherein (6-10C)aryl, (6-10C)aryl(1-4C)alkyl, (1-9C)heteroaryl or (1-9C)heteroaryl(1-4C)alkyl in R^4 are not substituted.

Still another aspect of the invention concerns compounds wherein $X = CH_2$ and in
25 which R^4 is phenyl, optionally substituted with the substituents as mentioned in the definitions.

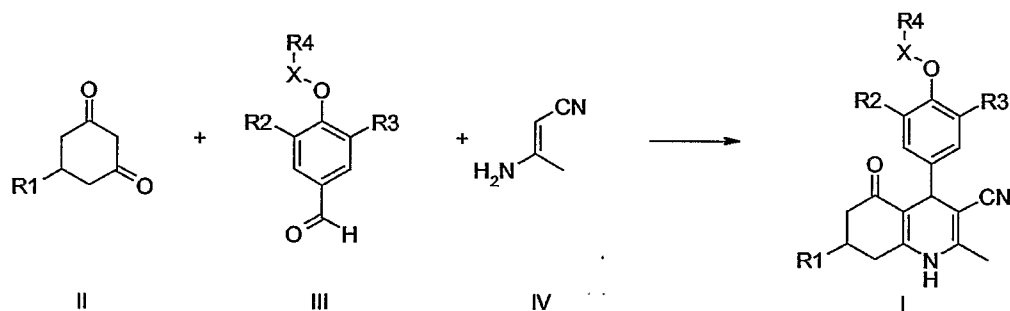
Yet another aspect of the invention concerns compounds wherein all specific definitions of the groups R^1 through R^4 and X as defined here above are combined in the dihydropyridine compound of formula I.

Excluded from the invention is the compound 2-methyl-5-oxo-7-phenyl-4-(3,4,5-trimethoxyphenyl)-1,4,5,6,7,8-hexahydroquinoline-3-carbonitrile.

The disclaimer relates to CAS330674-72-1, available from commercial sources like Chembridge Corp, MicroChemistry Ltd, Ambinter, Asinex, Scientific Exchange Inc,
5 and ChemDiv Inc.

Suitable methods for the preparation of the compounds of the invention are outlined below.

The 1,4-dihydropyridine derivatives I of the present invention can be prepared starting from cyclohexane-1,3-diones of general formula II, benzaldehydes of general formula
10 III and 3-aminocrotonitrile IV, in which R¹, R², R³, R⁴ and X are as previously defined, by the well-documented three component Hantzsch-type cyclo-condensation reaction.

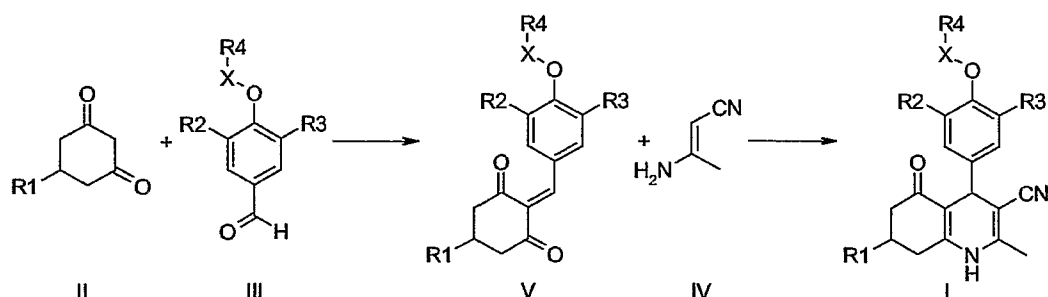


Related Hantzsch-type cyclo-condensation reactions can be found in: Bioorg. Med. Chem. Lett. 12 (2002) 1481-1484, J. Chem. Soc., Perkin Trans. 1 (2002) 1141-1156,
15 Synlett (2002) 89-92, Drug Dev. Res. 51 (2000) 233-243, J. Med. Chem. 42 (1999) 1422-1427, *ibid.* 5266-5271, *ibid.* 41 (1998) 2643-2650, WO 9408966, Arzneim.-Forsch./Drug Res. 45 (1995) 1054-1056, J. Med. Chem. 34 (1991) 2248-2260, *ibid.* 17 (1974) 956-65, Chem. Rev. 72 (1972), 1-42. The above mentioned reaction is typically conducted at elevated temperature in a protic solvent like for example acetic acid,
20 (iso)propanol, ethanol, methanol or mixtures thereof.

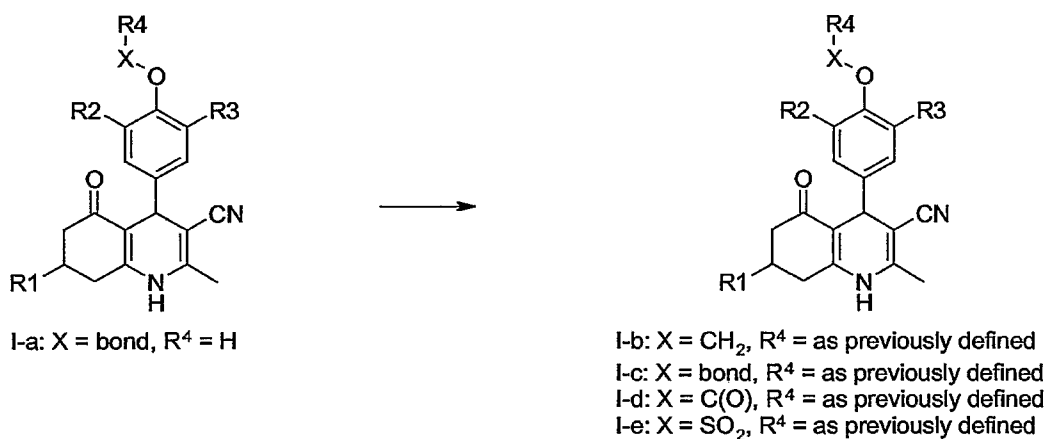
Alternatively, compounds of general formula I can be synthesized by first reacting the cyclohexane-1,3-diones of formula II with benzaldehydes of formula III in the presence of a base such as, but not limited to, ammonium acetate and then reacting the intermediate 2-benzylidene-cyclohexane-1,3-dione of general formula V, in which R¹,

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R^2 , R^3 , R^4 and X have the same meaning as previously defined, with 3-aminocrotonitrile IV.



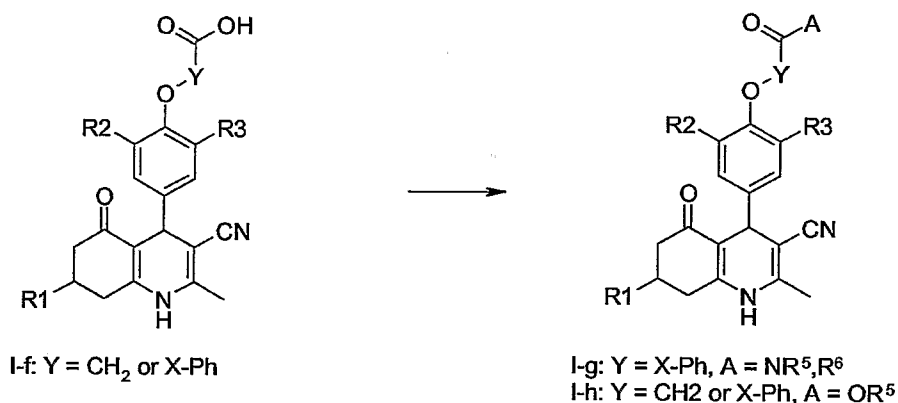
Compounds of general formula I-a wherein X = bond and R^4 = H, can be used to
 5 prepare compounds I-b-e by *O*-alkylation, *O*-(hetero)arylation, *O*-acylation or *O*-sulfonylation using standard conditions, well known to those skilled in the art.



In a typical experiment, compounds I-a are reacted in a solvent, such as dichloromethane, *N,N*-dimethylformamide, dimethyl sulfoxide, ethanol,
 10 tetrahydrofuran, dioxane, toluene, 1-methyl-pyrrolidin-2-one or pyridine with an alkyl halide or acyl halide or acid anhydride or sulfonyl halide, or (hetero)aryl halide in the presence of a base such as, but not limited to, triethylamine, *N,N*-diisopropylethylamine (DiPEA), potassium carbonate, cesium carbonate or sodium hydride, optionally in the presence of a catalytic amount of potassium iodide or
 15 tetrabutylammonium iodide, and/or a Cu- or Pd-catalyst, to give *O*-alkylated, *O*-

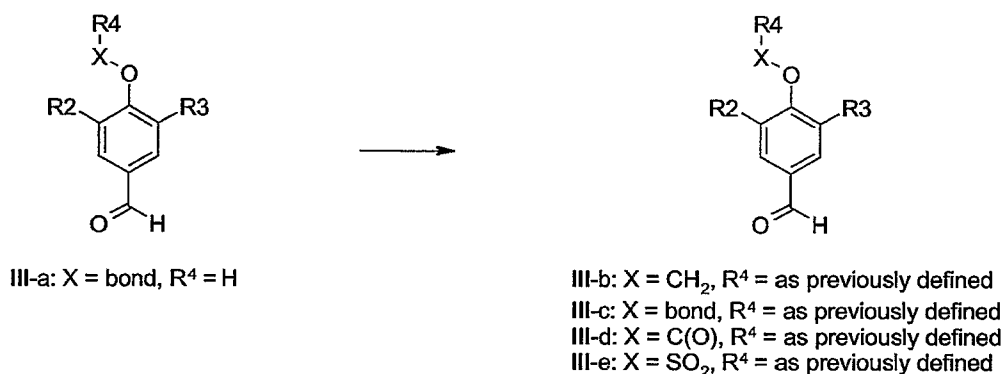
(hetero)arylated, *O*-acylated or *O*-sulfonylated derivatives of formula I-b, I-c, I-d, and I-e, respectively.

Compounds of formula I-f wherein $X = CH_2$ and $R^4 =$ alkyl acid derivative or
 5 (hetero)aryl acid derivative, obtained by base-mediated (*e.g.* NaOH) saponification of a corresponding alkyl ester, can be condensed with amines of general structure R^5, R^6NH or alcohols of general structure R^5OH using a coupling reagent such as diisopropyl carbodiimide (DIC), (3-dimethylaminopropyl)-ethyl-carbodiimide (EDCI), *O*-(benzotriazol-1-yl)-*N,N,N',N'*-tetramethyluronium hexafluorophosphate (TBTU) or
 10 (7-azabenzotriazol-1-yl)-*N,N,N',N'*-tetramethyluronium hexafluorophosphate (HATU) and a tertiary amine base (*e.g.* DiPEA) in a solvent such as *N,N*-dimethylformamide or dichloromethane at ambient or elevated temperature to give compounds of formula I-g and I-h.



15 The substituted cyclohexane-1,3-diones of general formula II are commercially available or can be prepared by literature procedures known in the art. Relevant examples are found in: J. Med. Chem. 43 (2000) 4678-4693, Tetrahedron 56 (2000) 4753-4758, J. Med. Chem. 35 (1992) 3429-3447, *ibid.* 24 (1981) 1026-1034, Org. Synt. Coll. Vol. V (1973) 400, Chem. Ber. 88 (1955) 316-327, Justus Liebig Ann.
 20 Chem. 570 (1950) 15-31.

Benzaldehydes of general formula III also are commercially available or can be prepared according to literature procedures: J. Chem. Soc., Perkin Trans. 2 (2000) 1119-1124, J. Chem. Soc., Chem. Commun. 4 (1993) 419-420, Synth. Commun. 20 (1990) 2659-2666, Chem. Pharm. Bull. 34 (1986) 121-129, Indian J. Chem. Sect. B 20
 5 (1981) 1010-1013, Monatsh. Chem. 106 (1975) 1191-1201, DE 1070162, J. Org. Chem. 23 (1958) 120.



Alternatively, compounds III-a wherein X = bond and R⁴ = H can be used to synthesize compounds III-b-e by *O*-alkylation, *O*-arylation, *O*-acylation or *O*-sulfonylation using
 10 the same standard conditions as described above for compounds I-a.

The compounds of the present invention possess at least two chiral carbon atoms and may therefore be obtained as pure enantiomers, or as a mixture of enantiomers, or as a mixture of diastereomers. Methods for obtaining the pure enantiomers are well known
 15 in the art, *e.g.* crystallization of salts which are obtained from optically active acids and the racemic mixture, or chromatography using chiral columns. For separation of diastereomers, straight phase or reversed phase columns may be used.

The compounds of the invention may form hydrates or solvates. It is known to those of skill in the art that charged compounds form hydrated species when lyophilized with
 20 water, or form solvated species when concentrated in a solution with an appropriate organic solvent. The compounds of this invention include the hydrates or solvates of the compounds listed.

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For selecting active compounds testing at 10^{-5} M must result in an activity of more than 20% of the maximal activity when FSH is used as a reference. Another criterion might be the EC_{50} value which must be $< 10^{-5}$ M, preferably $< 10^{-7}$ M, even more preferably $< 10^{-9}$ M.

- 5 The skilled artisan will recognize that desirable EC_{50} values are dependent on the compound tested. For example, a compound with an EC_{50} which is less than 10^{-5} M is generally considered a candidate for drug selection. Preferably this value is lower than 10^{-7} M. However, a compound which has a higher EC_{50} , but is selective for the particular receptor, may be even a better candidate.
- 10 Methods to determine receptor binding, as well as *in vitro* and *in vivo* assays to determine biological activity, of gonadotropins are well known. In general, expressed receptor is contacted with the compound to be tested and binding or stimulation or inhibition of a functional response is measured.

To measure a functional response, isolated DNA encoding the FSH receptor gene, preferably the human receptor, is expressed in suitable host cells. Such a cell might be
15 the Chinese Hamster Ovary cell, but other cells are also suitable. Preferably the cells are of mammalian origin (Jia et al, Mol.Endocrin., 5:759-776, 1991).

Methods to construct recombinant FSH expressing cell lines are well known in the art (Sambrook et al., Molecular Cloning: a Laboratory Manual, Cold Spring Harbor
20 Laboratory Press, Cold Spring Harbor, latest edition). Expression of receptor is attained by expression of the DNA encoding the desired protein. Techniques for site directed mutagenesis, ligation of additional sequences, PCR, and construction of suitable expression systems are all, by now, well known in the art. Portions, or all, of the DNA encoding the desired protein can be constructed synthetically using standard solid
25 phase techniques, preferably to include restriction sites for ease of ligation. Suitable control elements for transcription and translation of the included coding sequence can be provided to the DNA coding sequences. As is well known, expression systems are now available which are compatible with a wide variety of hosts, including prokaryotic hosts such as bacteria and eukaryotic hosts such as yeast, plant cells, insect cells,
30 mammalian cells, avian cells and the like.

Cells expressing the receptor are then contacted with the test compound to observe binding, or stimulation or inhibition of a functional response.

Alternatively, isolated cell membranes containing the expressed receptor may be used to measure binding of compound.

- 5 For measurement of binding, radioactive or fluorescent compounds may be used. As reference compound human recombinant FSH can be used.

In the alternative also competition binding assays may be performed.

- Another assay involves screening for FSH receptor agonist compounds by determining stimulation of receptor mediated cAMP accumulation. Thus, such a method involves
10 expression of the receptor on the cell surface of a host cell and exposing the cell to the test compound. The amount of cAMP is then measured. The level of cAMP will be increased, by the stimulating effect of the test compound upon binding to the receptor.

- In addition to direct measurement of e.g. cAMP levels in the exposed cell, cells lines can be used which in addition to transfection with receptor encoding DNA are also
15 transfected with a second DNA encoding a reporter gene the expression of which responds to the level of cAMP. Such reporter genes might be cAMP inducible or might be constructed in such a way that they are connected to novel cAMP responsive elements. In general, reporter gene expression might be controlled by any response element reacting to changing levels of cAMP. Suitable reporter genes are e.g. LacZ,
20 alkaline phosphatase, firefly luciferase and green fluorescence protein. The principles of such transactivation assays are well known in the art and are described e.g. in Stratowa, Ch., Himmler, A. and Czernilofsky, A.P., (1995) Curr.Opin.Biotechnol. 6:574.

- 25 The present invention also relates to a pharmaceutical composition comprising a dihydropyridine derivative or pharmaceutically acceptable salts thereof having the general formula I in admixture with pharmaceutically acceptable auxiliaries and optionally other therapeutic agents. The auxiliaries must be "acceptable" in the sense of being compatible with the other ingredients of the composition and not deleterious to
30 the recipients thereof. The pharmaceutical compositions may also comprise 2-methyl-

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5-oxo-7-phenyl-4-(3,4,5-trimethoxyphenyl)-1,4,5,6,7,8-hexahydroquinoline-3-carbonitrile.

Compositions include e.g. those suitable for oral, sublingual, subcutaneous, intravenous, intramuscular, nasal, local, or rectal administration, and the like, all in unit dosage forms for administration.

For oral administration, the active ingredient may be presented as discrete units, such as tablets, capsules, powders, granulates, solutions, suspensions, and the like.

For parenteral administration, the pharmaceutical composition of the invention may be presented in unit-dose or multi-dose containers, e.g. injection liquids in predetermined amounts, for example in sealed vials and ampoules, and may also be stored in a freeze dried (lyophilized) condition requiring only the addition of sterile liquid carrier, e.g. water, prior to use.

Mixed with such pharmaceutically acceptable auxiliaries, e.g. as described in the standard reference, Gennaro, A.R. et al., Remington: *The Science and Practice of Pharmacy* (20th Edition., Lippincott Williams & Wilkins, 2000, see especially Part 5: Pharmaceutical Manufacturing), the active agent may be compressed into solid dosage units, such as pills, tablets, or be processed into capsules or suppositories. By means of pharmaceutically acceptable liquids the active agent can be applied as a fluid composition, e.g. as an injection preparation, in the form of a solution, suspension, emulsion, or as a spray, e.g. a nasal spray.

For making solid dosage units, the use of conventional additives such as fillers, colorants, polymeric binders and the like is contemplated. In general any pharmaceutically acceptable additive which does not interfere with the function of the active compounds can be used. Suitable carriers with which the active agent of the invention can be administered as solid compositions include lactose, starch, cellulose derivatives and the like, or mixtures thereof, used in suitable amounts. For parenteral administration, aqueous suspensions, isotonic saline solutions and sterile injectable solutions may be used, containing pharmaceutically acceptable dispersing agents and/or wetting agents, such as propylene glycol or butylene glycol.

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The invention further includes a pharmaceutical composition, as hereinbefore described, in combination with packaging material suitable for said composition, said packaging material including instructions for the use of the composition for the use as hereinbefore described.

- 5 The exact dose and regimen of administration of the active ingredient, or a pharmaceutical composition thereof, may vary with the particular compound, the route of administration, and the age and condition of the individual subject to whom the medicament is to be administered.

In general parenteral administration requires lower dosages than other methods of administration which are more dependent upon absorption. However, a suitable dosage
10 for humans may be 0.05-25 mg per kg body weight. The desired dose may be presented as one dose or as multiple subdoses administered at appropriate intervals throughout the day, or, in case of female recipients, as doses to be administered at appropriate daily intervals throughout the menstrual cycle. The dosage as well as the regimen of
15 administration may differ between a female and a male recipient.

Thus, the compounds according to the invention can be used in therapy.

A further aspect of the invention resides in the use of a dihydropyridine derivative compound having the general formula I for the manufacture of a medicament to be
20 used for the treatment of disorders responsive to FSH receptor mediated pathways, preferably for the treatment of infertility.

The invention is illustrated by the following examples.

Examples

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Example 1

4-(3-Bromo-4-ethoxy-5-methoxyphenyl)-2-methyl-5-oxo-7-phenyl-1,4,5,6,7,8-hexahydroquinoline-3-carbonitrile

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a) 4-(3-Bromo-4-hydroxy-5-methoxyphenyl)-2-methyl-5-oxo-7-phenyl-1,4,5,6,7,8-hexahydroquinoline-3-carbonitrile

A mixture of 5-phenylcyclohexane-1,3-dione (0.51 g), 3-bromo-5-methoxy-4-hydroxybenzaldehyde (0.62 g) and 3-aminocrotonitrile (0.22 g) in 20 mL absolute
5 ethanol was stirred at 75 °C for 3 h. The reaction mixture was concentrated and the title compound was obtained as a off-white solid after flash column chromatography (silica gel, heptane/ethyl acetate (3/7, v/v), $R_f = 0.36$).

Yield: 0.95 g. MS-ESI: $[M-H]^- = 463/465$.

10 b) 4-(3-Bromo-4-ethoxy-5-methoxyphenyl)-2-methyl-5-oxo-7-phenyl-1,4,5,6,7,8-hexahydroquinoline-3-carbonitrile

A mixture of the product of step a (15 mg), ethyl iodide (6.4 μ L), sodium hydride (2.6 mg, 60% in oil) and tetrabutylammonium iodide (1.2 mg) in 0.5 mL of NMP was
15 stirred at 80 °C for 2 h. Water was added and the reaction mixture was extracted with ethyl acetate. The organic phases were concentrated and the title compound was obtained after flash column chromatography (silica gel, heptane/ethyl acetate (1/4, v/v), $R_f = 0.52$).

Yield: 2.2 mg. MS-ESI: $[M-H]^- = 491/493$.

20 **Example 2**

4-(3-Bromo-4-cyclohexylmethoxy-5-methoxyphenyl)-2-methyl-5-oxo-7-phenyl-1,4,5,6,7,8-hexahydroquinoline-3-carbonitrile

The title compound was obtained analogously to example 1b, starting from the product of example 1a (15 mg) and bromomethylcyclohexane (12 μ L).

25 Yield: 12 mg. R_f (heptane/ethyl acetate (1/4, v/v)) = 0.59. MS-ESI: $[M-H]^- = 559/561$.

Example 3

4-[3-Bromo-5-methoxy-4-(3-methylbutoxy)-phenyl]-2-methyl-5-oxo-7-phenyl-1,4,5,6,7,8-hexahydroquinoline-3-carbonitrile

The title compound was obtained analogously to example 1b, starting from the product of example 1a (15 mg) and 1-iodo-3-methylbutane (4.7 μ L).

Yield: 14 mg. R_f (heptane/ethyl acetate (1/4, v/v)) = 0.56. MS-ESI: $[M-H]^- = 533/535$.

Example 4

4-[3-Bromo-4-(5-chlorothiophen-2-ylmethoxy)-5-methoxyphenyl]-2-methyl-5-oxo-7-phenyl-1,4,5,6,7,8-hexahydroquinoline-3-carbonitrile

A mixture of the product of example 1a (15 mg), 2-chloro-5-chloromethylthiophene (4.3 μ L) and cesium carbonate (21 mg) in 1 mL of dioxane was stirred at 80 °C for 4 h. The reaction mixture was concentrated and the title compound was obtained after flash column chromatography (silica gel, heptane/ethyl acetate (3/7, v/v), R_f = 0.38).

Yield: 4.7 mg. MS-ESI: $[M-H]^- = 593/595/597$.

Example 5

[2-Bromo-4-(3-cyano-2-methyl-5-oxo-7-phenyl-1,4,5,6,7,8-hexahydroquinolin-4-yl)-6-methoxyphenoxy]-acetic acid methyl ester

The title compound was obtained analogously to example 4, starting from the product of example 1a (0.47 g) and bromoacetic acid methyl ester (1.0 mL).

Yield: 0.32 g. R_f (heptane/ethyl acetate (1/4, v/v)) = 0.46. MS-ESI: $[M-H]^- = 535/537$.

Example 6

3-Methoxybenzoic acid 2-bromo-4-(3-cyano-2-methyl-5-oxo-7-phenyl-1,4,5,6,7,8-hexahydroquinolin-4-yl)-6-methoxyphenyl ester

The title compound was obtained analogously to example 4, starting from the product of example 1a (15 mg) and 3-methoxy-benzoyl chloride (5.4 μ L).

Yield: 7.4 mg. R_f (heptane/ethyl acetate (1/4, v/v)) = 0.48. MS-ESI: $[M-H]^- = 597/599$.

Example 7

4-[3-Bromo-4-(3-cyanobenzyloxy)-5-methoxyphenyl]-2-methyl-5-oxo-7-phenyl-1,4,5,6,7,8-hexahydroquinoline-3-carbonitrile

The title compound was obtained analogously to example 4, starting from the product of example 1a (15 mg) and 3-bromomethylbenzonitrile (7.6 mg).

Yield: 15 mg. R_f (heptane/ethyl acetate (1/4, v/v)) = 0.51. MS-ESI: $[M-H]^- = 578/580$.

10 Example 8

4-[3-Bromo-5-methoxy-4-(naphthalen-2-ylmethoxy)-phenyl]-2-methyl-5-oxo-7-phenyl-1,4,5,6,7,8-hexahydroquinoline-3-carbonitrile

The title compound was obtained analogously to example 4, starting from the product of example 1a (15 mg) and 2-bromomethylnaphthalene (8.6 mg).

15 Yield: 11 mg. R_f (heptane/ethyl acetate (1/4, v/v)) = 0.60. MS-ESI: $[M-H]^- = 603/605$.

Example 9

Phenylmethanesulfonic acid 2-bromo-4-(3-cyano-2-methyl-5-oxo-7-phenyl-1,4,5,6,7,8-hexahydroquinolin-4-yl)-6-methoxyphenyl ester

20 A mixture of the product of example 1a (15 mg), phenylmethanesulfonyl chloride (9.2 mg) and triethylamine (9.4 μ L) in 1 mL of dichloromethane was stirred at room temperature for 2 h. The reaction mixture was concentrated and the title compound was obtained after flash column chromatography (silica gel, heptane/ethyl acetate (1/4, v/v), $R_f = 0.41$).

25 Yield: 15 mg. MS-ESI: $[M+H]^+ = 619/621$.

Example 10

Thiophene-2-sulfonic acid 2-bromo-4-(3-cyano-2-methyl-5-oxo-7-phenyl-1,4,5,6,7,8-hexahydroquinolin-4-yl)-6-methoxyphenyl ester

The title compound was obtained analogously to example 9, starting from the product of example 1a (15 mg) and thiophene-2-sulfonyl chloride (8.8 mg).

Yield: 20 mg. R_f (heptane/ethyl acetate (1/4, v/v)) = 0.30. MS-ESI: $[M-H]^-$ = 611/613.

Example 11

4-[3,5-Dibromo-4-(3-methoxybenzyloxy)-phenyl]-7-ethyl-2-methyl-5-oxo-1,4,5,6,7,8-hexahydroquinoline-3-carbonitrile

a) 3,5-dibromo-4-(3-methoxybenzyloxy)-benzaldehyde

A mixture of 3,5-dibromo-4-hydroxybenzaldehyde (0.28 g), 1-bromomethyl-3-methoxybenzene (0.15 mL), potassium carbonate (0.29 g) and potassium iodide (42 mg) in 10 mL absolute ethanol was stirred at 80 °C for 2 days. The reaction mixture was concentrated and the title compound was obtained as a off-white solid after flash column chromatography (silica gel, heptane/ethyl acetate (3/7, v/v)), R_f = 0.51).

Yield: 0.24 g. MS-ESI: $[M-H]^-$ = 463/465. 1H NMR ($CDCl_3$): δ = 9.88 (s, 1H), 8.06 (s, 1H), 7.34 (t, 1H), 7.18 (bs, 1H), 7.15 (d, 1H), 6.93 (dd, 1H), 5.10 (s, 2H), 3.85 (s, 3H).

b) 4-[3,5-Dibromo-4-(3-methoxybenzyloxy)-phenyl]-7-ethyl-2-methyl-5-oxo-1,4,5,6,7,8-hexahydroquinoline-3-carbonitrile

The title compound was obtained analogously to example 1a, starting from 5-ethylcyclohexane-1,3-dione (8.5 mg) and the product of step a (24 mg).

Yield: 26 mg. R_f (heptane/ethyl acetate (3/7, v/v)) = 0.40. MS-ESI: $[M+H]^+$ = 585/587/589.

Example 12

4-{3-Bromo-5-ethoxy-4-[2-(3-nitrophenyl)-2-oxoethoxy]-phenyl}-2-methyl-5-oxo-7-phenyl-1,4,5,6,7,8-hexahydroquinoline-3-carbonitrile

- 5 a) 4-(3-Bromo-5-ethoxy-4-hydroxyphenyl)-2-methyl-5-oxo-7-phenyl-1,4,5,6,7,8-hexahydroquinoline-3-carbonitrile

The title compound was obtained analogously to example 1a, starting from 3-bromo-5-ethoxy-4-hydroxybenzaldehyde (0.15 g).

Yield: 0.15 g. R_f (heptane/ethyl acetate (4/6, v/v)) = 0.18. MS-ESI: $[M+H]^+ = 479/481$.

10

- b) 4-{3-Bromo-5-ethoxy-4-[2-(3-nitrophenyl)-2-oxoethoxy]-phenyl}-2-methyl-5-oxo-7-phenyl-1,4,5,6,7,8-hexahydroquinoline-3-carbonitrile

The title compound was obtained analogously to example 4, starting from the product of step a (15 mg) and 2-bromo-1-(3-nitrophenyl)-ethanone (8.4 mg).

- 15 Yield: 14 mg. R_f (heptane/ethyl acetate (1/4, v/v)) = 0.58. MS-ESI: $[M+H]^+ = 642/644$.

Example 13

3-[2-Bromo-4-(3-cyano-2-methyl-5-oxo-7-phenyl-1,4,5,6,7,8-hexahydroquinolin-4-yl)-6-methoxyphenoxy-methyl]-N-thiophen-2-ylmethylbenzamide

20

- a) 3-[2-Bromo-4-(3-cyano-2-methyl-5-oxo-7-phenyl-1,4,5,6,7,8-hexahydroquinolin-4-yl)-6-methoxyphenoxy-methyl]-benzoic acid methyl ester

The title compound was obtained analogously to example 4, starting from the product of example 1a (0.35 g) and 3-bromomethylbenzoic acid methyl ester (0.18 g).

- 25 Yield: 0.35 g. R_f (heptane/ethyl acetate (3/7, v/v)) = 0.34. MS-ESI: $[M+H]^+ = 613/615$.

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b) 3-[2-Bromo-4-(3-cyano-2-methyl-5-oxo-7-phenyl-1,4,5,6,7,8-hexahydroquinolin-4-yl)-6-methoxyphenoxyethyl]-benzoic acid

A solution of the product of step a (0.35 g) was dissolved in 20 mL of dioxane/ water (7/3, v/v) and 2 mL of 2 M NaOH in water was added. The reaction mixture was stirred
5 for 5 days at room temperature. The reaction mixture was poured into water and acidified with 2 M HCl in water to pH 2 and was extracted several times with ethyl acetate. The organic phases were washed with water and saturated brine, dried over Na₂SO₄ and evaporated to give the title compound.

Yield: 0.35 g. MS-ESI: [M+H]⁺ = 599/601.

10

c) 3-[2-Bromo-4-(3-cyano-2-methyl-5-oxo-7-phenyl-1,4,5,6,7,8-hexahydroquinolin-4-yl)-6-methoxyphenoxyethyl]-N-thiophen-2-ylmethylbenzamide

To a solution of the product of step b (20 mg) in 2 mL of dichloromethane were added EDCI (7.0 mg), DiPEA (7 µL) and 2-thiophenemethylamine (4.1 µL) and the reaction
15 mixture was stirred for 3 h. at room temperature. The reaction mixture was concentrated and the title compound was obtained after flash column chromatography (silica gel, heptane/ethyl acetate (1/4, v/v), R_f = 0.78).

Yield: 11 mg. MS-ESI: [M+H]⁺ = 694/696.

20 **Example 14**

3-[2-Bromo-4-(3-cyano-2-methyl-5-oxo-7-phenyl-1,4,5,6,7,8-hexahydroquinolin-4-yl)-6-methoxyphenoxyethyl]-benzoic acid 2-morpholin-4-ylethyl ester

To a solution of the product of example 13b (20 mg) in 2 mL of dichloromethane were added TBTU (12 mg), DiPEA (7 µL) and 2-morpholin-4-ylethanol (4.8 µL) and the
25 reaction mixture was stirred for 3 h at room temperature. The reaction mixture was concentrated and the title compound was obtained after flash column chromatography (silica gel, heptane/ethyl acetate (1/4, v/v), R_f = 0.48).

Yield: 11 mg. MS-ESI: [M+H]⁺ = 694/696.

Example 15

4-{3-Bromo-5-ethoxy-4-[3-(piperidine-1-carbonyl)-benzyloxy]-phenyl}-2-methyl-5-oxo-7-phenyl-1,4,5,6,7,8-hexahydroquinoline-3-carbonitrile

5 a) 3-(2-Bromo-6-ethoxy-4-formylphenoxy-methyl)-benzoic acid methyl ester

3-Bromomethylbenzoic acid methyl ester (0.77 g), K₂CO₃ (1.0 g) and a catalytic amount of *n*-Bu₄NI were added to a solution of 5-bromo-3-ethoxy-4-hydroxybenzaldehyde (0.75 g) in 10 mL DMF and the reaction mixture was stirred at 70 °C for 1 h. A solution of 3% citric acid in water was added and the reaction mixture
10 was extracted with ethyl acetate. The organic phases were washed with water and brine, dried over MgSO₄ and concentrated. The title compound was obtained after flash column chromatography (silica gel, heptane/ethyl acetate (1/4, v/v), R_f = 0.25).

Yield: 1.08 g. ¹H NMR (CDCl₃): δ = 9.84 (s, 1H), 8.20 (bs, 1H), 8.02 (bd, 1H), 7.77 (d, 1H), 7.65 (d, 1H), 7.47 (t, 1H), 7.39 (d, 1H), 5.21 (s, 2H), 4.17 (q, 2H), 3.94 (s, 3H),
15 1.51 (t, 3H).

b) 3-[2-Bromo-4-(3-cyano-2-methyl-5-oxo-7-phenyl-1,4,5,6,7,8-hexahydroquinolin-4-yl)-6-ethoxyphenoxy-methyl]-benzoic acid methyl ester

The title compound was obtained analogously to example 1a, starting from the product
20 of step a (0.26 g).

Yield: 0.27 g. R_f (heptane/ethyl acetate (3/7, v/v)) = 0.34. MS-ESI: [M+H]⁺ = 613/615.

c) 3-[2-Bromo-4-(3-cyano-2-methyl-5-oxo-7-phenyl-1,4,5,6,7,8-hexahydroquinolin-4-yl)-6-ethoxyphenoxy-methyl]-benzoic acid

25 The title compound was obtained analogously to example 13b, starting from the product of step b (0.27 g).

Yield: 0.27 g. MS-ESI: [M+H]⁺ = 599/601.

d) 4-{3-Bromo-5-ethoxy-4-[3-(piperidine-1-carbonyl)-benzyloxy]-phenyl}-2-methyl-5-oxo-7-phenyl-1,4,5,6,7,8-hexahydroquinoline-3-carbonitrile

The title compound was obtained analogously to example 13c, starting the product of step c (20 mg) and piperidine (3.9 μ L).

5 Yield: 15 mg. R_f (heptane/ethyl acetate (1/4, v/v)) = 0.25. MS-ESI: $[M+H]^+ = 680/682$.

Example 16

Glycine, N-3-[2-bromo-4-(3-cyano-2-methyl-5-oxo-7-phenyl-1,4,5,6,7,8-hexahydroquinolin-4-yl)-6-ethoxyphenoxy-methyl]benzoyl, methyl ester

10 The title compound was obtained analogously to example 13c, starting from the product of example 15c (20 mg) and glycine methyl ester hydrochloride (4.9 mg).

Yield: 9.9 mg. R_f (heptane/ethyl acetate (3/7, v/v)) = 0.16. MS-ESI: $[M+H]^+ = 684/686$.

15 Example 17

3-[2-Bromo-4-(3-cyano-7-ethyl-2-methyl-5-oxo-1,4,5,6,7,8-hexahydroquinolin-4-yl)-6-ethoxyphenoxy-methyl]-benzoic acid methyl ester

The title compound was obtained analogously to example 1a, starting from 5-ethylcyclohexane-1,3-dione (0.25 g) and the product of 15a (0.64 g).

20 Yield: 0.45 g. R_f (heptane/ethyl acetate (1/4, v/v)) = 0.25. MS-ESI: $[M+H]^+ = 579/581$.

Example 18

3-[2-Bromo-4-(3-cyano-7-ethyl-2-methyl-5-oxo-1,4,5,6,7,8-hexahydro-quinolin-4-yl)-6-ethoxyphenoxy-methyl]-benzoic acid

25 The title compound was obtained analogously to example 13b, starting from the product of example 17 (0.43 g).

Yield: 0.38 g. R_f (heptane/ethyl acetate (1/4, v/v)) = 0.17. MS-ESI: $[M+H]^+ = 563/565$.

Example 19

3-[2-Bromo-4-(3-cyano-7-ethyl-2-methyl-5-oxo-1,4,5,6,7,8-hexahydroquinolin-4-yl)-6-ethoxyphenoxyethyl]-N-tert-butylbenzamide

To a solution of the product of example 18 (0.35 g) in 10 mL of dichloromethane were
5 added *tert*-butylamine (0.12 mL), DiPEA (0.39 mL) and HATU (0.30 g) and the
reaction mixture was stirred at 35 °C for 3 h. A solution of 3% citric acid in water was
added and the obtained mixture was extracted several times with ethyl acetate. The
organic phases were washed with water and brine, dried over MgSO₄ and concentrated.
The title compound was obtained after flash column chromatography (silica gel,
10 heptane/ethyl acetate (1/4, v/v), R_f = 0.34).

Yield: 0.28 g. MS-ESI: [M+H]⁺ = 620/622.

Example 20

3-[2-Bromo-4-(3-cyano-7-ethyl-2-methyl-5-oxo-1,4,5,6,7,8-hexahydroquinolin-4-yl)-6-ethoxyphenoxyethyl]-N-cyclohexylbenzamide

15 The title compound was prepared analogously to example 13c, starting from the
product of example 18 (20 mg) and cyclohexylamine (4.9 µL).

Yield: 7.9 mg. R_f (silica gel, heptane/ethyl acetate (1/4, v/v)) = 0.43. MS-ESI: [M+H]⁺
= 646/648.

20

Example 21

3-[2-Bromo-4-(3-cyano-7-ethyl-2-methyl-5-oxo-1,4,5,6,7,8-hexahydroquinolin-4-yl)-6-ethoxyphenoxyethyl]-N-(2-morpholin-4-yl-ethyl)-benzamide

The title compound was prepared analogously to example 13c, starting from the
25 product of example 18 (20 mg) and 4-(2-aminoethyl)-morpholine (5.5 µL).

Yield: 15 mg. R_f (dichloromethane/methanol (95/5, v/v)) = 0.22. MS-ESI: [M+H]⁺ =
677/679.

Example 22

4-[3-iodo-5-methoxy-4-(3-methoxybenzyloxy)-phenyl]-2-methyl-5-oxo-7-phenyl-1,4,5,6,7,8-hexahydroquinoline-3-carbonitrile

5 a) 3-Iodo-5-methoxy-4-(3-methoxybenzyloxy)-benzaldehyde

The title compound was obtained analogously to example 15a, starting from 4-hydroxy-3-iodo-5-methoxybenzaldehyde (0.70 g) and 1-bromomethyl-3-methoxybenzene (0.39 mL).

Yield: 0.56 g. R_f (heptane/ethyl acetate (4/6, v/v)) = 0.42. ^1H NMR (CDCl_3): δ = 9.83
10 (s, 1H), 7.86 (d, 1H), 7.43 (d, 1H), 7.29 (t, 1H), 7.16 (bs, 1H), 7.09 (d, 1H), 6.88 (dd, 1H), 5.14 (s, 2H), 3.95 (s, 3H), 3.84 (s, 3H).

b) 4-[3-iodo-5-methoxy-4-(3-methoxybenzyloxy)-phenyl]-2-methyl-5-oxo-7-phenyl-1,4,5,6,7,8-hexahydroquinoline-3-carbonitrile

15 The title compound was prepared analogously to example 1a, starting from the product of step a (24 mg).

Yield: 17 mg. R_f (heptane/ethyl acetate (1/4, v/v)) = 0.59. MS-ESI: $[\text{M}-\text{H}]^- = 631$.

Example 23

20 4-[3-Bromo-4-(2-chloro-3-methoxybenzyloxy)-5-ethoxyphenyl]-2-methyl-5-oxo-7-propyl-1,4,5,6,7,8-hexahydroquinoline-3-carbonitrile

The starting material was obtained according to the method described by McCarthy et al. (J. Org. Chem. 1986 (29) 1586):

25 a) 2-Chloro-3-methoxybenzaldehyde

At -40°C *n*-butyl lithium (6.25 mL, 1.6 M in hexane) was added to a solution of *N,N,N'*-trimethylethylenediamine (1.27 mL) in 10 mL tetrahydrofuran. After 15 min. the reaction mixture was cooled to -70°C and a solution of 3-methoxybenzaldehyde

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(1.22 mL) in 5 mL of tetrahydrofuran was added. The reaction mixture was allowed to warm to 0 °C and was cooled again to -70 °C and *n*-butyl lithium (6.25 mL, 1.6 M in hexane) was added. The reaction mixture was allowed to warm to 10 °C and was cooled again to -30 °C before it was added to a solution of hexachloroethane (7.10 g) in 10 mL tetrahydrofuran. The reaction mixture was stirred for 2 h. at room temperature, poured into 20 mL 10% HCl in water and extracted several times with ethyl acetate. The combined organic phases were washed with saturated brine, dried on MgSO₄ and concentrated. The title product was obtained after flash column chromatography (silica gel, heptane/ethyl acetate (75/25, v/v), R_f = 0.38), followed by crystallisation from heptane.

Yield: 1.06 g. ¹H NMR (CDCl₃): δ = 10.46 (s, 1H), 7.54 (dd, 1H), 7.35 (t, 1H), 7.17 (d, 1H), 3.96 (s, 3H).

b) 2-Chloro-1-chloromethyl-3-methoxybenzene

At 0 °C a solution of the product of step a (1.00 g) in 5 mL of tetrahydrofuran was added to a suspension of lithium aluminium hydride (0.34 g) in 5 mL of tetrahydrofuran. The reaction mixture was stirred at room temperature for 1 h and water (0.35 mL) in 5 mL tetrahydrofuran was added at 0 °C, followed by 2 M sodium hydroxide in water (0.70 mL) and water (0.70 mL). The obtained white suspension was stirred for 0.5 h. and filtered. The colourless oil obtained after concentration of the filtrate was dissolved in 10 mL of 1,2-dichloropropane and thionyl chloride (1.5 mL) was added. The reaction mixture was refluxed overnight and concentrated. The title compound was obtained after flash column chromatography (silica gel, heptane/ethyl acetate (75/25, v/v), R_f = 0.43) as a yellow oil, that crystallised on standing.

Yield: 0.80 g. ¹H NMR (CDCl₃): δ = 7.24 (t, 1H), 7.09 (dd, 1H), 6.93 (dd, 1H), 4.72 (s, 2H), 3.92 (s, 3H).

c) 3-Bromo-4-(2-chloro-3-methoxybenzyloxy)-5-ethoxybenzaldehyde

The title compound was obtained analogously to example 15a, starting from the product of step b (0.42 g) and 5-bromo-3-ethoxy-4-hydroxybenzaldehyde (0.49 g).

Yield: 0.56 g. ^1H NMR (CDCl_3): δ = 9.85 (s, 1H), 7.66 (dd, 1H), 7.40 (dd, 1H), 7.39 (d, 1H), 7.29 (t, 1H), 6.94 (dd, 1H), 5.32 (s, 2H), 4.15 (quar., 2H), 3.93 (s, 3H), 1.44 (t, 3H).

- 5 d) 4-[3-Bromo-4-(2-chloro-3-methoxybenzyloxy)-5-ethoxyphenyl]-2-methyl-5-oxo-7-propyl-1,4,5,6,7,8-hexahydroquinoline-3-carbonitrile

The title compound was obtained analogously to example 1a, starting from 5-propylcyclohexane-1,3-dione (21 mg) and the product of step c (53 mg).

Yield: 60 mg. R_f (heptane/ethyl acetate (4/6, v/v)) = 0.19. MS-ESI: $[\text{M}-\text{H}]^-$ = 597/599/601.

Example 24

Glycine, N-3-[2-bromo-4-(3-cyano-2-methyl-5-oxo-7-propyl-1,4,5,6,7,8-hexahydroquinolin-4-yl)-6-ethoxyphenoxyethyl]benzoyl, methyl ester

15

- a) 3-[2-Bromo-4-(3-cyano-2-methyl-5-oxo-7-propyl-1,4,5,6,7,8-hexahydroquinolin-4-yl)-6-ethoxyphenoxyethyl]-benzoic acid methyl ester

The title compound was obtained analogously to example 1a, starting from 5-propylcyclohexane-1,3-dione (0.95 g) and the product of example 15a (2.4 g).

20 Yield: 3.0 g. R_f (heptane/ethyl acetate (1/1, v/v)) = 0.20. MS-ESI: $[\text{M}-\text{H}]^-$ = 591/593.

- b) 3-[2-Bromo-4-(3-cyano-2-methyl-5-oxo-7-propyl-1,4,5,6,7,8-hexahydroquinolin-4-yl)-6-ethoxyphenoxyethyl]-benzoic acid

The title compound was obtained analogously to example 13b, starting from the product of step a (3.0 g).

25 Yield: 3.0 g. MS-ESI: $[\text{M}-\text{H}]^-$ = 577/579.

c) Glycine, N-3-[2-bromo-4-(3-cyano-2-methyl-5-oxo-7-propyl-1,4,5,6,7,8-hexahydroquinolin-4-yl)-6-ethoxyphenoxy-methyl]benzoyl, methyl ester

The title compound was obtained analogously to example 14, starting from the product of step b (90 mg) and glycine methyl ester hydrochloride (64 mg). Purification was accomplished via preparative HPLC (Luna C18 [5 μ m], flow: 20 ml min⁻¹, 0→90% CH₃CN, 1% TFA).

Yield: 59 mg. R_t (CH₂Cl₂/MeOH (95/5, v/v)) = 0.54. MS-ESI: [M+H]⁺ = 650/652.

Example 25

10 4-[3-Bromo-5-ethoxy-4-(3-methoxybenzyloxy)-phenyl]-7-(4-chlorophenyl)-2-methyl-5-oxo-1,4,5,6,7,8-hexahydroquinoline-3-carbonitrile

a) 3-Bromo-5-ethoxy-4-(3-methoxybenzyloxy)-benzaldehyde

The title compound was obtained analogously to example 15a, starting from 3-bromo-5-ethoxy-4-hydroxybenzaldehyde (0.75 g) and 1-bromomethyl-3-methoxybenzene (0.48 mL).

Yield: 0.91 g. R_f (heptane/ethyl acetate (2/1, v/v)) = 0.43. ¹H NMR (CDCl₃): δ = 9.83 (s, 1H), 7.65 (dd, 1H), 7.38 (dd, 1H), 7.29 (t, 1H), 7.13 (bs, 1H), 7.07 (d, 1H), 6.88 (dd, 1H), 5.16 (s, 2H), 4.16 (quar., 2H), 3.83 (s, 3H), 1.56 (t, 3H).

20

b) 4-[3-Bromo-5-ethoxy-4-(3-methoxybenzyloxy)-phenyl]-7-(4-chlorophenyl)-2-methyl-5-oxo-1,4,5,6,7,8-hexahydroquinoline-3-carbonitrile

The title compound was obtained analogously to example 1a, starting from 5-(4-chlorophenyl)-cyclohexane-1,3-dione (22 mg) and the product of step a (37 mg).

25 Yield: 32 mg. R_f (heptane/ethyl acetate (3/7, v/v)) = 0.19. MS-ESI: [M+H]⁺ = 633/635/637.

Example 26

4-[3-Bromo-5-ethoxy-4-(3-methoxybenzyloxy)-phenyl]-7-furan-2-yl-2-methyl-5-oxo-1,4,5,6,7,8-hexahydroquinoline-3-carbonitrile

The title compound was obtained analogously to example 1a, starting from 5-furan-2-ylcyclohexane-1,3-dione (18 mg) and the product of example 25a (37 mg).

Yield: 37 mg. R_f (heptane/ethyl acetate (3/7, v/v)) = 0.24. MS-ESI: $[M+H]^+ = 589/591$.

Example 27

4-[3,5-Dimethoxy-4-(3-methoxybenzyloxy)-phenyl]-2-methyl-5-oxo-7-propyl-1,4,5,6,7,8-hexahydroquinoline-3-carbonitrile

a) 3,5-Dimethoxy-4-(3-methoxybenzyloxy)-benzaldehyde

The title compound was obtained analogously to example 15a, starting from 4-hydroxy-3,5-dimethoxybenzaldehyde (0.91 g) and 1-bromomethyl-3-methoxybenzene (0.75 mL).

Yield: 1.42 g light-yellow oil. R_f (heptane/ethyl acetate (1/1, v/v)) = 0.40. 1H NMR ($CDCl_3$): $\delta = 9.86$ (s, 1H), 7.26 (d, 1H), 7.23 (d, 1H), 7.09 (bs, 1H), 7.04 (d, 1H), 6.85 (dd, 1H), 5.12 (s, 2H), 3.91 (s, 6H), 3.82 (s, 3H).

b) 4-[3,5-Dimethoxy-4-(3-methoxybenzyloxy)-phenyl]-2-methyl-5-oxo-7-propyl-1,4,5,6,7,8-hexahydroquinoline-3-carbonitrile

The title product was obtained analogously to example 1a, starting from 5-propylcyclohexane-1,3-dione (11 mg) and the product of step a (21 mg).

Yield: 22 mg. R_f (heptane/ethyl acetate (3/7, v/v)) = 0.21. MS-ESI: $[M+H]^+ = 503$; $[M+Na]^+ = 525$.

Example 28

4-[3-Bromo-5-ethoxy-4-(3-pyridinylmethoxy)phenyl]-2-methyl-5-oxo-7-propyl-1,4,5,6,7,8-hexahydroquinoline-3-carbonitrile trifluoroacetic acid

5 a) 3-Bromo-5-ethoxy-4-(3-pyridinylmethoxy)-benzaldehyde

The title compound was obtained analogously to example 15a, starting from 3-bromo-5-ethoxy-4-hydroxybenzaldehyde (0.25 g) and 3-picolyl chloride hydrochloride (0.16 g).

10 b) 4-[3-Bromo-5-ethoxy-4-(3-pyridinylmethoxy)phenyl]-2-methyl-5-oxo-7-propyl-1,4,5,6,7,8-hexahydroquinoline-3-carbonitrile trifluoroacetic acid

The title compound was obtained analogously to example 1a, starting from 5-propylcyclohexane-1,3-dione (0.15 g) and the crude product of step a. The compound was purified by semi-preparative HPLC (Luna C18 [5 μ m], flow: 20 ml min⁻¹,
15 10→90% CH₃CN, 0.1% TFA) and freeze-dried from a mixture of water and dioxane.

Yield: 0.25 g. MS-ESI: [M+H]⁺ = 536/538.

Example 29

4-[2-Bromo-4-(3-cyano-2-methyl-5-oxo-7-propyl-1,4,5,6,7,8-hexahydroquinolin-4-yl)-6-ethoxyphenoxy-methyl]-N-thiophen-2-ylmethylbenzamide

a) 4-(2-Bromo-6-ethoxy-4-formylphenoxy-methyl)-benzoic acid methyl ester

The title compound was obtained analogously to example 15a, starting from 4-bromomethylbenzoic acid methyl ester (3.7 g).

25 Yield: 6.4 g. ¹H NMR (CDCl₃): δ = 9.84 (s, 1H), 8.06 (d, 2H), 7.65 (d, 1H), 7.61 (d, 2H), 7.39 (d, 1H), 5.03 (s, 2H), 4.16 (q, 2H), 3.93 (s, 3H), 1.48 (t, 3H).

b) 4-[2-Bromo-4-(3-cyano-2-methyl-5-oxo-7-propyl-1,4,5,6,7,8-hexahydroquinolin-4-yl)-6-ethoxyphenoxy-methyl]-benzoic acid methyl ester

The title compound was obtained analogously to example 1a, starting from 5-propylcyclohexane-1,3-dione (2.5 g) and the product of step a (6.4 g).

Yield: 6.7 g. R_f (heptane/ethyl acetate (3/2, v/v)) = 0.20. MS-ESI: $[M-H]^- = 591/593$.

5 c) 4-[2-Bromo-4-(3-cyano-2-methyl-5-oxo-7-propyl-1,4,5,6,7,8-hexahydroquinolin-4-yl)-6-ethoxyphenoxy-methyl]-benzoic acid

The title compound was obtained analogously to example 13b, starting from the product of step b (6.7 g). The reaction mixture was stirred overnight at 50 °C.

Yield: 6.4 g. MS-ESI: $[M-H]^- = 577/579$.

10

d) 4-[2-Bromo-4-(3-cyano-2-methyl-5-oxo-7-propyl-1,4,5,6,7,8-hexahydroquinolin-4-yl)-6-ethoxyphenoxy-methyl]-N-thiophen-2-ylmethylbenzamide

The title compound was obtained analogously to example 14, starting from the product of step c (0.10 g) and 2-thiophenemethylamine (52 μ L). Purification was accomplished
15 via preparative HPLC (Luna C18 [5 μ m], flow: 20 ml min⁻¹, 10→90% CH₃CN, 1% TFA).

Yield: 54 mg. MS-ESI: $[M+H]^+ = 674/676$.

Example 30

20 4-[3-Bromo-5-ethoxy-4-(4-nitrophenoxy)-phenyl]-2-methyl-5-oxo-7-propyl-1,4,5,6,7,8-hexahydroquinoline-3-carbonitrile

a) 4-(3-Bromo-4-hydroxy-5-ethoxyphenyl)-2-methyl-5-oxo-7-propyl-1,4,5,6,7,8-hexahydroquinoline-3-carbonitrile

25 The title compound was obtained analogously to example 1a, starting from 3-bromo-5-ethoxy-4-hydroxybenzaldehyde (2.0 g) and 5-propylcyclohexane-1,3-dione (1.3 g).

Yield: 3.6 g. MS-ESI: $[M-H]^- = 443/445$.

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b) 4-(3-Bromo-4-mesyloxy-5-ethoxyphenyl)-2-methyl-5-oxo-7-propyl-1,4,5,6,7,8-hexahydroquinoline-3-carbonitrile

A mixture of the crude product of step a (0.99 g), mesyl chloride (0.46 mL) and sodium hydroxide 0.32 g in 4 mL of THF/water (1/1, v/v) was stirred at room temperature for 3 days. Water was added and the reaction mixture was extracted with dichloromethane. Crude title compound was obtained after concentration of the organic phases.

Yield: 1.0 g. MS-ESI: $[M-H]^- = 521/523$.

c) 4-[3-Bromo-5-ethoxy-4-(4-nitrophenoxy)-phenyl]-2-methyl-5-oxo-7-propyl-1,4,5,6,7,8-hexahydroquinoline-3-carbonitrile

A mixture of the product of step b (0.20 g), 1-fluoro-4-nitrobenzene (53 μ L) and cesium carbonate (0.22 g) was dissolved in dimethyl sulfoxide (1 mL) and stirred at 80 °C for 16 h. Dichloromethane was added and the reaction mixture was washed with a solution of 1% hydrochloric acid in water and with saturated brine. The organic phase was concentrated and the title compound was obtained after flash column chromatography (silica gel, heptane/ethyl acetate).

Yield: 0.19 g. MS-ESI: $[M-H]^- = 564/566$. 1H NMR ($CDCl_3$): $\delta = 8.17$ (d, 2H), 7.00 (d, 1H), 6.91 (m, 3H), 5.95 (bs, 1H), 4.63 (s, 1H), 4.04 (dq, 2H), 2.52 (dd, 1H), 2.42 (d, 2H), 2.25 (m, 1H), 2.20 (s, 3H), 2.15 (dd, 1H), 1.38 (m, 4H), 1.20 (t, 3H), 0.92 (t, 3H).

Example 31

4-[3-Bromo-5-ethoxy-4-(5-fluoro-2-propylamino-benzyloxy)-phenyl]-2-methyl-5-oxo-7-propyl-1,4,5,6,7,8-hexahydro-quinoline-3-carbonitrile

a) (5-Fluoro-2-nitro-phenyl)-methanol

To a solution of 5-fluoro-2-nitrobenzoic acid (4.58 g) in THF (50 ml) was added a 1 M solution of $BH_3 \cdot THF$ in THF (62 ml) while cooling with an ice-bath. The cooling bath was removed and stirring was continued for 1 h at ambient temperature, followed by refluxing for 4 h. The reaction mixture was cooled and MeOH was added to destroy the excess of borane. The mixture was concentrated and water and ethyl acetate were added to the residue. The organic layer was washed with brine, dried and concentrated.

Yield: 4.3 g.

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b) 4-[3-Bromo-5-ethoxy-4-(5-fluoro-2-nitro-benzyloxy)-phenyl]-2-methyl-5-oxo-7-propyl-1,4,5,6,7,8-hexahydro-quinoline-3-carbonitrile

A mixture of the crude product of step a (1.5 g), thionyl chloride (1.94 ml) and a few drops of DMF in dichloromethane (30 ml) was stirred for 72 h. The mixture was concentrated *in vacuo* and the residue was dissolved in DMF (20 ml). To the remaining solution was added the compound described in example 30a (3.9 g), K₂CO₃ (6.1 g) and a small amount of tetra-n-butylammonium bromide (ca 50 mg). The mixture was stirred at 60 °C for 5h. Water and ethyl acetate were added, and the aqueous layer was extracted with ethyl acetate. The combined organic fractions were washed with brine, dried and concentrated. The residue was recrystallized from toluene.

Yield: 3.8 g

c) 4-[4-(2-Amino-5-fluoro-benzyloxy)-3-bromo-5-ethoxy-phenyl]-2-methyl-5-oxo-7-propyl-1,4,5,6,7,8-hexahydro-quinoline-3-carbonitrile

15

To a solution of the product of step b (3.8 g) in THF (110 ml) were added acetic acid (3.6 ml) and zinc dust (8.2 g). The suspension was heated for 1 h at 50 °C. The reaction mixture was filtered and concentrated. The residue was dissolved in ethyl acetate and washed with sat. NaHCO₃ and brine. The organic layer was separated, dried (Na₂SO₄) and concentrated. The remaining solid was stirred with a small amount of ethyl acetate to give the title compound as a pale yellow solid after filtration.

Yield: 2.8 g

d) 4-[3-Bromo-5-ethoxy-4-(5-fluoro-2-propylamino-benzyloxy)-phenyl]-2-methyl-5-oxo-7-propyl-1,4,5,6,7,8-hexahydro-quinoline-3-carbonitrile

25

A solution of the compound described in step c (200 mg) and propionaldehyde (25 µl) in dichloromethane (5 ml) was stirred for 2 h. Then, acetic acid (81 µl) and sodium triacetoxyborohydride (300 mg) were added and the mixture was stirred for an additional 20h. A 2 M aqueous NaOH solution was added and stirring was continued for 15 min. The organic layer was washed with water and brine, dried and concentrated *in vacuo*. The title compound was obtained by purification of the residue by preparative HPLC (Luna C18 [5 µm], flow: 20 ml min⁻¹, 10→90% CH₃CN, 0.1% TFA) and

freeze-drying from a mixture of water and dioxane. Some di-alkylated product could be isolated as well (see example 32).

Yield: 109 mg. MS-ESI: $[M+H]^+ = 610/612$.

5 Example 32

4-[3-Bromo-4-(2-dipropylamino-5-fluoro-benzyloxy)-5-ethoxy-phenyl]-2-methyl-5-oxo-7-propyl-1,4,5,6,7,8-hexahydro-quinoline-3-carbonitrile

Obtained from the reaction mixture of example 31d after preparative HPLC (Luna C18 [5 μ m], flow: 20 ml min⁻¹, 10→90% CH₃CN, 0.1% TFA) and freeze-drying from a mixture of water and dioxane.

Yield: 12 mg. MS-ESI: $[M+H]^+ = 652/654$.

Example 33

CHO-FSH *in vitro* bioactivity

15 FSH activity of compounds were tested in Chinese Hamster Ovary (CHO) cells stably transfected with the human FSH receptor and cotransfected with a cAMP responsive element (CRE) / promotor directing the expression of a firefly luciferase reporter gene. Binding of ligand to the Gs-coupled FSH receptor will result in an increase of cAMP, which in turn will induce an increased transactivation of the luciferase reporter
20 construct. The luciferase signal was quantified using a luminescence counter. For test compounds, EC₅₀ values (concentration of test compound causing half-maximal (50 %) stimulation) were calculated. For that purpose the software program GraphPad PRISM, version 3.0 (GraphPad software Inc., San Diego) was used.

Compounds of all examples had an activity (EC₅₀) of less than 10⁻⁵ M. The compounds
25 of examples 13, 16, 17, 19-21, 23, 26, 28, 31 and 32 showed an EC₅₀ of between 10⁻⁷ and 10⁻⁹ M. The compounds of examples 24 and 29 showed an EC₅₀ of less than 10⁻⁹ M.

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- 4C)(di)alkylaminocarbonyl(1-4C)alkyl or (6-10C)arylamino carbonyl(1-4C)alkyl, (1-9C)heteroarylaminocarbonyl(1-4C)alkyl, (6-10C)aryl, (1-9C)heteroaryl, (6-10C)aryl(1-4C)alkyl, (1-9C)heteroaryl(1-4C)alkyl, the (hetero)aryl group optionally substituted with one or more substituents selected from hydroxy, amino, halogen, nitro, trifluoromethyl, cyano, (1-4C)alkyl, (2-4C)alkenyl, (2-4C)alkynyl, (1-4C)alkoxy, (1-4C)(di)alkylamino or
- 5 R^5 , R^6 in R^5, R^6 -aminocarbonyl may be joined in a (2-6C)heterocycloalkyl ring; with the proviso that the compound is not 2-methyl-5-oxo-7-phenyl-4-(3,4,5-trimethoxyphenyl)-1,4,5,6,7,8-hexahydroquinoline-3-carbonitrile.
- 10 2. The compound according to claim 1 wherein R^4 is phenyl optionally substituted with one or more substituents selected from hydroxy, amino, halogen, nitro, trifluoromethyl, cyano, (1-4C)alkyl, (2-4C)alkenyl, (2-4C)alkynyl, (1-4C)alkoxy, (1-4C)(di)alkylamino, (1-4C)alkylthio, (1-4C)alkylsulfonyl, R^5 -oxycarbonyl, R^5 -carbonyl or R^5, R^6 -aminocarbonyl.
- 15 3. The compound according to claim 2 wherein the substituent of phenyl at R^4 is R^5, R^6 -aminocarbonyl, (1-4C)alkoxy and/or halogen.
4. The compound according to claim 3 wherein R^5, R^6 in R^5, R^6 -aminocarbonyl is (1-4C)(di)alkylamino.
5. The compound according to claim 3 wherein R^5 in R^5, R^6 -aminocarbonyl is (1-4C)alkoxycarbonyl(1-4C)alkyl and R^6 is H.
- 20 6. The compound according to claim 3 wherein R^5 in R^5, R^6 -aminocarbonyl is (1-9C)heteroaryl(1-4C)alkyl, the (hetero)aryl group optionally substituted with one or more substituents selected from hydroxy, amino, halogen, nitro, trifluoromethyl, cyano, (1-4C)alkyl, (2-4C)alkenyl, (2-4C)alkynyl, (1-4C)alkoxy, (1-4C)(di)alkylamino or (1-4C)alkoxycarbonyl(1-4C)alkyl and R^6 is H.
- 25 7. The compound according to claims 1-6 wherein X is CH_2 .
8. The compound according to claims 1-7 wherein R^1 is (1-6C)alkyl, phenyl or (1-5C)heteroaryl.
9. The compound of claims 1-8 wherein R^2, R^3 is halogen and/or (1-4C)alkoxy.
- 30 10. Compound according to claims 1-9 for use in therapy.

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11. A pharmaceutical composition comprising the compound of any one of claims 1-9 including 2-methyl-5-oxo-7-phenyl-4-(3,4,5-trimethoxyphenyl)-1,4,5,6,7,8-hexahydroquinoline-3-carbonitrile, and pharmaceutically suitable auxiliaries.
12. Use of the compound of any one of claims 1-9 including 2-methyl-5-oxo-7-phenyl-4-(3,4,5-trimethoxyphenyl)-1,4,5,6,7,8-hexahydroquinoline-3-carbonitrile, or a pharmaceutically acceptable salt or solvate thereof for the manufacture of a medicament for the treatment of fertility disorders.