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(54) Title: TREATMENT OF H. PYLORI INFECTIONS USING MTAN INHIBITORS

(57) Abstract: Methods of treating infections due to *Helicobacter pylori* (*H. pylori*), in particular in subjects having a peptic ulcer, are disclosed where the methods comprise administering inhibitors of *H. pylori* MTAN (5'-methylthioadenosine nucleosidase) to the subject.



WO 2015/123101 A1

TREATMENT OF H. PYLORI INFECTIONS USING MTAN INHIBITORS

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of U.S. Provisional patent application No. 61/938,755, filed on February 12, 2014, the contents of which is herein incorporated by reference in its entirety.

STATEMENT OF GOVERNMENT SUPPORT

[0002] This invention was made with government support under grant number GM41916 awarded by the National Institutes of Health and under Center for Synchrotron Biosciences grant number P30-EB-009998 awarded by the National Institute of Biomedical Imaging and Bioengineering (NIBIB). The government has certain rights in the invention.

FIELD OF THE INVENTION

[0003] The invention relates to treating infections due to *Helicobacter pylori* (*H. pylori*) using inhibitors of *H. pylori* MTAN (5'-methylthioadenosine nucleosidase), in particular in subjects having a peptic ulcer.

BACKGROUND OF THE INVENTION

[0004] Throughout this application various publications are referred to in superscripts. Full citations for these references may be found at the end of the specification before the claims. The disclosures of these publications are hereby incorporated by reference in their entireties into the subject application to more fully describe the art to which the subject application pertains.

[0005] *H. pylori* is a gram-negative bacterium and lives microaerophilically in the gastric mucosa of its human host. It is related to 85 percent of gastric and 95 percent of duodenal ulcers¹. Drug resistance is prevalent in clinical isolates of *H. pylori*. After less than thirty years of specific antibiotic treatment, it is increasingly difficult to eradicate *H. pylori* using a combination of two antibiotics with two weeks therapy². Antibiotics with new targets and mechanisms of action are needed to treat *H. pylori* infections.

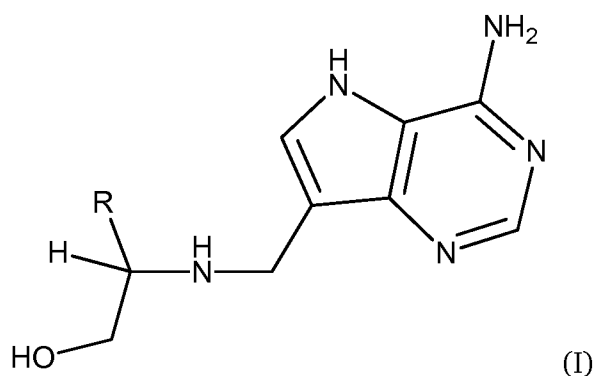
[0006] Gram negative bacteria are dependent on menaquinone as electron transporters in respiration and have maintained biosynthetic pathways for these essential metabolites³. In contrast, humans lack the pathway of menaquinone synthesis, and targeting the menaquinone

pathway provides an anti-bacterial drug design approach. Recently, a menaquinone synthetic pathway has been proposed in *Campylobacter* and *Helicobacter* that differs from most bacteria^{4,5}. In this pathway, 6-amino-6-deoxyfutalosine is synthesized by MqnA and cleaved at the *N*-ribosidic bond by a MTAN with specificity also extending to 5'-methylthioadenosine and adenosylhomocysteine as well as 6-amino-6-deoxyfutalosine. *Hp*MTAN converts 6-amino-6-deoxyfutalosine to adenine and dehypoxanthine futalosine, the latter being used as the processor of menaquinone synthesis. The early reactions of this pathway do not exist in the normal bacterial flora of humans, making enzymes catalyzing these reactions appealing drug targets. *Hp*MTAN is closely related to the 5'-methylthioadenosine/*S*-adenosylhomocysteine hydrolases (MTANs) found in other bacteria. The well-characterized MTANs are associated with quorum sensing and *S*-adenosylmethionine recycling in most species and are not essential for bacterial growth⁶. Transition state analogue inhibitors of picomolar to femtomolar affinity have been developed to interrupt bacterial functions associated with quorum sensing^{6,7}.

[0007] The present invention addresses the need for new compounds that selectively block the growth of *H. pylori*.

SUMMARY OF THE INVENTION

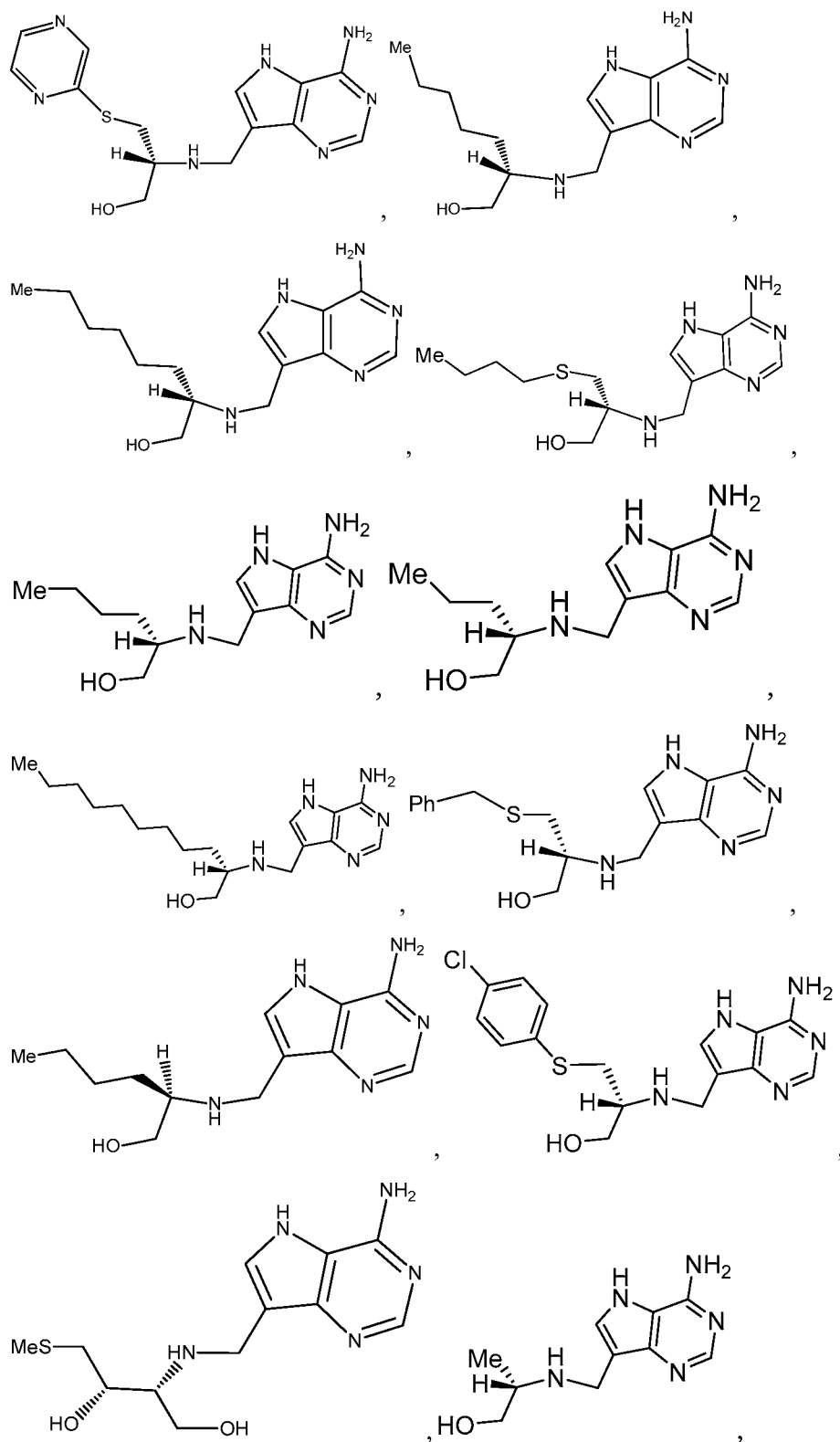
[0008] The invention provides methods of treating a *Helicobacter pylori* (*H. pylori*) infection in a subject comprising administering to the subject a compound of formula (I) in an amount effective to inhibit growth of *H. pylori*, wherein formula (I) is

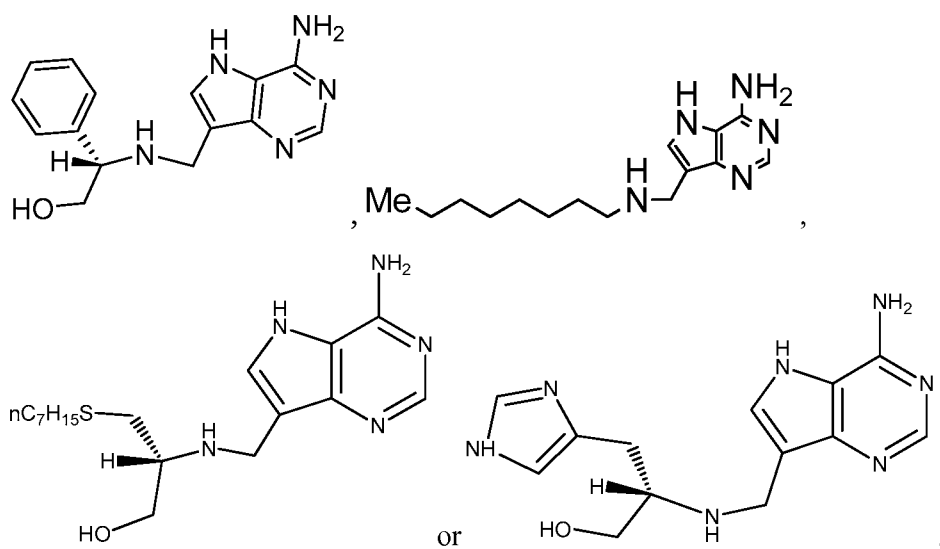


wherein R is Q or CH₂SQ, wherein Q is C1-C9 alkyl aryl, heteroaryl, aralkyl, or C4-C7 cycloalkyl and wherein Q is optionally substituted with one or more halogen, OH and/or NH₂ groups,

or a pharmaceutically acceptable salt thereof, or an ester thereof.

[0009] The invention further provides a compound having the structure:





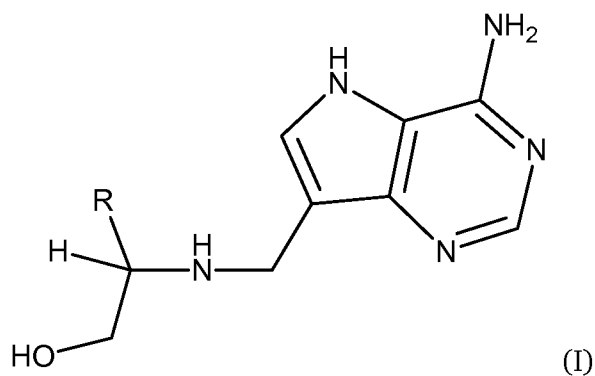
or a pharmaceutically acceptable salt thereof, or an ester thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] Fig. 1. Concentration of Hexyl-SerMe-Immucillin A in mouse gastric mucin versus time following a single dose of 10 mg/kg PO.

DETAILED DESCRIPTION OF THE INVENTION

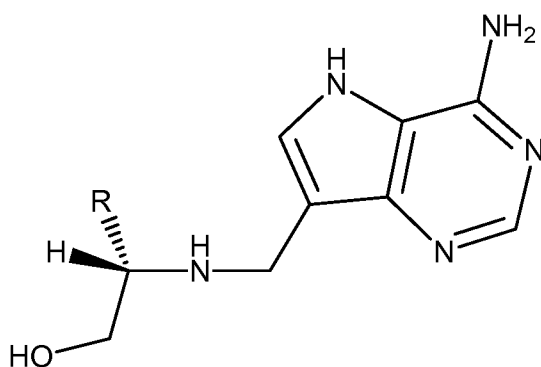
[0011] The invention provides a method of treating a *Helicobacter pylori* (*H. pylori*) infection in a subject comprising administering to the subject a compound of formula (I) in an amount effective to inhibit growth of *H. pylori*, wherein formula (I) is



wherein R is Q or CH₂SQ, wherein Q is C1-C9 alkyl, aryl, heteroaryl, aralkyl, or C4-C7 cycloalkyl, and wherein Q is optionally substituted with one or more halogen, OH and/or NH₂ groups,

or a pharmaceutically acceptable salt thereof, or an ester thereof.

[0012] Preferred compounds include those having the formula



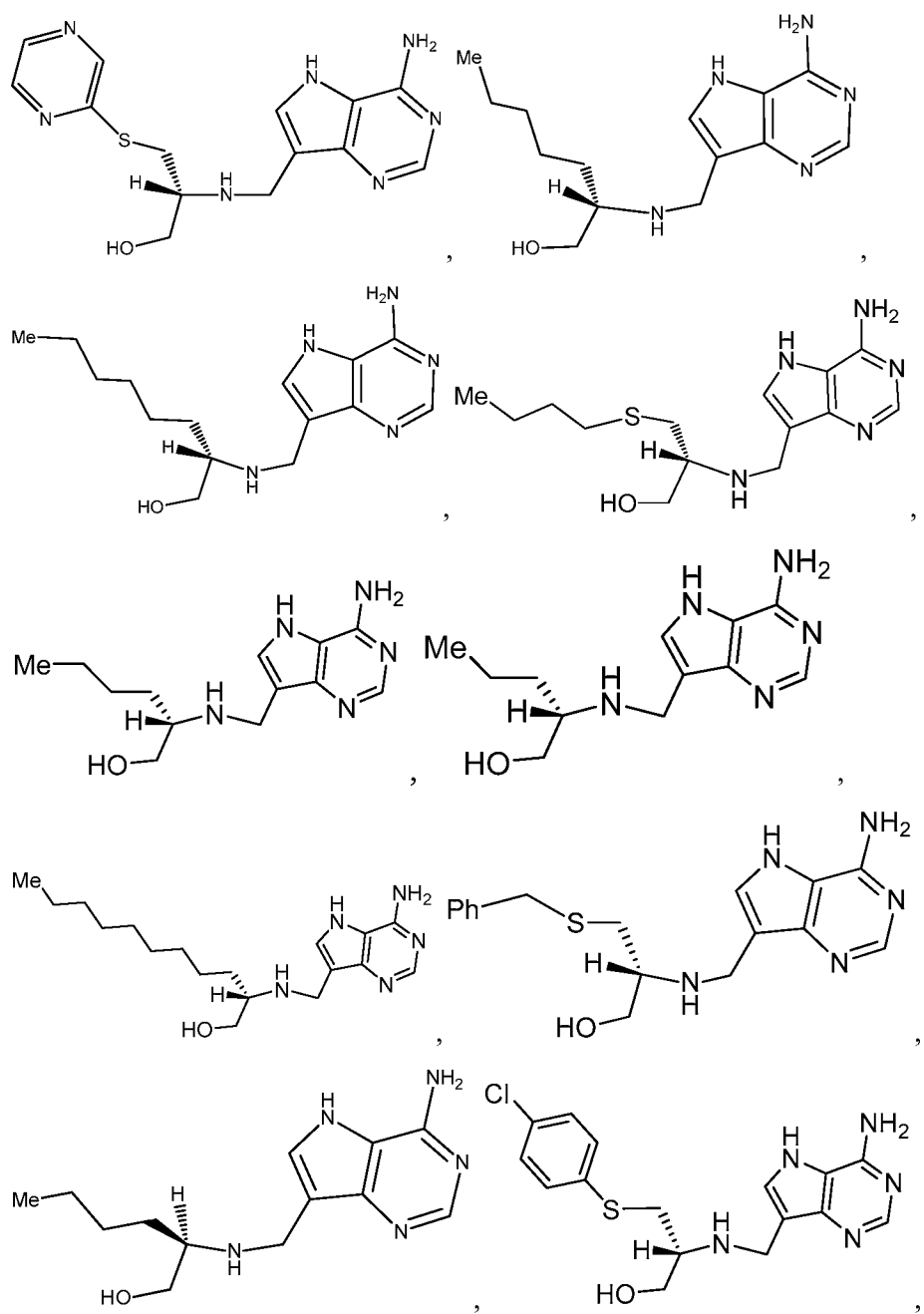
[0013] Q can be, for example, C1-C9 alkyl, e.g., C1-C5 alkyl; e.g., a methyl (Me), ethyl (Et), propyl (Pr), butyl or pentyl group. Q can be, for example, C4-C7 cycloalkyl, i.e., C4 cycloalkyl, C5 cycloalkyl, C6 cycloalkyl, or C7 cycloalkyl. Q can be, for example, aryl. The term “aryl” means an aromatic radical having 4 to 12 carbon atoms. Examples include phenyl, 1-naphthyl and 2-naphthyl. “Heteroaryl” means a 4 to 12 member ring that includes one or more N, S, or O atoms in the ring. Examples include imidazol-4-yl, imidazol-2-yl, thiazol-2-yl, thiazol-4-yl, thiazol-5-yl, pyridin-2-yl, pyridine-3-yl, pyridine-4-yl and pyrazin-2-yl. Preferred aryls and heteroaryl include those having 5 or 6 members in the ring. Preferably, the aralkyl includes a C1-C3 alkyl group and a 4-6 membered ring, which can include heteroatoms.

[0014] Q can be substituted with one or more halogen, hydroxyl or NH_2 groups. Preferred halogens are Cl, F, Br or I. Chlorine and fluorine are more preferred halogens. The substitution can be at an ortho, meta or para position.

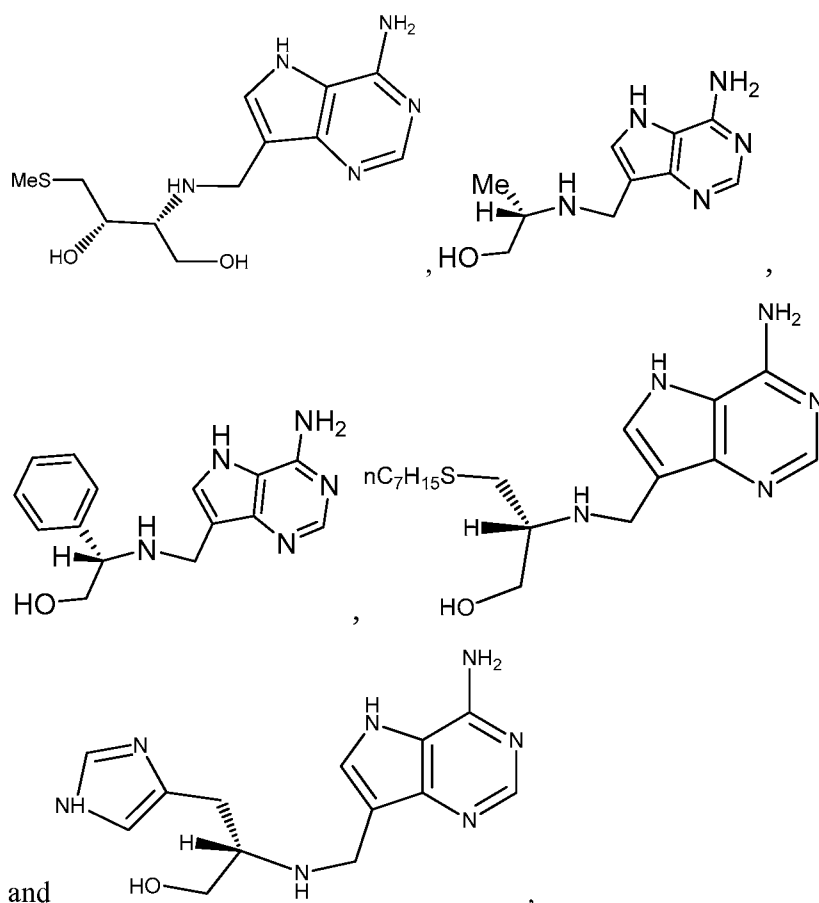
[0015] Preferred compounds include those where R is Q or CH_2SQ , wherein Q is C2-C9 linear alkyl, aryl, heteroaryl, aralkyl, or C4-C7 cycloalkyl, and wherein Q is optionally substituted with one or more halogen, OH and/or NH_2 groups. Preferred compounds also include those where Q is C3-C9 linear alkyl or heteroaryl.

[0016] Preferred compounds include those selected from the group consisting of

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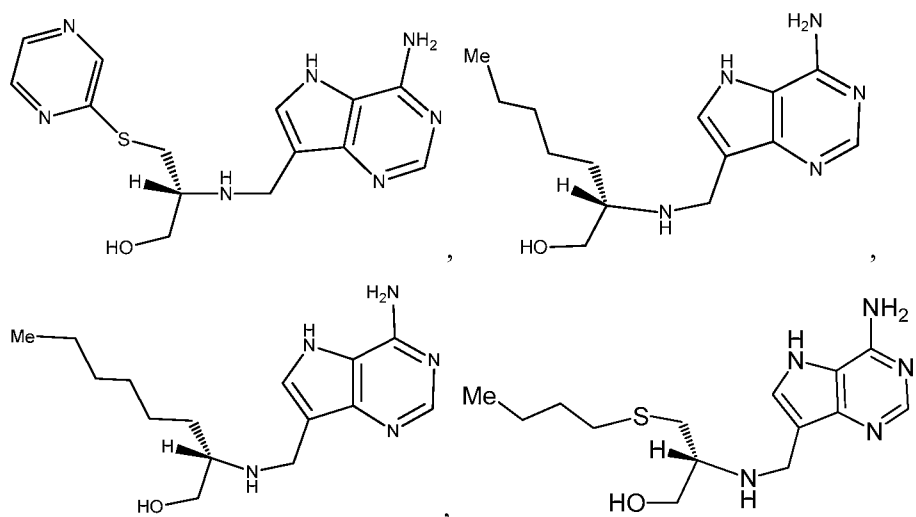


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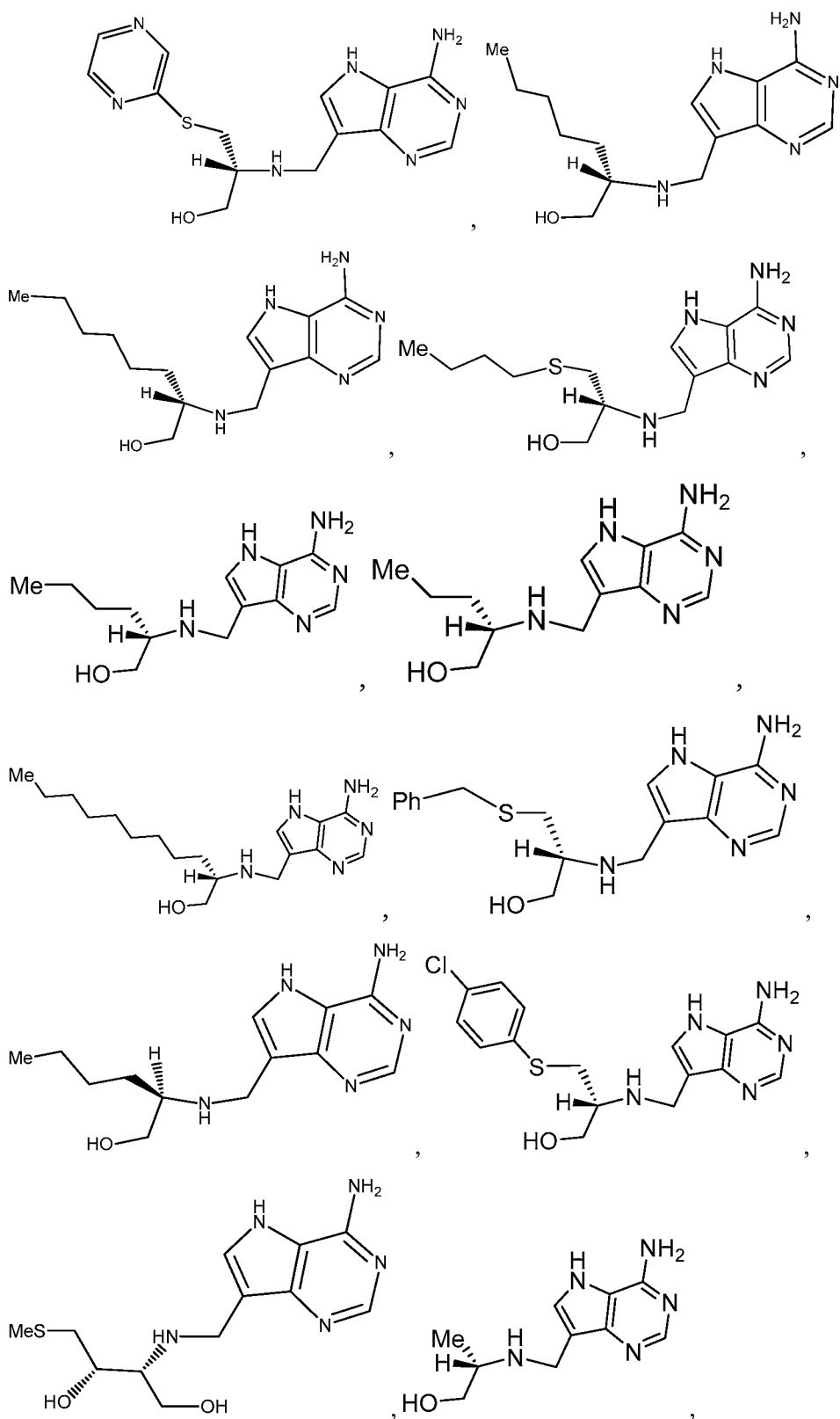
or a pharmaceutically acceptable salt thereof, or an ester thereof.

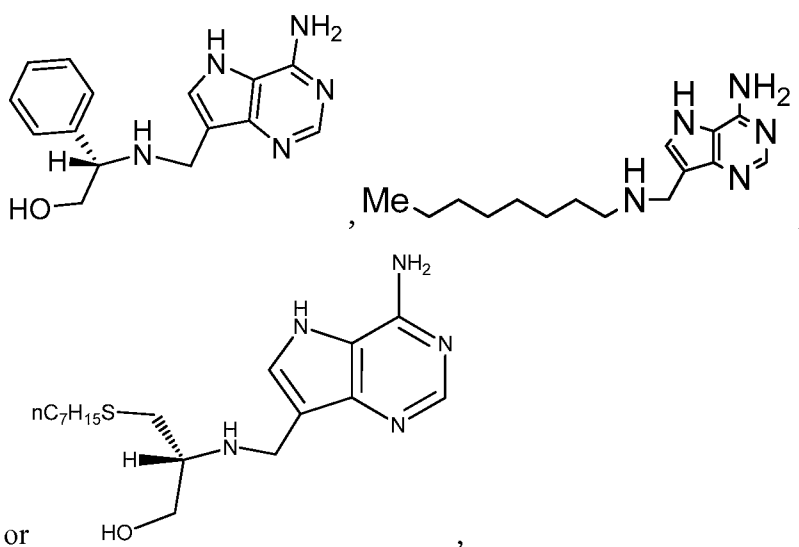
[0017] According, the invention provides a method of treating a *Helicobacter pylori* (*H. pylori*) infection in a subject comprising administering to the subject a compound in an amount effective to inhibit growth of *H. pylori*, wherein the compound is selected from the group consisting of:



or a pharmaceutically acceptable salt thereof, or an ester thereof.

[0018] The invention further provides a compound having the structure:





or a pharmaceutically acceptable salt thereof, or an ester thereof.

[0019] The term “pharmaceutically acceptable salts” includes non-toxic salts derived from inorganic or organic acids, including, for example, the following acid salts: acetate, adipate, alginate, aspartate, benzoate, benzenesulfonate, bisulfate, butyrate, citrate, camphorate, camphorsulfonate, cyclopentanepropionate, digluconate, dodecylsulfate, ethanesulfonate, formate, fumarate, glucoheptanoate, glycerophosphate, glycolate, hemisulfate, heptanoate, hexanoate, hydrochloride, hydrobromide, hydroiodide, 2-hydroxyethanesulfonate, lactate, maleate, malonate, methanesulfonate, 2-naphthalenesulfonate, nicotinate, nitrate, oxalate, palmoate, pectinate, persulfate, 3-phenylpropionate, phosphate, picrate, pivalate, propionate, *p*-toluenesulfonate, salicylate, succinate, sulfate, tartrate, thiocyanate, and undecanoate.

[0020] Preferably, the compound is administered in an amount that is effective to inhibit *H. pylori* 5'-methylthioadenosine nucleosidase (MTAN).

[0021] Preferably, the compound inhibits growth of *H. pylori* but does not inhibit the growth of one or more bacterium selected from the group consisting of *E. coli*, *V. cholerae*, *S. aureus*, *K. pneumoniae*, *S. flexneri*, *S. enterica* and *P. aeruginosa*. More preferably, the compound does not inhibit the growth of all of *E. coli*, *V. cholerae*, *S. aureus*, *K. pneumoniae*, *S. flexneri*, *S. enterica* and *P. aeruginosa*. Preferably, the compound is more effective in inhibiting growth of *H. pylori* than is amoxicillin, metronidazole or tetracyclin.

[0022] Preferably, the subject has a peptic ulcer, such as a gastric ulcer or a duodenal ulcer.

[0023] Preferably, the compound is administered orally. For oral administration, the compound can be formulated into solid or liquid preparations, for example tablets, capsules, powders, solutions, suspensions and dispersions. The compound can be formulated with agents such as, e.g., lactose, sucrose, corn starch, gelatin, potato starch, alginic acid and/or magnesium stearate.

[0024] The compound can also be administered to a subject by other routes known in the art, such as, e.g., parenterally, by inhalation, topically, rectally, nasally, buccally or via an implanted reservoir. The compound can be administered by means of sustained release.

[0025] The invention further provides for the use a compound that inhibits *Helicobacter pylori* (*H. pylori*) MTAN for the preparation of a medicament for treating a *H. pylori* infection. The invention still further provides a compound that inhibits *Helicobacter pylori* (*H. pylori*) MTAN for use for treating a *H. pylori* infection.

[0026] The invention further provides for the use a compound that inhibits *Helicobacter pylori* (*H. pylori*) MTAN for the preparation of a medicament for treating a peptic ulcer. The invention still further provides a compound that inhibits *Helicobacter pylori* (*H. pylori*) MTAN for use for treating a peptic ulcer.

[0027] The present methods can also be applied to treating infections due to other *Helicobacter* species and to *Campylobacter* species, such as *C. jejuni*.

[0028] The invention further provides a pharmaceutical composition comprising any of the compounds disclosed herein and a pharmaceutically acceptable carrier. As used herein, a "pharmaceutically acceptable carrier" is (i) compatible with the other ingredients of the composition without rendering the composition unsuitable for its intended purpose, and (ii) suitable for use with subjects as provided herein without undue adverse side effects (such as toxicity, irritation, and allergic response). Side effects are "undue" when their risk outweighs the benefit provided by the composition. Non-limiting examples of pharmaceutically acceptable carriers include any of the standard pharmaceutical carriers such as phosphate buffered saline solutions, water, and emulsions such as oil/water emulsions and microemulsions.

[0029] This invention will be better understood from the Experimental Details that follow. However, one skilled in the art will readily appreciate that the specific methods and results discussed are merely illustrative of the invention as described more fully in the claims that follow thereafter.

EXPERIMENTAL DETAILS

EXAMPLE 1

Materials and Methods

[0030] *Materials.* *H. pylori* (J99 and 43504), *K. pneumoniae*, *S. flexneri*, *S. enterica*, *S. aureus* and *P. aeruginosa* were purchased from the American Type Culture Collection. Defibrinated horse blood (DHB) was from Hemostat Laboratories (Dixon, CA). Tryptic soy agar (TSA) was purchased from Becton Dickinson and Company (Sparks, MD). MacConkey agar was from Oxoid LTD. (Basingstoke, Hampshire, England). Xanthine oxidase and 5'-methylthioadenosine were purchased from Sigma-Aldrich (St Louis, MO). The rest of the materials were purchased with the highest purity available.

[0031] *HpMTAN purification.* The purification procedure of *HpMTAN* was described previously¹⁰. Briefly, BL21 (DE3) cells harboring a plasmid encoding *HpMTAN* with an N-terminal His6-tag were grown to an optical density of 0.7 measured at 595 nm and IPTG was introduced to a final concentration of 0.5 mM. After another 15 h at 22 °C, cells were collected by centrifugation. The pellet was suspended and later disrupted by pressure cell and sonication. The soluble portion was applied to a Ni-NTA column and *HpMTAN* was eluted with an imidazole concentration gradient of 200 to 500 mM. The protein was desalted using a Superdex G15 gel-filtration column then equilibrated and concentrated in 10 mM Hepes, 30 mM KCl, pH 7.6. The purity was confirmed by SDS-PAGE.

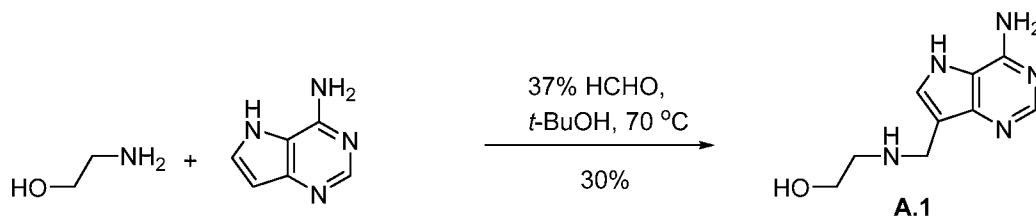
[0032] *K_i determination.* Kinetics of *HpMTAN* were determined using a direct assay involving absorbance decrease at 274 nm continuously as a consequence of formation of free adenine from 5'-methylthioadenosine. The *K_i* and *K_i** values were determined using coupled assays, in which xanthine oxidase was used as the coupling enzyme and absorbance increase was followed at 292 nm as the product adenine is converted to 2,8-dihydroxyadenine. Both assays have been previously described⁸.

[0033] *Bacterial growth.* *H. pylori* were grown for 72 hours under microaerophilic condition (5% O₂, 10% CO₂ and 85% N₂) at 37 °C on tryptic soy agar with 5% horse blood. To determine the MIC values, the test substance was added to the gel solution right before pouring. To compare the zones of inhibition, specific antibiotics were added to the center of disc after spreading *H. pylori*, and then *H. pylori* was allowed to grow for 72 hours under microaerophilic condition at 37 °C.

[0034] *General experimental for compounds.* All reactions were performed under an argon atmosphere. Organic solutions were dried over anhydrous MgSO₄ and the solvents

were evaporated under reduced pressure. Anhydrous and chromatography solvents were obtained commercially and used without any further purification. Potassium *tert*-butoxide was sublimed at 220 °C/0.1 torr. Thin layer chromatography (TLC) was performed on glass or aluminum sheets coated with 60 F₂₅₄ silica gel. Organic compounds were visualized under UV light and/or a dip of 0.1% ninhydrin in EtOH, Ehrlich's solution or ammonium molybdate (5 mass%) and cerium(IV) sulfate 4 H₂O (0.2 mass%) in aq. H₂SO₄ (2 M). Chromatography (flash column or an automated system with continuous gradient facility) was performed on silica gel (40-63 μm). Optical rotations were recorded at a path length of 1 dm and are in units of 10⁻¹ deg cm² g⁻¹; concentrations are in g/100 mL. ¹H NMR spectra were measured in CDCl₃ or CD₃OD (internal Me₄Si, δ 0) and ¹³C NMR spectra in CDCl₃ (center line as stated) or CD₃OD (center line as stated). Assignments of ¹H and ¹³C resonances were based on 2D (¹H-¹H DQF-COSY, ¹H-¹³C HSQC) and DEPT experiments. Abbreviations used: s, singlet, d, doublet, t, triplet, q, quartet, bs, broad singlet, bt, broad triplet, dd, doublet of doublets, ddd, doublet of doublets of doublets, dt, doublet of triplets. High resolution electrospray mass spectra (ESI-HRMS) were recorded on a Q-TOF Tandem Mass Spectrometer.

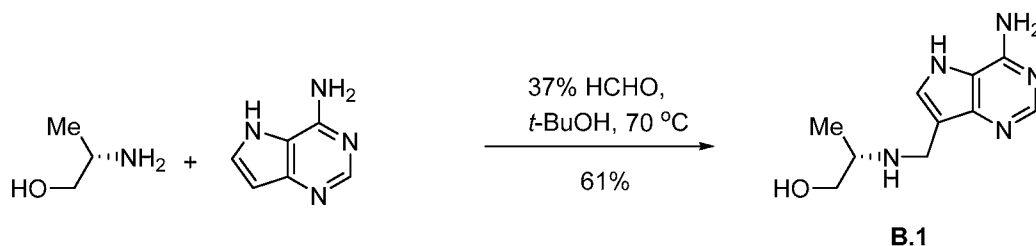
[0035] *Example A. Synthesis of 2-[(4-amino-5H-pyrrolo[3,2-d]pyrimidin-7-yl)methyl]amino]ethan-1-ol (A.1).*



[0036] *2-[(4-Amino-5H-pyrrolo[3,2-d]pyrimidin-7-yl)methyl]amino]ethan-1-ol (A.1).* 2-Aminoethanol (0.099 mL, 1.64 mmol), 9-deazaadenine (0.220 g, 1.64 mmol) and aq. formaldehyde solution (37%, 0.15 mL, 1.99 mmol) were stirred together in *tert*-butanol (3 mL) at 70 °C for 16 h. Silica gel was added to absorb all the solvent then the solvent was evaporated and the residue purified by chromatography on silica gel (CHCl₃-MeOH-28% aq. NH₄OH, 70:25:5). Fractions containing product were evaporated and the residue chromatographed again on silica gel (2-PrOH-28% aq. NH₄OH, 92:8) to give **A.1** as a colourless solid (0.101 g, 30%). ¹H NMR (500 MHz, CD₃OD): δ 8.16 (s, 1H), 7.47 (s, 1H), 3.95 (s, 2H), 3.68 (t, *J* = 5.6 Hz, 2H), 2.78 (t, *J* = 5.6 Hz, 2H). ¹³C NMR (125.7 MHz, CD₃OD, centre line δ 49.0): δ 152.1 (C), 150.9 (CH), 146.6 (C), 129.0 (CH), 115.4 (C), 114.4

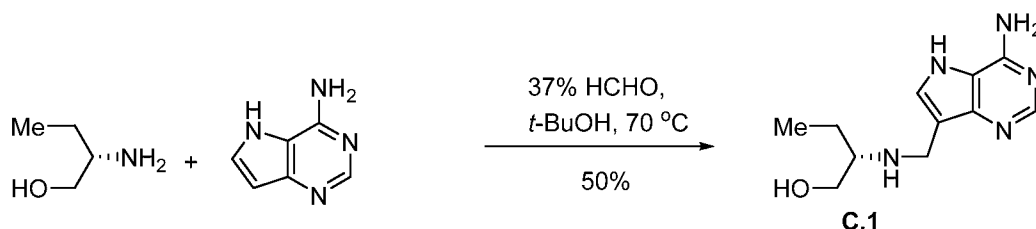
(C), 61.6 (CH₂), 51.6 (CH₂), 43.4 (CH₂). ESI-HRMS calcd for C₉H₁₄N₅O⁺, (M+H)⁺, 208.1193, found 208.1192.

[0037] Example B. Synthesis of (2*S*)-2-[(4-*amino*-5*H*-pyrrolo[3,2-*d*]pyrimidin-7-yl)methyl]amino]propan-1-ol (B.1).



[0038] (2*S*)-2-[(4-*Amino*-5*H*-pyrrolo[3,2-*d*]pyrimidin-7-yl)methyl]amino]propan-1-ol (B.1). (2*S*)-2-Aminopropan-1-ol (0.120 g, 1.60 mmol), 9-deazaadenine (0.179 g, 1.33 mmol) and aq. formaldehyde solution (37%, 0.12 mL, 1.60 mmol) were stirred together in *tert*-butanol (3 mL) at 70 °C for 16 h. Silica gel was added to absorb all the solvent then the solvent was evaporated and the residue purified by chromatography on silica gel (CHCl₃-MeOH-28% aq.NH₄OH, 80:18.5:1.5) to afford **B.1** as a colourless solid (0.180 g, 61%). ¹H NMR (500 MHz, CD₃OD): δ 8.16 (s, 1H), 7.47 (s, 1H), 4.01 (d, *J* = 13.6 Hz, 1H), 3.92 (d, *J* = 13.6 Hz, 1H), 3.54 (dd, *J* = 11.0, 4.8 Hz, 1H), 3.43 (dd, *J* = 11.0, 7.0 Hz, 1H), 2.84 (m, 1H), 1.09 (d, *J* = 6.5 Hz, 3H). ¹³C NMR (125.7 MHz, CD₃OD, centre line δ 49.0): δ 152.1 (C), 150.9 (CH), 146.5 (C), 128.9 (CH), 115.4 (C), 114.5 (C), 66.6 (CH₂), 54.8 (CH), 41.0 (CH₂), 16.5 (CH₃). ESI-HRMS calcd for C₁₀H₁₆N₅O⁺, (M+H)⁺, 222.1350, found, 222.1349.

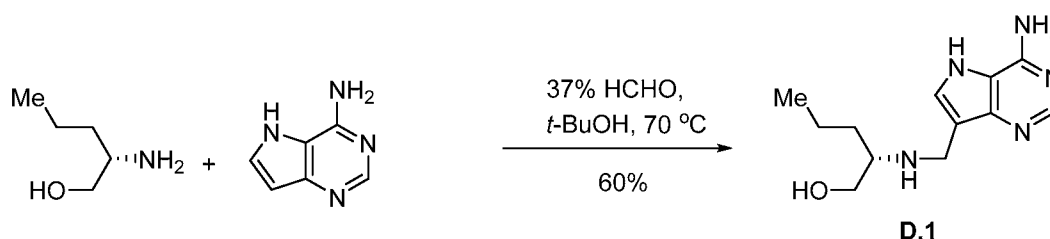
[0039] Example C. Synthesis of (2*S*)-2-[(4-*amino*-5*H*-pyrrolo[3,2-*d*]pyrimidin-7-yl)methyl]amino]butan-1-ol (C.1).



[0040] (2*S*)-2-[(4-*Amino*-5*H*-pyrrolo[3,2-*d*]pyrimidin-7-yl)methyl]amino]butan-1-ol (C.1). (2*S*)-2-Aminobutan-1-ol (0.100 g, 1.12 mmol), 9-deazaadenine (0.150 g, 1.12 mmol) and aq. formaldehyde solution (37%, 0.101 mL, 1.35 mmol) were stirred together in *tert*-butanol (3 mL) at 70 °C for 16 h. Silica gel was added to absorb all the solvent then the solvent was evaporated and the residue purified by chromatography on silica gel (CHCl₃-7M

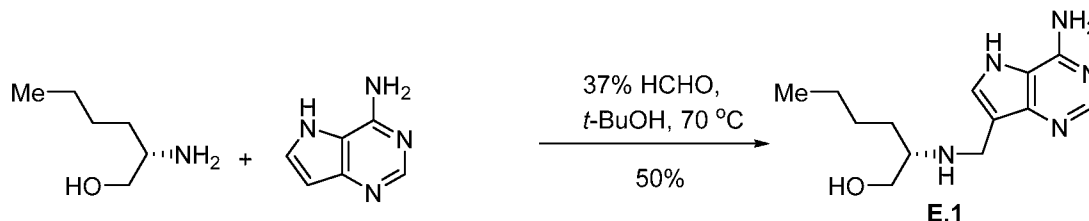
NH₃/MeOH, 9:1 then 85:15) to afford **C.1** as a colourless solid (0.133 g, 50%). ¹H NMR (500 MHz, CD₃OD): δ 8.16 (s, 1H), 7.47 (s, 1H), 3.99 (d, *J* = 13.6 Hz, 1H), 3.95 (d, *J* = 13.6 Hz, 1H), 3.67 (dd, *J* = 11.2, 4.4 Hz, 1H), 3.48 (dd, *J* = 11.2, 6.5 Hz, 1H), 2.61 (m, 1H), 1.62-1.53 (m, 1H), 1.51-1.42 (m, 1H), 0.91 (t, *J* = 7.5 Hz, 3H). ¹³C NMR (125.7 MHz, CD₃OD, centre line δ 49.0): δ 152.1 (C), 150.8 (CH), 146.6 (C), 128.9 (CH), 115.4 (C), 114.8 (C), 63.9 (CH₂), 60.9 (CH), 41.1 (CH₂), 24.6 (CH₂), 10.7 (CH₃). ESI-HRMS calcd for C₁₁H₁₇N₅NaO⁺, (M+Na)⁺, 258.1326, found 258.1321.

[0041] Example D. Synthesis of (2*S*)-2-[(4-amino-5*H*-pyrrolo[3,2-*d*]pyrimidin-7-yl)methyl]amino]pentan-1-ol (D.1).



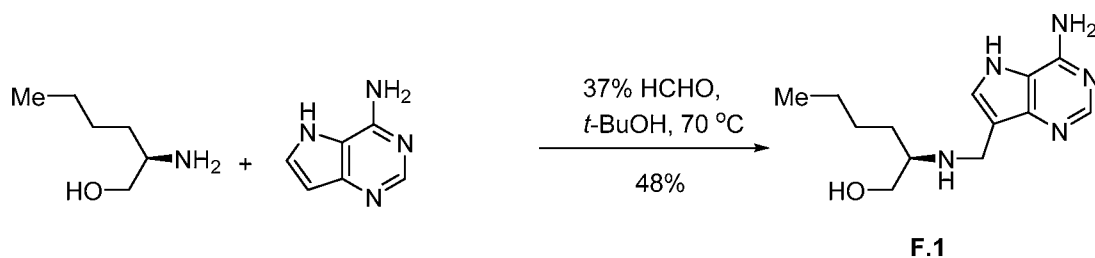
[0042] (2*S*)-2-[(4-Amino-5*H*-pyrrolo[3,2-*d*]pyrimidin-7-yl)methyl]amino]pentan-1-ol (D.1). (2*S*)-2-Aminopentanol (0.050 g, 0.48 mmol), 9-deazaadenine (0.065 g, 0.48 mmol) and aq. formaldehyde solution (37%, 0.044 mL, 0.59 mmol) were stirred in *tert*-butanol (2 mL) at 70 °C overnight. Silica gel was added to absorb all the solvent then the solvent was evaporated and the residue purified by chromatography on silica gel (CHCl₃-7M NH₃/MeOH, 9:1 then 85:15) to afford **D.1** as a colourless solid (0.073 g, 60%). ¹H NMR (500 MHz, CD₃OD): δ 8.16 (s, 1H), 7.47 (s, 1H), 3.99 (d, *J* = 13.7 Hz, 1H), 3.96 (d, *J* = 13.7 Hz, 1H), 3.66 (dd, *J* = 11.3, 4.4 Hz, 1H), 3.48 (dd, *J* = 11.3, 6.6 Hz, 1H), 2.69 (m, 1H), 1.54-1.30 (m, 4H), 0.89 (t, *J* = 7.2 Hz, 3H). ¹³C NMR (125.7 MHz, CD₃OD, centre line δ 49.0): δ 152.1 (C), 150.8 (CH), 146.6 (C), 128.9 (CH), 115.4 (C), 114.7 (C), 62.3 (CH₂), 59.2 (CH), 41.1 (CH₂), 34.3 (CH₂), 20.3 (CH₂), 14.6 (CH₃). ESI-HRMS calcd for C₁₂H₂₀N₅O⁺, (M+H)⁺, 250.1663, found 250.1663.

[0043] Example E. Synthesis of (2*S*)-2-[(4-amino-5*H*-pyrrolo[3,2-*d*]pyrimidin-7-yl)methyl]amino]hexan-1-ol (E.1).



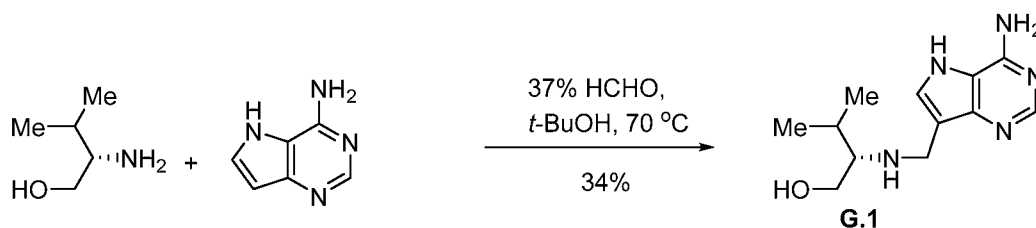
[0044] (2*S*)-2-[(*{4-Amino-5H-pyrrolo[3,2-*d*]pyrimidin-7-yl}*methyl)amino]hexan-1-ol (*E.1*). (2*S*)-2-Aminohexan-1-ol (0.100 g, 0.85 mmol), 9-deazaadenine (0.114 g, 0.85 mmol) and aq. formaldehyde solution (37%, 0.077 mL, 1.02 mmol) were stirred together at 70 °C in *tert*-butanol (3 mL) for 16 h. Silica gel was added to absorb all the solvent then the solvent was evaporated and the residue purified by chromatography on silica gel (CHCl₃-7M NH₃/MeOH, 9:1 then 85:15) to afford **E.1** as a colourless solid (0.112 g, 50%). ¹H NMR (500 MHz, CD₃OD): δ 8.16 (s, 1H), 7.47 (s, 1H), 3.97 (s, 2H), 3.65 (dd, *J* = 11.2, 4.4 Hz, 1H), 3.48 (dd, *J* = 11.2, 6.6 Hz, 1H), 2.66 (m, 1H), 1.55-1.38 (m, 2H), 1.32-1.22 (m, 4H), 0.88 (t, *J* = 7.1 Hz, 3H). ¹³C NMR (125.7 MHz, CD₃OD, centre line δ 49.0): δ 152.1 (C), 150.8 (CH), 146.6 (C), 128.9 (CH), 115.4 (C), 114.7 (C), 64.4 (CH₂), 59.3 (CH), 41.2 (CH₂), 31.7 (CH₂), 29.3 (CH₂), 23.9 (CH₂), 14.3 (CH₃). ESI-HRMS calcd for C₁₃H₂₁N₅NaO⁺, (*M*+Na)⁺, 286.1644, found 286.1644.

[0045] *Example F. Synthesis of (2R)-2-[(*{4-amino-5H-pyrrolo[3,2-*d*]pyrimidin-7-yl}*methyl)amino]hexan-1-ol (F.1).*



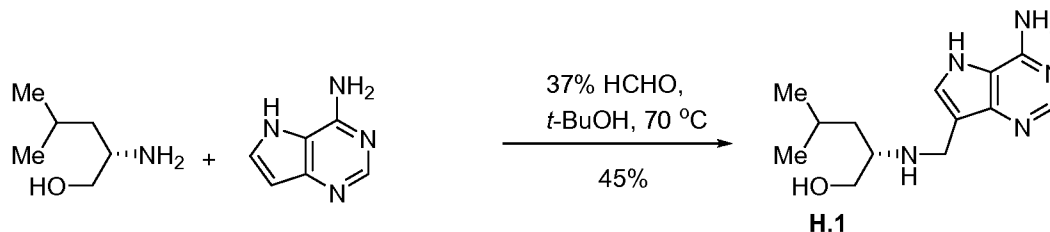
[0046] (2*R*)-2-[(*{4-Amino-5H-pyrrolo[3,2-*d*]pyrimidin-7-yl}*methyl)amino]hexan-1-ol (*F.1*). (2*R*)-2-Aminohexan-1-ol (0.100 g, 0.85 mmol), 9-deazaadenine (0.114 g, 0.85 mmol) and aq. formaldehyde solution (37%, 0.077 mL, 1.02 mmol) were stirred together at 70 °C in *tert*-butanol (3 mL) for 16 h. Silica gel was added to absorb all the solvent then the solvent was evaporated and the residue purified by chromatography on silica gel (CHCl₃-7M NH₃/MeOH, 9:1 then 85:15) to afford **F.1** as a colourless solid (0.108 g, 48%). The ¹H and ¹³C NMR were identical to the enantiomer **E.1**. ESI-HRMS calcd for C₁₃H₂₂N₅O⁺ (*M*+H)⁺, 264.1819, found 264.1717.

[0047] *Example G. Synthesis of (2S)-2-[(*{4-amino-5H-pyrrolo[3,2-*d*]pyrimidin-7-yl}*methyl)amino]-3-methylbutan-1-ol (G.1).*



[0048] (2*S*)-2-[(4-Amino-5*H*-pyrrolo[3,2-*d*]pyrimidin-7-yl)methyl]amino]-3-methylbutan-1-ol (**G.1**). (2*S*)-2-Amino-3-methylbutan-1-ol (0.100 g, 0.97 mmol), 9-deazaadenine (0.130 g, 0.97 mmol), and aq. formaldehyde solution (37%, 0.087 mL, 1.16 mmol) were stirred in *tert*-butanol (3 mL) at 70 °C for 16 h. Silica gel was added to absorb all the solvent then the solvent was evaporated and the residue purified by chromatography on silica gel (CHCl₃-7M NH₃/MeOH, 93:7 then 85:15) to give **G.1** as a colourless solid (0.082 g, 34%). ¹H NMR (500 MHz, CD₃OD): δ 8.16 (s, 1H), 7.47 (s, 1H), 3.99 (d, *J* = 13.6 Hz, 1H), 3.95 (d, *J* = 13.6 Hz, 1H), 3.68 (dd, *J* = 11.3, 4.8 Hz, 1H), 3.54 (dd, *J* = 11.3, 6.5 Hz, 1H), 2.49 (m, 1H), 1.90 (m, 1H), 0.93 (d, *J* = 6.9 Hz, 3H), 0.88 (d, *J* = 6.9 Hz, 3H). ¹³C NMR (125.7 MHz, CD₃OD, centre line δ 49.0): δ 152.1 (C), 150.8 (CH), 146.7 (C), 129.0 (CH), 115.4 (C), 115.0 (C), 64.6 (CH₂), 62.3 (CH), 41.9 (CH), 29.8 (CH₂), 19.2 (CH₃), 18.9 (CH₃). ESI-HRMS calcd for C₁₂H₂₀N₅O⁺ (M+H)⁺, 250.1663, found 250.1661.

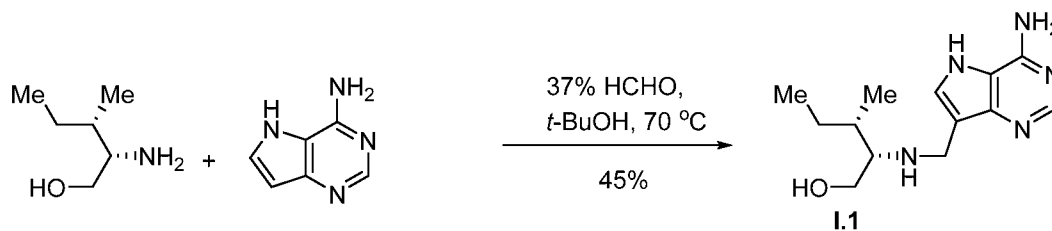
[0049] Example H. Synthesis of (2*S*)-2-[(4-amino-5*H*-pyrrolo[3,2-*d*]pyrimidin-7-yl)methyl]amino]-4-methylpentan-1-ol (**H.1**).



[0050] (2*S*)-2-[(4-Amino-5*H*-pyrrolo[3,2-*d*]pyrimidin-7-yl)methyl]amino]-4-methylpentan-1-ol (**H.1**). (2*S*)-2-Amino-4-methyl-pentan-1-ol (0.100 g, 0.85 mmol), 9-deazaadenine (0.114 g, 0.85 mmol), and aq. formaldehyde solution (37%, 0.077 mL, 1.02 mmol) were stirred in *tert*-butanol (3 mL) at 70 °C for 16 h. Silica gel was added to absorb all the solvent then the solvent was evaporated and the residue purified by chromatography on silica gel (CHCl₃-7M NH₃/MeOH, 93:7 then 85:15) to give **H.1** as a colourless solid (0.102 g, 45%). ¹H NMR (500 MHz, CD₃OD): δ 8.16 (s, 1H), 7.47 (s, 1H), 3.97 (s, 2H), 3.65 (dd, *J* = 11.3, 4.4 Hz, 1H), 3.47 (dd, *J* = 11.3, 6.5 Hz, 1H), 2.75 (m, 1H), 1.62 (m, 1H), 1.35 (ddd, *J* = 13.7, 7.4, 6.2 Hz, 1H), 1.28 (ddd, *J* = 13.9, 7.2, 7.2 Hz, 1H), 0.88 (d, *J* = 6.6 Hz, 3H), 0.80

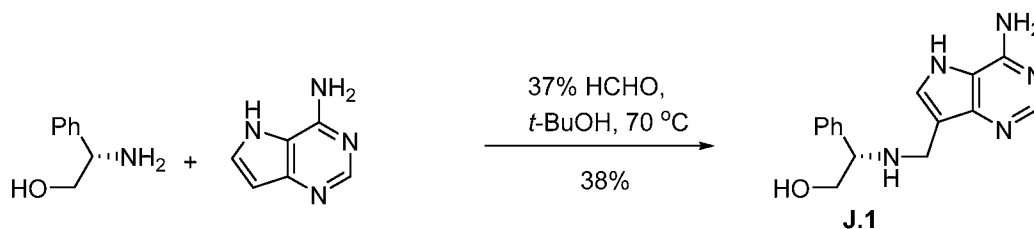
(d, $J = 6.6$ Hz, 3H). ^{13}C NMR (125.7 MHz, CD_3OD , centre line δ 49.0): δ 152.1 (C), 150.8 (CH), 146.6 (C), 129.0 (CH), 115.5 (C), 114.7 (C), 64.6 (CH_2), 57.2 (CH), 41.6 (CH_2), 41.0 (CH_2), 26.0 (CH), 23.3 (CH_3), 23.1 (CH_3). ESI-HRMS calcd for $\text{C}_{13}\text{H}_{22}\text{N}_5\text{O}^+$, ($\text{M}+\text{H}$) $^+$, 264.1819, found 264.1820.

[0051] *Example I. Synthesis of (2S,3S)-2-[(4-amino-5H-pyrrolo[3,2-d]pyrimidin-7-yl)methyl]amino]-3-methylpentan-1-ol (I.1).*



[0052] *(2S,3S)-2-[(4-Amino-5H-pyrrolo[3,2-d]pyrimidin-7-yl)methyl]amino]-3-methylpentan-1-ol (I.1).* (2S,3S)-2-Amino-3-methylpentan-1-ol (0.120 g, 1.02 mmol), 9-deazaadenine (0.137 g, 1.02 mmol), and aq. formaldehyde solution (37%, 0.092 mL, 1.22 mmol) were heated and stirred in *tert*-butanol (3 mL) at 70 °C for 16 h. Silica gel was added to absorb all the solvent then the solvent was evaporated and the residue purified by chromatography on silica gel (CHCl_3 -7M NH_3/MeOH , 92:8 then 89:11 then 85:15) to afford **I.1** as a colourless waxy solid (0.120 g, 45%). ^1H NMR (500 MHz, CD_3OD): δ 8.16 (s, 1H), 7.47 (s, 1H), 3.98 (s, 2H), 3.69 (dd, $J = 11.3$, 4.3 Hz, 1H), 3.51 (dd, $J = 11.3$, 7.1 Hz, 1H), 2.62 (ddd, $J = 7.0$, 4.4, 4.4 Hz, 1H), 1.67 (m, 1H), 1.46 (m, 1H), 1.17 (m, 1H), 0.89-0.85 (m, 6H). ^{13}C NMR (125.7 MHz, CD_3OD , centre line δ 49.0): δ 152.1 (C), 150.8 (CH), 146.7 (C), 129.0 (CH), 115.4 (C), 114.9 (C), 63.1 (CH), 62.1 (CH_2), 41.8 (CH_2), 36.7 (CH), 27.2 (CH_2), 15.0 (CH_3), 12.3 (CH_3). ESI-HRMS calcd for $\text{C}_{13}\text{H}_{22}\text{N}_5\text{O}^+$, ($\text{M}+\text{H}$) $^+$, 264.1819, found 264.1820.

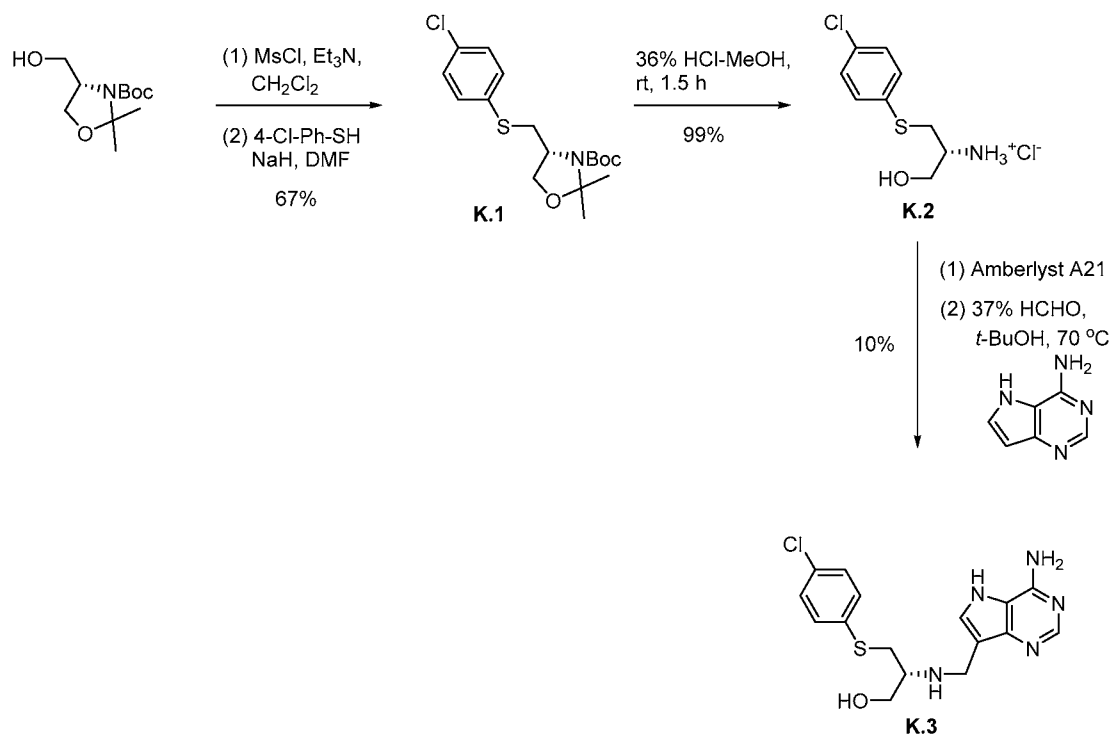
[0053] *Example J. Synthesis of (2S)-2-[(4-amino-5H-pyrrolo[3,2-d]pyrimidin-7-yl)methyl]amino]-2-phenylethan-1-ol (J.1).*



[0054] *(2S)-2-[(4-Amino-5H-pyrrolo[3,2-d]pyrimidin-7-yl)methyl]amino]-2-phenylethan-1-ol (J.1).* (2S)-2-Amino-2-phenyl-ethanol (0.150 g, 1.09 mmol) 9-

deazaadenine (0.147 g, 1.10 mmol), and aq. formaldehyde solution (37%, 0.098 mL, 1.31 mmol) were stirred and heated in *tert*-butanol (3 mL) at 70 °C for 16 h. Silica gel was added to absorb all the solvent then the solvent was evaporated and the residue purified by chromatography on silica gel (CHCl₃-7M NH₃/MeOH, 92:8 then 89:11 then 85:15) to afford **J.1** as a colourless foam (0.117 g, 38%). ¹H NMR (500 MHz, CD₃OD): δ 8.14 (s, 1H), 7.38-7.31 (m, 5H), 7.28-7.24 (m, 1H), 3.88-3.82 (m, 2H), 3.75 (d, *J* = 13.8 Hz, 1H), 3.65 (dd, *J* = 11.0, 4.9 Hz, 1H), 3.60 (dd, *J* = 11.0, 8.4 Hz, 1H). ¹³C NMR (125.7 MHz, CD₃OD, centre line δ 49.0): δ 152.0 (C), 150.8 (CH), 146.6 (C), 141.5 (C), 129.6 (CH), 129.0 (CH), 128.8 (CH), 128.6 (CH), 115.5 (C), 114.7 (C), 67.7 (CH₂), 65.4 (CH), 41.7 (CH₂). ESI-HRMS calcd for C₁₅H₁₈N₅O⁺, (M+H)⁺, 284.1506, found 284.1501.

[0055] *Example K. Synthesis of (2R)-2-[(4-amino-5H-pyrrolo[3,2-d]pyrimidin-7-yl)methyl]amino]-3-[(4-chlorophenyl)sulfanyl]propan-1-ol (K.3).*



[0056] *tert*-Butyl (4*R*)-4-[(4-chlorophenyl)sulfanyl]methyl}-2,2-dimethyl-1,3-oxazolidine-3-carboxylate (**K.1**). *Step 1.* Methanesulfonyl chloride (0.40 ml, 5.19 mmol) was added dropwise to a stirred solution of *tert*-butyl (4*S*)-4-(hydroxymethyl)-2,2-dimethyl-1,3-oxazolidine-3-carboxylate [prepared as for its enantiomer, Dondoni, et al.¹³] (1.00 g, 4.32 mmol) and triethylamine (1.22 ml, 8.65 mmol) in CH₂Cl₂ (15 mL) at 0 °C. The mixture was

warmed to rt and stirred for 20 min then washed with sat NaHCO_3 (3 x 5 mL), dried, and the solvent evaporated to give the crude mesylate as an oil (1.22 g, 3.94 mmol).

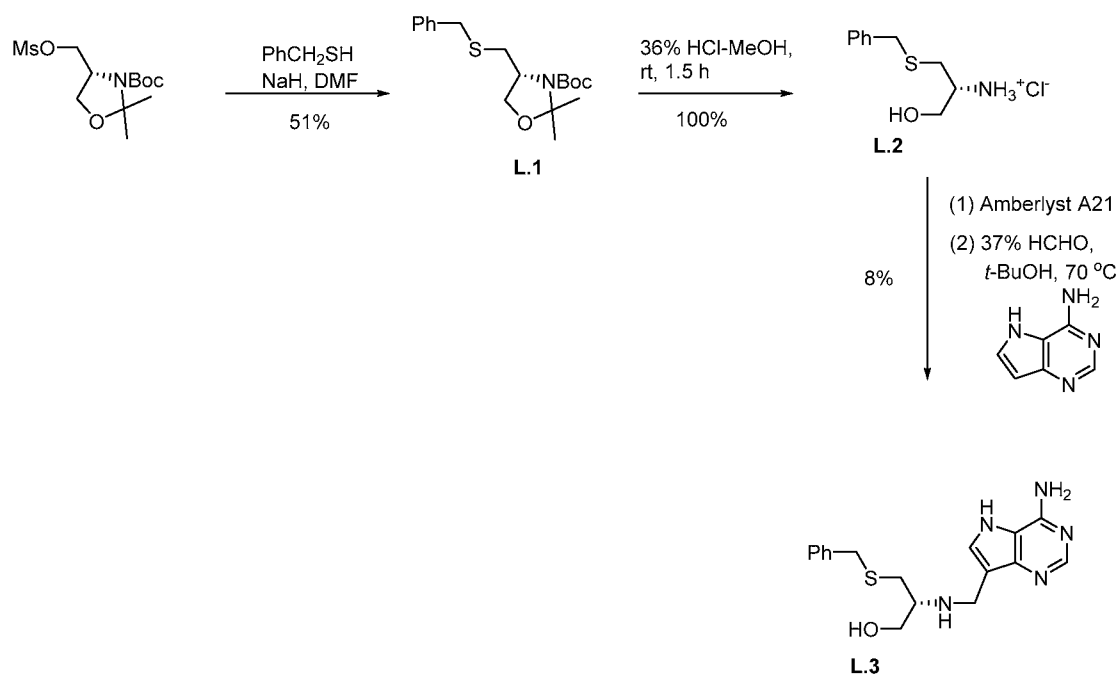
[0057] *Step 2.* 4-chlorobenzene-1-thiol (0.351 g, 2.42 mmol) was added to a solution of sodium hydride (60%, 0.089 g, 2.23 mmol) in DMF (3 mL) at 0 °C. After 20 min a solution of the mesylate from *step 1* above (0.30 g, 0.97 mmol) in DMF (0.75 mL) was added and the mixture warmed to rt and stirred for 16 h. Water (2 mL) was added and the mixture extracted with Et_2O (60 mL). The extract was washed with H_2O (3 x 5 mL), brine (5 mL), dried and the solvent evaporated to a colourless oil that was chromatographed on silica gel (gradient of 0 – 6% EtOAc in hexanes) to give **K.1** as a colourless gum (0.234 g, 67%). $[\alpha]_{\text{D}}^{20}$ –17.9 (c 1.05, CHCl_3). ^1H NMR (500 MHz, CDCl_3): δ 7.40-7.30 (m, 2H), 7.28-7.22 (m, 2H), 4.11-3.98 (m, 1.5H), 3.94-3.89 (m, 1.5H), 3.50 (d, J = 13.7 Hz, 0.5H), 3.27 (d, J = 13.4 Hz, 0.5H), 2.79 (dd, J = 13.5, 10.7 Hz, 1H), 1.63-1.56 (m, 3H), 1.51-1.42 (m, 12H). ^{13}C NMR (125.7 MHz, CDCl_3 , centre line δ 77.0): δ 152.1, 151.4 (C), 134.2, 133.8 (C), 132.5, 131.6 (C), 130.9, 129.3 (CH), 129.1 (CH), 94.5, 93.9 (C), 80.5, 80.3 (C), 66.0 (CH_2), 56.6, 56.3 (CH), 35.7, 33.8 (CH_2), 28.5, 28.4 (CH_3), 27.7, 27.0 (CH_3), 24.3, 23.1 (CH_3). ESI-HRMS calcd for $\text{C}_{17}\text{H}_{24}^{35}\text{ClNNaO}_3\text{S}^+$, ($\text{M}+\text{Na}$) $^+$, 380.1058, found 380.1056.

[0058] *(2R)-2-Amino-3-[(4-chlorophenyl)sulfanyl]propan-1-ol hydrochloride (K.2).* Compound **K.1** (0.228 g, 0.64 mmol) was dissolved in MeOH (3 mL), cooled to 0 °C and aq. hydrochloric acid (36%, 2 mL) added. The mixture was stirred at rt for 16 h, then the solvent was evaporated to give **K.2** as a colourless solid (0.161 g, 99%). $[\alpha]_{\text{D}}^{20}$ –27.7 (c 1.09, MeOH). ^1H NMR (500 MHz, CD_3OD): δ 7.47 (d, J = 8.6 Hz, 2H), 7.36 (d, J = 8.7 Hz, 2H), 3.82 (dd, J = 11.7, 3.4 Hz, 1H), 3.74 (dd, J = 11.7, 5.0 Hz, 1H), 3.30-3.25 (m, 2H), 3.19 (dd, J = 16.3, 9.2 Hz, 1H). ^{13}C NMR (125.7 MHz, CD_3OD , centre line δ 49.0): δ 134.31 (C), 134.26 (C), 132.9 (CH), 130.5 (CH), 61.2 (CH_2), 53.5 (CH), 34.1 (CH_2). ESI-HRMS calcd for $\text{C}_9\text{H}_{13}^{35}\text{ClINOS}^+$, ($\text{M}-\text{HCl}+\text{H}$) $^+$, 218.0401, found 218.0408.

[0059] *(2R)-2-[(4-Amino-5H-pyrrolo[3,2-d]pyrimidin-7-yl)methyl]amino]-3-[(4-chlorophenyl)sulfanyl]propan-1-ol (K.3).* Compound **K.2** (0.151 g, 0.59 mmol) was dissolved in MeOH (10 mL) and neutralized with Amberlyst A21 resin. The mixture was then passed through a short column of the same resin and eluted with MeOH to give the free amino form of **K.2** as a yellow oil (129 mg). This was dissolved in *tert*-butanol (3 mL) then aq. formaldehyde solution (37%, 0.060 mL, 0.80 mmol) and 9-deazaadenine (0.080 g, 0.60 mmol) were added and the mixture stirred at 70 °C for 16 h. Silica gel was added to absorb all the solvent then the solvent was evaporated and the residue purified by chromatography on

silica gel (CHCl₃-7M NH₃/MeOH, 92:8 then 85:15) and the fractions containing the product were evaporated. The residue was further purified on silica gel (CHCl₃-MeOH-28% aq. NH₄OH, 92:8:0.5) to give **K.3** as a colourless foam (0.022 g, 10%). ¹H NMR (500 MHz, CD₃OD): δ 8.16 (s, 1H), 7.35 (s, 1H), 7.13-7.08 (m, 4H), 4.02 (d, *J* = 14.0 Hz, 1H), 3.92 (d, *J* = 14.0 Hz, 1H), 3.70 (dd, *J* = 11.3, 5.2 Hz, 1H), 3.66 (dd, *J* = 11.3, 5.2 Hz, 1H), 3.13 (dd, *J* = 13.8, 6.2 Hz, 1H), 2.92 (dd, *J* = 13.8, 6.9 Hz, 1H), 2.75 (m, 1H). ¹³C NMR (125.7 MHz, CD₃OD, centre line δ 49.0): δ 152.0 (C), 150.8 (CH), 146.5 (C), 135.8 (C), 133.0 (C), 131.8 (CH), 129.8 (CH), 129.1 (CH), 115.5 (C), 114.4 (C), 63.5 (CH₂), 57.0 (CH), 41.0 (CH₂), 36.1 (CH₂). ESI-HRMS calcd for C₁₆H₁₈³⁵ClN₅NaOS⁺ (M+Na)⁺, 386.0813, found 386.0816.

[0060] *Example L. Synthesis of (2R)-2-[(4-amino-5H-pyrrolo[3,2-d]pyrimidin-7-yl)methyl]amino]-3-(benzylsulfanyl)propan-1-ol (L.3).*



[0061] *tert-Butyl (4R)-4-[(benzylsulfanyl)methyl]-2,2-dimethyl-1,3-oxazolidine-3-carboxylate (L.1).* Phenylmethanethiol (0.285 ml, 2.42 mmol) was added to a stirred solution of sodium hydride (60%, 0.089 g, 2.23 mmol) in DMF (3 mL) at 0 °C. After 20 min a solution of the crude mesylate (0.3 g, 0.97 mmol, from *step 1* of the preparation of **K.1**) in DMF (0.75 ml) was added then the mixture was warmed to rt and stirred for 16 h. Water (2 ml) was added and the mixture extracted with Et₂O (60 mL). The extract was washed with H₂O (3 x 5 mL), brine (5 mL), dried and the solvent evaporated to a colourless oil that was chromatographed on silica gel (gradient of 0 – 6% EtOAc in hexanes) to give **L.1** as a

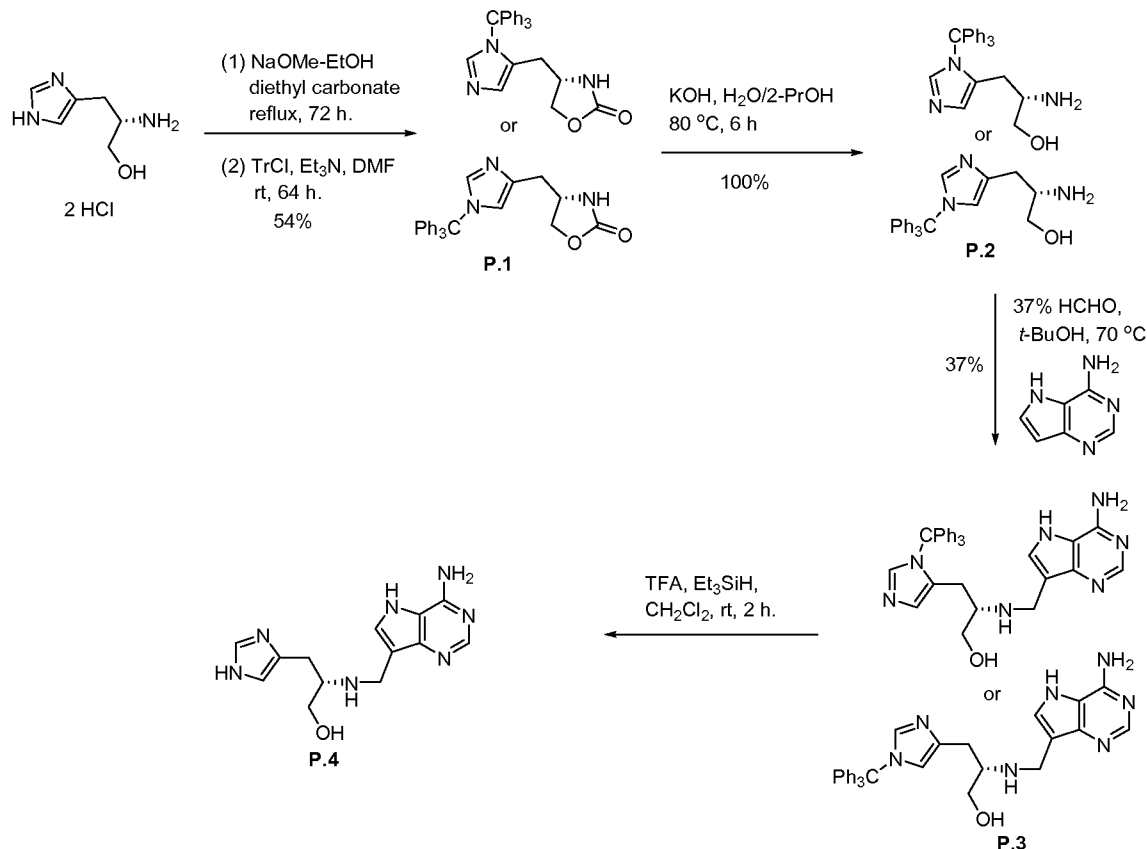
colourless gum (0.166 g, 51%). $[\alpha]_D^{20} +61.7$ (c 1.12, CHCl_3). ^1H NMR (500 MHz, CDCl_3): δ 7.40-7.28 (m, 4H), 7.26-7.20 (m, 1H), 4.09 (d, $J = 7.1$ Hz, 0.5H), 3.99-3.85 (m, 2.5H), 3.76 (s, 2H), 2.86 (m, 1H), 2.51 (q, $J = 13.0$ Hz, 1H), 1.58, 1.53, 1.49, 1.47, 1.46, 1.42 (6 x s, 15H). ^{13}C NMR (125.7 MHz, CDCl_3 , centre line δ 77.0): δ 152.0, 151.4 (C), 138.5, 138.1 (C), 129.0, 128.7 (CH), 128.6, 128.4 (CH), 127.2, 126.9 (CH), 94.2, 93.7 (C), 80.3, 79.9 (C), 66.5 (CH_2), 57.2, 56.9 (CH), 36.9, 36.4 (CH_2), 34.8, 33.6 (CH_2), 28.4 (CH_3), 27.6, 26.8 (CH_3), 24.4, 23.2 (CH_3). ESI-HRMS calcd for $\text{C}_{18}\text{H}_{27}^{35}\text{ClNNaO}_3\text{S}^+$ ($\text{M}+\text{Na}$) $^+$, 360.1604, found 360.1592.

[0062] (2R)-2-Amino-3-(benzylsulfanyl)propan-1-ol hydrochloride (L.2). Compound **L.1** (0.166 g, 0.49 mmol) was dissolved in MeOH (3 mL), cooled to 0 °C and aq. hydrochloric acid (36%, 2 mL) added. After stirring at rt for 1.5 h, the solvent was evaporated to a colourless gum that scratched down to a colourless solid (0.115 g, 100%). $[\alpha]_D^{20} -52.6$ (c 0.91, MeOH). ^1H NMR (500 MHz, CD_3OD): δ 7.38-7.35 (m, 2H), 7.34-7.30 (m, 2H), 7.25 (m, 1H), 3.81 (s, 2H), 3.77 (dd, $J = 11.7, 3.8$ Hz, 1H), 3.65 (dd, $J = 11.7, 5.7$ Hz, 1H), 3.27 (m, 1H), 2.74 (dd, $J = 14.2, 6.7$ Hz, 1H), 2.67 (dd, $J = 14.2, 7.4$ Hz, 1H). ^{13}C NMR (125.7 MHz, CD_3OD , centre line δ 49.0): δ 139.2 (C), 130.1 (CH), 129.7 (CH), 128.3 (CH), 61.5 (CH_2), 53.7 (CH), 37.1 (CH_2), 31.2 (CH_2). ESI-HRMS calcd for $\text{C}_{10}\text{H}_{16}^{35}\text{ClNOS}^+$, ($\text{M}-\text{HCl}+\text{H}$) $^+$, 198.0948, found 198.0948.

[0063] (2R)-2-[(4-Amino-5H-pyrrolo[3,2-d]pyrimidin-7-yl)methylamino]-3-(benzylsulfanyl)propan-1-ol (L.3). Compound **L.2** (0.170 g, 0.73 mmol) was dissolved in MeOH (10 mL) and neutralized with Amberlyst A21 resin. The mixture was then passed through a small column of the same resin and eluted with MeOH to give the free amino form of **L.2** as a yellow oil. This was dissolved in *tert*-butanol (3 mL) then aq. formaldehyde solution (37%, 0.071 mL, 0.95 mmol) and 9-deazaadenine (0.098 g, 0.73 mmol) added and the mixture was stirred at 70 °C for 16 h. Silica gel was added to absorb all the solvent then the solvent was evaporated and the residue purified by chromatography on silica gel (CHCl_3 -MeOH-28% aq. NH_4OH , 92:8:0.5). The fractions containing the product were evaporated and the residue was further purified on silica gel (gradient of 2 – 10% 7M NH_3 /MeOH- CHCl_3) to give **L.3** as a colourless solid (0.021 g, 8%). ^1H NMR (500 MHz, CD_3OD): δ 8.17 (s, 1H), 7.43 (s, 1H), 7.25-7.21 (m, 2H), 7.19-7.15 (m, 3H), 3.99 (d, $J = 13.8$ Hz, 1H), 3.91 (d, $J = 13.8$ Hz, 1H), 3.66 (dd, $J = 11.2, 4.9$ Hz, 1H), 3.57 (dd, $J = 11.2, 5.5$ Hz, 1H), 3.53 (d, $J = 1.6$ Hz, 2H), 2.77 (m, 1H), 2.60 (dd, $J = 13.6, 6.4$ Hz, 1H), 2.49 (dd, $J = 13.6, 6.9$ Hz, 1H). ^{13}C NMR (125.7 MHz, CD_3OD , centre line δ 49.0): δ 152.1 (C), 150.9 (CH), 146.6 (C),

139.8 (C), 129.9 (CH), 129.4 (CH), 129.1 (CH), 127.9 (CH), 115.5 (C), 114.7 (C), 63.8 (CH₂), 57.8 (CH), 41.2 (CH₂), 36.9 (CH₂), 33.9 (CH₂). ESI-HRMS calcd for C₁₇H₂₁N₃NaOS⁺ (M+Na)⁺, 366.1360, found 366.1362.

[0064] *Example P. Synthesis of (2S)-2-[(4-amino-5H-pyrrolo[3,2-d]pyrimidin-7-yl)methylamino]-3-(1H-imidazol-4-yl)propan-1-ol (P.4).*



[0065] *(4S)-4-{[1-(Triphenylmethyl)-1H-imidazol-4-yl]methyl}-1,3-oxazolidin-2-one or (4S)-4-{[1-(triphenylmethyl)-1H-imidazol-5-yl]methyl}-1,3-oxazolidin-2-one (P.1).* A modified literature procedure [Madrigal, et al.¹⁴] was followed. (S)-Histidinol dihydrochloride (0.500 g, 2.34 mmol) and diethyl carbonate (2.86 mL, 23.61 mmol) were stirred together in ethanol (24 mL), then sodium methoxide in methanol solution (25%, 1.6 mL, 7.0 mmol) added. The mixture was heated under reflux for 72 h then the solvent was evaporated and the residue chromatographed on silica gel (CHCl₃-MeOH-28% aq. NH₄OH, 9:1:0.1) to give (4S)-4-(1H-imidazol-4-ylmethyl)-1,3-oxazolidin-2-one as a colourless solid (0.26 g, 1.56 mmol, 90 – 95% pure). ¹H NMR (500 MHz, CD₃OD): δ 7.61 (d, *J* = 1.0 Hz, 1H), 6.93 (s, 1H), 4.45-4.40 (m, 1H), 4.18-4.12 (m, 2H), 2.86 (dd, *J* = 14.7, 4.8 Hz, 1H), 2.80 (dd, *J* = 14.8, 6.1 Hz, 1H). It was dissolved in DMF (4 mL) then triethylamine (0.42 mL, 3.00

mmol) and trityl chloride (0.489 g, 1.70 mmol) were added. The mixture was stirred for 60 h at rt then diluted with Et₂O (60 mL) and the mixture washed with H₂O (4 x 5mL), brine (5 mL), dried and the solvent evaporated. The residue was chromatographed on silica gel (gradient of 0 – 5% MeOH in EtOAc) to give **P.1** as a colourless foam (0.520 g, 54%). ¹H NMR (500 MHz, CD₃OD): δ 7.41 (d, *J* = 1.4 Hz, 1H), 7.39-7.34 (m, 9H), 7.16-7.11 (m, 6H), 6.82 (m, 1H), 4.39 (t, *J* = 8.4 Hz, 1H), 4.19-4.11 (m, 2H), 2.78 (dd, *J* = 14.6, 4.9 Hz, 1H), 2.73 (dd, *J* = 14.6, 6.1 Hz, 1H). ¹³C NMR (125.7 MHz, CD₃OD, centre line δ 49.0): δ 162.1 (C), 143.6 (C x 3), 139.8 (CH), 136.6 (C), 130.9 (CH), 129.32 (CH), 129.27 (CH), 121.6 (CH), 76.9 (C), 70.4 (CH₂), 53.4 (CH), 33.9 (CH₂). ESI-HRMS calcd for C₂₆H₂₃N₃NaO₂⁺, (M+Na)⁺, 432.1683, found 432.1677.

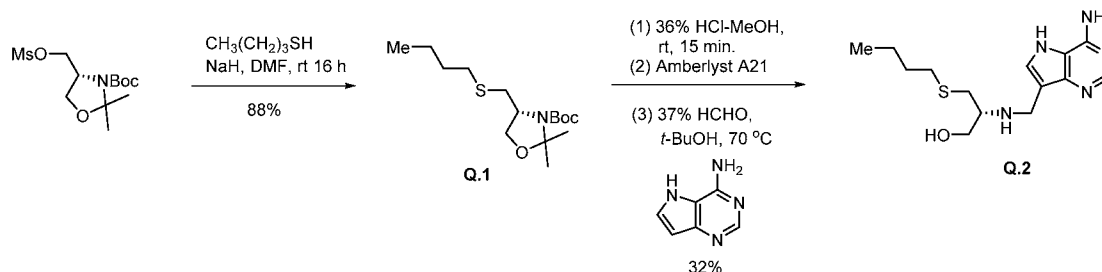
[0066] (2S)-2-Amino-3-[1-(triphenylmethyl)-1H-imidazol-4-yl]propan-1-ol or (2S)-2-amino-3-[1-(triphenylmethyl)-1H-imidazol-5-yl]propan-1-ol (P.2). Compound **P.1** (0.510 g, 1.25 mmol) was dissolved in 2-propanol (7 mL) and potassium hydroxide (2 M, 3 mL, 6 mmol) added. The mixture was heated at 80 °C for 6 h then silica gel was added to absorb all the solvent then the solvent was evaporated and the residue chromatographed on silica gel (CHCl₃-MeOH-28% aq. NH₄OH, 9:1:0.1) to give **P.2** as a colourless gum (0.478 g, 100%). ¹H NMR (500 MHz, CD₃OD): δ 7.40 (d, *J* = 1.4 Hz, 1H), 7.38-7.34 (m, 9H), 7.18-7.13 (m, 6H), 6.75 (m, 1H), 3.52 (dd, *J* = 10.9, 4.5 Hz, 1H), 3.35 (dd, *J* = 10.9, 6.8 Hz, 1H), 3.09-3.03 (m, 1H), 2.65 (dd, *J* = 14.4, 6.0 Hz, 1H), 2.50 (dd, *J* = 14.4, 7.4 Hz, 1H). ¹³C NMR (125.7 MHz, CD₃OD, centre line δ 49.0): δ 143.7 (C), 139.7 (CH), 139.2 (C), 130.8 (CH), 129.3 (CH), 129.2 (CH), 121.0 (CH), 76.8 (C), 66.7 (CH₂), 53.8 (CH), 33.0 (CH₂). ESI-HRMS calcd for C₂₅H₂₆N₃O⁺, (M+H)⁺, 384.2071, found 384.2068.

[0067] (2S)-2-[(4-Amino-5H-pyrrolo[3,2-d]pyrimidin-7-yl)methyl]amino]-3-[1-(triphenylmethyl)-1H-imidazol-4-yl]propan-1-ol or (2S)-2-[(4-amino-5H-pyrrolo[3,2-d]pyrimidin-7-yl)methyl]amino]-3-[1-(triphenylmethyl)-1H-imidazol-5-yl]propan-1-ol (P.3). Compound **P.2** (0.200 g, 0.52 mmol), 9-deazaadenine (0.070 g, 0.52 mmol) and aq. formaldehyde solution (37%, 0.051 mL, 0.68 mmol) were heated at 70 °C in tert-butanol (3 mL) for 16 h. Silica gel was added to absorb all the solvent then the solvent was evaporated and the residue chromatographed on silica gel (10% 7M NH₃/MeOH-CHCl₃) to give **P.3** as a colourless foam (0.101 g, 37%). ¹H NMR (500 MHz, CD₃OD): δ 8.03 (s, 1H), 7.39 (s, 1H), 7.35 (d, *J* = 1.3 Hz, 1H), 7.33-7.29 (m, 9H), 7.12-7.08 (m, 6H), 6.75 (d, *J* = 1.2 Hz, 1H), 3.96 (d, *J* = 13.7 Hz, 1H), 3.93 (d, *J* = 13.6 Hz, 1H), 3.61 (dd, *J* = 11.3, 4.8 Hz, 1H), 3.49 (dd, *J* = 11.3, 6.1 Hz, 1H), 3.02-2.97 (m, 1H), 2.72 (dd, *J* = 14.5, 6.5 Hz, 1H), 2.69 (dd, *J* = 14.5, 6.7

Hz, 1H). ^{13}C NMR (125.7 MHz, CD_3OD , centre line δ 49.0): δ 152.0 (C), 150.8 (CH), 146.6 (C), 143.7 (C x 3), 139.5 (CH), 139.2 (C), 130.8 (CH), 129.24 (CH), 129.20 (CH), 128.9 (CH), 121.2 (CH), 115.4 (C), 114.8 (C), 76.8 (C), 64.3 (CH_2), 59.4 (CH), 41.3 (CH_2), 30.7 (CH_2). ESI-HRMS calcd for $\text{C}_{32}\text{H}_{32}\text{N}_7\text{O}^+$, $(\text{M}+\text{H})^+$, 530.2663, found 530.2666.

[0068] (2*S*)-2-[(4-Amino-5*H*-pyrrolo[3,2-*d*]pyrimidin-7-yl)methyl]amino]-3-(1*H*-imidazol-4-yl)propan-1-ol (*P.4*). Trifluoroacetic acid (0.6 mL, 8 mmol) was added to a stirred solution of **P.3** (0.100 g, 0.19 mmol) and triethylsilane (0.090 mL, 0.57 mmol) in CH_2Cl_2 (3 mL). After 2 h, the solvent was evaporated and the residue dissolved in MeOH and the solvent evaporated (3 x). The residue was again dissolved in MeOH, silica gel added and the solvent evaporated. Flash chromatography on silica gel (CHCl_3 -MeOH-28% aq. NH_4OH , 7:2.5:0.5) gave **P.4** as a colourless gum which crystallized on standing (0.050 g, 92%). ^1H NMR (500 MHz, CD_3OD): δ 8.14 (s, 1H), 7.52 (d, J = 0.9 Hz, 1H), 7.42 (s, 1H), 6.80 (s, 1H), 4.01 (d, J = 13.6 Hz, 1H), 3.98 (d, J = 13.6 Hz, 1H), 3.63 (dd, J = 11.3, 4.7 Hz, 1H), 3.50 (dd, J = 11.3, 5.9 Hz, 1H), 3.01-2.96 (m, 1H), 2.76 (d, J = 6.7 Hz, 2H). ^{13}C NMR (125.7 MHz, CD_3OD , centre line δ 49.0): δ 152.0 (C), 150.8 (CH), 146.6 (C), 136.1 (CH), 134.8 (b, C), 129.0 (CH), 119.4 (b, CH), 115.4 (C), 114.3 (C), 64.0 (CH_2), 59.3 (CH), 41.3 (CH_2), 29.2 (CH_2). ESI-HRMS calcd for $\text{C}_{13}\text{H}_{18}\text{N}_7\text{O}^+$, $(\text{M}+\text{H})^+$, 288.1568, found 288.1567.

[0069] Example Q. Synthesis of (2*R*)-2-[(4-amino-5*H*-pyrrolo[3,2-*d*]pyrimidin-7-yl)methyl]amino]-3-(butylsulfanyl)propan-1-ol (*Q.2*).

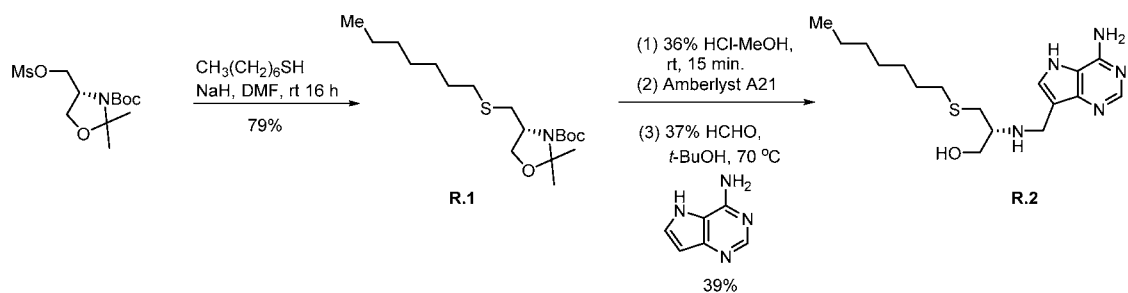


[0070] *tert*-Butyl (4*R*)-4-[(butylsulfanyl)methyl]-2,2-dimethyl-1,3-oxazolidine-3-carboxylate (*Q.1*). Sodium hydride (60%, 0.097 g, 2.4 mmol) was added in portions to a solution of butane-1-thiol (0.53 mL, 4.85 mmol) in DMF (5 mL). After 15 min a solution of the crude mesylate (0.500 g, 1.62 mmol, from *step 1* of the preparation of **K.1**) in DMF (1 mL) was added. The mixture was stirred for 16 h then H_2O (6 mL) added. After extraction with Et_2O (100 mL), the extract was washed with H_2O (4 x 5 mL), brine (5 mL), dried and the solvent evaporated. The residue was chromatographed on silica gel (gradient of 0 – 10% EtOAc in hexanes) to give **Q.1** as a colourless oil (0.429 g, 88%). ^1H NMR (500 MHz,

CDCl₃): δ 4.06-3.92 (m, 2.5H), 3.91-3.85 (m, 0.5H), 2.94 (d, J = 13.0 Hz, 0.5H), 2.80 (d, J = 13.0 Hz, 0.5H), 2.62-2.47 (m, 3H), 1.65-1.53 (m, 5H), 1.50-1.35 (m, 14H), 0.91 (t, J = 7.1 Hz, 3H). ¹³C NMR (125.7 MHz, CDCl₃, centre line δ 77.0): δ 152.1, 151.4 (C), 94.3, 93.7 (C), 80.2, 79.9 (C), 66.5, 66.3 (CH₂), 57.4, 57.2 (CH), 34.6, 33.9 (CH₂), 32.0, 31.9, (2 x CH₂), 28.5, 28.4 (CH₃), 27.7, 26.9 (CH₃), 24.5, 23.2 (CH₃), 21.9 (CH₂), 13.6 (CH₃). ESI-HRMS calcd for C₁₅H₂₉NNaO₃S⁺, (M+Na)⁺, 326.1761, found 326.1760.

[0071] (2*R*)-2-[(4-Amino-5*H*-pyrrolo[3,2-*d*]pyrimidin-7-yl)methylamino]-3-(butylsulfanyl)propan-1-ol (*Q.2*). Compound **Q.1** (0.400 g, 1.32 mmol) was dissolved in MeOH (4 mL) and aq. hydrochloric acid (36%, 1 mL) was added. After 15 min the solvent was evaporated and the resulting gum dissolved in MeOH (10 mL) and neutralized with Amberlyst A21 resin then passed through a short column of the same resin and eluted with MeOH. The fractions containing product were evaporated to an oily residue that was dissolved in *tert* butanol (4 mL) then 9-deazaadenine (0.177 g, 1.32 mmol) and aq. formaldehyde solution (37%, 0.12 mL, 1.60 mmol) added and the mixture stirred at 70 °C for 16 h. Silica gel was added to absorb all the solvent then the solvent was evaporated and the residue chromatographed on silica gel (gradient of 5 – 15% 7M NH₃/MeOH in CHCl₃) to give **Q.2** as a colourless solid (0.131 g, 32%). ¹H NMR (500 MHz, CD₃OD): δ 8.16 (s, 1H), 7.49 (s, 1H), 4.06 (d, J = 13.8 Hz, 1H), 3.97 (d, J = 13.9 Hz, 1H), 3.69 (dd, J = 11.2, 5.1 Hz, 1H), 3.63 (dd, J = 11.2, 5.4 Hz, 1H), 2.81-2.76 (m, 1H), 2.69 (dd, J = 13.5, 6.3 Hz, 1H), 2.53 (dd, J = 13.5, 6.9 Hz, 1H), 2.31 (ddd, J = 12.5, 8.0, 6.5 Hz, 1H), 2.25 (ddd, J = 12.5, 8.1, 6.7 Hz, 1H), 1.45-1.35 (m, 2H), 1.33-1.25 (m, 2H), 0.85 (t, J = 7.3 Hz, 3H). ¹³C NMR (125.7 MHz, CD₃OD, centre line δ 49.0): δ 152.1 (C), 150.9 (CH), 146.6 (C), 129.1 (CH), 115.5 (C), 114.6 (C), 63.9 (CH₂), 57.8 (CH), 41.2 (CH₂), 34.5 (CH₂), 32.7 (CH₂), 32.6 (CH₂), 22.9 (CH₂), 13.9 (CH₃). ESI-HRMS calcd for C₁₄H₂₄N₅OS⁺, (M+H)⁺, 310.1697, found 310.1702.

[0072] Example R. Synthesis of (2*R*)-2-[(4-amino-5*H*-pyrrolo[3,2-*d*]pyrimidin-7-yl)methylamino]-3-(heptylsulfanyl)propan-1-ol (*R.2*).

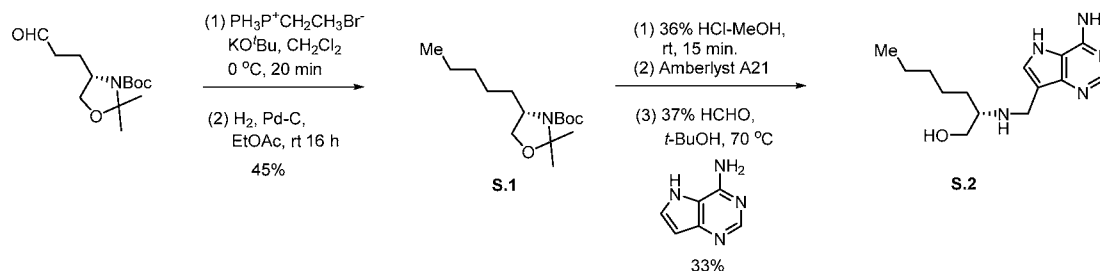


[0073] *tert-Butyl (4R)-4-[(heptylsulfanyl)methyl]-2,2-dimethyl-1,3-oxazolidine-3-carboxylate (R.1)*. Sodium hydride (60%, 0.162 g, 4.05 mmol) was added in portions to a solution of heptane-1-thiol (0.641 g, 4.85 mmol) in DMF (5 mL) at rt. After 15 min, a solution of the crude mesylate (0.500 g, 1.62 mmol, from *step 1* of the preparation of **K.1**) in DMF (1 mL) was added. The mixture was stirred for 16 h then H₂O (6 mL) added. After extraction with Et₂O (100 mL), the extract was washed with H₂O (4 x 5 mL), brine (5 mL) dried and evaporated to an oily residue that was chromatographed on silica gel (gradient of 0 – 12% EtOAc in hexanes) to give **R.1** as a colourless oil (0.443 g, 79%). ¹H NMR (500 MHz, CDCl₃): δ 4.05-3.98 (m, 1.5H), 3.97-3.93 (m, 1H), 3.91-3.85 (m, 0.5H), 2.93 (d, *J* = 13.5 Hz, 0.5H), 2.80 (d, *J* = 12.9 Hz, 0.5H), 2.62-2.45 (m, 3H), 1.63-1.53 (m, 5H), 1.51-1.43 (m, 12H), 1.41-1.22 (m, 8H), 0.88 (t, *J* = 6.8 Hz, 3H). ¹³C NMR (125.7 MHz, CDCl₃, centre line δ 77.0): δ 152.1, 151.5 (C), 94.3, 93.7 (C), 80.2, 79.9 (C), 66.5, 66.3 (CH₂), 57.4, 57.2 (CH), 34.7, 33.8 (CH₂), 32.4, 31.7 (2 x CH₂), 30.0, 29.8 (CH₂), 28.9, 28.8, (2 x CH₂), 28.5, 28.4 (CH₃), 27.7, 26.9 (CH₃), 24.5, 23.2 (CH₃), 22.6 (CH₂), 14.0 (CH₃). ESI-HRMS calcd for C₁₈H₃₅NNaO₃S⁺, (M+Na)⁺, 368.2230, found 368.2227.

[0074] *(2R)-2-[(4-Amino-5H-pyrrolo[3,2-d]pyrimidin-7-yl)methyl]amino]-3-(heptylsulfanyl)propan-1-ol (R.2)*. Compound **R.1** (0.420 g, 1.22 mmol) was dissolved in MeOH (4 mL) and aq. hydrochloric acid (36%, 1 mL) added. After 15 min the solvent was evaporated to a gum that was dissolved in a 7:3 mixture of MeOH-CHCl₃ (10 mL) and neutralized with Amberlyst A21 resin then passed through a short column of the same resin and eluted with a 7:3 mixture of MeOH-CHCl₃. The fractions containing product were evaporated to an oily residue that was dissolved in *tert*-butanol (4 mL) then 9-deazaadenine (0.130 g, 0.97 mmol) and aq. formaldehyde solution (37%, 0.087 mL, 1.16 mmol) were added and the mixture stirred at 70 °C for 16 h. Silica gel was added to absorb all the solvent then the solvent was evaporated and the residue chromatographed on silica gel (gradient of 5 – 15% 7M NH₃/MeOH in CHCl₃) to give crude **R.2** (210 mg). Further chromatography on silica gel (gradient of 0 – 5% aq. NH₄OH (28%) in 2-PrOH) gave **R.2** as a colourless solid (0.134 g, 34%). ¹H NMR (500 MHz, CD₃OD): δ 8.16 (s, 1H), 7.49 (s, 1H), 4.06 (d, *J* = 13.8 Hz, 1H), 3.97 (d, *J* = 13.8 Hz, 1H), 3.69 (dd, *J* = 11.2, 5.1 Hz, 1H), 3.63 (dd, *J* = 11.2, 5.4 Hz, 1H), 2.81-2.76 (m, 1H), 2.69 (dd, *J* = 13.5, 6.3 Hz, 1H), 2.54 (dd, *J* = 13.5, 6.9 Hz, 1H), 2.32 (ddd, *J* = 12.5, 7.9, 6.8 Hz, 1H), 2.26 (ddd, *J* = 12.6, 7.9, 6.9 Hz, 1H), 1.47-1.37 (m, 2H), 1.33-1.20 (m, 8H), 0.88 (t, *J* = 7.1 Hz, 3H). ¹³C NMR (125.7 MHz, CD₃OD, centre line δ 49.0): δ 152.1 (C), 150.9 (CH), 146.6 (C), 129.1 (CH), 115.4 (C), 114.6 (C), 63.8 (CH₂), 57.9

(CH), 41.2 (CH₂), 34.5 (CH₂), 32.9 (CH₂ x 2), 30.6 (CH₂), 30.0 (CH₂), 29.8 (CH₂), 26.6 (CH₂), 14.4 (CH₃). ESI-HRMS calcd for C₁₇H₃₀N₅O⁺, (M+H)⁺, 352.2166, found 352.2157.

[0075] *Example S. Synthesis of (2S)-2-[(4-amino-5H-pyrrolo[3,2-d]pyrimidin-7-yl)methyl]amino]heptan-1-ol (S.2).*

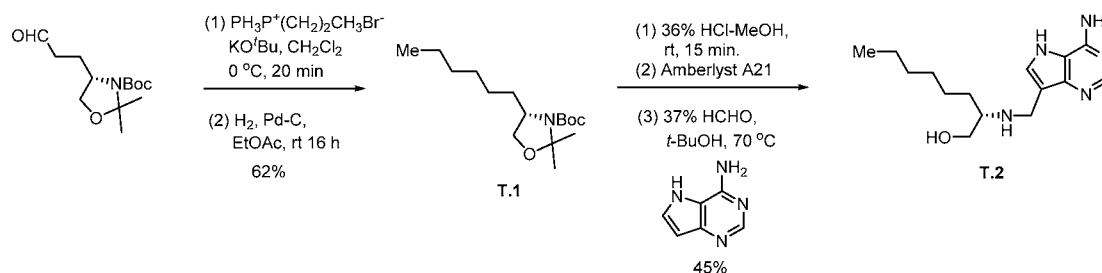


[0076] *tert-Butyl (4S)-2,2-dimethyl-4-pentyl-1,3-oxazolidine-3-carboxylate (S.1).* *tert-Butyl (4S)-2,2-dimethyl-4-(3-oxopropyl)-1,3-oxazolidine-3-carboxylate* [Goswami, et al.¹⁵] (0.400 g, 1.55 mmol, purified on silica gel with a gradient of 0 – 50% EtOAc in hexanes) and ethyltriphenylphosphonium bromide [Paleček, J. et al.¹⁶] (0.866 g, 2.33 mmol, dried over P_2O_5 then evaporated 2 x from dry toluene) were dissolved in anhydrous CH_2Cl_2 (7 mL) and cooled at $0\text{ }^\circ\text{C}$. A solution of potassium *tert*-butoxide in THF (1.6 M, 1.5 mL, 2.4 mmol) was added dropwise and the mixture stirred for 20 min. [method similar to that described in Ksander, et al.¹⁷] Silica gel was added to absorb all the solvent then the solvent was evaporated and the residue chromatographed on silica gel (gradient of 0 – 5% EtOAc in hexanes) to give the Wittig product as a colourless oil (0.304 g, 73%). The latter product (0.430 g, 1.60 mmol) and 10% Pd on carbon (60 mg) were stirred together in EtOAc (15 mL) under a hydrogen atmosphere for 16 h. The mixture was filtered through Celite then the filtrate evaporated and the residue chromatographed on silica gel (gradient of 0 – 5% EtOAc in hexanes) to give **S.1** as a colourless oil (0.359 g, 61%). ¹H NMR (500 MHz, CDCl_3): δ 3.93-3.71 (m, 3H), 1.83-1.42 (m, 17H), 1.36-1.20 (m, 6H), 0.93-0.80 (m, 3H). ¹³C NMR (125.7 MHz, CDCl_3 , centre line δ 77.0): δ 152.1, 151.9 (C), 93.6, 93.0 (C), 79.8, 79.3 (C), 67.1, 66.8 (CH₂), 57.8, 57.4 (CH), 33.6, 32.8 (CH₂), 31.7 (CH₂), 28.5 (CH₃), 27.5, 26.7 (CH₃), 25.9 (CH₂), 24.6, 23.3 (CH₃), 22.6 (CH₂), 13.9 (CH₃). ESI-HRMS calcd for C₁₅H₂₉NNaO₃⁺, (M+Na)⁺, 294.2040, found 294.2038.

[0077] *(2S)-2-[(4-Amino-5H-pyrrolo[3,2-d]pyrimidin-7-yl)methyl]amino]heptan-1-ol (S.2).* Compound **S.1** (0.358 g, 1.32 mmol) was dissolved in MeOH (4 mL) and aq. hydrochloric acid (36%, 1 mL) added. After 15 min the solvent was evaporated to a colourless solid that was dissolved in MeOH (10 mL), neutralized with Amberlyst A21 resin

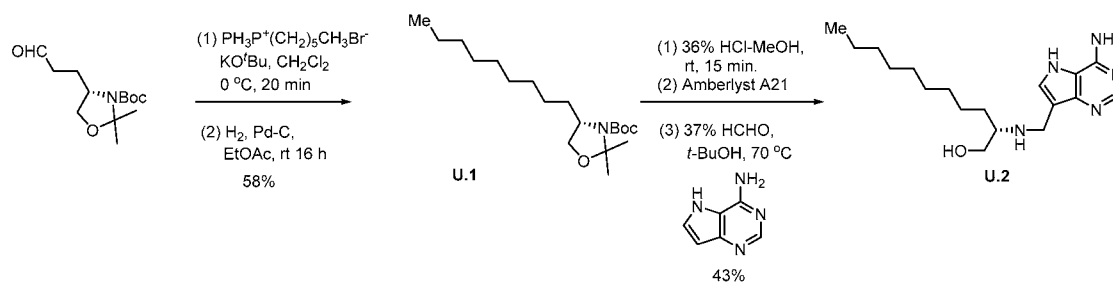
then passed through a short column of the same resin and eluted with MeOH. The fractions containing product were evaporated to an oily residue that was dissolved in *tert*-butanol (4 mL) then 9-deazaadenine (0.177 g, 1.32 mmol) and aq. formaldehyde solution (0.12 mL, 1.59 mmol) were added and the mixture stirred at 70 °C for 16 h. Silica gel was added to absorb all the solvent then the solvent was evaporated and the residue chromatographed on silica gel (gradient of 5 – 15% 7M NH₃/MeOH in CHCl₃) to give **S.2** as a colourless solid (0.122 g, 33%). ¹H NMR (500 MHz, CD₃OD): δ 8.16 (s, 1H), 7.47 (s, 1H), 3.64 (dd, *J* = 11.2, 4.5 Hz, 1H), 3.48 (dd, *J* = 11.2, 6.5 Hz, 1H), 2.68-2.64 (m, 1H), 1.52-1.38 (m, 2H), 1.32-1.17 (m, 6H), 0.86 (t, *J* = 7.1 Hz, 3H). ¹³C NMR (125.7 MHz, CD₃OD, centre line δ 49.0): δ 152.1 (C), 150.8 (CH), 146.6 (C), 129.0 (CH), 115.4 (C), 114.8 (C), 64.4 (CH₂), 59.2 (CH), 41.2 (CH₂), 33.1 (CH₂), 32.0 (CH₂), 26.8 (CH₂), 23.6 (CH₂), 14.4 (CH₃). ESI-HRMS calcd for C₁₄H₂₄N₅O⁺, (M+H)⁺, 278.1976, found 278.1974.

[0078] *Example T. Synthesis of (2S)-2-[(4-amino-5H-pyrrolo[3,2-d]pyrimidin-7-yl)methyl]amino]octan-1-ol (T.2).*



[0079] *tert-Butyl (4S)-4-hexyl-2,2-dimethyl-1,3-oxazolidine-3-carboxylate (T.1).* *tert*-Butyl (4S)-2,2-dimethyl-4-(3-oxopropyl)-1,3-oxazolidine-3-carboxylate [Goswami, et al.¹⁵] (0.500 g, 1.94 mmol, purified on silica gel with a gradient of 0 – 50% EtOAc in hexanes) and *n*-propyltriphenylphosphonium bromide (1.12 g, 2.91 mmol, dried over P₂O₅ then evaporated 2 x from dry toluene) were dissolved in anhydrous CH₂Cl₂ (7 mL) and cooled to 0 °C. A solution of potassium *tert*-butoxide in THF (1.6 M, 1.8 mL, 2.90 mmol) was added dropwise and the mixture stirred for 20 min. [method similar to that described in Ksander, et al.¹⁷] Silica gel was added to absorb all the solvent then the solvent was evaporated and the residue chromatographed on silica gel (gradient of 0 – 4% EtOAc in hexanes) to give the Wittig product as a colourless oil (0.361 g, 66%). The latter product (0.360 g, 1.27 mmol) and 10% Pd on carbon (60 mg) were stirred together in EtOAc (15 mL) under a hydrogen atmosphere for 16 h. The mixture was filtered through Celite then the filtrate evaporated and the residue chromatographed on silica gel (gradient of 0 – 5% EtOAc in hexanes) to give **T.1** as a

[0081] Example U. Synthesis of (2*S*)-2-[(4-amino-5*H*-pyrrolo[3,2-*d*]pyrimidin-7-yl)methyl]amino]undecan-1-ol (U.2).



[0082] *tert*-Butyl (4*S*)-2,2-dimethyl-4-nonyl-1,3-oxazolidine-3-carboxylate (U.1).

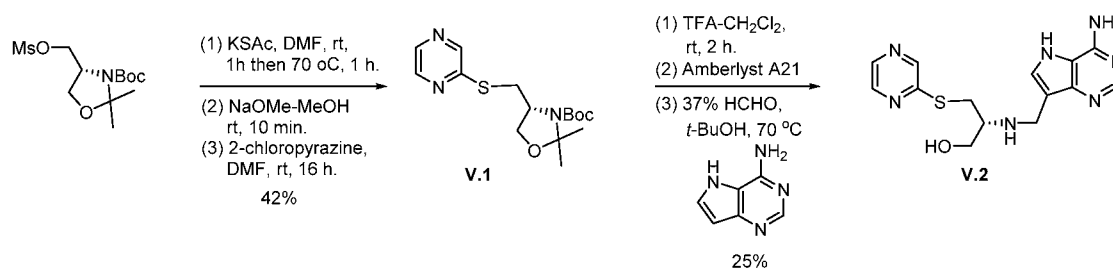
Step 1. Ttriphenylphosphine (3.70 g, 14.11 mmol) and 1-bromohexane (2.97 mL, 21.16 mmol) were stirred and heated under reflux in toluene (10 mL) for 16 h. The resulting *n*-hexyltriphenylphosphonium bromide (3.30 g, 55%) was filtered off and dried over P₂O₅ then evaporated 2 x from dry toluene.

[0083] *Step 2.* The phosphonium salt from step 1 (1.30 g, 3.04 mmol) and *tert*-butyl (4*S*)-2,2-dimethyl-4-(3-oxopropyl)-1,3-oxazolidine-3-carboxylate [Goswami, et al.¹⁵] (0.500 g, 1.94 mmol, purified on silica gel with a gradient of 0 - 50% EtOAc in hexanes) were dissolved in CH₂Cl₂ (7 mL) and cooled at 0 °C. A solution of potassium *tert*-butoxide in THF (1.6 M, 1.9 mL, 3.00 mmol) was added dropwise and the mixture stirred for 20 min. [method similar to that described in Ksander, et al.¹⁷]. Silica gel was added to absorb all the solvent then the solvent was evaporated and the residue chromatographed on silica gel (gradient of 0 - 5% EtOAc in hexanes) to give the Wittig product as a colourless oil (0.370 g, 59%). The latter product (0.340 g, 1.04 mmol) and 10% Pd on carbon (60 mg) were stirred together in EtOAc (15 mL) under a hydrogen atmosphere for 16 h. The mixture was filtered through Celite and the filtrate evaporated and the residue chromatographed on silica gel (gradient of 0 - 5% EtOAc in hexanes) to give U.1 as a colourless oil (0.340 g, 99%). ¹H NMR (500 MHz, CDCl₃): δ 3.93-3.70 (m, 3H), 1.82-1.42 (m, 17H), 1.35-1.82 (m, 14H), 0.88 (t, *J* = 6.9 Hz, 3H). ¹³C NMR (125.7 MHz, CDCl₃, centre line δ 77.0): δ 152.2, 151.9 (C), 93.6, 93.0 (C), 79.8, 79.3 (C), 67.1, 66.8 (CH₂), 57.8, 57.5 (CH), 33.6, 32.9 (CH₂), 31.9 (CH₂), 29.6, 29.5, 29.3 (4 x CH₂), 28.5 (CH₃), 27.5, 26.8 (CH₃), 26.3 (CH₂), 24.6, 23.3 (CH₃), 22.6 (CH₂), 14.1 (CH₃). ESI-HRMS calcd for C₁₉H₃₇NNaO₃⁺, (M+Na)⁺, 350.2666, found 350.2663.

[0084] (2*S*)-2-[(4-Amino-5*H*-pyrrolo[3,2-*d*]pyrimidin-7-yl)methyl]amino]undecan-1-ol (U.2). Compound U.1 (0.310 g, 0.947 mmol) was dissolved in MeOH (4 mL) and aq. hydrochloric acid (36%, 1 mL) added. After 15 min the solvent was evaporated to a colourless solid that was dissolved in a 4:1 mixture MeOH-CHCl₃, neutralized with Amberlyst A21 resin then passed through a short column of the same resin and eluted with 4:1 MeOH-CHCl₃. The fractions containing product were evaporated to a yellow oil that was dissolved in *tert*-butanol (4 mL) then 9-deazaadenine (0.127 g, 0.95 mmol) and aq. formaldehyde solution (37%, 0.085 mL, 1.10 mmol) were added and the mixture was stirred at 70 °C for 16 h. Silica gel was added to absorb all the solvent then the solvent was evaporated and the residue chromatographed on silica gel (gradient of 5 - 15% 7M NH₃/MeOH in CHCl₃) to give U.2 as a colourless solid (0.135 g, 43%). ¹H NMR (500 MHz,

1:1 CD₃OD-CDCl₃): δ 8.20 (s, 1H), 7.40 (s, 1H), 3.96 (s, 1H), 3.73 (dd, J = 11.4, 3.9 Hz, 1H), 3.50 (dd, J = 11.4, 6.6 Hz, 1H), 2.74-2.69 (m, 1H), 1.55-1.39 (m, 2H), 1.35-1.21 (m, 14H), 0.89 (t, J = 7.0 Hz, 3H). ¹³C NMR (125.7 MHz, 1:1 CD₃OD-CDCl₃, centre lines δ 49.0 and δ 78.3): δ 151.2 (C), 150.2 (CH), 146.0 (C), 128.1 (CH), 115.0 (C), 114.2 (C), 63.6 (CH₂), 59.0 (CH), 40.7 (CH₂), 32.5 (CH₂), 31.6 (CH₂), 30.4 (CH₂), 30.1 (2 x CH₂), 29.9 (CH₂), 26.8 (CH₂), 23.2 (CH₂), 14.3 (CH₃). ESI-HRMS calcd for C₁₈H₃₂N₅O⁺, (M+H)⁺, 334.2602, found 334.2605.

[0085] *Example V. Synthesis of (2R)-2-[(4-amino-5H-pyrrolo[3,2-d]pyrimidin-7-yl)methyl]amino]-3-(pyrazin-2-ylsulfanyl)propan-1-ol (V.2).*



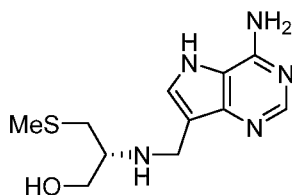
[0086] *tert-Butyl (4R)-2,2-dimethyl-4-[(pyrazin-2-ylsulfanyl)methyl]-1,3-oxazolidine-3-carboxylate (V.1). Step 1.* Potassium thioacetate (0.588 g, 5.05 mmol) and mesylate from *step 1* of the preparation of **K.1** (0.520 g, 1.68 mmol) were stirred together in DMF (5 mL) at rt for 16 h then at 70 °C for 1 h. Water (5 mL) was added and the mixture extracted with Et₂O (100 mL). The extract was washed with H₂O (4 x 5 mL), brine (5 mL), dried, the solvent evaporated and the residue chromatographed on silica gel (gradient of 0 – 30% EtOAc in hexanes) to give *tert*-butyl (4R)-4-[(acetylsulfanyl)methyl]-2,2-dimethyl-1,3-oxazolidine-3-carboxylate as a colourless oil (0.347 g, 71%)

[0087] *Step 2.* Sodium methoxide in methanol solution (25%, 0.27 mL, 1.2 mmol) was added to a solution of the thioacetate from *step 1* (0.340 g, 1.17 mmol) in MeOH (5 mL). After 10 mins the solvent was evaporated and the residue dissolved in DMF (5 mL) then 2-chloropyrazine (0.32 mL, 3.6 mmol) added and the mixture stirred for 16 h. Water (5 mL) was added then the mixture was extracted with Et₂O (100 mL). The extract was washed with H₂O (4 x 5 mL), brine (5 mL), dried and evaporated. The residue was chromatographed on silica gel (gradient of 0 – 30% EtOAc in hexanes) to give **V.1** as a colourless oil (0.224 g, 59%). ¹H NMR (500 MHz, CDCl₃): δ 8.55, 8.48 (2 x bs, 1H), 8.36, 8.33 (2 x bs, 1H), 8.22 (bs, 1H), 4.23, 4.14 (2 x bs, 1H), 4.06-3.93 (m, 2H), 3.76-3.63 (m, 1H), 3.37-3.27 (m, 0.5H), 3.17-3.07 (m, 0.5H), 1.67-1.59 (m, 3H), 1.53-1.45 (m, 12H). ¹³C NMR (125.7 MHz, CDCl₃,

centre line δ 77.0): δ 156.5, 156.1 (C), 152.2, 151.6 (C), 143.7, 143.6 (2 x CH), 139.8, 139.7 (CH), 94.5, 93.9 (C), 80.5, 80.2 (C), 66.4, 66.3 (CH₂), 56.9, 56.5 (CH), 31.4, 31.0 (CH₂), 28.5 (CH₃), 27.5, 26.9 (CH₃), 24.4, 23.2 (CH₃). ESI-HRMS calcd for C₁₅H₂₃N₃NaO₃S⁺ (M+Na)⁺, 348.1353, found 348.1350.

[0088] (2*R*)-2-[(*{4-Amino-5H-pyrrolo[3,2-*d*]pyrimidin-7-yl}methylamino*]-3-(*pyrazin-2-ylsulfanyl*)propan-1-ol (V.2). Compound **V.1** (0.220 g, 0.68 mmol) was dissolved in CH₂Cl₂ (8 mL) and trifluoroacetic acid (2 mL) added. After 2 h the solvent was evaporated and the residue dissolved in MeOH (10 mL) and neutralized with Amberlyst A21 resin then passed through a short column of the same resin and eluted with MeOH. The fractions containing product were evaporated to a yellow gum that was dissolved in *tert*-butanol (4 mL) then aq. formaldehyde solution (37%, 0.061 mL, 0.81 mmol) and 9-deazaadenine (0.091 g, 0.68 mmol) were added and the mixture heated at 70 °C for 16 h. Silica gel was added to absorb all the solvent then the solvent was evaporated and the residue chromatographed on silica gel (gradient of 10 – 15% 7M NH₃/MeOH in CHCl₃) to give **V.2** as a colourless solid (0.055 g, 25%). ¹H NMR (500 MHz, CD₃OD): δ 8.35 (d, *J* = 1.5 Hz, 1H), 8.28 (dd, *J* = 2.6, 1.7 Hz, 1H), 8.14 (d, *J* = 2.7 Hz, 1H), 8.12 (s, 1H), 7.43 (s, 1H), 4.05 (d, *J* = 13.9 Hz, 1H), 4.02 (d, *J* = 13.8 Hz, 1H), 3.74 (dd, *J* = 11.3, 4.9 Hz, 1H), 3.64 (dd, *J* = 11.3, 5.5 Hz, 1H), 3.39-3.31 (m, 2H + residual deuterated solvent), 3.01-2.97 (m, 1H). ¹³C NMR (125.7 MHz, CD₃OD, centre line δ 49.0): δ 158.2 (C), 152.0 (C), 150.8 (CH), 146.5 (C), 145.2 (CH), 144.6 (CH), 140.3 (CH), 129.0 (CH), 115.4 (C), 114.7 (C), 63.7 (CH₂), 58.4 (CH), 41.4 (CH₂), 31.6 (CH₂). ESI-HRMS calcd C₁₄H₁₈N₇OS⁺ (M+H)⁺, 332.1289, found 332.1287.

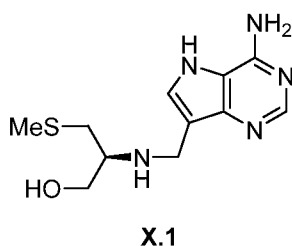
[0089] Example W. (2*R*)-2-[(*{4-Amino-5H-pyrrolo[3,2-*d*]pyrimidin-7-yl}methylamino*]-3-(*methylsulfanyl*)propan-1-ol (W.1).



W.1

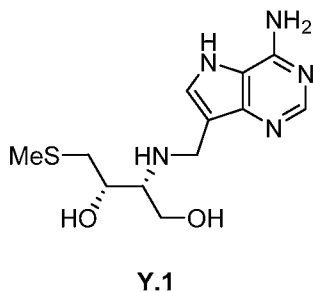
[0090] Prepared according to the literature [Clinch, et al.¹⁸].

[0091] Example X. (2*S*)-2-[(*{4-Amino-5H-pyrrolo[3,2-*d*]pyrimidin-7-yl}methylamino*]-3-(*methylsulfanyl*)propan-1-ol (X.1).



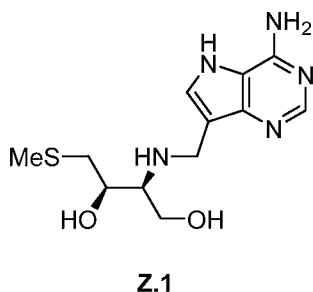
[0092] Prepared according to the literature [Clinch, et al.¹⁸].

[0093] *Example Y. (2R,3S)-2-[(4-Amino-5H-pyrrolo[3,2-d]pyrimidin-7-yl)methyl]amino]-4-(methylsulfanyl)butane-1,3-diol (Y.1).*



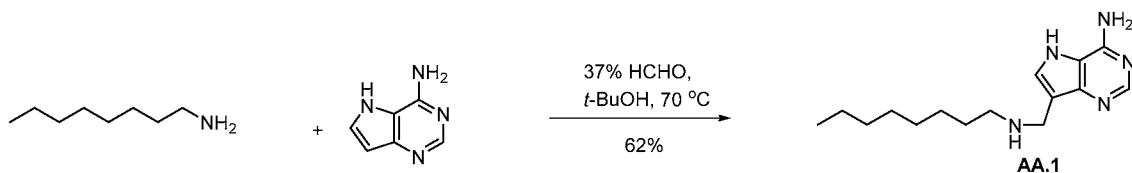
[0094] Prepared according to the literature [Clinch, et al.¹⁸].

[0095] *Example Z. (2S,3R)-2-[(4-Amino-5H-pyrrolo[3,2-d]pyrimidin-7-yl)methyl]amino]-4-(methylsulfanyl)butane-1,3-diol (Z.1).*



[0096] Prepared according to the literature [Clinch, et al.¹⁸].

[0097] *Example AA. Synthesis of 7-[(octylamino)methyl]-5H-pyrrolo[3,2-d]pyrimidin-4-amine (AA.1).*



[0098] *7-[(Octylamino)methyl]-5H-pyrrolo[3,2-d]pyrimidin-4-amine (AA.1)* Octan-1-amine (0.100 g, 0.77 mmol), aq. formaldehyde solution (37%, 0.076 mL, 1.01 mmol) and

9-deazaadenine (0.105 g, 0.78 mmol) were heated in *tert*-butanol (3 mL) at 70 °C for 16 h. Silica gel was added to absorb all the solvent then the solvent was evaporated and the residue chromatographed on silica gel (gradient of 5 – 15% 7 M NH₃/MeOH in CHCl₃) to give **AA.1** as a colourless solid (0.132 g, 62%). ¹H NMR (500 MHz, CD₃OD): δ 8.16 (s, 1H), 7.46 (s, 1H), 3.91 (s, 2H), 2.61 (t, *J* = 7.5 Hz, 2H), 1.52 (pent, *J* = 7.4 Hz, 2H), 1.34-1.21 (m, 10H), 0.88 (t, *J* = 7.1 Hz, 3H). ¹³C NMR (125.7 MHz, CD₃OD, centre line δ 49.0): δ 152.1 (C), 150.8 (CH), 146.6 (C), 129.0 (CH), 115.4 (C), 114.5 (C), 49.9 (CH₂), 43.7 (CH₂), 33.0 (CH₂), 30.5 (CH₂), 30.4 (CH₂), 30.3 (CH₂), 28.4 (CH₂), 23.7 (CH₂), 14.4 (CH₃). ESI-HRMS calcd for C₁₅H₂₆N₅⁺, (M+H)⁺, 276.2183, found 276.2181.

Results and Discussion

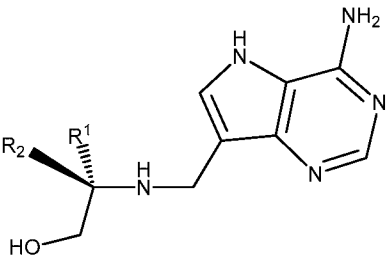
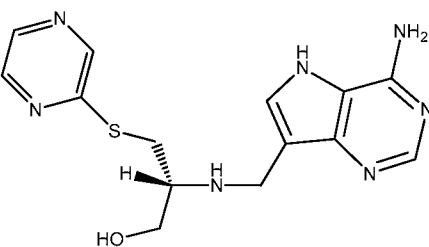
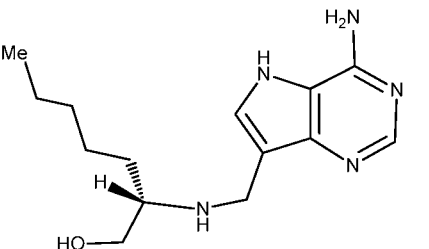
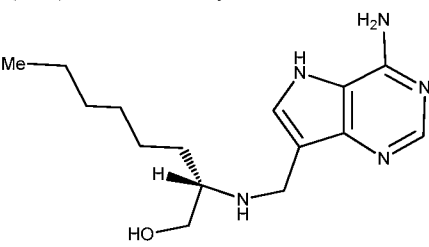
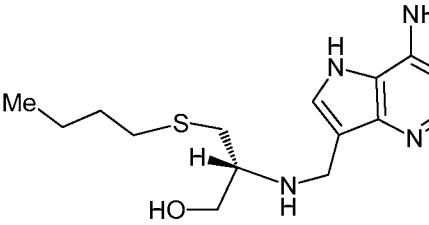
[0099] Commonly used antibiotics in *H. pylori* infections include amoxicillin, metronidazole and tetracycline. The anti-*H. pylori* effects of selected compounds were compared to those antibiotics in common use.

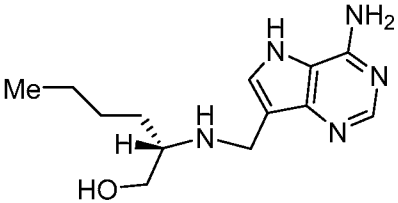
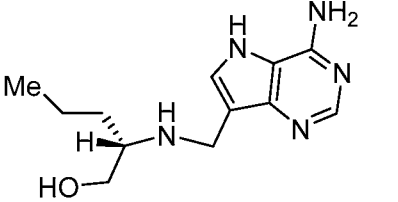
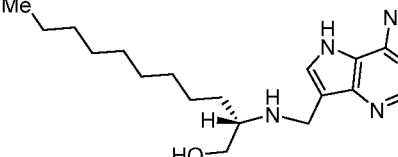
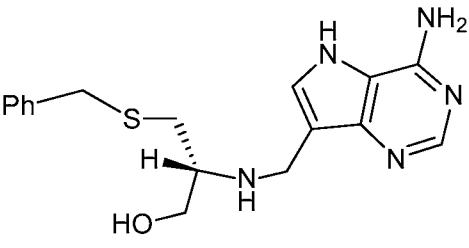
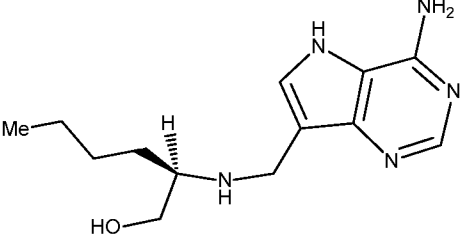
[00100] In most bacteria, MTANs are expressed and catalyze the hydrolysis of the *N*-ribosidic bonds of 5'- methylthioadenosine and S-adenosylhomocysteine. The two reactions are involved in bacterial quorum sensing, sulfur recycling via S-adenosylmethionine and polyamine synthesis¹³; however, most bacterial MTANs are not essential for bacterial proliferation as judged by planktonic growth conditions.

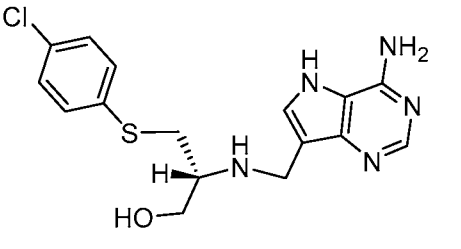
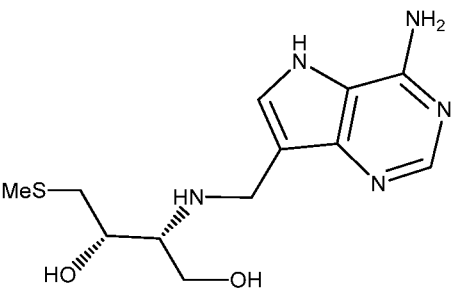
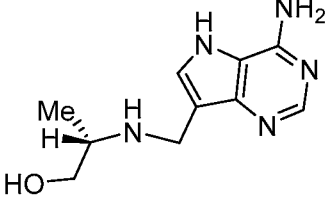
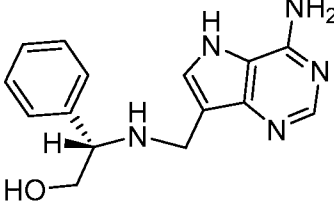
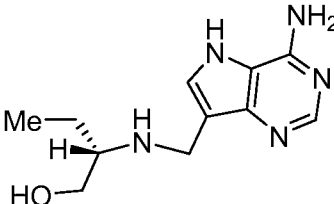
[00101] Bacterial genome analysis predicts the *Hp*MTAN-mediated pathway for menaquinone biosynthesis to be rare, but also to be present in *Campylobacter* species⁴. *Campylobacter jejuni* is the world's leading cause of bacterial gastroenteritis¹¹.

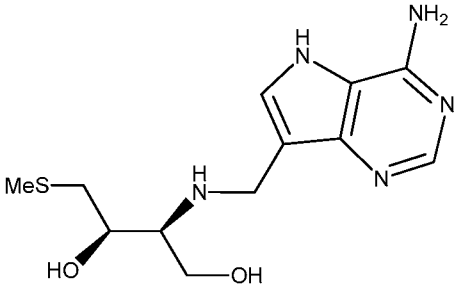
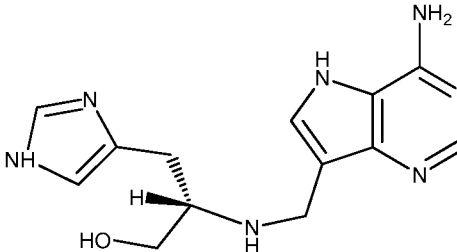
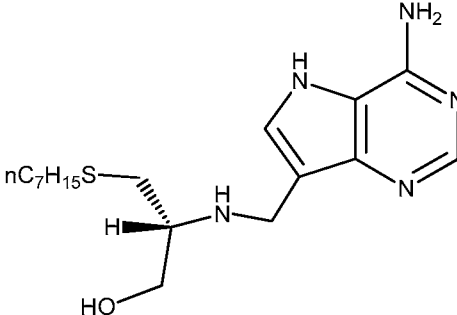
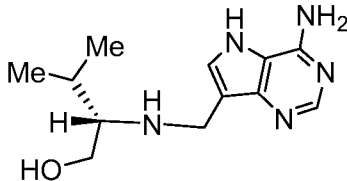
[00102] Drug resistance has developed quickly in *H. pylori*, and currently, approximately 30% of *H. pylori* infection are resistant to single-agent first line drugs¹². As a result, the current approach commonly uses triple-agent therapy for *H. pylori* infections and includes two antibiotics with different mechanisms of action. Even with triple-agent therapy, more than 20% of *H. pylori* infections are not readily eradicated². Resistance in the *H. pylori* population is no doubt partially due to exposing *H. pylori* to broad spectrum antibiotics during the treatment of other bacterial infections. In addition, current eradication of *H. pylori* requires antibiotics for two weeks or longer and there is an increase in the development of resistance if treatment is interrupted. Table 1 summarizes the dissociation constants versus *H. pylori* MTAN and the MIC90 values against *H. pylori* for specific compounds of the invention. Drug combinations using these compounds may also address current issues of antibiotic resistance.

Table 1. Acyclic Amine Inhibitors of *Helicobacter pylori* MTAN and their MIC90 values against *H. pylori*.

	Inhibition of <i>H. pylori</i> MTAN		Inhibition of <i>H. pylori</i> growth
	Ki (nM)	Ki* (nM)	MIC90 (ng/mL)
(V.2) R ¹ = Pyrazin-2-ylthiomethyl, R ² = H 	0.10 ± 0.01		8
(S.2) R ¹ = n-Pentyl, R ² = H 	0.10 ± 0.01		8
(T.2) R ¹ = n-Hexyl, R ² = H 	0.030 ± 0.003		8
(Q.2) R ¹ = n-Butylthiomethyl, R ² = H 	0.11 ± 0.01		16

(E.1), R¹ = n-Butyl, R² = H 	0.9 ± 0.2		16
(D.1) R¹ = n-Propyl, R² = H 	1.2 ± 0.4		40
(U.2) R¹ = H, R² = n-Nonyl 	0.12 ± 0.01		80
(L.3) R¹ = Benzylthiomethyl, R² = H 	0.7 ± 0.1	0.21 ± 0.02	>80
(F.1) R¹ = H, R² = n-Butyl 	0.8 ± 0.1		>80

(K.3) R^1 = 4-Chlorophenylthiomethyl, R^2 = H 	0.9 ± 0.1		>80
(Y.1) R^1 = (S)-1-Hydroxy-2-methylthioeth-1-yl, R^2 = H (Synthesis in WO 08 030118) 	5 ± 2		>80
(B.1) R^1 = Methyl, R^2 = H 	13 ± 2		>80
(J.1) R^1 = Phenyl, R^2 = H 	13 ± 2		>80
(C.1) R^1 = Ethyl, R^2 = H 	>5		>80

(Z.1) $R^1 = H$, $R^2 = (R)$-1-Hydroxy-2-methylthioeth-1-yl (Synthesis in WO 08 030118) 	>10		>80
(P.4) $R^1 = \text{Imidazol-4-ylmethyl}$, $R^2 = H$ 	>50		>80
(R.2) $R^1 = n\text{-Heptylthiomethyl}$, $R^2 = H$ 	0.05 ± 0.01		80
(G.1) $R^1 = 2\text{-Propyl}$, $R^2 = H$ 	>5		>80

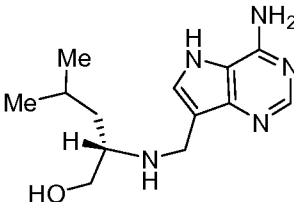
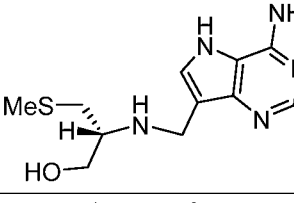
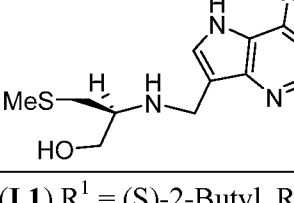
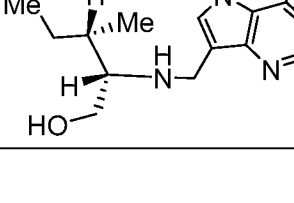
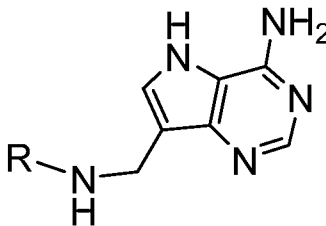
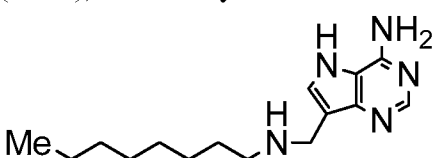
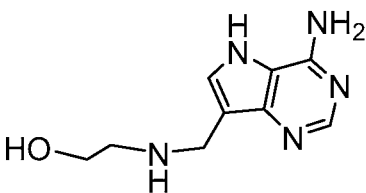
(H.1) $R^1 = 2\text{-Methylpropyl}$, $R^2 = H$ 	>5		>80
(W.1) $R^1 = \text{Methylthiomethyl}$, $R^2 = H$ 	>5		>80
(X.1) $R^1 = H$, $R^2 = \text{Methylthiomethyl}$ 	>5		>80
(L.1) $R^1 = (S)\text{-}2\text{-Butyl}$, $R^2 = H$ 	>5		>80

Table 2. Other Acyclic Amine Inhibitors of *Helicobacter pylori* MTAN and their MIC90 values against *H. pylori*.

 Compound number, R =	Inhibition of <i>H. pylori</i> MTAN		Inhibition of <i>H. pylori</i> growth
	Ki (nM)	Ki* (nM)	MIC90 (ng/mL)

(AA.1), R = n-Octyl 	0.2 ± 0.04		>80
(A.1), R = 2-Hydroxyethyl 	>5		>80

EXAMPLE 2

In vitro Activity of Compound T.2 (Hexyl-SerMe-immucillin A)

[00103] These following experiments were conducted at UNT Health Science Center (Study lead: William J Weiss, Director of Pre-Clinical Services), Fort Worth, TX, USA.

[00104] (a) *Sample plate preparation:* Aliquots of a 2-fold serial dilution of Hexyl-SerMe-Immucillin A (from 62.5 µg/mL - 6.25 µg/mL in DMSO, 0.02 mL) were mixed into separate 2 mL molten MHIb agar, and poured into separate wells on each well of a 12-well plate, allowed to set for 20-30 minutes and dry in a biosafety cabinet for 10 minutes prior to Inoculation.

[00105] (b) *Inoculation:* Frozen inoculate stock of *H. pylori* strains UNT020-1 (Sydney Strain SS1) and UNT189-1 (ATCC43504) was separately streaked onto Columbia + 5% sheep blood agar and microaerophilically incubated for 72 h at 37 °C. The plate cultures of the *H. pylori* strains were then harvested in 0.9% sterile saline solution and the OD at 530 nm of the suspension was determined. The OD of each suspension was adjusted to 1.5 - 2.0 by dilution into 0.9% sterile saline. The UNT020-1 suspension was further diluted 2:5, but the UNT189-1 suspension was not further diluted, and these were used to inoculate the agar plates. Samples of the suspensions (3 µL) were spotted onto the MHIb agar wells in the 12-well plate. The CFU/mL of each inoculum was confirmed by generating a 10-fold serial dilution of each inoculum in 0.9% sterile saline and spotting 8 µL of each dilution onto Columbia + 5% sheep blood agar plates. After allowing the spots to dry for 10 min, the plates were placed into a microaerophilic chamber and incubated at 37 °C for 72 h.

[00106] *Results:* The Minimum Inhibitory Concentrations (MICs) for the Hexyl-SerMe-immucillin A was determined against *H. pylori* isolates UNT020-1 (Sydney Strain SS1) and UNT189-1 (ATCC43504). Hexyl-SerMe-Immucillin A exhibited excellent activity against the two *H. pylori* strains with an MIC of 1.9 ng/mL in each case.

The concentration of Compound T.2 (Hexyl-SerMe-immucillin A) in the gastric mucin of mouse following a single oral dose at 10 mg/kg

[00107] These following experiments were conducted at UNT Health Science Center (Study lead: William J Weiss, Director of Pre-Clinical Services), Fort Worth, TX, USA.

[00108] (a) *Oral dosing of mice with 10 mg/kg Hexyl-SerMe-Immucillin A:* Female C57/BL6 mice ranging from 5 - 6 weeks in age and 18 - 22 grams in weight (Harlan Laboratories) were dosed by oral gavage with of Hexyl-SerMe-Immucillin A (0.4 mL of a 0.5 mg/mL solution in water for injection).

[00109] (b) *Mucin sampling:* Mice (3 mice/time point) were euthanized via CO₂ inhalation at 0.25, 0.5, 1, 2, 4, 8, 12 and 24 h, then the mucin layer was scraped from the longitudinally dissected stomach using a glass slide, collected and weighed.

[00110] (c) *Preparation of gastric mucin homogenates:* Approximately 30 mg of mouse mucin was weighted into a 2 mL homogenizer tube (prefilled with 3.0 mm i.d. zirconium beads) and mixed with 0.2 mL PBS buffer. This was homogenized for 3 min at 4,000 rpm in a Beadbug D1030 (Benchmark Scientific) homogenizer.

[00111] (d) *Extraction of gastric mucin homogenates:* Samples of mucin homogenate (50 µL) and of internal standard (see below) in water (10 µL) were treated with trichloroacetic acid (30% w/v, 30 µL), diluted with water (160 µL), vortexed for 10 sec and sonicated for 10 min, then centrifuged at 14,500 rpm for 5 min. A sample of the supernatant (160 µL) was transferred into autosampler vials. The internal standard was Butylthio-DADMe-Immucillin-H at 5.0 and 20.0 µg/mL.

[00112] (f) *HPLC-MS-MS analysis:* Aliquots of supernatant (10 µL) were injected for analysis on Surveyor HPLC system (Thermo) fitted with an ACE 3 C18 Column (50 × 3 mm, 3 µm particles), with gradient elution at 30 °C with 400 µL/min mobile phase comprised of mixtures of 0.1% trifluoroacetic acid in water (A) and methanol (B) as follows: 0 - 5 min, A:B 9:1; 5 - 6.1 min, A:B 1:9; 6.1-10 min A:B 9:1. Hexyl-SerMe-Immucillin A eluted at 4.41 ± 0.003 min. Detection was ESI MS/MS using a LCQ Deca (Thermo) in selected-reaction monitoring (SRM) positive mode using the MS/MS event *m/z* 292.2 → 147.2 and ion spray voltage of 4.5 kV.

[00113] (g) *Results:* The results for Hexyl-SerMe-Immucillin A in gastric mucin following administration of 10 mg/kg by oral gavage in mice are shown in the Table and Figure below. A high and prolonged level of Hexyl-SerMe-Immucillin A was detected in the gastric mucin, with the $C_{\max}$ value was 65.5 $\mu\text{g/g}$, total exposure [$\text{AUC}_{(0-\text{inf})}$] was 78.6 $\mu\text{g-h/g}$ and the terminal half-life was 2.72 h.

Table 3. The concentration of Hexyl-SerMe-Immucillin A in mouse gastric mucin versus time following a single dose of 10 mg/kg PO.

Time (h)	Hexyl-SerMe-Immucillin A ($\mu\text{g/g}$)					
	Animal-1	Animal-2	Animal-3	Mean	SD	SEM
0.25	60.42	64.36	45.91	56.89	9.71	4.34
0.50	46.24	90.18	60.18	65.53	22.46	10.04
1.00	20.39	12.20	12.04	14.88	4.77	2.13
2.00	2.02	1.08	16.24	6.44	8.49	3.80
4.00	0.67*	3.74	0.91	1.77	1.71	0.76
8.00	0.65*	1.62	0.53*	0.93	0.60	0.27
12.0	0.96	0.95	0.33*	0.74	0.36	0.16
24.0	0.54*	0.39*	0.30*	0.41	0.12	0.06
* below LLOQ						

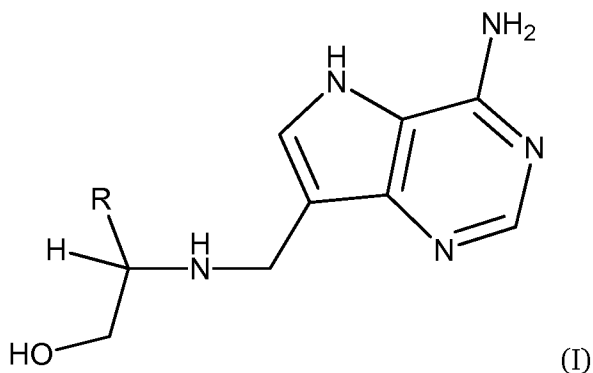
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19. PCT International Patent Application Publication No. WO 2008/030118, published March 13, 2008.

What is claimed is:

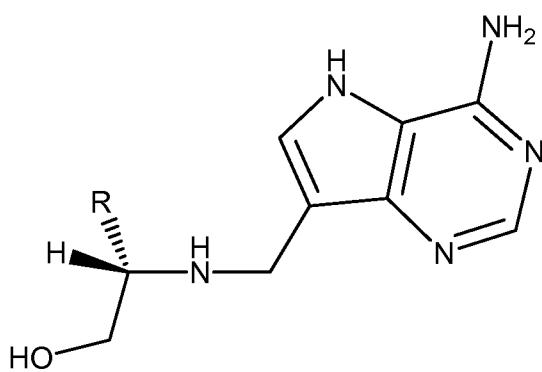
1. A method of treating a *Helicobacter pylori* (*H. pylori*) infection in a subject comprising administering to the subject a compound of formula (I) in an amount effective to inhibit growth of *H. pylori*, wherein formula (I) is



wherein R is Q or CH₂SQ, wherein Q is C1-C9 alkyl, aryl, heteroaryl, aralkyl, or C4-C7 cycloalkyl, and wherein Q is optionally substituted with one or more halogen, OH and/or NH₂ groups,

or a pharmaceutically acceptable salt thereof, or an ester thereof.

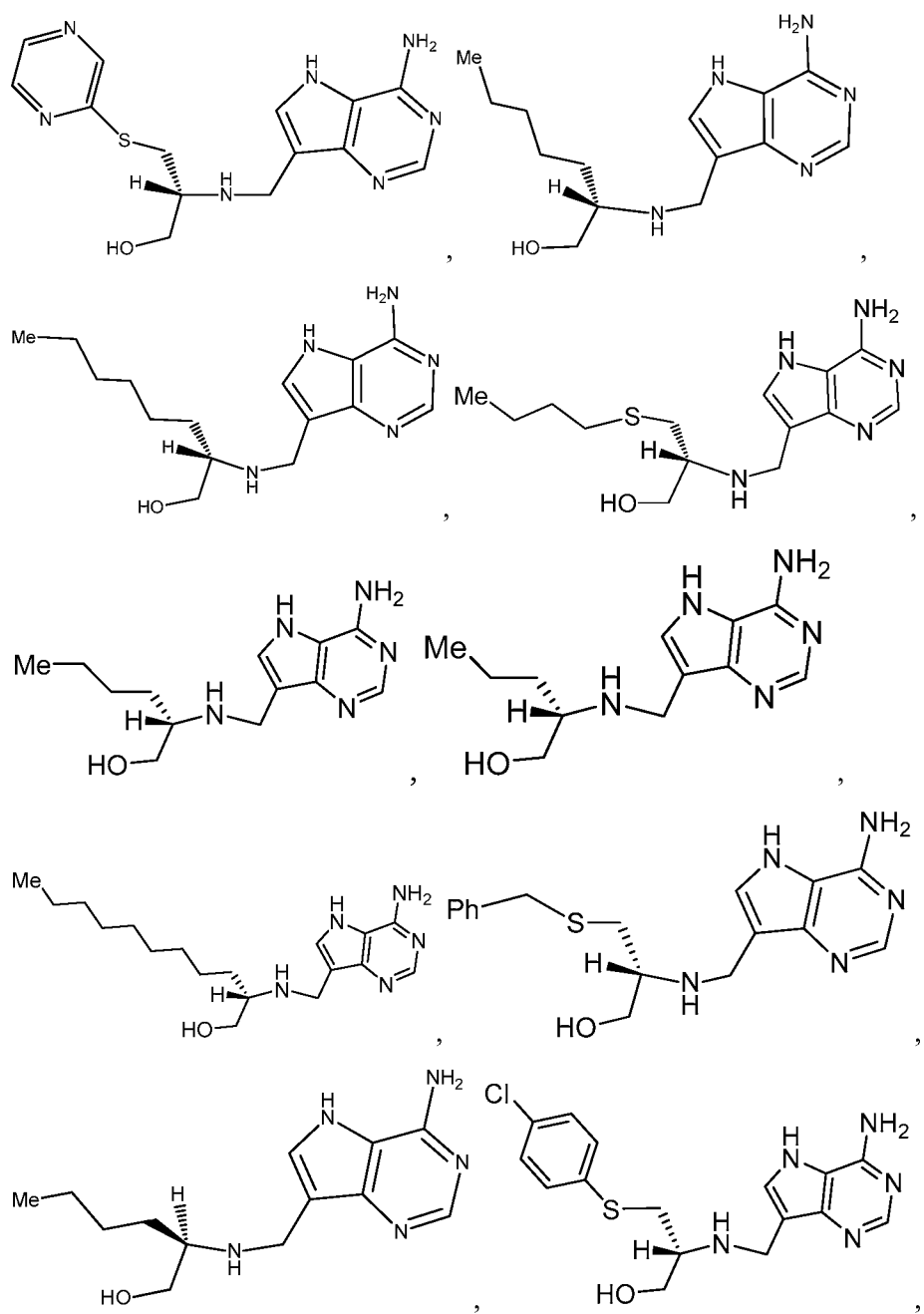
2. The method of claim 1, wherein the compound has the formula



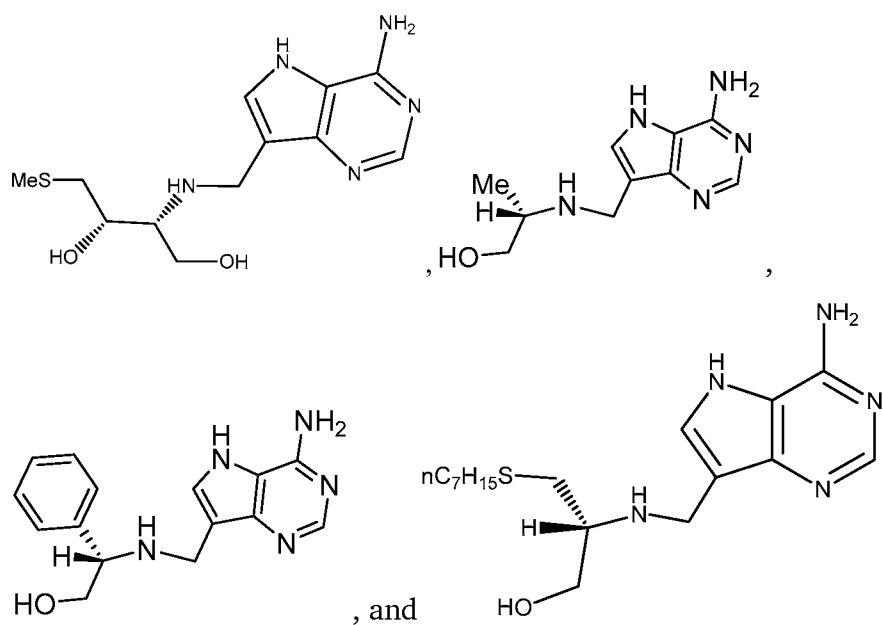
3. The method of claim 1 or 2, wherein R is Q.
4. The method of claim 1 or 2, wherein R is CH₂SQ.

5. The method of any of claims 1-4, wherein Q is C1-C9 alkyl.
6. The method of any of claims 1-4, wherein Q is C4-C7 cycloalkyl.
7. The method of any of claims 1-4, wherein Q is aryl.
8. The method of any of claims 1-4, wherein Q is heteroaryl.
9. The method of any of claims 1-4, wherein Q is aralkyl.
10. The method of any of claims 1-4, wherein Q is aryl, heteroaryl or aralkyl substituted with a halogen.
11. The method of any of claims 1-4, wherein R is Q or CH₂SQ, wherein Q is C2-C9 linear alkyl, aryl, heteroaryl, aralkyl, or C4-C7 cycloalkyl, and wherein Q is optionally substituted with one or more halogen, OH and/or NH₂ groups.
12. The method of claim 10 or 11, wherein the halogen is at an ortho, meta or para position.
13. The method of any of claims 1-12, wherein the halogen is Cl, F, Br or I.
14. The method of any of claims 1-4, wherein Q is C3-C9 linear alkyl or heteroaryl.
15. The method of claim 1 or 2, wherein the compound is selected from the group consisting of

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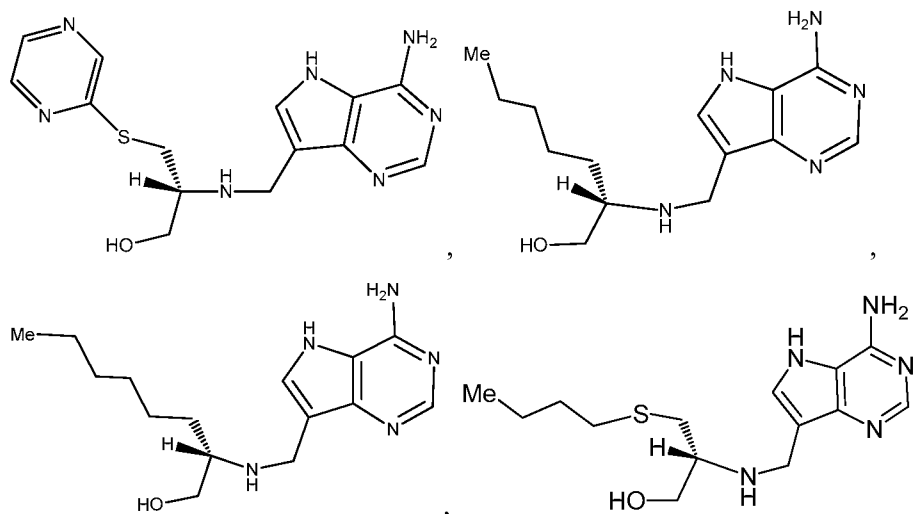


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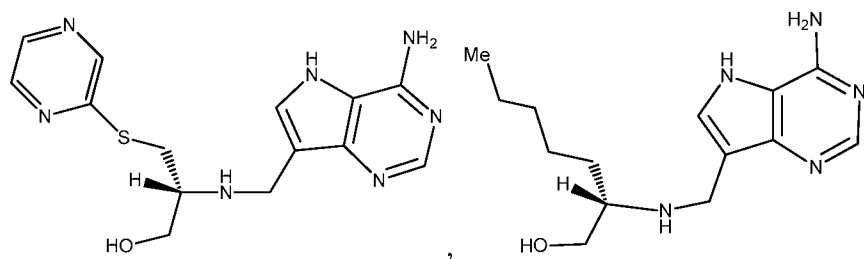
or a pharmaceutically acceptable salt thereof, or an ester thereof.

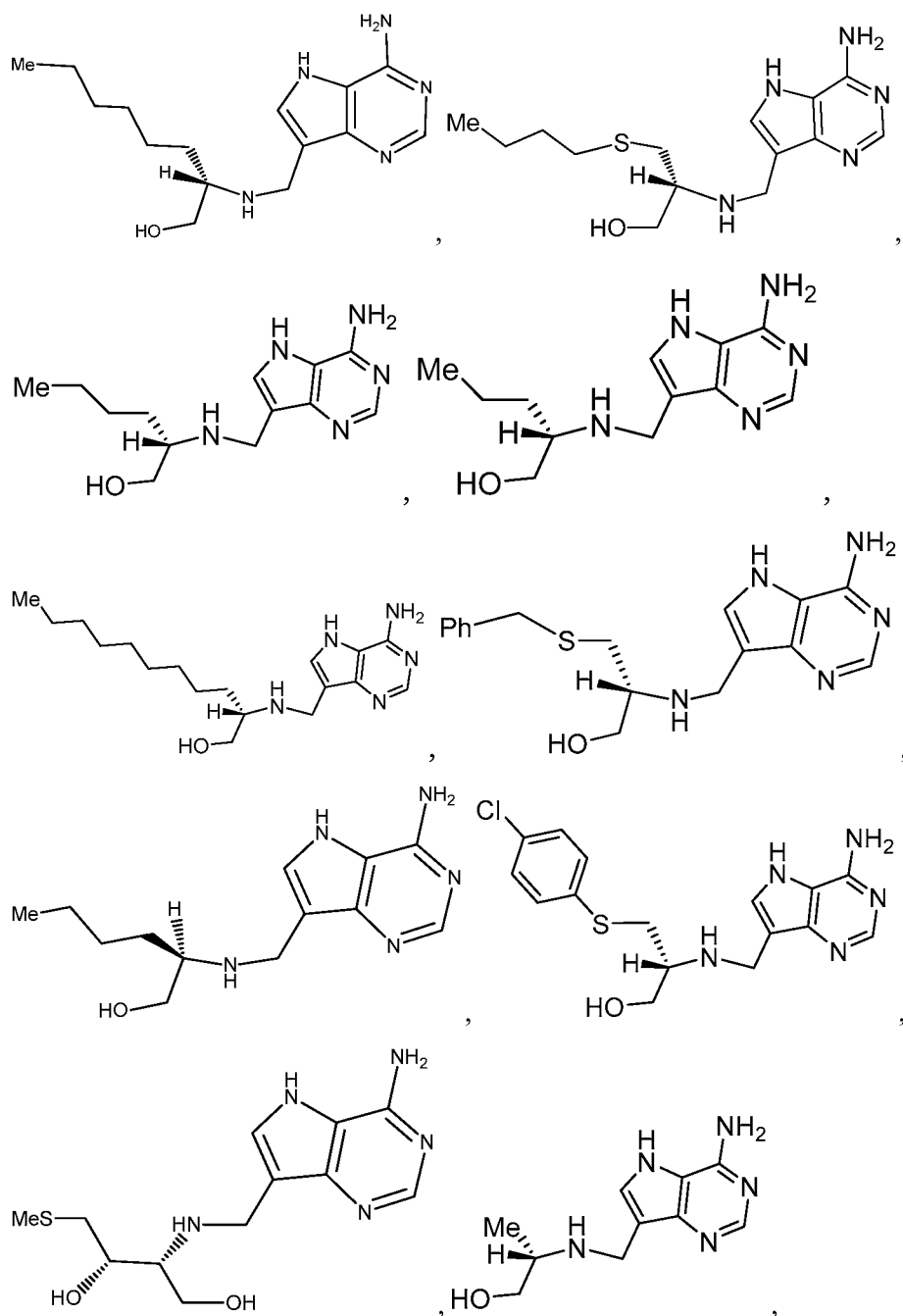
16. A method of treating a *Helicobacter pylori* (*H. pylori*) infection in a subject comprising administering to the subject a compound in an amount effective to inhibit growth of *H. pylori*, wherein the compound is selected from the group consisting of

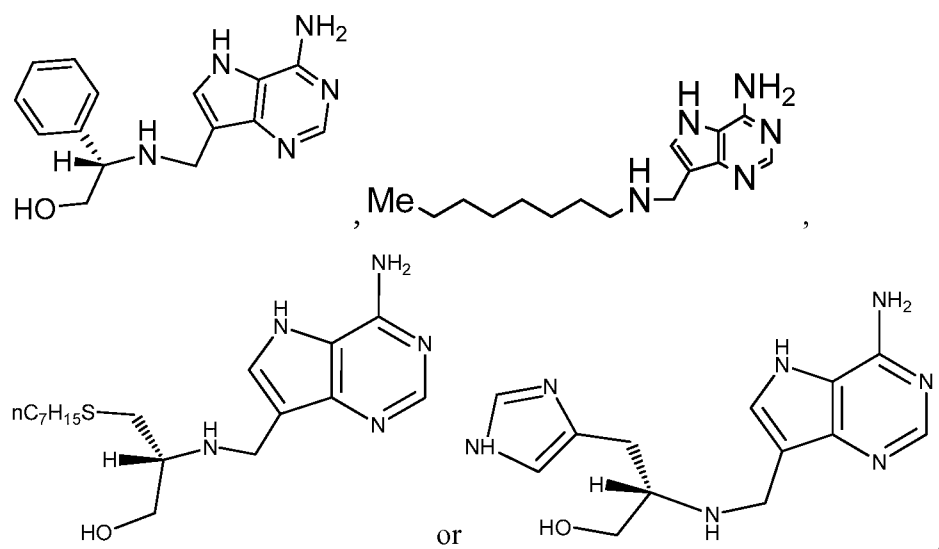


or a pharmaceutically acceptable salt thereof, or an ester thereof.

17. The method of any of claims 1-16, wherein the compound is administered in an amount that is effective to inhibit *H. pylori* 5'-methylthioadenosine nucleosidase (MTAN).
18. The method of any of claims 1-17, wherein the compound inhibits growth of *H. pylori* but does not inhibit the growth of one or more bacterium selected from the group consisting of *E. coli*, *V. cholerae*, *S. aureus*, *K. pneumoniae*, *S. flexneri*, *S. enterica* and *P. aeruginosa*.
19. The method of claim 18, wherein the compound does not inhibit the growth of all of *E. coli*, *V. cholerae*, *S. aureus*, *K. pneumoniae*, *S. flexneri*, *S. enterica* and *P. aeruginosa*.
20. The method of any of claims 1-19, wherein the compound is more effective in inhibiting growth of *H. pylori* than amoxicillin, metronidazole or tetracyclin.
21. The method of any of claims 1-20, wherein the subject has a peptic ulcer.
22. The method of any of claims 1-21, wherein the subject has a gastric ulcer or a duodenal ulcer.
23. The method of any of claims 1-23, wherein the compound is administered orally.
24. A compound having the structure







or a pharmaceutically acceptable salt thereof, or an ester thereof.

25. A pharmaceutical composition comprising a compound of claim 24 and a pharmaceutically acceptable carrier.

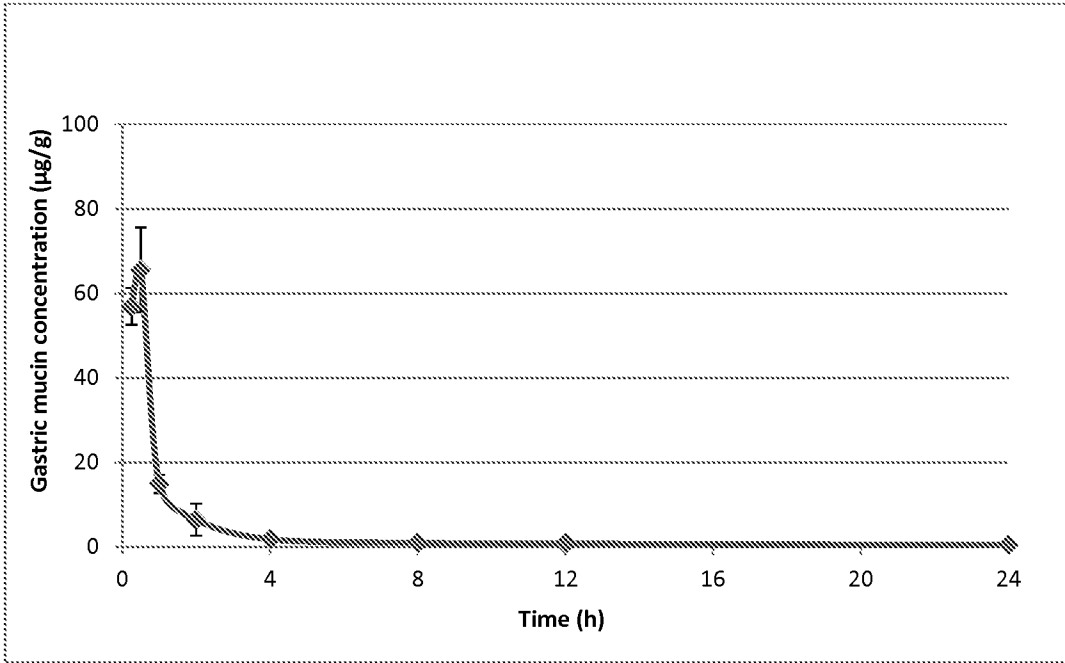


Fig. 1

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 15/14778

A. CLASSIFICATION OF SUBJECT MATTER IPC(8) - A01N 43/90 (2015.01) CPC - C07D 487/04; C07D 471/04; A61K 31/519 According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) USPC- 514/265.1		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched IPC(8)- A01N 43/90 (2015.01) CPC- C07D 487/04; C07D 471/04; A61K 31/519; USPC- 514/265.1; 544/280		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) PatBase (PGPB, USPT, USOC, EPAB, JPAB, DWPI, TDBD), FreePatentsOnline (US Pat, PgPub, EPO, JPO, WIPO, NPL), GoogleScholar (PL, NPL); search terms: treat Helicobacter pylori H pylori infection inhibit growth pylori pyrimidine purine nucleoside phosphorylase pyrrolo pyrimidine		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2011/0046167 A1 (Clinch et al.) 24 February 2011 (24.02.2011) Abstract, para [0001], [0021]-[0041], [0093]-[0095], [0115]-[0119], [0166]-[0228]	1-4, 15-16, 24-25
Y	US 2013/0274220 A1 (Schramm et al.) 17 October 2013 (17.10.2013) Abstract, para [0014]-[0022], pg 18, col 2	1-4, 15-16, 24-25
Y	WO 2008/115531 A1 (Lalani et al.) 25 September 2008 (25.09.2008) Abstract, para [0020], [0028], [0038]-[0041]	1-4, 15-16, 24-25
☐ Further documents are listed in the continuation of Box C. ☐		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 26 March 2015 (26.03.2015)		Date of mailing of the international search report 01 MAY. 2015
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300		Authorized officer: Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 15/14778

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☒ Claims Nos.: 5-14,17-23
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

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

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

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.