



(43) International Publication Date  
22 May 2014 (22.05.2014)

(10) International Publication Number  
**WO 2014/078645 A1**

(51) International Patent Classification:

*C07D 417/06* (2006.01) *A61P 35/00* (2006.01)  
*C07D 417/14* (2006.01) *A61P 37/00* (2006.01)  
*A61K 31/501* (2006.01) *A61P 25/28* (2006.01)

(21) International Application Number:

PCT/US2013/070277

(22) International Filing Date:

15 November 2013 (15.11.2013)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

61/727,195 16 November 2012 (16.11.2012) US  
61/824,434 17 May 2013 (17.05.2013) US

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

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

Published:

— with international search report (Art. 21(3))

(54) Title: HETEROCYCLIC GLUTAMINASE INHIBITORS

(57) Abstract: Disclosed herein are heterocyclic compounds containing thiadiazole and/or pyridazine rings, as well as pharmaceutic-  
al preparations thereof. The compounds herein are further made known to be useful as glutaminase inhibitors with potential uses in  
treating cancer, immunological and neurological diseases.



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## **Heterocyclic Glutaminase Inhibitors**

### **Related Applications**

This application claims the benefit of priority to U.S. Provisional Patent Application No. 61/727,195, filed November 16, 2012, and U.S. Provisional Patent Application No. 61/824,434, filed May 17, 2013, which applications are hereby  
5 incorporated by reference in their entirety.

### **Background**

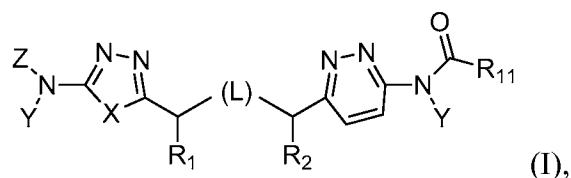
Glutamine supports cell survival, growth and proliferation through metabolic and non-metabolic mechanisms. In actively proliferating cells, the metabolism of  
10 glutamine to lactate, also referred to as “glutaminolysis” is a major source of energy in the form of NADPH. The first step in glutaminolysis is the deamination of glutamine to form glutamate and ammonia, which is catalyzed by the glutaminase enzyme. Thus, deamination via glutaminase is a control point for glutamine metabolism.

15 Ever since Warburg’s observation that ascites tumor cells exhibited high rates of glucose consumption and lactate secretion in the presence of oxygen (Warburg, 1956), researchers have been exploring how cancer cells utilize metabolic pathways to be able to continue actively proliferating. Several reports have demonstrated how glutamine metabolism supports macromolecular synthesis necessary for cells to  
20 replicate (Curthoys, 1995; DeBardinis, 2008).

Thus, glutaminase has been theorized to be a potential therapeutic target for the treatment of diseases characterized by actively proliferating cells, such as cancer. The lack of suitable glutaminase inhibitors has made validation of this target impossible. Therefore, the creation of glutaminase inhibitors that are specific and  
25 capable of being formulated for in vivo use could lead to a new class of therapeutics.


### **Summary of Invention**

The present invention provides a compound of formula I,



or a pharmaceutically acceptable salt thereof, wherein:

L represents  $\text{CH}_2\text{SCH}_2$ ,  $\text{CH}_2\text{CH}_2$ ,  $\text{CH}_2\text{CH}_2\text{CH}_2$ ,  $\text{CH}_2$ ,  $\text{CH}_2\text{S}$ ,  $\text{SCH}_2$ ,  $\text{CH}_2\text{NHCH}_2$ ,

$\text{CH}=\text{CH}$ , or , preferably  $\text{CH}_2\text{CH}_2$ , wherein any hydrogen atom of a CH or  $\text{CH}_2$  unit may be replaced by alkyl or alkoxy, any hydrogen of an NH unit may be replaced by alkyl, and any hydrogen atom of a  $\text{CH}_2$  unit of

5  $\text{CH}_2\text{CH}_2$ ,  $\text{CH}_2\text{CH}_2\text{CH}_2$  or  $\text{CH}_2$  may be replaced by hydroxy;

X represents S, O or  $\text{CH}=\text{CH}$ , preferably S or  $\text{CH}=\text{CH}$ , wherein any hydrogen atom of a CH unit may be replaced by alkyl;

Y, independently for each occurrence, represents H or  $\text{CH}_2\text{O}(\text{CO})\text{R}_7$ ;

10  $\text{R}_7$ , independently for each occurrence, represents H or substituted or unsubstituted alkyl, alkoxy, aminoalkyl, alkylaminoalkyl, heterocyclalkyl, arylalkyl, or heterocyclalkoxy;

Z represents H or  $\text{R}_3(\text{CO})$ ;

$\text{R}_1$  and  $\text{R}_2$  each independently represent H, alkyl, alkoxy or hydroxy;

15  $\text{R}_3$  represents substituted or unsubstituted alkyl, hydroxyalkyl, aminoalkyl, acylaminoalkyl, alkenyl, alkoxy, alkoxyalkyl, aryl, arylalkyl, aryloxy, aryloxyalkyl, cycloalkyl, cycloalkylalkyl, heterocycl, heterocyclalkyl, heteroaryl, heteroarylalkyl, heteroaryloxy, heteroaryloxyalkyl or  $\text{C}(\text{R}_8)(\text{R}_9)(\text{R}_{10})$ ,  $\text{N}(\text{R}_4)(\text{R}_5)$  or  $\text{OR}_6$ , wherein any free hydroxyl group may be acylated to form  $\text{C}(\text{O})\text{R}_7$ ;

20  $\text{R}_4$  and  $\text{R}_5$  each independently for each occurrence represent H or substituted or unsubstituted alkyl, hydroxyalkyl, acyl, aminoalkyl, acylaminoalkyl, alkenyl, alkoxyalkyl, aryl, arylalkyl, aryloxy, aryloxyalkyl, cycloalkyl, cycloalkylalkyl, heterocycl, heterocyclalkyl, heteroaryl, heteroarylalkyl, heteroaryloxy, or heteroaryloxyalkyl, wherein any free hydroxyl group may be acylated to form  $\text{C}(\text{O})\text{R}_7$ ;

25  $\text{R}_6$  represents substituted or unsubstituted alkyl, hydroxyalkyl, aminoalkyl, acylaminoalkyl, alkenyl, alkoxyalkyl, aryl, arylalkyl, aryloxy, aryloxyalkyl, cycloalkyl, cycloalkylalkyl, heterocycl, heterocyclalkyl, heteroaryl, heteroarylalkyl, heteroaryloxy, or heteroaryloxyalkyl, wherein any free hydroxyl group may be acylated to form  $\text{C}(\text{O})\text{R}_7$ ;

30  $\text{R}_8$ ,  $\text{R}_9$  and  $\text{R}_{10}$  each independently for each occurrence represent H or substituted or unsubstituted alkyl, hydroxy, hydroxyalkyl, amino, acylamino, aminoalkyl,

acylaminoalkyl, alkoxycarbonyl, alkoxycarbonylamino, alkenyl, alkoxy, alkoxyalkyl, aryl, arylalkyl, aryloxy, aryloxyalkyl, cycloalkyl, cycloalkylalkyl, heterocyclyl, heterocyclylalkyl, heteroaryl, heteroarylalkyl, heteroaryloxy, or heteroaryloxyalkyl, or R<sub>8</sub> and R<sub>9</sub> together with the carbon to which they are attached, form a carbocyclic or heterocyclic ring system, wherein any free hydroxyl group may be acylated to form C(O)R<sub>7</sub>, and wherein at least two of R<sub>8</sub>, R<sub>9</sub> and R<sub>10</sub> are not H;

R<sub>11</sub> represents aryl, arylalkyl, aryloxy, aryloxyalkyl, heteroaryl, heteroarylalkyl, heteroaryloxy, or heteroaryloxyalkyl, wherein the aryl or heteroaryl ring is substituted with either -OCHF<sub>2</sub> or -OCF<sub>3</sub> and is optionally further substituted, or R<sub>11</sub> represents C(R<sub>12</sub>)(R<sub>13</sub>)(R<sub>14</sub>), N(R<sub>4</sub>)(R<sub>14</sub>) or OR<sub>14</sub>, wherein any free hydroxyl group may be acylated to form C(O)R<sub>7</sub>;

R<sub>12</sub> and R<sub>13</sub> each independently represent H or substituted or unsubstituted alkyl, hydroxy, hydroxyalkyl, amino, acylamino, aminoalkyl, acylaminoalkyl, alkoxy, alkoxyalkyl, aryl, arylalkyl, aryloxy, aryloxyalkyl, cycloalkyl, cycloalkylalkyl, heterocyclyl, heterocyclylalkyl, heteroaryl, heteroarylalkyl, heteroaryloxy, or heteroaryloxyalkyl, wherein any free hydroxyl group may be acylated to form C(O)R<sub>7</sub>, and wherein both of R<sub>12</sub> and R<sub>13</sub> are not H; and

R<sub>14</sub> represents aryl, arylalkyl, aryloxy, aryloxyalkyl, heteroaryl, heteroarylalkyl, heteroaryloxy, or heteroaryloxyalkyl, wherein the aryl or heteroaryl ring is substituted with either -OCHF<sub>2</sub> or -OCF<sub>3</sub> and is optionally further substituted.

In certain embodiments, the present invention provides a pharmaceutical preparation suitable for use in a human patient, comprising an effective amount of any of the compounds described herein (e.g., a compound of the invention, such as a compound of formula I), and one or more pharmaceutically acceptable excipients. In certain embodiments, the pharmaceutical preparations may be for use in treating or preventing a condition or disease as described herein. In certain embodiments, the pharmaceutical preparations have a low enough pyrogen activity to be suitable for intravenous use in a human patient.

The present invention further provides methods of treating or preventing cancer, immunological or neurological diseases as described herein, comprising administering a compound of the invention.

### Detailed Description of the Drawings

Figures 1 shows the plasma concentration of compounds 585 and 295 over time following oral dosing of 50 mg/kg to female CD-1 mice.

Figure 2 shows the plasma concentration of compounds 447 and 318 over time following oral dosing of 50 mg/kg to female CD-1 mice.

Figure 3 shows the plasma concentration of compound 670 over time following oral dosing of 500, 250, 80 and 25 mg/kg, to female Sprague Dawley rats.

Figure 4 shows that oral administration of compound 670 to mice results in reduced tumor size in a H2122 lung adenocarcinoma xenograft model.

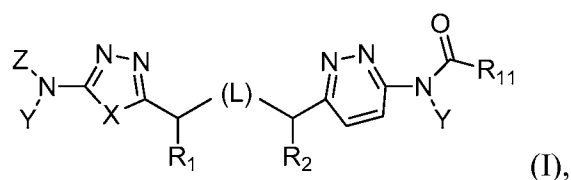
Figure 5 shows a combination study with compound 670 and paclitaxel in a JIMT-1 triple negative breast cancer xenograft model.

Figure 6 shows that oral administration of compound 670 to mice results in reduced tumor size in a RPMI-8226 multiple myeloma xenograft model.

Figure 7 shows that compound 670 synergizes with pomalidomide or dexamethasone to produce an anti-tumor effect in multiple myeloma cells.


### Detailed Description of the Invention

The present invention provides a compound of formula I,



or a pharmaceutically acceptable salt thereof, wherein:

L represents CH<sub>2</sub>SCH<sub>2</sub>, CH<sub>2</sub>CH<sub>2</sub>, CH<sub>2</sub>CH<sub>2</sub>CH<sub>2</sub>, CH<sub>2</sub>, CH<sub>2</sub>S, SCH<sub>2</sub>, CH<sub>2</sub>NHCH<sub>2</sub>,

CH=CH, or , preferably CH<sub>2</sub>CH<sub>2</sub>, wherein any hydrogen atom of a CH or CH<sub>2</sub> unit may be replaced by alkyl or alkoxy, any hydrogen of an NH unit may be replaced by alkyl, and any hydrogen atom of a CH<sub>2</sub> unit of CH<sub>2</sub>CH<sub>2</sub>, CH<sub>2</sub>CH<sub>2</sub>CH<sub>2</sub> or CH<sub>2</sub> may be replaced by hydroxy;

X represents S, O or CH=CH, preferably S or CH=CH, wherein any hydrogen atom of a CH unit may be replaced by alkyl;

Y, independently for each occurrence, represents H or CH<sub>2</sub>O(CO)R<sub>7</sub>;

R<sub>7</sub>, independently for each occurrence, represents H or substituted or unsubstituted

5       alkyl, alkoxy, aminoalkyl, alkylaminoalkyl, heterocyclalkyl, arylalkyl, or heterocyclalkoxy;

Z represents H or R<sub>3</sub>(CO);

R<sub>1</sub> and R<sub>2</sub> each independently represent H, alkyl, alkoxy or hydroxy;

R<sub>3</sub> represents substituted or unsubstituted alkyl, hydroxyalkyl, aminoalkyl,

10       acylaminoalkyl, alkenyl, alkoxy, alkoxyalkyl, aryl, arylalkyl, aryloxy, aryloxyalkyl, cycloalkyl, cycloalkylalkyl, heterocycl, heterocyclalkyl, heteroaryl, heteroarylalkyl, heteroaryloxy, heteroaryloxyalkyl or C(R<sub>8</sub>)(R<sub>9</sub>)(R<sub>10</sub>), N(R<sub>4</sub>)(R<sub>5</sub>) or OR<sub>6</sub>, wherein any free hydroxyl group may be acylated to form C(O)R<sub>7</sub>;

15       R<sub>4</sub> and R<sub>5</sub> each independently for each occurrence represent H or substituted or unsubstituted alkyl, hydroxyalkyl, acyl, aminoalkyl, acylaminoalkyl, alkenyl, alkoxyalkyl, aryl, arylalkyl, aryloxy, aryloxyalkyl, cycloalkyl, cycloalkylalkyl, heterocycl, heterocyclalkyl, heteroaryl, heteroarylalkyl, heteroaryloxy, or heteroaryloxyalkyl, wherein any free hydroxyl group may be acylated to form  
20       C(O)R<sub>7</sub>;

R<sub>6</sub> represents substituted or unsubstituted alkyl, hydroxyalkyl, aminoalkyl, acylaminoalkyl, alkenyl, alkoxyalkyl, aryl, arylalkyl, aryloxy, aryloxyalkyl, cycloalkyl, cycloalkylalkyl, heterocycl, heterocyclalkyl, heteroaryl, heteroarylalkyl, heteroaryloxy, or heteroaryloxyalkyl, wherein any free  
25       hydroxyl group may be acylated to form C(O)R<sub>7</sub>; and

R<sub>8</sub>, R<sub>9</sub> and R<sub>10</sub> each independently for each occurrence represent H or substituted or unsubstituted alkyl, hydroxy, hydroxyalkyl, amino, acylamino, aminoalkyl, acylaminoalkyl, alkoxycarbonyl, alkoxycarbonylamino, alkenyl, alkoxy, alkoxyalkyl, aryl, arylalkyl, aryloxy, aryloxyalkyl, cycloalkyl, cycloalkylalkyl, heterocycl, heterocyclalkyl, heteroaryl, heteroarylalkyl, heteroaryloxy, or heteroaryloxyalkyl, or R<sub>8</sub> and R<sub>9</sub> together with the carbon to which they are  
30       attached, form a carbocyclic or heterocyclic ring system, wherein any free

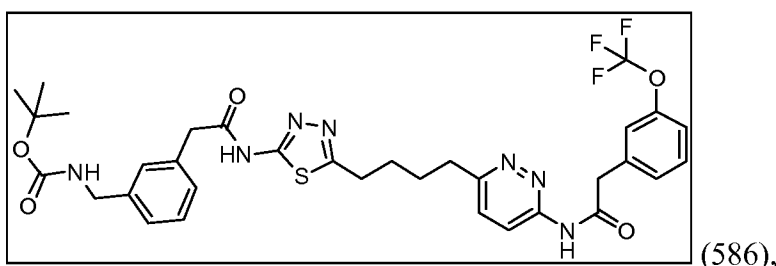
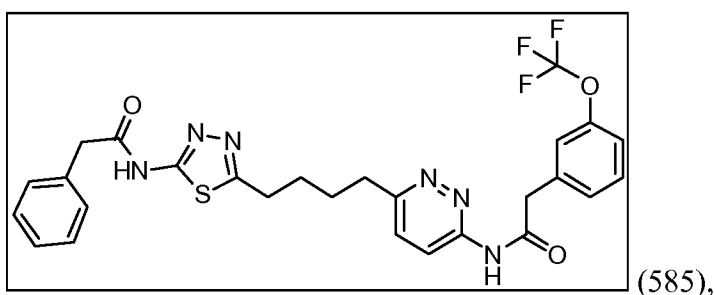
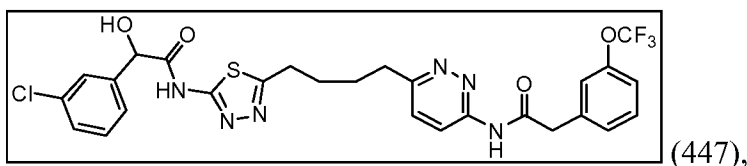
hydroxyl group may be acylated to form C(O)R<sub>7</sub>, and wherein at least two of R<sub>8</sub>, R<sub>9</sub> and R<sub>10</sub> are not H;

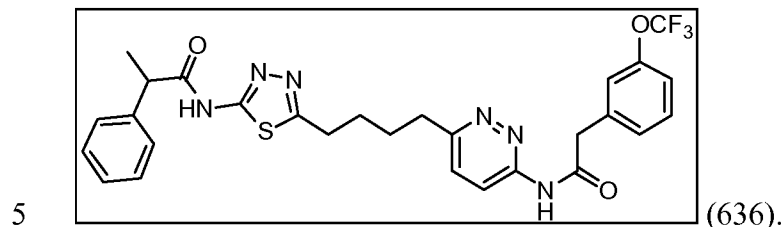
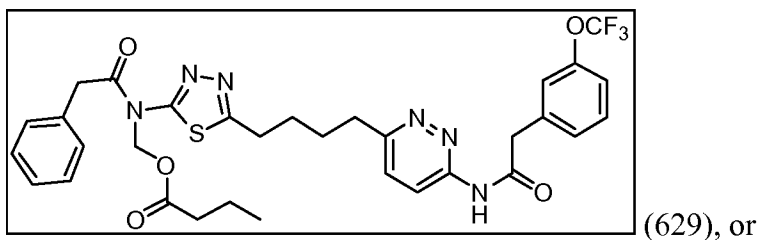
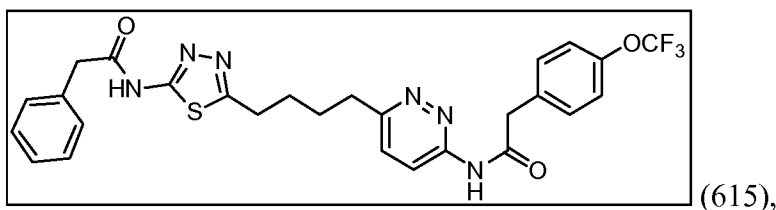
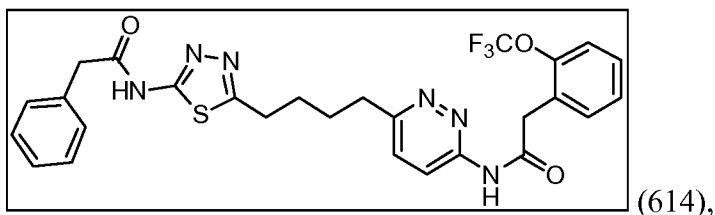
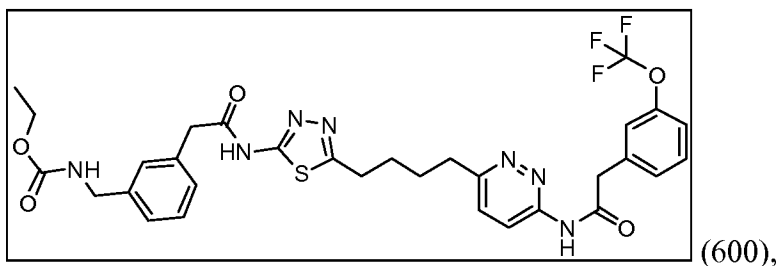
R<sub>11</sub> represents aryl, arylalkyl, aryloxy, aryloxyalkyl, heteroaryl, heteroarylalkyl, heteroaryloxy, or heteroaryloxyalkyl, wherein the aryl or heteroaryl ring is substituted with either -OCHF<sub>2</sub> or -OCF<sub>3</sub> and is optionally further substituted, or R<sub>11</sub> represents C(R<sub>12</sub>)(R<sub>13</sub>)(R<sub>14</sub>), N(R<sub>4</sub>)(R<sub>14</sub>) or OR<sub>14</sub>, wherein any free hydroxyl group may be acylated to form C(O)R<sub>7</sub>;

R<sub>12</sub> and R<sub>13</sub> each independently represent H or substituted or unsubstituted alkyl, hydroxy, hydroxyalkyl, amino, acylamino, aminoalkyl, acylaminoalkyl, alkoxy, alkoxyalkyl, aryl, arylalkyl, aryloxy, aryloxyalkyl, cycloalkyl, cycloalkylalkyl, heterocycl, heterocyclalkyl, heteroaryl, heteroarylalkyl, heteroaryloxy, or heteroaryloxyalkyl, wherein any free hydroxyl group may be acylated to form C(O)R<sub>7</sub>, and wherein both of R<sub>12</sub> and R<sub>13</sub> are not H; and

R<sub>14</sub> represents aryl, arylalkyl, aryloxy, aryloxyalkyl, heteroaryl, heteroarylalkyl, heteroaryloxy, or heteroaryloxyalkyl, wherein the aryl or heteroaryl ring is substituted with either -OCHF<sub>2</sub> or -OCF<sub>3</sub> and is optionally further substituted.

In certain embodiments, the compound is not one of the following:



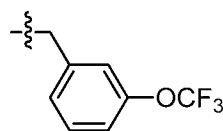


In certain embodiments wherein alkyl, hydroxyalkyl, amino, acylamino, aminoalkyl, acylaminoalkyl, alkenyl, alkoxy, alkoxyalkyl, aryl, arylalkyl, aryloxy, aryloxyalkyl, cycloalkyl, cycloalkylalkyl, heterocyclyl, heterocyclylalkyl, heteroaryl, heteroarylalkyl, heteroaryloxy, or heteroaryloxyalkyl are substituted, they are substituted with one or more substituents selected from substituted or unsubstituted alkyl, such as perfluoroalkyl (e.g., trifluoromethyl), alkenyl, alkoxy, alkoxyalkyl, aryl, aralkyl, arylalkoxy, aryloxy, aryloxyalkyl, hydroxyl, halo, alkoxy, such as perfluoroalkoxy (e.g., trifluoromethoxy), alkoxyalkoxy, hydroxyalkyl, hydroxyalkylamino, hydroxyalkoxy, amino, aminoalkyl, alkylamino, aminoalkylalkoxy, aminoalkoxy, acylamino, acylaminoalkyl, such as perfluoro acylaminoalkyl (e.g., trifluoromethylacylaminoalkyl), acyloxy, cycloalkyl,



cycloalkylalkyl, cycloalkylalkoxy, heterocyclyl, heterocyclylalkyl, heterocyclloxy, heterocyclylalkoxy, heteroaryl, heteroarylalkyl, heteroarylalkoxy, heteroaryloxy, heteroaryloxyalkyl, heterocyclylaminoalkyl, heterocyclylaminoalkoxy, amido, amidoalkyl, amidine, imine, oxo, carbonyl (such as carboxyl, alkoxycarbonyl, formyl, or acyl, including perfluoroacyl (e.g., C(O)CF<sub>3</sub>)), carbonylalkyl (such as carboxyalkyl, alkoxycarbonylalkyl, formylalkyl, or acylalkyl, including perfluoroacylalkyl (e.g., -alkylC(O)CF<sub>3</sub>)), carbamate, carbamatealkyl, urea, ureaalkyl, sulfate, sulfonate, sulfamoyl, sulfone, sulfonamide, sulfonamidealkyl, cyano, nitro, azido, sulfhydryl, alkylthio, thiocarbonyl (such as thioester, thioacetate, or thioformate), phosphoryl, phosphate, phosphonate or phosphinate.

In certain embodiments, R<sub>11</sub> represents arylalkyl, such as benzyl, wherein the aryl group is substituted with -OCF<sub>3</sub>, such as meta-substituted with -OCF<sub>3</sub>. In certain such embodiments, the aryl ring is not further substituted. In certain embodiments,



R<sub>11</sub> represents trifluoromethoxybenzyl, such as

In certain embodiments, L represents CH<sub>2</sub>SCH<sub>2</sub>, CH<sub>2</sub>CH<sub>2</sub>, CH<sub>2</sub>CH<sub>2</sub>CH<sub>2</sub>, CH<sub>2</sub>, CH<sub>2</sub>S, SCH<sub>2</sub>, or CH<sub>2</sub>NHCH<sub>2</sub>, wherein any hydrogen atom of a CH<sub>2</sub> unit may be replaced by alkyl or alkoxy, and any hydrogen atom of a CH<sub>2</sub> unit of CH<sub>2</sub>CH<sub>2</sub>, CH<sub>2</sub>CH<sub>2</sub>CH<sub>2</sub> or CH<sub>2</sub> may be replaced by hydroxyl. In certain embodiments, L represents CH<sub>2</sub>SCH<sub>2</sub>, CH<sub>2</sub>CH<sub>2</sub>, CH<sub>2</sub>S or SCH<sub>2</sub>. In certain embodiments, L represents CH<sub>2</sub>CH<sub>2</sub>. In certain embodiments, L is not CH<sub>2</sub>SCH<sub>2</sub>.

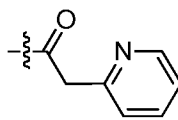
In certain embodiments, Y represents H.

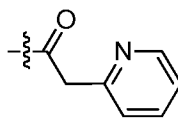
In certain embodiments, X represents S or CH=CH. In certain embodiments, X represents S.

In certain embodiments, Z represents R<sub>3</sub>(CO). In certain embodiments wherein Z is R<sub>3</sub>(CO), R<sub>3</sub> and R<sub>11</sub> are not identical (e.g., the compound of formula I is not symmetrical).

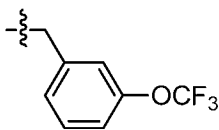
In certain embodiments, R<sub>1</sub> and R<sub>2</sub> each represent H.

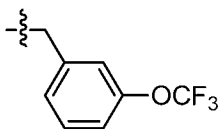
In certain embodiments, Z represents R<sub>3</sub>(CO) and R<sub>3</sub> represents arylalkyl, heteroarylalkyl, cycloalkyl or heterocycloalkyl. In certain embodiments, Z represents R<sub>3</sub>(CO) and R<sub>3</sub> represents heteroarylalkyl, such as pyridylalkyl (e.g., pyridylmethyl).

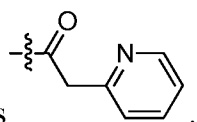


In certain such embodiments, Z represents . In certain embodiments, Z represents  $R_3(CO)$  and  $R_3$  represents  $C(R_8)(R_9)(R_{10})$ , wherein  $R_8$  represents aryl, arylalkyl, heteroaryl or heteroaralkyl, such as aryl, arylalkyl or heteroaryl,  $R_9$  represents H, and  $R_{10}$  represents hydroxy, hydroxyalkyl, alkoxy or alkoxyalkyl, such as hydroxy, hydroxyalkyl or alkoxy.

In certain embodiments, L represents  $CH_2SCH_2$ ,  $CH_2CH_2$ ,  $CH_2S$  or  $SCH_2$ , such as  $CH_2CH_2$ , Y represents H, X represents S, Z represents  $R_3(CO)$ ,  $R_1$  and  $R_2$  each represent H,  $R_3$  represents arylalkyl, heteroarylalkyl, cycloalkyl or heterocycloalkyl, such as heteroarylalkyl (e.g., pyridylalkyl), and  $R_{11}$  represents arylalkyl, such

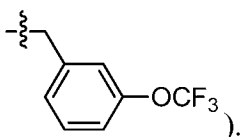


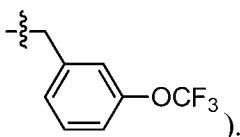
trifluoromethoxybenzyl (e.g., ). In certain such embodiments, Z represents  $R_3(CO)$  and  $R_3$  represents pyridylmethyl, such as wherein Z



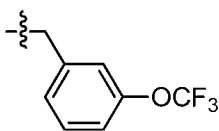
represents

In certain embodiments, L represents  $CH_2SCH_2$ ,  $CH_2CH_2$ ,  $CH_2S$  or  $SCH_2$ , such as  $CH_2CH_2$ , Y represents H, X represents S, Z represents  $R_3(CO)$ ,  $R_1$  and  $R_2$  each represent H, and each  $R_3$  represents  $C(R_8)(R_9)(R_{10})$ , wherein  $R_8$  represents aryl, arylalkyl, heteroaryl or heteroaralkyl, such as aryl, arylalkyl or heteroaryl,  $R_9$  represents H, and  $R_{10}$  represents hydroxy, hydroxyalkyl, alkoxy or alkoxyalkyl, such as hydroxy, hydroxyalkyl or alkoxy, and  $R_{11}$  represents arylalkyl, such



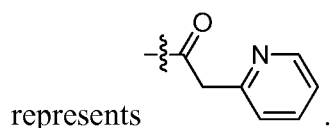
trifluoromethoxybenzyl (e.g., ).

In certain embodiments, L represents  $CH_2CH_2$ , Y represents H, X represents S or  $CH=CH$ , such as S, Z represents  $R_3(CO)$ ,  $R_1$  and  $R_2$  each represent H,  $R_3$  represents substituted or unsubstituted arylalkyl, heteroarylalkyl, cycloalkyl or heterocycloalkyl, such as heteroarylalkyl (e.g., pyridylalkyl), and  $R_{11}$  represents arylalkyl, such

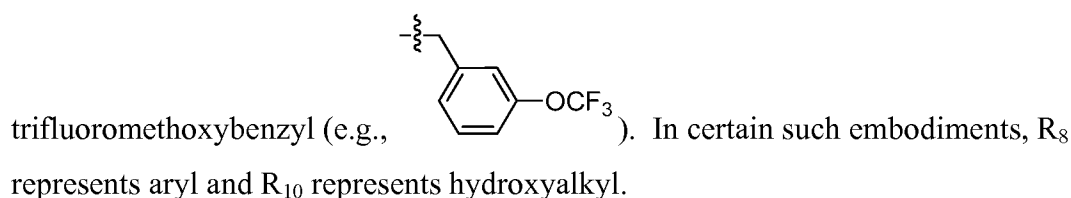


trifluoromethoxybenzyl (e.g., ). In certain such embodiments, Z

represents  $R_3(CO)$  and  $R_3$  represents pyridylmethyl, such as wherein Z



In certain embodiments, L represents  $CH_2CH_2$ , Y represents H, X represents S, Z represents  $R_3(CO)$ ,  $R_1$  and  $R_2$  each represent H,  $R_3$  represents  $C(R_8)(R_9)(R_{10})$ ,  
 5 wherein  $R_8$  represents aryl, arylalkyl or heteroaryl,  $R_9$  represents H, and  $R_{10}$  represents hydroxy, hydroxyalkyl or alkoxy, and  $R_{11}$  represents arylalkyl, such



In certain embodiments, the compound is selected from compound 447, 585,  
 10 586, 600, 614, 615, 629, 636, 657, 658, 659, 660, 661, 662, 663, 666, 668, 669, 670, 671, 672, 673, 674, 675, 676, 677, 678, 679, 680, 681, 682, 683, 684, 685, 686, 687, 688, 689, 690, 692, 693, 694, 695, 696, 697, 698, 699, 700, 701, 702, 703, 704, 705, 706, 707, 708, 709, 715, 716, 717, 718, 719, 720, 721, 722, 723, 724, 725, 726, 727, 728, 729, or 730. In certain embodiments, the compound is selected from compound  
 15 657, 658, 659, 660, 661, 662, 663, 666, 668, 669, 670, 671, 672, 673, 674, 675, 676, 677, 678, 679, 680, 681, 682, 683, 684, 685, 686, 687, 688, 689, 690, 692, 693, 694, 695, 696, 697, 698, 699, 700, 701, 702, 703, 704, 705, 706, 707, 708, 709, 715, 716, 717, 718, 719, 720, 721, 722, 723, 724, 725, 726, 727, 728, 729, or 730.

In certain embodiments, compounds of the invention may be prodrugs of the  
 20 compounds of formula I, e.g., wherein a hydroxyl in the parent compound is presented as an ester or a carbonate, or carboxylic acid present in the parent compound is presented as an ester. In certain such embodiments, the prodrug is metabolized to the active parent compound in vivo (e.g., the ester is hydrolyzed to the corresponding hydroxyl, or carboxylic acid).

25 In certain embodiments, compounds of the invention may be racemic. In certain embodiments, compounds of the invention may be enriched in one enantiomer. For example, a compound of the invention may have greater than 30% ee, 40% ee, 50% ee, 60% ee, 70% ee, 80% ee, 90% ee, or even 95% or greater ee. In certain embodiments, compounds of the invention may have more than one

stereocenter. In certain such embodiments, compounds of the invention may be enriched in one or more diastereomer. For example, a compound of the invention may have greater than 30% de, 40% de, 50% de, 60% de, 70% de, 80% de, 90% de, or even 95% or greater de.

5           In certain embodiments, the present invention relates to methods of treatment with a compound of formula I, or a pharmaceutically acceptable salt thereof. In certain embodiments, the therapeutic preparation may be enriched to provide predominantly one enantiomer of a compound (e.g., of formula I). An enantiomerically enriched mixture may comprise, for example, at least 60 mol percent  
10 of one enantiomer, or more preferably at least 75, 90, 95, or even 99 mol percent. In certain embodiments, the compound enriched in one enantiomer is substantially free of the other enantiomer, wherein substantially free means that the substance in question makes up less than 10%, or less than 5%, or less than 4%, or less than 3%, or less than 2%, or less than 1% as compared to the amount of the other enantiomer, *e.g.*,  
15 in the composition or compound mixture. For example, if a composition or compound mixture contains 98 grams of a first enantiomer and 2 grams of a second enantiomer, it would be said to contain 98 mol percent of the first enantiomer and only 2% of the second enantiomer.

          In certain embodiments, the therapeutic preparation may be enriched to  
20 provide predominantly one diastereomer of a compound (e.g., of formula I). A diastereomerically enriched mixture may comprise, for example, at least 60 mol percent of one diastereomer, or more preferably at least 75, 90, 95, or even 99 mol percent.

          In certain embodiments, the present invention relates to methods of treatment  
25 with a compound of formula I, or a pharmaceutically acceptable salt thereof. In certain embodiments, the therapeutic preparation may be enriched to provide predominantly one enantiomer of a compound (e.g., of formula I). An enantiomerically enriched mixture may comprise, for example, at least 60 mol percent of one enantiomer, or more preferably at least 75, 90, 95, or even 99 mol percent. In  
30 certain embodiments, the compound enriched in one enantiomer is substantially free of the other enantiomer, wherein substantially free means that the substance in question makes up less than 10%, or less than 5%, or less than 4%, or less than 3%, or less than 2%, or less than 1% as compared to the amount of the other enantiomer, *e.g.*,

in the composition or compound mixture. For example, if a composition or compound mixture contains 98 grams of a first enantiomer and 2 grams of a second enantiomer, it would be said to contain 98 mol percent of the first enantiomer and only 2% of the second enantiomer.

5 In certain embodiments, the therapeutic preparation may be enriched to provide predominantly one diastereomer of a compound (e.g., of formula I). A diastereomerically enriched mixture may comprise, for example, at least 60 mol percent of one diastereomer, or more preferably at least 75, 90, 95, or even 99 mol percent.

10 In certain embodiments, the present invention provides a pharmaceutical preparation suitable for use in a human patient, comprising any of the compounds shown above (e.g., a compound of the invention, such as a compound of formula I), and one or more pharmaceutically acceptable excipients. In certain embodiments, the pharmaceutical preparations may be for use in treating or preventing a condition or  
15 disease as described herein. In certain embodiments, the pharmaceutical preparations have a low enough pyrogen activity to be suitable for use in a human patient.

Compounds of any of the above structures may be used in the manufacture of medicaments for the treatment of any diseases or conditions disclosed herein.

#### Uses of enzyme inhibitors

20 Glutamine plays an important role as a carrier of nitrogen, carbon, and energy. It is used for hepatic urea synthesis, for renal ammoniogenesis, for gluconeogenesis, and as respiratory fuel for many cells. The conversion of glutamine into glutamate is initiated by the mitochondrial enzyme, glutaminase ("GLS"). There are two major forms of the enzyme, K-type and L-type, which are distinguished by  
25 their  $K_m$  values for glutamine and response to glutamate, wherein the  $K_m$  value, or Michaelis constant, is the concentration of substrate required to reach half the maximal velocity. The L-type, also known as "liver-type" or GLS2, has a high  $K_m$  for glutamine and is glutamate resistant. The K-type, also known as "kidney-type" or GLS1, has a low  $K_m$  for glutamine and is inhibited by glutamate. An alternative  
30 splice form of GLS1, referred to as glutaminase C or "GAC", has been identified recently and has similar activity characteristics of GLS1. In certain embodiments, the compounds may selectively inhibit GLS1, GLS2 and GAC. In a preferred embodiment, the compounds selectively inhibit GLS1 and GAC.

In addition to serving as the basic building blocks of protein synthesis, amino acids have been shown to contribute to many processes critical for growing and dividing cells, and this is particularly true for cancer cells. Nearly all definitions of cancer include reference to dysregulated proliferation. Numerous studies on

5 glutamine metabolism in cancer indicate that many tumors are avid glutamine consumers (Souba, Ann. Surg., 1993; Collins et al., J. Cell. Physiol., 1998; Medina, J. Nutr., 2001; Shanware et al., J. Mol. Med., 2011). An embodiment of the invention is the use of the compounds described herein for the treatment of cancer.

In certain embodiments, the cancer may be one or a variant of Acute

10 Lymphoblastic Leukemia (ALL), Acute Myeloid Leukemia (AML), Adrenocortical Carcinoma, AIDS-Related Cancers (Kaposi Sarcoma and Lymphoma), Anal Cancer, Appendix Cancer, Atypical Teratoid/Rhabdoid Tumor, Basal Cell Carcinoma, Bile Duct Cancer (including Extrahepatic), Bladder Cancer, Bone Cancer (including Osteosarcoma and Malignant Fibrous Histiocytoma), Brain Tumor (such as

15 Astrocytomas, Brain and Spinal Cord Tumors, Brain Stem Glioma, Central Nervous System Atypical Teratoid/Rhabdoid Tumor, Central Nervous System Embryonal Tumors, Craniopharyngioma, Ependymoblastoma, Ependymoma, Medulloblastoma, Medulloepithelioma, Pineal Parenchymal Tumors of Intermediate Differentiation, Supratentorial Primitive Neuroectodermal Tumors and Pineoblastoma), Breast

20 Cancer, Bronchial Tumors, Burkitt Lymphoma, Basal Cell Carcinoma, Bile Duct Cancer (including Extrahepatic), Bladder Cancer, Bone Cancer (including Osteosarcoma and Malignant Fibrous Histiocytoma), Carcinoid Tumor, Carcinoma of Unknown Primary, Central Nervous System (such as Atypical Teratoid/Rhabdoid Tumor, Embryonal Tumors and Lymphoma), Cervical Cancer, Childhood Cancers,

25 Chordoma, Chronic Lymphocytic Leukemia (CLL), Chronic Myelogenous Leukemia (CML), Chronic Myeloproliferative Disorders, Colon Cancer, Colorectal Cancer, Craniopharyngioma, Cutaneous T-Cell Lymphoma (Mycosis Fungoides and Sézary Syndrome), Duct, Bile (Extrahepatic), Ductal Carcinoma In Situ (DCIS), Embryonal Tumors (Central Nervous System), Endometrial Cancer, Ependymoblastoma,

30 Ependymoma, Esophageal Cancer, Esthesioneuroblastoma, Ewing Sarcoma Family of Tumors, Extracranial Germ Cell Tumor, Extragonadal Germ Cell Tumor, Extrahepatic Bile Duct Cancer, Eye Cancer (like Intraocular Melanoma, Retinoblastoma), Fibrous Histiocytoma of Bone (including Malignant and

Osteosarcoma) Gallbladder Cancer, Gastric (Stomach) Cancer, Gastrointestinal  
 Carcinoid Tumor, Gastrointestinal Stromal Tumors (GIST), Germ Cell Tumor  
 (Extracranial, Extragonadal, Ovarian), Gestational Trophoblastic Tumor, Glioma,  
 Hairy Cell Leukemia, Head and Neck Cancer, Heart Cancer, Hepatocellular (Liver)  
 5 Cancer, Histiocytosis, Langerhans Cell, Hodgkin Lymphoma, Hypopharyngeal  
 Cancer, Intraocular Melanoma, Islet Cell Tumors (Endocrine, Pancreas), Kaposi  
 Sarcoma, Kidney (including Renal Cell), Langerhans Cell Histiocytosis, Laryngeal  
 Cancer, Leukemia (including Acute Lymphoblastic (ALL), Acute Myeloid (AML),  
 Chronic Lymphocytic (CLL), Chronic Myelogenous (CML), Hairy Cell), Lip and  
 10 Oral Cavity Cancer, Liver Cancer (Primary), Lobular Carcinoma In Situ (LCIS), Lung  
 Cancer (Non-Small Cell and Small Cell), Lymphoma (AIDS-Related, Burkitt,  
 Cutaneous T-Cell (Mycosis Fungoides and Sézary Syndrome), Hodgkin, Non-  
 Hodgkin, Primary Central Nervous System (CNS), Macroglobulinemia,  
 Waldenström, Male Breast Cancer, Malignant Fibrous Histiocytoma of Bone and  
 15 Osteosarcoma, Medulloblastoma, Medulloepithelioma, Melanoma (including  
 Intraocular (Eye)), Merkel Cell Carcinoma, Mesothelioma (Malignant), Metastatic  
 Squamous Neck Cancer with Occult Primary, Midline Tract Carcinoma Involving  
*NUT* Gene, Mouth Cancer, Multiple Endocrine Neoplasia Syndromes, Multiple  
 Myeloma/Plasma Cell Neoplasm, Mycosis Fungoides, Myelodysplastic Syndromes,  
 20 Myelodysplastic/Myeloproliferative Neoplasms, Myelogenous Leukemia, Chronic  
 (CML), Myeloid Leukemia, Acute (AML), Myeloma and Multiple Myeloma,  
 Myeloproliferative Disorders (Chronic), Nasal Cavity and Paranasal Sinus Cancer,  
 Nasopharyngeal Cancer, Neuroblastoma, Non-Hodgkin Lymphoma (both B-cell and  
 T-cell subtypes), Non-Small Cell Lung Cancer, Oral Cancer, Oral Cavity Cancer, Lip  
 25 and, Oropharyngeal Cancer, Osteosarcoma and Malignant Fibrous Histiocytoma of  
 Bone, Ovarian Cancer (such as Epithelial, Germ Cell Tumor, and Low Malignant  
 Potential Tumor), Pancreatic Cancer (including Islet Cell Tumors), Papillomatosis,  
 Paraganglioma, Paranasal Sinus and Nasal Cavity Cancer, Parathyroid Cancer, Penile  
 Cancer, Pharyngeal Cancer, Pheochromocytoma, Pineal Parenchymal Tumors of  
 30 Intermediate Differentiation, Pineoblastoma and Supratentorial Primitive  
 Neuroectodermal Tumors, Pituitary Tumor, Plasma Cell Neoplasm/Multiple  
 Myeloma, Pleuropulmonary Blastoma, Pregnancy and Breast Cancer, Primary Central  
 Nervous System (CNS) Lymphoma, Prostate Cancer, Rectal Cancer, Renal Cell

(Kidney) Cancer (RCC), Renal Pelvis and Ureter, Transitional Cell Cancer, Retinoblastoma, Rhabdomyosarcoma, Salivary Gland Cancer, Sarcoma (like Ewing Sarcoma Family of Tumors, Kaposi, Soft Tissue, Uterine), Sézary Syndrome, Skin Cancer (such as Melanoma, Merkel Cell Carcinoma, Nonmelanoma), Small Cell Lung Cancer, Small Intestine Cancer, Soft Tissue Sarcoma, Squamous Cell Carcinoma, Squamous cell carcinoma of the head and neck (HNSCC), Squamous Neck Cancer with Occult Primary, Metastatic, Stomach (Gastric) Cancer, Supratentorial Primitive Neuroectodermal Tumors, T-Cell Lymphoma (Cutaneous, Mycosis Fungoides and Sézary Syndrome), Testicular Cancer, Throat Cancer, Thymoma and Thymic Carcinoma, Thyroid Cancer, Transitional Cell Cancer of the Renal Pelvis and Ureter, Triple Negative Breast Cancer (TNBC), Trophoblastic Tumor (Gestational), Unknown Primary, Unusual Cancers of Childhood, Ureter and Renal Pelvis, Transitional Cell Cancer, Urethral Cancer, Uterine Cancer, Endometrial, Uterine Sarcoma, Waldenström Macroglobulinemia and Wilms Tumor. Figures 4, 5 and 6 show that a compound of the invention reduces tumor sizes in xenograft models of lung adenocarcinoma, breast cancer and multiple myeloma, demonstrating that the compounds described herein may be used for the treatment of a variety of cancers.

In some instances, oncogenic mutations promote glutamine metabolism. Cells expressing oncogenic K-Ras exhibit increased utilization of glutamine (Weinberg et al., Proc. Natl. Acad. Sci. USA, 2010; Gaglio et al., Mol. Syst. Biol., 2011). In certain embodiments, the cancer cells have a mutated K-Ras gene. In certain embodiments, the cancer is associated with tissue of the bladder, bone marrow, breast, colon, kidney, liver, lung, ovary, pancreas, prostate, skin or thyroid. The c-Myc gene is known to be altered in numerous cancers (Zeller et al., Genome biology, 2003). Increased Myc protein expression has been correlated with increased expression of glutaminase, leading to up-regulation of glutamine metabolism (Dang et al., Clin. Cancer Res., 2009; Gao et al., Nature, 2009). In certain embodiments, the cancer cells have an oncogenic c-Myc gene or elevated Myc protein expression. In some embodiments, the cancer is associated with tissue of the bladder, bone, bowel, breast, central nervous system (like brain), colon, gastric system (such as stomach and intestine), liver, lung, ovary, prostate, muscle, and skin.

While many cancer cells depend on exogenous glutamine for survival, the degree of glutamine dependence among tumor cell subtypes may make a population



of cells more susceptible to the reduction of glutamine. As an example, gene expression analysis of breast cancers has identified five intrinsic subtypes (luminal A, luminal B, basal, HER2+, and normal-like) (Sorlie et al., Proc Natl Acad Sci USA, 2001). Although glutamine deprivation has an impact on cell growth and viability, 5 basal-like cells appear to be more sensitive to the reduction of exogenous glutamine (Kung et al., PLoS Genetics, 2011). This supports the concept that glutamine is a very important energy source in basal-like breast cancer cell lines, and suggests that inhibition of the glutaminase enzyme would be beneficial in the treatment of breast cancers comprised of basal-like cells. Triple-negative breast cancer (TNBC) is 10 characterized by a lack of estrogen receptor, progesterone receptor and human epidermal growth factor receptor 2 expression. It has a higher rate of relapse following chemotherapy, and a poorer prognosis than with the other breast cancer subtypes (Dent et al., Clin Cancer res, 2007). Interestingly, there appears to be significant similarities in metabolic profiling between TNBC cells and basal-like 15 breast cancer cells (unpublished data). Figure 5 shows that a compound as described herein reduces a TNBC xenograft tumor. The compound in combination with paclitaxel further reduced the tumor size. Therefore, the invention contemplates the use of the compounds described herein for the treatment of TNBC and basal-type breast cancers.

20 Cachexia, the massive loss of muscle mass, is often associated with poor performance status and high mortality rate of cancer patients. A theory behind this process is that tumors require more glutamine than is normally supplied by diet, so muscle, a major source of glutamine, starts to breakdown in order to supply enough nutrient to the tumor. Thus, inhibition of glutaminase may reduce the need to 25 breakdown muscle. An embodiment of the invention is the use of the present compounds to prevent, inhibit or reduce cachexia.

The most common neurotransmitter is glutamate, derived from the enzymatic conversion of glutamine via glutaminase. High levels of glutamate have been shown to be neurotoxic. Following traumatic insult to neuronal cells, there occurs a rise in 30 neurotransmitter release, particularly glutamate. Accordingly, inhibition of glutaminase has been hypothesized as a means of treatment following an ischemic insult, such as stroke (Newcomb, PCT WO 99/09825, Kostandy, Neurol. Sci., 2011). Huntington's disease is a progressive, fatal neurological condition. In genetic mouse

models of Huntington's disease, it was observed that the early manifestation of the disease correlated with dysregulated glutamate release (Raymond et al., Neuroscience, 2011). In HIV-associated dementia, HIV infected macrophages exhibit upregulated glutaminase activity and increased glutamate release, leading to neuronal damage  
5 (Huang et al., J Neurosci., 2011). Similarly, in another neurological disease, the activated microglia in Rett Syndrome release glutamate causing neuronal damage. The release of excess glutamate has been associated with the up-regulation of glutaminase (Maezawa et al., J. Neurosci, 2010). In mice bred to have reduced glutaminase levels, sensitivity to psychotic-stimulating drugs, such as amphetamines,  
10 was dramatically reduced, thus suggesting that glutaminase inhibition may be beneficial in the treatment of schizophrenia (Gaisler-Salomon et al., Neuropsychopharmacology, 2009). Bipolar disorder is a devastating illness that is marked by recurrent episodes of mania and depression. This disease is treated with mood stabilizers such as lithium and valproate; however, chronic use of these drugs  
15 appear to increase the abundance of glutamate receptors (Nanavati et al., J. Neurochem., 2011), which may lead to a decrease in the drug's effectiveness over time. Thus, an alternative treatment may be to reduce the amount of glutamate by inhibiting glutaminase. This may or may not be in conjunction with the mood stabilizers. Memantine, a partial antagonist of N-methyl-D-aspartate receptor  
20 (NMDAR), is an approved therapeutic in the treatment of Alzheimer's disease. Currently, research is being conducted looking at memantine as a means of treating vascular dementia and Parkinson's disease (Oliverares et al., Curr. Alzheimer Res., 2011). Since memantine has been shown to partially block the NMDA glutamate receptor also, it is not unreasonable to speculate that decreasing glutamate levels by  
25 inhibiting glutaminase could also treat Alzheimer's disease, vascular dementia and Parkinson's disease. Alzheimer's disease, bipolar disorder, HIV-associated dementia, Huntington's disease, ischemic insult, Parkinson's disease, schizophrenia, stroke, traumatic insult and vascular dementia are but a few of the neurological diseases that have been correlated to increased levels of glutamate. Thus, inhibiting glutaminase  
30 with a compound described herein can reduce or prevent neurological diseases. Therefore, in one embodiment, the compounds may be used for the treatment or prevention of neurological diseases.

Activation of T lymphocytes induces cell growth, proliferation, and cytokine production, thereby placing energetic and biosynthetic demands on the cell.

Glutamine serves as an amine group donor for nucleotide synthesis, and glutamate, the first component in glutamine metabolism, plays a direct role in amino acid and glutathione synthesis, as well as being able to enter the Krebs cycle for energy production (Carr et al., J. Immunol., 2010). Mitogen-induced T cell proliferation and cytokine production require high levels of glutamine metabolism, thus inhibiting glutaminase may serve as a means of immune modulation. In multiple sclerosis, an inflammatory autoimmune disease, the activated microglia exhibit up-regulated glutaminase and release increased levels of extracellular glutamate. Glutamine levels are lowered by sepsis, injury, burns, surgery and endurance exercise (Calder et al., Amino Acids, 1999). These situations put the individual at risk of immunosuppression. In fact, in general, glutaminase gene expression and enzyme activity are both increased during T cell activity. Patients given glutamine following bone marrow transplantation resulted in a lower level of infection and reduced graft v. host disease (Crowther, Proc. Nutr. Soc., 2009). T cell proliferation and activation is involved in many immunological diseases, such as inflammatory bowel disease, Crohn's disease, sepsis, psoriasis, arthritis (including rheumatoid arthritis), multiple sclerosis, graft v. host disease, infections, lupus and diabetes. In an embodiment of the invention, the compounds described herein can be used to treat or prevent immunological diseases.

Hepatic encephalopathy (HE) represents a series of transient and reversible neurologic and psychiatric dysfunction in patients with liver disease or portosystemic shunting. HE is not a single clinical entity and may reflect reversible metabolic encephalopathy, brain atrophy, brain edema, or a combination of these factors; however, the current hypothesis is that the accumulation of ammonia, mostly derived from the intestine, plays a key role in the pathophysiology (Khunger et al., Clin Liver Dis, 2012). The deamination of glutamine in small intestine, renal and muscle synthesis all contribute to ammonia production. Impaired hepatic clearance caused by hepatocellular clearance or portosystemic shunting causes increased accumulation of ammonia. Ammonia toxicity affects astrocytes in the brain via glutamine synthetase, which metabolizes the ammonia to produce increased glutamine. Glutamine, in turn, attracts water into the astrocytes, leading to swelling and oxidative dysfunction of the

mitochondria. The resulting cerebral edema is thought to contribute to neurologic dysfunction seen in HE (Kavitt et al., Clin Gastroenterol Hepatol, 2008). In an embodiment of the invention, the compounds described herein can be used to treat or prevent HE.

5 Primary sensory neurons in the dorsal root ganglion have been shown to elevate their glutaminase enzyme activity following inflammation (Miller et al., Pain Research and Treatment, 2012). It is believed that the resulting increased glutamate production contributes to both central and peripheral sensitization, identified as pain. An aspect of the invention is the use of the present compounds herein for the  
10 treatment or diminishment of pain. In certain embodiments, the pain can be neuropathic pain, chemotherapy-induced pain or inflammatory pain.

High blood glucose levels, high insulin levels, and insulin resistance are risk factors for developing diabetes mellitus. Similarly, high blood pressure is a risk factor for developing cardiovascular disease. In a recent report from a large human  
15 cohort study, these four risk factors were inversely correlated with glutamine-to-glutamate ratios in the blood stream (Chen et al, Circulation, 2012). Furthermore, plasma glutamine-to-glutamate ratios were inversely correlated with the eventual incidence of diabetes mellitus over 12 years (Cheng et al, Circulation, 2012).

Experiments with animal models were consistent with these findings. Mice fed  
20 glutamine-rich diets exhibited lower blood glucose levels in a glucose tolerance test after 6 hours of fasting, and intraperitoneal injection of glutamine into mice rapidly decreased their blood pressure (Cheng et al, Circulation, 2012). Therefore, it is plausible that glutaminase inhibitors, which cause increased glutamine levels and decrease glutamate levels, would decrease the incidence of diabetes mellitus and  
25 cardiovascular disease. In particular, the liver and small intestine are major sites of glutamine utilization in diabetic animals, and glutaminase activity is higher than normal in these organs in streptozotocin-induced diabetic rats (Watford et al, Biochem J, 1984; Mithieux et al, Am J Physiol Endocrinol Metab, 2004). In an embodiment of the invention, the compounds described herein can be used to treat diabetes. In  
30 another embodiment of the invention, the present compounds can be used to reduce high blood pressure.

In one embodiment, the method of treating or preventing cancer, immunological and neurological diseases may comprise administering a compound of

the invention conjointly with a chemotherapeutic agent. Chemotherapeutic agents that may be conjointly administered with compounds of the invention include:

aminoglutethimide, amsacrine, anastrozole, asparaginase, bcr, bicalutamide, bleomycin, bortezomib, buserelin, busulfan, camptothecin, capecitabine, carboplatin, 5 carfilzomib, carmustine, chlorambucil, chloroquine, cisplatin, cladribine, clodronate, colchicine, cyclophosphamide, cyproterone, cytarabine, dacarbazine, dactinomycin, daunorubicin, demethoxyviridin, dexamethasone, dichloroacetate, dienestrol, diethylstilbestrol, docetaxel, doxorubicin, epirubicin, estradiol, estramustine, etoposide, everolimus, exemestane, filgrastim, fludarabine, fludrocortisone, 10 fluorouracil, fluoxymesterone, flutamide, gemcitabine, genistein, goserelin, hydroxyurea, idarubicin, ifosfamide, imatinib, interferon, irinotecan, irinotecan, lenalidomide, letrozole, leucovorin, leuprolide, levamisole, lomustine, lonidamine, mechlorethamine, medroxyprogesterone, megestrol, melphalan, mercaptopurine, mesna, metformin, methotrexate, mitomycin, mitotane, mitoxantrone, nilutamide, 15 nocodazole, octreotide, oxaliplatin, paclitaxel, pamidronate, pentostatin, perfosine, plicamycin, pomalidomide, porfimer, procarbazine, raltitrexed, rituximab, sorafenib, streptozocin, sunitinib, suramin, tamoxifen, temozolomide, temsirolimus, teniposide, testosterone, thalidomide, thioguanine, thiotepa, titanocene dichloride, topotecan, trastuzumab, tretinoin, vinblastine, vincristine, vindesine, and vinorelbine.

20 Many combination therapies have been developed for the treatment of cancer. In certain embodiments, compounds of the invention may be conjointly administered with a combination therapy. Examples of combination therapies with which compounds of the invention may be conjointly administered are included in Table 1.

Table 1: Exemplary combinatorial therapies for the treatment of cancer.

Name	Therapeutic agents
ABV	Doxorubicin, Bleomycin, Vinblastine
ABVD	Doxorubicin, Bleomycin, Vinblastine, Dacarbazine
AC (Breast)	Doxorubicin, Cyclophosphamide
AC (Sarcoma)	Doxorubicin, Cisplatin
AC (Neuroblastoma)	Cyclophosphamide, Doxorubicin
ACE	Cyclophosphamide, Doxorubicin, Etoposide
ACe	Cyclophosphamide, Doxorubicin

<b>Name</b>	<b>Therapeutic agents</b>
AD	Doxorubicin, Dacarbazine
AP	Doxorubicin, Cisplatin
ARAC-DNR	Cytarabine, Daunorubicin
B-CAVe	Bleomycin, Lomustine, Doxorubicin, Vinblastine
BCVPP	Carmustine, Cyclophosphamide, Vinblastine, Procarbazine, Prednisone
BEACOPP	Bleomycin, Etoposide, Doxorubicin, Cyclophosphamide, Vincristine, Procarbazine, Prednisone, Filgrastim
BEP	Bleomycin, Etoposide, Cisplatin
BIP	Bleomycin, Cisplatin, Ifosfamide, Mesna
BOMP	Bleomycin, Vincristine, Cisplatin, Mitomycin
CA	Cytarabine, Asparaginase
CABO	Cisplatin, Methotrexate, Bleomycin, Vincristine
CAF	Cyclophosphamide, Doxorubicin, Fluorouracil
CAL-G	Cyclophosphamide, Daunorubicin, Vincristine, Prednisone, Asparaginase
CAMP	Cyclophosphamide, Doxorubicin, Methotrexate, Procarbazine
CAP	Cyclophosphamide, Doxorubicin, Cisplatin
CaT	Carboplatin, Paclitaxel
CAV	Cyclophosphamide, Doxorubicin, Vincristine
CAVE ADD	CAV and Etoposide
CA-VP16	Cyclophosphamide, Doxorubicin, Etoposide
CC	Cyclophosphamide, Carboplatin
CDDP/VP-16	Cisplatin, Etoposide
CEF	Cyclophosphamide, Epirubicin, Fluorouracil
CEPP(B)	Cyclophosphamide, Etoposide, Prednisone, with or without/ Bleomycin
CEV	Cyclophosphamide, Etoposide, Vincristine
CF	Cisplatin, Fluorouracil or Carboplatin Fluorouracil
CHAP	Cyclophosphamide or Cyclophosphamide, Altretamine,

Name	Therapeutic agents
	Doxorubicin, Cisplatin
ChlVPP	Chlorambucil, Vinblastine, Procarbazine, Prednisone
CHOP	Cyclophosphamide, Doxorubicin, Vincristine, Prednisone
CHOP-BLEO	Add Bleomycin to CHOP
CISCA	Cyclophosphamide, Doxorubicin, Cisplatin
CLD-BOMP	Bleomycin, Cisplatin, Vincristine, Mitomycin
CMF	Methotrexate, Fluorouracil, Cyclophosphamide
CMFP	Cyclophosphamide, Methotrexate, Fluorouracil, Prednisone
CMFVP	Cyclophosphamide, Methotrexate, Fluorouracil, Vincristine, Prednisone
CMV	Cisplatin, Methotrexate, Vinblastine
CNF	Cyclophosphamide, Mitoxantrone, Fluorouracil
CNOP	Cyclophosphamide, Mitoxantrone, Vincristine, Prednisone
COB	Cisplatin, Vincristine, Bleomycin
CODE	Cisplatin, Vincristine, Doxorubicin, Etoposide
COMLA	Cyclophosphamide, Vincristine, Methotrexate, Leucovorin, Cytarabine
COMP	Cyclophosphamide, Vincristine, Methotrexate, Prednisone
Cooper Regimen	Cyclophosphamide, Methotrexate, Fluorouracil, Vincristine, Prednisone
COP	Cyclophosphamide, Vincristine, Prednisone
COPE	Cyclophosphamide, Vincristine, Cisplatin, Etoposide
COPP	Cyclophosphamide, Vincristine, Procarbazine, Prednisone
CP(Chronic lymphocytic leukemia)	Chlorambucil, Prednisone
CP (Ovarian Cancer)	Cyclophosphamide, Cisplatin
CT	Cisplatin, Paclitaxel
CVD	Cisplatin, Vinblastine, Dacarbazine
CVI	Carboplatin, Etoposide, Ifosfamide, Mesna
CVP	Cyclophosphamide, Vincristine, Prednisone

<b>Name</b>	<b>Therapeutic agents</b>
CVPP	Lomustine, Procarbazine, Prednisone
CYVADIC	Cyclophosphamide, Vincristine, Doxorubicin, Dacarbazine
DA	Daunorubicin, Cytarabine
DAT	Daunorubicin, Cytarabine, Thioguanine
DAV	Daunorubicin, Cytarabine, Etoposide
DCT	Daunorubicin, Cytarabine, Thioguanine
DHAP	Cisplatin, Cytarabine, Dexamethasone
DI	Doxorubicin, Ifosfamide
DTIC/Tamoxifen	Dacarbazine, Tamoxifen
DVP	Daunorubicin, Vincristine, Prednisone
EAP	Etoposide, Doxorubicin, Cisplatin
EC	Etoposide, Carboplatin
EFP	Etoposide, Fluorouracil, Cisplatin
ELF	Etoposide, Leucovorin, Fluorouracil
EMA 86	Mitoxantrone, Etoposide, Cytarabine
EP	Etoposide, Cisplatin
EVA	Etoposide, Vinblastine
FAC	Fluorouracil, Doxorubicin, Cyclophosphamide
FAM	Fluorouracil, Doxorubicin, Mitomycin
FAMTX	Methotrexate, Leucovorin, Doxorubicin
FAP	Fluorouracil, Doxorubicin, Cisplatin
F-CL	Fluorouracil, Leucovorin
FEC	Fluorouracil, Cyclophosphamide, Epirubicin
FED	Fluorouracil, Etoposide, Cisplatin
FL	Flutamide, Leuprolide
FZ	Flutamide, Goserelin acetate implant
HDMTX	Methotrexate, Leucovorin
Hexa-CAF	Altretamine, Cyclophosphamide, Methotrexate, Fluorouracil
ICE-T	Ifosfamide, Carboplatin, Etoposide, Paclitaxel, Mesna



<b>Name</b>	<b>Therapeutic agents</b>
IDMTX/6-MP	Methotrexate, Mercaptopurine, Leucovorin
IE	Ifosfamide, Etoposide, Mesna
IfoVP	Ifosfamide, Etoposide, Mesna
IPA	Ifosfamide, Cisplatin, Doxorubicin
M-2	Vincristine, Carmustine, Cyclophosphamide, Prednisone, Melphalan
MAC-III	Methotrexate, Leucovorin, Dactinomycin, Cyclophosphamide
MACC	Methotrexate, Doxorubicin, Cyclophosphamide, Lomustine
MACOP-B	Methotrexate, Leucovorin, Doxorubicin, Cyclophosphamide, Vincristine, Bleomycin, Prednisone
MAID	Mesna, Doxorubicin, Ifosfamide, Dacarbazine
m-BACOD	Bleomycin, Doxorubicin, Cyclophosphamide, Vincristine, Dexamethasone, Methotrexate, Leucovorin
MBC	Methotrexate, Bleomycin, Cisplatin
MC	Mitoxantrone, Cytarabine
MF	Methotrexate, Fluorouracil, Leucovorin
MICE	Ifosfamide, Carboplatin, Etoposide, Mesna
MINE	Mesna, Ifosfamide, Mitoxantrone, Etoposide
mini-BEAM	Carmustine, Etoposide, Cytarabine, Melphalan
MOBP	Bleomycin, Vincristine, Cisplatin, Mitomycin
MOP	Mechlorethamine, Vincristine, Procarbazine
MOPP	Mechlorethamine, Vincristine, Procarbazine, Prednisone
MOPP/ABV	Mechlorethamine, Vincristine, Procarbazine, Prednisone, Doxorubicin, Bleomycin, Vinblastine
MP (multiple myeloma)	Melphalan, Prednisone
MP (prostate cancer)	Mitoxantrone, Prednisone
MTX/6-MO	Methotrexate, Mercaptopurine
MTX/6-MP/VP	Methotrexate, Mercaptopurine, Vincristine, Prednisone

<b>Name</b>	<b>Therapeutic agents</b>
MTX-CDDPAdr	Methotrexate, Leucovorin, Cisplatin, Doxorubicin
MV (breast cancer)	Mitomycin, Vinblastine
MV (acute myelocytic leukemia)	Mitoxantrone, Etoposide
M-VAC Methotrexate	Vinblastine, Doxorubicin, Cisplatin
MVP Mitomycin	Vinblastine, Cisplatin
MVPP	Mechlorethamine, Vinblastine, Procarbazine, Prednisone
NFL	Mitoxantrone, Fluorouracil, Leucovorin
NOVP	Mitoxantrone, Vinblastine, Vincristine
OPA	Vincristine, Prednisone, Doxorubicin
OPPA	Add Procarbazine to OPA.
PAC	Cisplatin, Doxorubicin
PAC-I	Cisplatin, Doxorubicin, Cyclophosphamide
PA-CI	Cisplatin, Doxorubicin
PC	Paclitaxel, Carboplatin or Paclitaxel, Cisplatin
PCV	Lomustine, Procarbazine, Vincristine
PE	Paclitaxel, Estramustine
PFL	Cisplatin, Fluorouracil, Leucovorin
POC	Prednisone, Vincristine, Lomustine
ProMACE	Prednisone, Methotrexate, Leucovorin, Doxorubicin, Cyclophosphamide, Etoposide
ProMACE/cytaBOM	Prednisone, Doxorubicin, Cyclophosphamide, Etoposide, Cytarabine, Bleomycin, Vincristine, Methotrexate, Leucovorin, Cotrimoxazole
PRoMACE/MOPP	Prednisone, Doxorubicin, Cyclophosphamide, Etoposide, Mechlorethamine, Vincristine, Procarbazine, Methotrexate, Leucovorin
Pt/VM	Cisplatin, Teniposide
PVA	Prednisone, Vincristine, Asparaginase
PVB	Cisplatin, Vinblastine, Bleomycin
PVDA	Prednisone, Vincristine, Daunorubicin, Asparaginase

Name	Therapeutic agents
SMF	Streptozocin, Mitomycin, Fluorouracil
TAD	Mechlorethamine, Doxorubicin, Vinblastine, Vincristine, Bleomycin, Etoposide, Prednisone
TCF	Paclitaxel, Cisplatin, Fluorouracil
TIP	Paclitaxel, Ifosfamide, Mesna, Cisplatin
TTT	Methotrexate, Cytarabine, Hydrocortisone
Topo/CTX	Cyclophosphamide, Topotecan, Mesna
VAB-6	Cyclophosphamide, Dactinomycin, Vinblastine, Cisplatin, Bleomycin
VAC	Vincristine, Dactinomycin, Cyclophosphamide
VACAdr	Vincristine, Cyclophosphamide, Doxorubicin, Dactinomycin, Vincristine
VAD	Vincristine, Doxorubicin, Dexamethasone
VATH	Vinblastine, Doxorubicin, Thiotepa, Flouxymesterone
VBAP	Vincristine, Carmustine, Doxorubicin, Prednisone
VBCMP	Vincristine, Carmustine, Melphalan, Cyclophosphamide, Prednisone
VC	Vinorelbine, Cisplatin
VCAP	Vincristine, Cyclophosphamide, Doxorubicin, Prednisone
VD	Vinorelbine, Doxorubicin
VelP	Vinblastine, Cisplatin, Ifosfamide, Mesna
VIP	Etoposide, Cisplatin, Ifosfamide, Mesna
VM	Mitomycin, Vinblastine
VMCP	Vincristine, Melphalan, Cyclophosphamide, Prednisone
VP	Etoposide, Cisplatin
V-TAD	Etoposide, Thioguanine, Daunorubicin, Cytarabine
5 + 2	Cytarabine, Daunorubicin, Mitoxantrone
7 + 3	Cytarabine with/, Daunorubicin or Idarubicin or Mitoxantrone
"8 in 1"	Methylprednisolone, Vincristine, Lomustine, Procarbazine, Hydroxyurea, Cisplatin, Cytarabine,

Name	Therapeutic agents
	Dacarbazine

The proliferation of cancer cells requires lipid synthesis. Normally, acetyl-coA used for lipid synthesis is formed from a mitochondrial pool of pyruvate that is derived from glycolysis. Yet under hypoxic conditions, such as those normally found in a tumor environment, the conversion of pyruvate to acetyl-coA within the mitochondria is downregulated. Recent studies from Metallo et al. (2011) and Mullen et al. (2011) revealed that under such hypoxic conditions, cells instead largely switch to using a pathway involving the reductive carboxylation of alpha-ketoglutarate to make acetyl-coA for lipid synthesis. The first step in this pathway involves converting glutamine to glutamate via glutaminase enzymes. Subsequently, glutamate is converting to alpha-ketoglutarate, and the resulting alpha-ketoglutarate is converted to isocitrate in a reductive carboxylation step mediated by the isocitrate dehydrogenase enzymes. A switch to this reductive carboxylation pathway also occurs in some renal carcinoma cell lines that contain either impaired mitochondria or an impaired signal for induction of the enzyme responsible for converting glycolytic pyruvate to acetyl-coA (Mullen et al 2011). A similar switch occurs in cells exposed to mitochondrial respiratory chain inhibitors such as metformin, rotenone, and antimycin (Mullen et al. 2011). Therefore, in some embodiments of this invention, we propose using combinations of mitochondrial respiratory chain inhibitors and glutaminase inhibitors to simultaneously increase cancer cells' dependence on glutaminase-dependent pathways for lipid synthesis while inhibiting those very pathways.

The increased dependence on glycolysis in tumor cells is likely because the hypoxic tumor environment impairs mitochondrial respiration. Furthermore, depletion of glucose induces apoptosis in cells transformed with the MYC oncogene. These findings suggest that inhibiting glycolysis would have a therapeutic value in preventing cancer cell proliferation. There are currently many documented glycolytic inhibitors (Pelicano et al. 2006). However, as pointed out by Zhao et al. (2012), "available glycolytic inhibitors are generally not very potent, and high doses are required, which may cause high levels of systemic toxicity." Since cancer cells typically use both glucose and glutamine at higher levels than normal cells, impairing utilization of each of those metabolites will likely have a synergistic effect.

Therefore, in some embodiments of this invention, we propose using combinations of glycolytic pathway inhibitors and glutaminase inhibitors. Such glycolytic inhibitors include 2-deoxyglucose, lonidamine, 3-bromopyruvate, imatinib, oxythiamine, rapamycin, and their pharmacological equivalents. Glycolysis can be inhibited indirectly by depleting NAD<sup>+</sup> via DNA damage induced by DNA alkylating agents through a pathway activated by poly(ADP-ribose) polymerase (Zong et al. 2004). Therefore, in one embodiment of this invention, we propose using a combination of DNA alkylating agents and glutaminase inhibitors. Cancer cells use the pentose phosphate pathway along with the glycolytic pathway to create metabolic intermediates derived from glucose. Therefore, in another embodiment of this invention, we propose using a combination of pentose phosphate inhibitors such as 6-aminonicotinamide along with glutaminase inhibitors.

In certain embodiments, a compound of the invention may be conjointly administered with non-chemical methods of cancer treatment. In certain embodiments, a compound of the invention may be conjointly administered with radiation therapy. In certain embodiments, a compound of the invention may be conjointly administered with surgery, with thermoablation, with focused ultrasound therapy, with cryotherapy, or with any combination of these.

In certain embodiments, different compounds of the invention may be conjointly administered with one or more other compounds of the invention. Moreover, such combinations may be conjointly administered with other therapeutic agents, such as other agents suitable for the treatment of cancer, immunological or neurological diseases, such as the agents identified above. In certain embodiments, conjointly administering one or more additional chemotherapeutic agents with a compound of the invention provides a synergistic effect, such as shown in Figure 7. In certain embodiments, conjointly administering one or more additional chemotherapeutics agents provides an additive effect.

In certain embodiments, the present invention provides a kit comprising: a) one or more single dosage forms of a compound of the invention; b) one or more single dosage forms of a chemotherapeutic agent as mentioned above; and c) instructions for the administration of the compound of the invention and the chemotherapeutic agent.

The present invention provides a kit comprising:

- a) a pharmaceutical formulation (e.g., one or more single dosage forms) comprising a compound of the invention; and
- b) instructions for the administration of the pharmaceutical formulation, e.g., for treating or preventing any of the conditions discussed above.

In certain embodiments, the kit further comprises instructions for the administration of the pharmaceutical formulation comprising a compound of the invention conjointly with a chemotherapeutic agent as mentioned above. In certain embodiments, the kit further comprises a second pharmaceutical formulation (e.g., as one or more single dosage forms) comprising a chemotherapeutic agent as mentioned above.

#### *Definitions*

The term “acyl” is art-recognized and refers to a group represented by the general formula hydrocarbylC(O)-, preferably alkylC(O)-.

The term “acylamino” is art-recognized and refers to an amino group substituted with an acyl group and may be represented, for example, by the formula hydrocarbylC(O)NH-.

The term “acyloxy” is art-recognized and refers to a group represented by the general formula hydrocarbylC(O)O-, preferably alkylC(O)O-.

The term “alkoxy” refers to an alkyl group, preferably a lower alkyl group, having an oxygen attached thereto. Representative alkoxy groups include methoxy, ethoxy, propoxy, tert-butoxy and the like.

The term “alkoxyalkyl” refers to an alkyl group substituted with an alkoxy group and may be represented by the general formula alkyl-O-alkyl.

The term “alkenyl”, as used herein, refers to an aliphatic group containing at least one double bond and is intended to include both "unsubstituted alkenyls" and "substituted alkenyls", the latter of which refers to alkenyl moieties having substituents replacing a hydrogen on one or more carbons of the alkenyl group. Such substituents may occur on one or more carbons that are included or not included in one or more double bonds. Moreover, such substituents include all those contemplated for alkyl groups, as discussed below, except where stability is prohibitive. For example, substitution of alkenyl groups by one or more alkyl, carbocyclyl, aryl, heterocyclyl, or heteroaryl groups is contemplated.

An "alkyl" group or "alkane" is a straight chained or branched non-aromatic hydrocarbon which is completely saturated. Typically, a straight chained or branched alkyl group has from 1 to about 20 carbon atoms, preferably from 1 to about 10 unless otherwise defined. Examples of straight chained and branched alkyl groups include methyl, ethyl, n-propyl, iso-propyl, n-butyl, sec-butyl, tert-butyl, pentyl, hexyl, pentyl and octyl. A C<sub>1</sub>-C<sub>6</sub> straight chained or branched alkyl group is also referred to as a "lower alkyl" group.

Moreover, the term "alkyl" (or "lower alkyl") as used throughout the specification, examples, and claims is intended to include both "unsubstituted alkyls" and "substituted alkyls", the latter of which refers to alkyl moieties having substituents replacing a hydrogen on one or more carbons of the hydrocarbon backbone. Such substituents, if not otherwise specified, can include, for example, a halogen, a hydroxyl, a carbonyl (such as a carboxyl, an alkoxy carbonyl, a formyl, or an acyl), a thiocarbonyl (such as a thioester, a thioacetate, or a thioformate), an alkoxy, a phosphoryl, a phosphate, a phosphonate, a phosphinate, an amino, an amido, an amidine, an imine, a cyano, a nitro, an azido, a sulfhydryl, an alkylthio, a sulfate, a sulfonate, a sulfamoyl, a sulfonamido, a sulfonyl, a heterocyclyl, an aralkyl, or an aromatic or heteroaromatic moiety. It will be understood by those skilled in the art that the moieties substituted on the hydrocarbon chain can themselves be substituted, if appropriate. For instance, the substituents of a substituted alkyl may include substituted and unsubstituted forms of amino, azido, imino, amido, phosphoryl (including phosphonate and phosphinate), sulfonyl (including sulfate, sulfonamido, sulfamoyl and sulfonate), and silyl groups, as well as ethers, alkylthios, carbonyls (including ketones, aldehydes, carboxylates, and esters), -CF<sub>3</sub>, -CN and the like. Exemplary substituted alkyls are described below. Cycloalkyls can be further substituted with alkyls, alkenyls, alkoxy, alkylthios, aminoalkyls, carbonyl-substituted alkyls, -CF<sub>3</sub>, -CN, and the like.

The term "C<sub>x-y</sub>" when used in conjunction with a chemical moiety, such as, acyl, acyloxy, alkyl, alkenyl, alkynyl, or alkoxy is meant to include groups that contain from x to y carbons in the chain. For example, the term "C<sub>x-y</sub>alkyl" refers to substituted or unsubstituted saturated hydrocarbon groups, including straight-chain alkyl and branched-chain alkyl groups that contain from x to y carbons in the chain, including haloalkyl groups such as trifluoromethyl and 2,2,2-trifluoroethyl, etc. C<sub>0</sub>

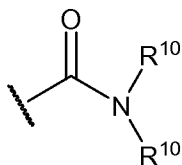
alkyl indicates a hydrogen where the group is in a terminal position, a bond if internal. The terms “C<sub>2-y</sub>alkenyl” and “C<sub>2-y</sub>alkynyl” refer to substituted or unsubstituted unsaturated aliphatic groups analogous in length and possible substitution to the alkyls described above, but that contain at least one double or triple bond respectively.

5           The term “alkylamino”, as used herein, refers to an amino group substituted with at least one alkyl group.

          The term “alkylthio”, as used herein, refers to a thiol group substituted with an alkyl group and may be represented by the general formula alkylS-.

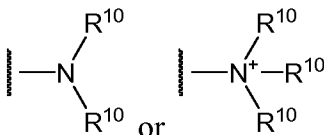
          The term “alkynyl”, as used herein, refers to an aliphatic group containing at  
10   least one triple bond and is intended to include both "unsubstituted alkynyls" and "substituted alkynyls", the latter of which refers to alkynyl moieties having substituents replacing a hydrogen on one or more carbons of the alkynyl group. Such substituents may occur on one or more carbons that are included or not included in one or more triple bonds. Moreover, such substituents include all those contemplated  
15   for alkyl groups, as discussed above, except where stability is prohibitive. For example, substitution of alkynyl groups by one or more alkyl, carbocyclyl, aryl, heterocyclyl, or heteroaryl groups is contemplated.

          The term “amide”, as used herein, refers to a group



20   wherein each R<sup>10</sup> independently represent a hydrogen or hydrocarbyl group, or two R<sup>10</sup> are taken together with the N atom to which they are attached complete a heterocycle having from 4 to 8 atoms in the ring structure.

          The terms “amine” and “amino” are art-recognized and refer to both unsubstituted and substituted amines and salts thereof, e.g., a moiety that can be  
25   represented by





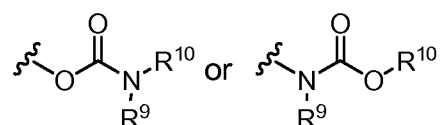
wherein each R<sup>10</sup> independently represents a hydrogen or a hydrocarbyl group, or two R<sup>10</sup> are taken together with the N atom to which they are attached complete a heterocycle having from 4 to 8 atoms in the ring structure.

The term “aminoalkyl”, as used herein, refers to an alkyl group substituted  
5 with an amino group.

The term “aralkyl”, as used herein, refers to an alkyl group substituted with an aryl group.

The term “aryl” as used herein include substituted or unsubstituted single-ring aromatic groups in which each atom of the ring is carbon. Preferably the ring is a 5-  
10 to 7-membered ring, more preferably a 6-membered ring. The term “aryl” also includes polycyclic ring systems having two or more cyclic rings in which two or more carbons are common to two adjoining rings wherein at least one of the rings is aromatic, e.g., the other cyclic rings can be cycloalkyls, cycloalkenyls, cycloalkynyls, aryls, heteroaryls, and/or heterocyclyls. Aryl groups include benzene, naphthalene,  
15 phenanthrene, phenol, aniline, and the like.

The term “carbamate” is art-recognized and refers to a group



wherein R<sup>9</sup> and R<sup>10</sup> independently represent hydrogen or a hydrocarbyl group, such as an alkyl group, or R<sup>9</sup> and R<sup>10</sup> taken together with the intervening atom(s) complete a  
20 heterocycle having from 4 to 8 atoms in the ring structure.

The terms “carbocycle”, and “carbocyclic”, as used herein, refers to a saturated or unsaturated ring in which each atom of the ring is carbon. The term carbocycle includes both aromatic carbocycles and non-aromatic carbocycles. Non-aromatic carbocycles include both cycloalkane rings, in which all carbon atoms are  
25 saturated, and cycloalkene rings, which contain at least one double bond.

“Carbocycle” includes 5-7 membered monocyclic and 8-12 membered bicyclic rings. Each ring of a bicyclic carbocycle may be selected from saturated, unsaturated and aromatic rings. Carbocycle includes bicyclic molecules in which one, two or three or more atoms are shared between the two rings. The term “fused carbocycle” refers to a  
30 bicyclic carbocycle in which each of the rings shares two adjacent atoms with the other ring. Each ring of a fused carbocycle may be selected from saturated,

unsaturated and aromatic rings. In an exemplary embodiment, an aromatic ring, e.g., phenyl, may be fused to a saturated or unsaturated ring, e.g., cyclohexane, cyclopentane, or cyclohexene. Any combination of saturated, unsaturated and aromatic bicyclic rings, as valence permits, is included in the definition of carbocyclic. Exemplary "carbocycles" include cyclopentane, cyclohexane, bicyclo[2.2.1]heptane, 1,5-cyclooctadiene, 1,2,3,4-tetrahydronaphthalene, bicyclo[4.2.0]oct-3-ene, naphthalene and adamantane. Exemplary fused carbocycles include decalin, naphthalene, 1,2,3,4-tetrahydronaphthalene, bicyclo[4.2.0]octane, 4,5,6,7-tetrahydro-1H-indene and bicyclo[4.1.0]hept-3-ene. "Carbocycles" may be substituted at any one or more positions capable of bearing a hydrogen atom.

A "cycloalkyl" group is a cyclic hydrocarbon which is completely saturated. "Cycloalkyl" includes monocyclic and bicyclic rings. Typically, a monocyclic cycloalkyl group has from 3 to about 10 carbon atoms, more typically 3 to 8 carbon atoms unless otherwise defined. The second ring of a bicyclic cycloalkyl may be selected from saturated, unsaturated and aromatic rings. Cycloalkyl includes bicyclic molecules in which one, two or three or more atoms are shared between the two rings. The term "fused cycloalkyl" refers to a bicyclic cycloalkyl in which each of the rings shares two adjacent atoms with the other ring. The second ring of a fused bicyclic cycloalkyl may be selected from saturated, unsaturated and aromatic rings. A

"cycloalkenyl" group is a cyclic hydrocarbon containing one or more double bonds.

The term "carbocyclalkyl", as used herein, refers to an alkyl group substituted with a carbocycle group.

The term "carbonate" is art-recognized and refers to a group  $-\text{OCO}_2\text{-R}^{10}$ , wherein  $\text{R}^{10}$  represents a hydrocarbyl group.

The term "carboxy", as used herein, refers to a group represented by the formula  $-\text{CO}_2\text{H}$ .

The term "ester", as used herein, refers to a group  $-\text{C}(\text{O})\text{OR}^{10}$  wherein  $\text{R}^{10}$  represents a hydrocarbyl group.

The term "ether", as used herein, refers to a hydrocarbyl group linked through an oxygen to another hydrocarbyl group. Accordingly, an ether substituent of a hydrocarbyl group may be hydrocarbyl-O-. Ethers may be either symmetrical or unsymmetrical. Examples of ethers include, but are not limited to, heterocycle-O-

heterocycle and aryl-O-heterocycle. Ethers include “alkoxyalkyl” groups, which may be represented by the general formula alkyl-O-alkyl.

The terms “halo” and “halogen” as used herein means halogen and includes chloro, fluoro, bromo, and iodo.

5           The terms “hetaralkyl” and “heteroaralkyl”, as used herein, refers to an alkyl group substituted with a hetaryl group.

The term "heteroalkyl", as used herein, refers to a saturated or unsaturated chain of carbon atoms and at least one heteroatom, wherein no two heteroatoms are adjacent.

10           The terms “heteroaryl” and “hetaryl” include substituted or unsubstituted aromatic single ring structures, preferably 5- to 7-membered rings, more preferably 5- to 6-membered rings, whose ring structures include at least one heteroatom, preferably one to four heteroatoms, more preferably one or two heteroatoms. The terms “heteroaryl” and “hetaryl” also include polycyclic ring systems having two or  
15 more cyclic rings in which two or more carbons are common to two adjoining rings wherein at least one of the rings is heteroaromatic, e.g., the other cyclic rings can be cycloalkyls, cycloalkenyls, cycloalkynyls, aryls, heteroaryls, and/or heterocyclyls. Heteroaryl groups include, for example, pyrrole, furan, thiophene, imidazole, oxazole, thiazole, pyrazole, pyridine, pyrazine, pyridazine, and pyrimidine, and the like.

20           The term “heteroatom” as used herein means an atom of any element other than carbon or hydrogen. Preferred heteroatoms are nitrogen, oxygen, and sulfur.

The terms “heterocyclyl”, “heterocycle”, and “heterocyclic” refer to substituted or unsubstituted non-aromatic ring structures, preferably 3- to 10-membered rings, more preferably 3- to 7-membered rings, whose ring structures  
25 include at least one heteroatom, preferably one to four heteroatoms, more preferably one or two heteroatoms. The terms “heterocyclyl” and “heterocyclic” also include polycyclic ring systems having two or more cyclic rings in which two or more carbons are common to two adjoining rings wherein at least one of the rings is heterocyclic, e.g., the other cyclic rings can be cycloalkyls, cycloalkenyls,  
30 cycloalkynyls, aryls, heteroaryls, and/or heterocyclyls. Heterocyclyl groups include, for example, piperidine, piperazine, pyrrolidine, morpholine, lactones, lactams, and the like.

The term “heterocyclalkyl”, as used herein, refers to an alkyl group substituted with a heterocycle group.

The term “hydrocarbyl”, as used herein, refers to a group that is bonded through a carbon atom that does not have a =O or =S substituent, and typically has at least one carbon-hydrogen bond and a primarily carbon backbone, but may optionally include heteroatoms. Thus, groups like methyl, ethoxyethyl, 2-pyridyl, and trifluoromethyl are considered to be hydrocarbyl for the purposes of this application, but substituents such as acetyl (which has a =O substituent on the linking carbon) and ethoxy (which is linked through oxygen, not carbon) are not. Hydrocarbyl groups include, but are not limited to aryl, heteroaryl, carbocycle, heterocyclalkyl, alkyl, alkenyl, alkynyl, and combinations thereof.

The term “hydroxyalkyl”, as used herein, refers to an alkyl group substituted with a hydroxy group.

The term “lower” when used in conjunction with a chemical moiety, such as, acyl, acyloxy, alkyl, alkenyl, alkynyl, or alkoxy is meant to include groups where there are ten or fewer non-hydrogen atoms in the substituent, preferably six or fewer. A “lower alkyl”, for example, refers to an alkyl group that contains ten or fewer carbon atoms, preferably six or fewer. In certain embodiments, acyl, acyloxy, alkyl, alkenyl, alkynyl, or alkoxy substituents defined herein are respectively lower acyl, lower acyloxy, lower alkyl, lower alkenyl, lower alkynyl, or lower alkoxy, whether they appear alone or in combination with other substituents, such as in the recitations hydroxyalkyl and aralkyl (in which case, for example, the atoms within the aryl group are not counted when counting the carbon atoms in the alkyl substituent).

The terms “polycyclalkyl”, “polycycle”, and “polycyclic” refer to two or more rings (e.g., cycloalkyls, cycloalkenyls, cycloalkynyls, aryls, heteroaryls, and/or heterocyclalkyls) in which two or more atoms are common to two adjoining rings, e.g., the rings are “fused rings”. Each of the rings of the polycycle can be substituted or unsubstituted. In certain embodiments, each ring of the polycycle contains from 3 to 10 atoms in the ring, preferably from 5 to 7.

The term “silyl” refers to a silicon moiety with three hydrocarbyl moieties attached thereto.

The term “substituted” refers to moieties having substituents replacing a hydrogen on one or more carbons of the backbone. It will be understood that

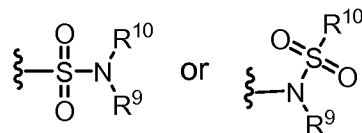
“substitution” or “substituted with” includes the implicit proviso that such substitution is in accordance with permitted valence of the substituted atom and the substituent, and that the substitution results in a stable compound, e.g., which does not spontaneously undergo transformation such as by rearrangement, cyclization,

5 elimination, etc. As used herein, the term “substituted” is contemplated to include all permissible substituents of organic compounds. In a broad aspect, the permissible substituents include acyclic and cyclic, branched and unbranched, carbocyclic and heterocyclic, aromatic and non-aromatic substituents of organic compounds. The permissible substituents can be one or more and the same or different for appropriate organic compounds. For purposes of this invention, the heteroatoms such as nitrogen may have hydrogen substituents and/or any permissible substituents of organic compounds described herein which satisfy the valences of the heteroatoms.

Substituents can include any substituents described herein, for example, a halogen, a hydroxyl, a carbonyl (such as a carboxyl, an alkoxycarbonyl, a formyl, or an acyl), a  
15 thiocarbonyl (such as a thioester, a thioacetate, or a thioformate), an alkoxyl, a phosphoryl, a phosphate, a phosphonate, a phosphinate, an amino, an amido, an amidine, an imine, a cyano, a nitro, an azido, a sulfhydryl, an alkylthio, a sulfate, a sulfonate, a sulfamoyl, a sulfonamido, a sulfonyl, a heterocyclyl, an aralkyl, or an aromatic or heteroaromatic moiety. It will be understood by those skilled in the art  
20 that substituents can themselves be substituted, if appropriate. Unless specifically stated as “unsubstituted,” references to chemical moieties herein are understood to include substituted variants. For example, reference to an “aryl” group or moiety implicitly includes both substituted and unsubstituted variants.

The term “sulfate” is art-recognized and refers to the group  $-\text{OSO}_3\text{H}$ , or a  
25 pharmaceutically acceptable salt thereof.

The term “sulfonamide” is art-recognized and refers to the group represented by the general formulae



wherein  $\text{R}^9$  and  $\text{R}^{10}$  independently represents hydrogen or hydrocarbyl, such as alkyl,  
30 or  $\text{R}^9$  and  $\text{R}^{10}$  taken together with the intervening atom(s) complete a heterocycle having from 4 to 8 atoms in the ring structure.

The term “sulfoxide” is art-recognized and refers to the group  $-S(O)-R^{10}$ , wherein  $R^{10}$  represents a hydrocarbonyl.

The term “sulfonate” is art-recognized and refers to the group  $SO_3H$ , or a pharmaceutically acceptable salt thereof.

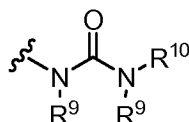
5        The term “sulfone” is art-recognized and refers to the group  $-S(O)_2-R^{10}$ , wherein  $R^{10}$  represents a hydrocarbonyl.

The term “thioalkyl”, as used herein, refers to an alkyl group substituted with a thiol group.

10        The term “thioester”, as used herein, refers to a group  $-C(O)SR^{10}$  or  $-SC(O)R^{10}$  wherein  $R^{10}$  represents a hydrocarbonyl.

The term “thioether”, as used herein, is equivalent to an ether, wherein the oxygen is replaced with a sulfur.

The term “urea” is art-recognized and may be represented by the general formula



wherein  $R^9$  and  $R^{10}$  independently represent hydrogen or a hydrocarbonyl, such as alkyl, or either occurrence of  $R^9$  taken together with  $R^{10}$  and the intervening atom(s) complete a heterocycle having from 4 to 8 atoms in the ring structure.

“Protecting group” refers to a group of atoms that, when attached to a reactive  
20 functional group in a molecule, mask, reduce or prevent the reactivity of the functional group. Typically, a protecting group may be selectively removed as desired during the course of a synthesis. Examples of protecting groups can be found in Greene and Wuts, *Protective Groups in Organic Chemistry*, 3<sup>rd</sup> Ed., 1999, John Wiley & Sons, NY and Harrison et al., *Compendium of Synthetic Organic Methods*, Vols. 1-  
25 8, 1971-1996, John Wiley & Sons, NY. Representative nitrogen protecting groups include, but are not limited to, formyl, acetyl, trifluoroacetyl, benzyl, benzyloxycarbonyl (“CBZ”), tert-butoxycarbonyl (“Boc”), trimethylsilyl (“TMS”), 2-trimethylsilyl-ethanesulfonyl (“TES”), trityl and substituted trityl groups, allyloxycarbonyl, 9-fluorenylmethyloxycarbonyl (“Fmoc”), nitro-  
30 veratryloxycarbonyl (“NVOC”) and the like. Representative hydroxylprotecting groups include, but are not limited to, those where the hydroxyl group is either

acylated (esterified) or alkylated such as benzyl and trityl ethers, as well as alkyl ethers, tetrahydropyranyl ethers, trialkylsilyl ethers (e.g., TMS or TIPS groups), glycol ethers, such as ethylene glycol and propylene glycol derivatives and allyl ethers.

5           The term "healthcare providers" refers to individuals or organizations that provide healthcare services to a person, community, etc. Examples of "healthcare providers" include doctors, hospitals, continuing care retirement communities, skilled nursing facilities, subacute care facilities, clinics, multispecialty clinics, freestanding ambulatory centers, home health agencies, and HMO's.

10           As used herein, a therapeutic that "prevents" a disorder or condition refers to a compound that, in a statistical sample, reduces the occurrence of the disorder or condition in the treated sample relative to an untreated control sample, or delays the onset or reduces the severity of one or more symptoms of the disorder or condition relative to the untreated control sample.

15           The term "treating" includes prophylactic and/or therapeutic treatments. The term "prophylactic or therapeutic" treatment is art-recognized and includes administration to the host of one or more of the subject compositions. If it is administered prior to clinical manifestation of the unwanted condition (e.g., disease or other unwanted state of the host animal) then the treatment is prophylactic (i.e., it  
20 protects the host against developing the unwanted condition), whereas if it is administered after manifestation of the unwanted condition, the treatment is therapeutic, (i.e., it is intended to diminish, ameliorate, or stabilize the existing unwanted condition or side effects thereof).

          The term "prodrug" is intended to encompass compounds which, under  
25 physiologic conditions, are converted into the therapeutically active agents of the present invention (e.g., a compound of formula I). A common method for making a prodrug is to include one or more selected moieties which are hydrolyzed under physiologic conditions to reveal the desired molecule. In other embodiments, the prodrug is converted by an enzymatic activity of the host animal. For example, esters  
30 or carbonates (e.g., esters or carbonates of alcohols or carboxylic acids) are preferred prodrugs of the present invention. In certain embodiments, some or all of the compounds of formula I in a formulation represented above can be replaced with the corresponding suitable prodrug, e.g., wherein a hydroxyl in the parent compound is

presented as an ester or a carbonate or carboxylic acid present in the parent compound is presented as an ester.

#### *Pharmaceutical Compositions*

The compositions and methods of the present invention may be utilized to  
5 treat an individual in need thereof. In certain embodiments, the individual is a mammal such as a human, or a non-human mammal. When administered to an animal, such as a human, the composition or the compound is preferably administered as a pharmaceutical composition comprising, for example, a compound of the invention and a pharmaceutically acceptable carrier. Pharmaceutically acceptable  
10 carriers are well known in the art and include, for example, aqueous solutions such as water or physiologically buffered saline or other solvents or vehicles such as glycols, glycerol, oils such as olive oil, or injectable organic esters. In a preferred embodiment, when such pharmaceutical compositions are for human administration, particularly for invasive routes of administration (i.e., routes, such as injection or  
15 implantation, that circumvent transport or diffusion through an epithelial barrier), the aqueous solution is pyrogen-free, or substantially pyrogen-free. The excipients can be chosen, for example, to effect delayed release of an agent or to selectively target one or more cells, tissues or organs. The pharmaceutical composition can be in dosage unit form such as tablet, capsule (including sprinkle capsule and gelatin capsule),  
20 granule, lyophile for reconstitution, powder, solution, syrup, suppository, injection or the like. The composition can also be present in a transdermal delivery system, e.g., a skin patch. The composition can also be present in a solution suitable for topical administration, such as an eye drop.

A pharmaceutically acceptable carrier can contain physiologically acceptable  
25 agents that act, for example, to stabilize, increase solubility or to increase the absorption of a compound such as a compound of the invention. Such physiologically acceptable agents include, for example, carbohydrates, such as glucose, sucrose or dextrans, antioxidants, such as ascorbic acid or glutathione, chelating agents, low molecular weight proteins or other stabilizers or excipients. The choice of a  
30 pharmaceutically acceptable carrier, including a physiologically acceptable agent, depends, for example, on the route of administration of the composition. The preparation of pharmaceutical composition can be a selfemulsifying drug delivery system or a selfmicroemulsifying drug delivery system. The pharmaceutical



composition (preparation) also can be a liposome or other polymer matrix, which can have incorporated therein, for example, a compound of the invention. Liposomes, for example, which comprise phospholipids or other lipids, are nontoxic, physiologically acceptable and metabolizable carriers that are relatively simple to make and

5 administer.

The phrase "pharmaceutically acceptable" is employed herein to refer to those compounds, materials, compositions, and/or dosage forms which are, within the scope of sound medical judgment, suitable for use in contact with the tissues of human beings and animals without excessive toxicity, irritation, allergic response, or other  
10 problem or complication, commensurate with a reasonable benefit/risk ratio.

The phrase "pharmaceutically acceptable carrier" as used herein means a pharmaceutically acceptable material, composition or vehicle, such as a liquid or solid filler, diluent, excipient, solvent or encapsulating material. Each carrier must be "acceptable" in the sense of being compatible with the other ingredients of the  
15 formulation and not injurious to the patient. Some examples of materials which can serve as pharmaceutically acceptable carriers include: (1) sugars, such as lactose, glucose and sucrose; (2) starches, such as corn starch and potato starch; (3) cellulose, and its derivatives, such as sodium carboxymethyl cellulose, ethyl cellulose and cellulose acetate; (4) powdered tragacanth; (5) malt; (6) gelatin; (7) talc; (8)  
20 excipients, such as cocoa butter and suppository waxes; (9) oils, such as peanut oil, cottonseed oil, safflower oil, sesame oil, olive oil, corn oil and soybean oil; (10) glycols, such as propylene glycol; (11) polyols, such as glycerin, sorbitol, mannitol and polyethylene glycol; (12) esters, such as ethyl oleate and ethyl laurate; (13) agar; (14) buffering agents, such as magnesium hydroxide and aluminum hydroxide; (15)  
25 alginic acid; (16) pyrogen-free water; (17) isotonic saline; (18) Ringer's solution; (19) ethyl alcohol; (20) phosphate buffer solutions; and (21) other non-toxic compatible substances employed in pharmaceutical formulations.

A pharmaceutical composition (preparation) can be administered to a subject by any of a number of routes of administration including, for example, orally (for  
30 example, drenches as in aqueous or non-aqueous solutions or suspensions, tablets, capsules (including sprinkle capsules and gelatin capsules), boluses, powders, granules, pastes for application to the tongue); absorption through the oral mucosa (e.g., sublingually); anally, rectally or vaginally (for example, as a pessary, cream or

foam); parenterally (including intramuscularly, intravenously, subcutaneously or intrathecally as, for example, a sterile solution or suspension); nasally; intraperitoneally; subcutaneously; transdermally (for example as a patch applied to the skin); and topically (for example, as a cream, ointment or spray applied to the skin, or as an eye drop). The compound may also be formulated for inhalation. In certain  
5       embodiments, a compound may be simply dissolved or suspended in sterile water. Details of appropriate routes of administration and compositions suitable for same can be found in, for example, U.S. Pat. Nos. 6,110,973, 5,763,493, 5,731,000, 5,541,231, 5,427,798, 5,358,970 and 4,172,896, as well as in patents cited therein.

10       The formulations may conveniently be presented in unit dosage form and may be prepared by any methods well known in the art of pharmacy. The amount of active ingredient which can be combined with a carrier material to produce a single dosage form will vary depending upon the host being treated, the particular mode of administration. The amount of active ingredient that can be combined with a carrier  
15       material to produce a single dosage form will generally be that amount of the compound which produces a therapeutic effect. Generally, out of one hundred percent, this amount will range from about 1 percent to about ninety-nine percent of active ingredient, preferably from about 5 percent to about 70 percent, most preferably from about 10 percent to about 30 percent.

20       Methods of preparing these formulations or compositions include the step of bringing into association an active compound, such as a compound of the invention, with the carrier and, optionally, one or more accessory ingredients. In general, the formulations are prepared by uniformly and intimately bringing into association a compound of the present invention with liquid carriers, or finely divided solid  
25       carriers, or both, and then, if necessary, shaping the product.

Formulations of the invention suitable for oral administration may be in the form of capsules (including sprinkle capsules and gelatin capsules), cachets, pills, tablets, lozenges (using a flavored basis, usually sucrose and acacia or tragacanth), lyophile, powders, granules, or as a solution or a suspension in an aqueous or non-  
30       aqueous liquid, or as an oil-in-water or water-in-oil liquid emulsion, or as an elixir or syrup, or as pastilles (using an inert base, such as gelatin and glycerin, or sucrose and acacia) and/or as mouth washes and the like, each containing a predetermined amount

of a compound of the present invention as an active ingredient. Compositions or compounds may also be administered as a bolus, electuary or paste.

To prepare solid dosage forms for oral administration (capsules (including sprinkle capsules and gelatin capsules), tablets, pills, dragees, powders, granules and the like), the active ingredient is mixed with one or more pharmaceutically acceptable carriers, such as sodium citrate or dicalcium phosphate, and/or any of the following: (1) fillers or extenders, such as starches, lactose, sucrose, glucose, mannitol, and/or silicic acid; (2) binders, such as, for example, carboxymethylcellulose, alginates, gelatin, polyvinyl pyrrolidone, sucrose and/or acacia; (3) humectants, such as glycerol; (4) disintegrating agents, such as agar-agar, calcium carbonate, potato or tapioca starch, alginic acid, certain silicates, and sodium carbonate; (5) solution retarding agents, such as paraffin; (6) absorption accelerators, such as quaternary ammonium compounds; (7) wetting agents, such as, for example, cetyl alcohol and glycerol monostearate; (8) absorbents, such as kaolin and bentonite clay; (9) lubricants, such as talc, calcium stearate, magnesium stearate, solid polyethylene glycols, sodium lauryl sulfate, and mixtures thereof; (10) complexing agents, such as, modified and unmodified cyclodextrins; and (11) coloring agents.. In the case of capsules (including sprinkle capsules and gelatin capsules), tablets and pills, the pharmaceutical compositions may also comprise buffering agents. Solid compositions of a similar type may also be employed as fillers in soft and hard-filled gelatin capsules using such excipients as lactose or milk sugars, as well as high molecular weight polyethylene glycols and the like.

A tablet may be made by compression or molding, optionally with one or more accessory ingredients. Compressed tablets may be prepared using binder (for example, gelatin or hydroxypropylmethyl cellulose), lubricant, inert diluent, preservative, disintegrant (for example, sodium starch glycolate or cross-linked sodium carboxymethyl cellulose), surface-active or dispersing agent. Molded tablets may be made by molding in a suitable machine a mixture of the powdered compound moistened with an inert liquid diluent.

The tablets, and other solid dosage forms of the pharmaceutical compositions, such as dragees, capsules (including sprinkle capsules and gelatin capsules), pills and granules, may optionally be scored or prepared with coatings and shells, such as enteric coatings and other coatings well known in the pharmaceutical-formulating art.

They may also be formulated so as to provide slow or controlled release of the active ingredient therein using, for example, hydroxypropylmethyl cellulose in varying proportions to provide the desired release profile, other polymer matrices, liposomes and/or microspheres. They may be sterilized by, for example, filtration through a bacteria-retaining filter, or by incorporating sterilizing agents in the form of sterile solid compositions that can be dissolved in sterile water, or some other sterile injectable medium immediately before use. These compositions may also optionally contain opacifying agents and may be of a composition that they release the active ingredient(s) only, or preferentially, in a certain portion of the gastrointestinal tract, optionally, in a delayed manner. Examples of embedding compositions that can be used include polymeric substances and waxes. The active ingredient can also be in micro-encapsulated form, if appropriate, with one or more of the above-described excipients.

Liquid dosage forms useful for oral administration include pharmaceutically acceptable emulsions, lyophiles for reconstitution, microemulsions, solutions, suspensions, syrups and elixirs. In addition to the active ingredient, the liquid dosage forms may contain inert diluents commonly used in the art, such as, for example, water or other solvents, cyclodextrins and derivatives thereof, solubilizing agents and emulsifiers, such as ethyl alcohol, isopropyl alcohol, ethyl carbonate, ethyl acetate, benzyl alcohol, benzyl benzoate, propylene glycol, 1,3-butylene glycol, oils (in particular, cottonseed, groundnut, corn, germ, olive, castor and sesame oils), glycerol, tetrahydrofuryl alcohol, polyethylene glycols and fatty acid esters of sorbitan, and mixtures thereof.

Besides inert diluents, the oral compositions can also include adjuvants such as wetting agents, emulsifying and suspending agents, sweetening, flavoring, coloring, perfuming and preservative agents.

Suspensions, in addition to the active compounds, may contain suspending agents as, for example, ethoxylated isostearyl alcohols, polyoxyethylene sorbitol and sorbitan esters, microcrystalline cellulose, aluminum metahydroxide, bentonite, agar-agar and tragacanth, and mixtures thereof.

Formulations of the pharmaceutical compositions for rectal, vaginal, or urethral administration may be presented as a suppository, which may be prepared by mixing one or more active compounds with one or more suitable nonirritating

excipients or carriers comprising, for example, cocoa butter, polyethylene glycol, a suppository wax or a salicylate, and which is solid at room temperature, but liquid at body temperature and, therefore, will melt in the rectum or vaginal cavity and release the active compound.

5           Formulations of the pharmaceutical compositions for administration to the mouth may be presented as a mouthwash, or an oral spray, or an oral ointment.

Alternatively or additionally, compositions can be formulated for delivery via a catheter, stent, wire, or other intraluminal device. Delivery via such devices may be especially useful for delivery to the bladder, urethra, ureter, rectum, or intestine.

10           Formulations which are suitable for vaginal administration also include pessaries, tampons, creams, gels, pastes, foams or spray formulations containing such carriers as are known in the art to be appropriate.

Dosage forms for the topical or transdermal administration include powders, sprays, ointments, pastes, creams, lotions, gels, solutions, patches and inhalants. The  
15           active compound may be mixed under sterile conditions with a pharmaceutically acceptable carrier, and with any preservatives, buffers, or propellants that may be required.

The ointments, pastes, creams and gels may contain, in addition to an active compound, excipients, such as animal and vegetable fats, oils, waxes, paraffins,  
20           starch, tragacanth, cellulose derivatives, polyethylene glycols, silicones, bentonites, silicic acid, talc and zinc oxide, or mixtures thereof.

Powders and sprays can contain, in addition to an active compound, excipients such as lactose, talc, silicic acid, aluminum hydroxide, calcium silicates and polyamide powder, or mixtures of these substances. Sprays can additionally contain  
25           customary propellants, such as chlorofluorohydrocarbons and volatile unsubstituted hydrocarbons, such as butane and propane.

Transdermal patches have the added advantage of providing controlled delivery of a compound of the present invention to the body. Such dosage forms can be made by dissolving or dispersing the active compound in the proper medium.

30           Absorption enhancers can also be used to increase the flux of the compound across the skin. The rate of such flux can be controlled by either providing a rate controlling membrane or dispersing the compound in a polymer matrix or gel.

Ophthalmic formulations, eye ointments, powders, solutions and the like, are also contemplated as being within the scope of this invention. Exemplary ophthalmic formulations are described in U.S. Publication Nos. 2005/0080056, 2005/0059744, 2005/0031697 and 2005/004074 and U.S. Patent No. 6,583,124, the contents of which are incorporated herein by reference. If desired, liquid ophthalmic formulations have properties similar to that of lacrimal fluids, aqueous humor or vitreous humor or are compatible with such fluids. A preferred route of administration is local administration (*e.g.*, topical administration, such as eye drops, or administration via an implant).

The phrases "parenteral administration" and "administered parenterally" as used herein means modes of administration other than enteral and topical administration, usually by injection, and includes, without limitation, intravenous, intramuscular, intraarterial, intrathecal, intracapsular, intraorbital, intracardiac, intradermal, intraperitoneal, transtracheal, subcutaneous, subcuticular, intraarticular, subcapsular, subarachnoid, intraspinal and intrasternal injection and infusion.

Pharmaceutical compositions suitable for parenteral administration comprise one or more active compounds in combination with one or more pharmaceutically acceptable sterile isotonic aqueous or nonaqueous solutions, dispersions, suspensions or emulsions, or sterile powders which may be reconstituted into sterile injectable solutions or dispersions just prior to use, which may contain antioxidants, buffers, bacteriostats, solutes which render the formulation isotonic with the blood of the intended recipient or suspending or thickening agents.

Examples of suitable aqueous and nonaqueous carriers that may be employed in the pharmaceutical compositions of the invention include water, ethanol, polyols (such as glycerol, propylene glycol, polyethylene glycol, and the like), and suitable mixtures thereof, vegetable oils, such as olive oil, and injectable organic esters, such as ethyl oleate. Proper fluidity can be maintained, for example, by the use of coating materials, such as lecithin, by the maintenance of the required particle size in the case of dispersions, and by the use of surfactants.

These compositions may also contain adjuvants such as preservatives, wetting agents, emulsifying agents and dispersing agents. Prevention of the action of microorganisms may be ensured by the inclusion of various antibacterial and antifungal agents, for example, paraben, chlorobutanol, phenol sorbic acid, and the

like. It may also be desirable to include isotonic agents, such as sugars, sodium chloride, and the like into the compositions. In addition, prolonged absorption of the injectable pharmaceutical form may be brought about by the inclusion of agents that delay absorption such as aluminum monostearate and gelatin.

- 5           In some cases, in order to prolong the effect of a drug, it is desirable to slow the absorption of the drug from subcutaneous or intramuscular injection. This may be accomplished by the use of a liquid suspension of crystalline or amorphous material having poor water solubility. The rate of absorption of the drug then depends upon its rate of dissolution, which, in turn, may depend upon crystal size and crystalline form.
- 10       Alternatively, delayed absorption of a parenterally administered drug form is accomplished by dissolving or suspending the drug in an oil vehicle.

- Injectable depot forms are made by forming microencapsulated matrices of the subject compounds in biodegradable polymers such as polylactide-polyglycolide. Depending on the ratio of drug to polymer, and the nature of the particular polymer
- 15       employed, the rate of drug release can be controlled. Examples of other biodegradable polymers include poly(orthoesters) and poly(anhydrides). Depot injectable formulations are also prepared by entrapping the drug in liposomes or microemulsions that are compatible with body tissue.

- For use in the methods of this invention, active compounds can be given per se
- 20       or as a pharmaceutical composition containing, for example, 0.1 to 99.5% (more preferably, 0.5 to 90%) of active ingredient in combination with a pharmaceutically acceptable carrier.

- Methods of introduction may also be provided by rechargeable or biodegradable devices. Various slow release polymeric devices have been developed
- 25       and tested *in vivo* in recent years for the controlled delivery of drugs, including proteinacious biopharmaceuticals. A variety of biocompatible polymers (including hydrogels), including both biodegradable and non-degradable polymers, can be used to form an implant for the sustained release of a compound at a particular target site.

- Actual dosage levels of the active ingredients in the pharmaceutical
- 30       compositions may be varied so as to obtain an amount of the active ingredient that is effective to achieve the desired therapeutic response for a particular patient, composition, and mode of administration, without being toxic to the patient.

The selected dosage level will depend upon a variety of factors including the activity of the particular compound or combination of compounds employed, or the ester, salt or amide thereof, the route of administration, the time of administration, the rate of excretion of the particular compound(s) being employed, the duration of the treatment, other drugs, compounds and/or materials used in combination with the particular compound(s) employed, the age, sex, weight, condition, general health and prior medical history of the patient being treated, and like factors well known in the medical arts.

A physician or veterinarian having ordinary skill in the art can readily determine and prescribe the therapeutically effective amount of the pharmaceutical composition required. For example, the physician or veterinarian could start doses of the pharmaceutical composition or compound at levels lower than that required in order to achieve the desired therapeutic effect and gradually increase the dosage until the desired effect is achieved. By “therapeutically effective amount” is meant the concentration of a compound that is sufficient to elicit the desired therapeutic effect. It is generally understood that the effective amount of the compound will vary according to the weight, sex, age, and medical history of the subject. Other factors which influence the effective amount may include, but are not limited to, the severity of the patient's condition, the disorder being treated, the stability of the compound, and, if desired, another type of therapeutic agent being administered with the compound of the invention. A larger total dose can be delivered by multiple administrations of the agent. Methods to determine efficacy and dosage are known to those skilled in the art (Isselbacher *et al.* (1996) Harrison's Principles of Internal Medicine 13 ed., 1814-1882, herein incorporated by reference).

In general, a suitable daily dose of an active compound used in the compositions and methods of the invention will be that amount of the compound that is the lowest dose effective to produce a therapeutic effect. Such an effective dose will generally depend upon the factors described above.

If desired, the effective daily dose of the active compound may be administered as one, two, three, four, five, six or more sub-doses administered separately at appropriate intervals throughout the day, optionally, in unit dosage forms. In certain embodiments of the present invention, the active compound may be



administered two or three times daily. In preferred embodiments, the active compound will be administered once daily.

The patient receiving this treatment is any animal in need, including primates, in particular humans, and other mammals such as equines, cattle, swine and sheep;  
5 and poultry and pets in general.

In certain embodiments, compounds of the invention may be used alone or conjointly administered with another type of therapeutic agent. As used herein, the phrase "conjoint administration" refers to any form of administration of two or more different therapeutic compounds such that the second compound is administered while  
10 the previously administered therapeutic compound is still effective in the body (*e.g.*, the two compounds are simultaneously effective in the patient, which may include synergistic effects of the two compounds). For example, the different therapeutic compounds can be administered either in the same formulation or in a separate formulation, either concomitantly or sequentially. In certain embodiments, the  
15 different therapeutic compounds can be administered within one hour, 12 hours, 24 hours, 36 hours, 48 hours, 72 hours, or a week of one another. Thus, an individual who receives such treatment can benefit from a combined effect of different therapeutic compounds.

This invention includes the use of pharmaceutically acceptable salts of  
20 compounds of the invention in the compositions and methods of the present invention. In certain embodiments, contemplated salts of the invention include, but are not limited to, alkyl, dialkyl, trialkyl or tetra-alkyl ammonium salts. In certain embodiments, contemplated salts of the invention include, but are not limited to, L-arginine, benenthamine, benzathine, betaine, calcium hydroxide, choline, deanol,  
25 diethanolamine, diethylamine, 2-(diethylamino)ethanol, ethanolamine, ethylenediamine, N-methylglucamine, hydrabamine, 1H-imidazole, lithium, L-lysine, magnesium, 4-(2-hydroxyethyl)morpholine, piperazine, potassium, 1-(2-hydroxyethyl)pyrrolidine, sodium, triethanolamine, tromethamine, and zinc salts. In certain embodiments, contemplated salts of the invention include, but are not limited  
30 to, Na, Ca, K, Mg, Zn or other metal salts.

The pharmaceutically acceptable acid addition salts can also exist as various solvates, such as with water, methanol, ethanol, dimethylformamide, and the like. Mixtures of such solvates can also be prepared. The source of such solvate can be

from the solvent of crystallization, inherent in the solvent of preparation or crystallization, or adventitious to such solvent.

Wetting agents, emulsifiers and lubricants, such as sodium lauryl sulfate and magnesium stearate, as well as coloring agents, release agents, coating agents,  
5    sweetening, flavoring and perfuming agents, preservatives and antioxidants can also be present in the compositions.

Examples of pharmaceutically acceptable antioxidants include: (1) water-soluble antioxidants, such as ascorbic acid, cysteine hydrochloride, sodium bisulfate, sodium metabisulfite, sodium sulfite and the like; (2) oil-soluble antioxidants, such as  
10    ascorbyl palmitate, butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), lecithin, propyl gallate, alpha-tocopherol, and the like; and (3) metal-chelating agents, such as citric acid, ethylenediamine tetraacetic acid (EDTA), sorbitol, tartaric acid, phosphoric acid, and the like.

In certain embodiments, the invention relates to a method for conducting a  
15    pharmaceutical business, by manufacturing a formulation of a compound of the invention, or a kit as described herein, and marketing to healthcare providers the benefits of using the formulation or kit for treating or preventing any of the diseases or conditions as described herein.

In certain embodiments, the invention relates to a method for conducting a  
20    pharmaceutical business, by providing a distribution network for selling a formulation of a compound of the invention, or kit as described herein, and providing instruction material to patients or physicians for using the formulation for treating or preventing any of the diseases or conditions as described herein.

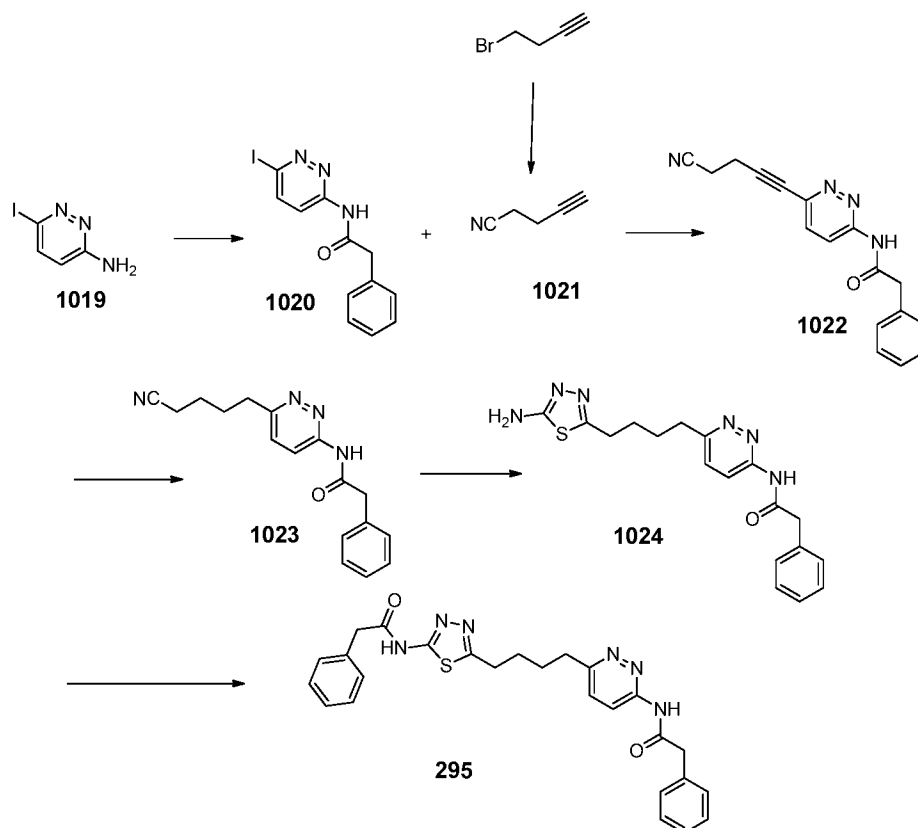
In certain embodiments, the invention comprises a method for conducting a  
25    pharmaceutical business, by determining an appropriate formulation and dosage of a compound of the invention for treating or preventing any of the diseases or conditions as described herein, conducting therapeutic profiling of identified formulations for efficacy and toxicity in animals, and providing a distribution network for selling an identified preparation as having an acceptable therapeutic profile. In certain  
30    embodiments, the method further includes providing a sales group for marketing the preparation to healthcare providers.

In certain embodiments, the invention relates to a method for conducting a pharmaceutical business by determining an appropriate formulation and dosage of a

compound of the invention for treating or preventing any of the disease or conditions as described herein, and licensing, to a third party, the rights for further development and sale of the formulation.

### Examples

#### 5 Example 1: Synthetic Protocols



- To a suspension of **1019** (1.5 g, 6.8 mmol) in CH<sub>2</sub>Cl<sub>2</sub> (15 mL) at 0 °C was added Et<sub>3</sub>N (1.9 ml, 13.6 mmol) dropwise followed by benzoyl chloride (1.07 ml, 8.1 mmol) dropwise. The resulting mixture was stirred at 0 °C and then slowly warmed up to room temperature for 2 days. The crude material was purified by silica gel chromatography eluting with 0-25% EtOAc in hexane to afford **1020**.

- To a solution of 4-bromo-1-butyne (7 g, 53 mmol) in DMSO (30 ml) at 0 °C was added NaI (7.94 g, 53 mmol). The mixture was stirred at room temperature for 2 h before it was cooled to 0 °C and followed by addition of NaCN (5.2 g, 106 mmol). The resulting mixture was heated at 80 °C for 2.5 h and then stirred at room temperature overnight. The mixture was partitioned between water and EtOAc. The

organic extract was washed with water, dried over sodium sulfate, filtered and evaporated to afford **1021**.

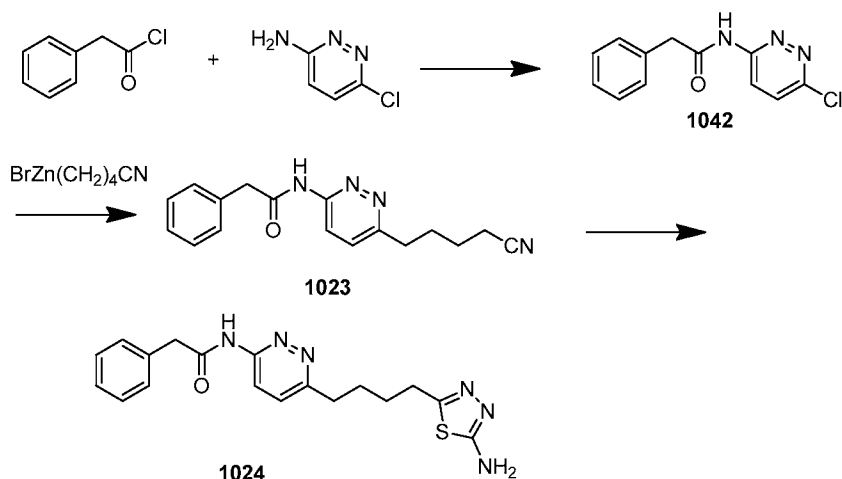
To a mixture of **1020** (400 mg, 1.18 mmol), PdCl<sub>2</sub>(PPh<sub>3</sub>)<sub>2</sub> (41 mg, 0.059 mmol) and CuI (11 mg, 0.059 mmol) in Et<sub>3</sub>N (3 ml) and THF (6 ml) under argon atmosphere was added **1021** (187 mg, 2.36 mmol), then heated at 60 °C overnight. After removal of the solvent, the residue was purified by silica gel chromatography eluting with 0-60% EtOAc in Hexane to afford **1022**.

To a solution of **1022** (118 mg, 0.406 mmol) in the mixture of EtOAc (60 ml) and EtOH (15 ml) was added Pd(OH)<sub>2</sub>/C (50 mg, 0.356 mmol). Hydrogen was bubbled through the resulting mixture and stirred for 1 h. The Pd catalyst was filtered off and the filtrate was concentrated to afford **1023**.

A mixture of **1023** (127 mg, 0.431 mmol) and thiosemicarbazide (51 mg, 0.561 mmol) in TFA (3 mL) was heated at 85 °C for 5 h. The reaction was cooled to room temperature and poured onto a mixture of ice-water. The mixture was basified with NaOH pellets (pH 10). The crude material was purified by silica gel chromatography eluting with 0-6% MeOH in CH<sub>2</sub>Cl<sub>2</sub> to afford **1024**.

To a solution of **1024** (38.4 mg, 0.104 mmol) in NMP (1 mL) at 0 °C was added phenyl acetyl chloride (0.017 mL, 0.125 mmol) dropwise. The resulting mixture was stirred at 0 °C for 1.5 h before it was quenched by addition of water (~10 mL). The mixture was partitioned between water and EtOAc. The organic extract was washed with water, dried over sodium sulfate, filtered and evaporated. The crude material was purified by silica gel chromatography eluting with 0-6% MeOH in CH<sub>2</sub>Cl<sub>2</sub> to afford **295**. <sup>1</sup>H NMR (300 MHz, DMSO-d<sub>6</sub>) δ 12.65 (s, 1H), 11.26 (s, 1H), 8.22-8.19 (d, *J* = 8.82 Hz, 1H), 7.58-7.54 (d, *J* = 9.72 Hz, 1H), 7.36-7.28 (m, 10H), 3.81-3.78 (d, *J* = 8.43 Hz, 4H), 3.01 (bs, 2H), 2.90 (bs, 2H), 1.73 (bs, 4H).

Compound **1024** can also be prepared according to the following procedure:



To a solution of 3-amino-6-chloropyridazine (11.14 g, 86.0 mmol) in NMP (279 mL) at 19°C was added phenylacetyl chloride (18.2 mL, 137.6 mmol) dropwise over 5 minutes with the internal temperature of the solution maintained  $T_i \leq 28^\circ\text{C}$ . The resulting mixture was stirred at 19°C for 90 minutes and poured into ice water (557 mL). The white precipitate was collected by suction filtration, rinsed with water (2x110 mL) and diethyl ether (110 mL). The product was dried overnight under high vacuum to afford N-(6-chloropyridazin-3-yl)-2-phenylacetamide (xxx, 18.8 g).  $^1\text{H}$  NMR (300 MHz, DMSO- $d_6$ )  $\delta$  11.57(s, 1H), 8.40(d,  $J=9.636$  Hz, 1H), 7.90(d,  $J=9.516$  Hz, 1H), 7.36(m, 5H) 3.82(s, 2H)

A 1000 mL three-neck flask fitted with internal temperature probe and addition funnel was flushed with  $\text{Ar}_{(\text{g})}$ . Under positive Argon pressure 4-cyanobutylzinc bromide (0.5M in THF, 500mL, 250 mmol) was charged into the addition funnel then added to the reaction vessel at room temperature. Solid N-(6-chloropyridazin-3-yl)-2-phenylacetamide (20.6 g, 83.3 mmol) was added to the stirred solution at RT under  $\text{Ar}_{(\text{g})}$  flow, followed by the addition of  $\text{NiCl}_2(\text{dppp})$  (4.52 g, 8.33 mmol). The resulting mixture was stirred at 19°C for 240 minutes and then quenched with ethanol (120 mL). Water (380mL) added to the stirred red solution, giving a thick precipitate. Ethyl acetate (760 mL) added and stirred well for 30 minutes. The solids were removed by filtration through a pad of celite. The mother liquor was then transferred to a separatory funnel and the organic layer was washed with  $\text{H}_2\text{O}$  (380mL), 0.5% ethylenediaminetetraacetic acid solution (380 mL) and again with  $\text{H}_2\text{O}$  (380mL). The organic layer was concentrated by rotoevaporation. Resulting red oil was redissolved in EtOAc (200 mL) and 1M HCl (380 mL) was added to the well stirred flask. After

30 minutes the mixture was transferred to separatory funnel and the aqueous layer collected. The organic layer was extracted with 1M HCl (2x380mL). The aqueous layer's pH was then adjusted to ~7 using 7.5% sodium bicarbonate solution and the pale yellow precipitate was collected by suction filtration, rinsed with water (200 mL)

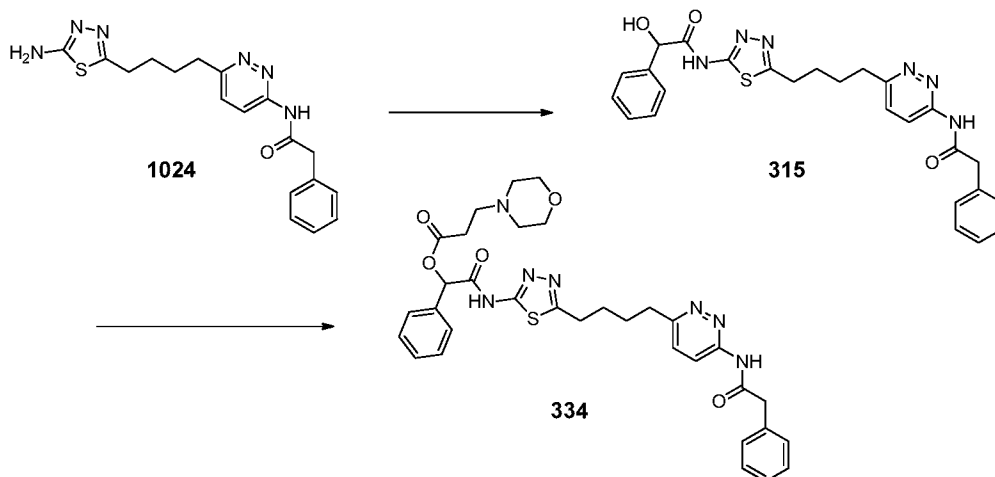
5 and diethyl ether (2x200mL). The solid was dried overnight under high vacuum to afford N-(6-(4-cyanobutyl)pyridazin-3-yl)-2-phenylacetamide (**1023**, 14.76 g). <sup>1</sup>H NMR (300 MHz, DMSO-d<sub>6</sub>) δ 11.29(s, 1H), 8.23(d, *J*=9.036 Hz, 1H), 7.59(d, *J*=9.246 Hz, 1H), 7.32(m, 5H), 3.79(s, 2H), 2.90(t, *J*= 7.357 Hz, 2H), 2.56(t, *J*= 7.038 Hz, 2H), 1.79(t, *J*= 7.311 Hz, 2H), 1.63(t, *J*= 7.01 Hz, 2H)

10 N-(6-(4-cyanobutyl)pyridazin-3-yl)-2-phenylacetamide (14.7 g, 50.2 mmol) was charged into a 250 mL round bottom flask fitted with an open top reflux condenser. To the flask was added thiosemicarbazide (5.03 g, 55.2 mmol) and trifluoroacetic acid (88 mL). The reaction slurry was heated in a 65°C bath for 2 h. After cooling to RT, H<sub>2</sub>O (150 mL) was added and stirred for 30 minutes. The mixture was then slowly

15 transferred to a stirred 7.5% sodium bicarbonate solution (1400mL) cooled in a 0°C bath. The precipitate was collected by suction filtration, rinsed with water (2x200 mL), diethyl ether (2x200mL) and dried under high vacuum overnight. The off-white solid was slurried in DMSO (200 mL) and heated in an 80°C bath until the internal temperature reached 65°C. DMSO (105 mL) was used to rinse sides of flask. H<sub>2</sub>O

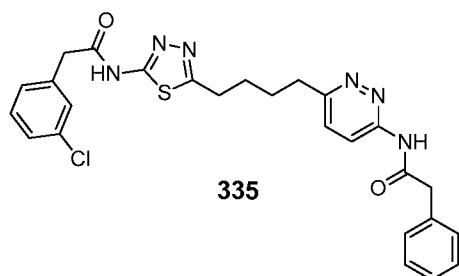
20 (120 mL) was slowly added until the solution became slightly cloudy and then the mixture was removed from heat bath and allowed to cool to ambient temperature while stirring. The pale green precipitate was collected by suction filtration, rinsed with water (200 mL) and diethyl ether (2x200mL). The solid was dried overnight under high vacuum to provide N-(6-(4-(5-amino-1,3,4-thiadiazol-2-

25 yl)butyl)pyridazin-3-yl)-2-phenylacetamide (**1024**, 15.01 g). <sup>1</sup>H NMR (300 MHz, DMSO-d<sub>6</sub>) δ 11.28(s, 1H), 8.23(d, *J*=8.916 Hz, 1H), 7.59(d, *J*=8.826 Hz, 1H), 7.36(m, 5H), 7.07(s, 2H), 3.78(s, 2H), 2.87(t, *J*= 6.799 Hz, 4H), 1.69(bm, 4H).

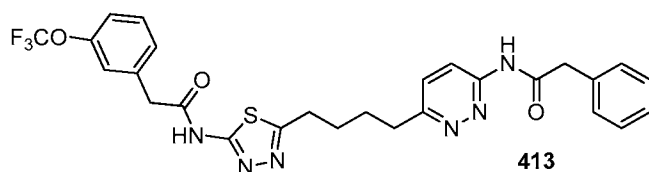


A flask was charged with **1024** (500 mg, 1.36 mmol), DL-mandelic acid (248 mg, 1.63 mmol) in DMF (10 ml) at 0 °C was added HOBT (441 mg, 3.26 mmol) followed by EDCI (781 mg, 4.08 mmol). The resulting mixture was stirred at 0 °C for 10 minutes then warmed up to room temperature and stirred for 10 minutes before it was quenched by addition of water (~50 mL) at 0 °C. The white precipitate was collected by suction filtration, rinsed with more water and dried to afford **315**. <sup>1</sup>H NMR (300 MHz, DMSO-d<sub>6</sub>) δ 12.65 (s, 1H), 11.26 (s, 1H), 8.22-8.19 (d, *J* = 8.82 Hz, 1H), 7.58-7.50 (m, 3H), 7.36-7.28 (m, 8H), 6.35 (s, 1H), 5.32 (s, 1H), 3.78 (s, 2H), 3.01 (bs, 2H), 2.90 (bs, 2H), 1.73 (bs, 4H).

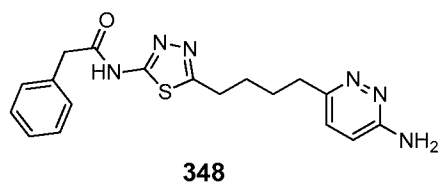
To a suspension of 3-morpholin-4-yl-propionic acid hydrochloride (209 mg, 1.07 mmol) in DMF (10 ml) was added EDCI (308 mg, 1.61 mmol). The resulting mixture was stirred at 0 °C for 1 hour and followed by addition of **315** (447 mg, 0.889 mmol) and 4-DMAP (261 mg, 2.14 mmol). The resulting mixture was stirred from 0 °C to room temperature over a period of 6 h before it was quenched by addition of ice water (~50mL). The white precipitate was collected by suction filtration, rinsed with more water. The crude material was purified by silica gel chromatography eluting with 0–6% MeOH in EtOAc to afford **334**. <sup>1</sup>H NMR (300 MHz, DMSO-d<sub>6</sub>) δ 12.95 (s, 1H), 11.26 (s, 1H), 8.22-8.19 (d, *J* = 9.45 Hz, 1H), 7.58-7.26 (m, 11H), 6.14 (s, 1H), 3.78 (s, 2H), 3.54 (bs, 4H), 3.01 (bs, 2H), 2.90 (bs, 2H), 2.63 (bs, 4H), 2.38 (bs, 4H), 1.73 (bs, 4H).



A flask was charged with **1024** (50 mg, 0.135 mmol), 3-chlorophenylacetic acid (28 mg, 0.163 mmol) in DMF (1 ml) at 0 °C was added HOBT (44 mg, 0.326 mmol) followed by EDCI (78 mg, 0.408 mmol). The resulting mixture was slowly warmed up to room temperature and stirred for 1 h before it was quenched by addition of water (~5 mL). The white precipitate was collected by suction filtration, rinsed with more water and ether then dried to afford **335**. <sup>1</sup>H NMR (300 MHz, DMSO-d<sub>6</sub>) δ 12.65 (s, 1H), 11.26 (s, 1H), 8.22-8.19 (d, *J* = 8.82 Hz, 1H), 7.58-7.54 (d, *J* = 9.72 Hz, 1H), 7.36-7.28 (m, 9H), 3.84 (s, 2H), 3.78 (s, 2H), 3.01 (bs, 2H), 2.90 (bs, 2H), 1.73 (bs, 4H).



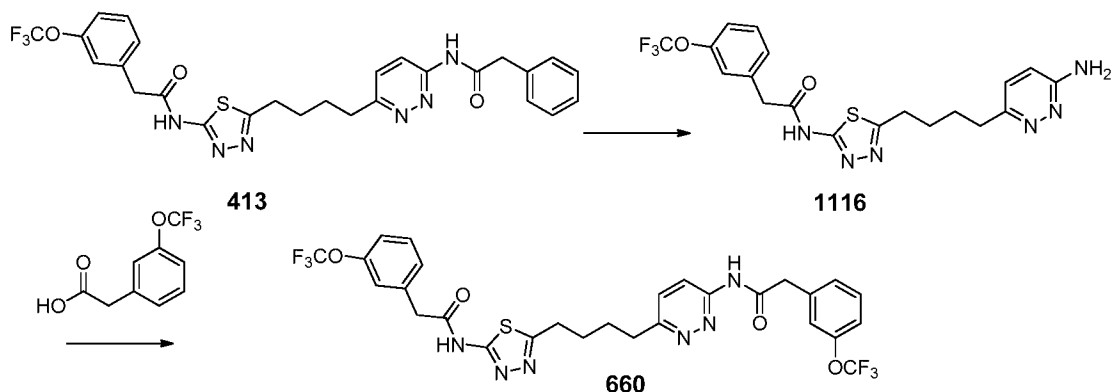
Compound **413** was prepared according to the procedure above for the preparation of compound **315**. <sup>1</sup>H NMR (300 MHz, DMSO-d<sub>6</sub>) δ 12.68 (bs, 1H), 11.26 (s, 1H), 8.20 (d, *J* = 9.46 Hz, 1H), 7.58-7.26 (m, 10H), 3.90 (s, 2H), 3.78 (s, 2H), 3.02 (bs, 2H), 2.90 (bs, 2H), 1.74 (bs, 4H).



To a suspension of **295** (30 mg, 0.0617 mmol) in MeOH (2 ml) at 0 °C was added 2N NaOH (2 ml) solution. The resulting mixture was stirred at room temperature overnight. The solvent was evaporated under vacuo and the mixture was acidified with 1N HCl to pH 6. The white precipitate was collected by suction filtration, rinsed



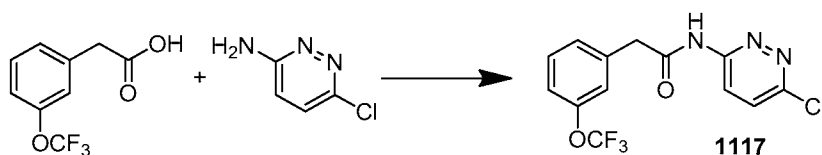
with more water and dried to afford **348**.  $^1\text{H}$  NMR (300 MHz, DMSO- $d_6$ )  $\delta$  7.32-7.24 (m, 5H), 7.15-7.12 (d,  $J$  = 9.57 Hz, 1H), 6.72-6.69 (d,  $J$  = 9.15 Hz, 1H), 6.09 (s, 2H), 3.77 (s, 2H), 2.99-2.96 (bs, 2H), 2.76-2.70 (bs, 2H), 1.70 (bs, 4H).



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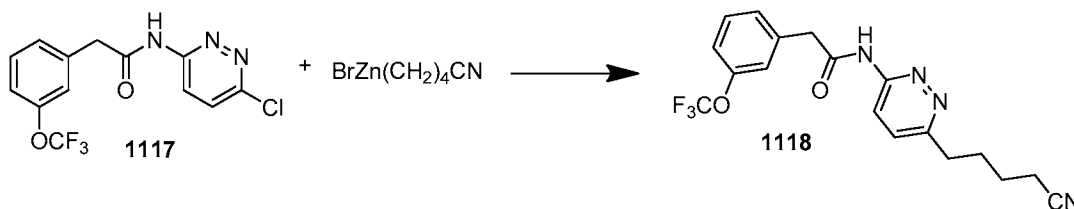
To a mixture of **413** (1.62 g) in MeOH (25 mL), THF (10 mL) and H<sub>2</sub>O (10 mL) at room temperature was added 1N aq. NaOH (8 mL). This mixture was stirred for 24 h before the organic volatile was removed under reduced pressure. The residue was neutralized to pH 7 with 1N aq. HCl solution and extracted with EtOAc (2×20 mL).

- 10 The combined extract was dried (MgSO<sub>4</sub>) and concentrated. The crude was purified by silica gel chromatography eluting with 1–15% MeOH in dichloromethane (DCM) to afford amine **1116**. The resulting amine **1116** was converted to **660** as described for **335**.  $^1\text{H}$  NMR (300 MHz, DMSO- $d_6$ )  $\delta$  12.68 (bs, 1H), 11.31 (s, 1H), 8.20 (d,  $J$  = 9.2 Hz, 1H), 7.57 (d,  $J$  = 8.8 Hz, 1H), 7.52–7.21 (m, 8H), 3.90 (s, 2H), 3.87 (s, 2H),
- 15 3.06–2.86 (m, 4H), 1.77–1.72 (m, 4H).

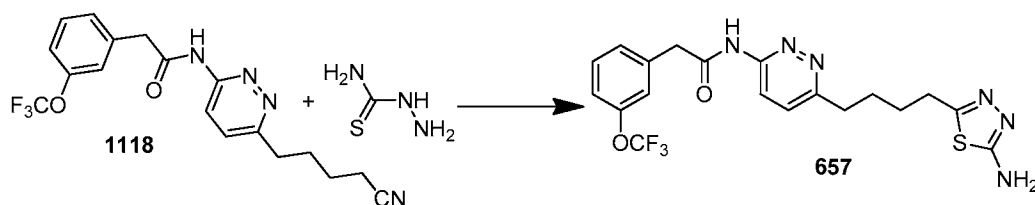


- 3-Amino-6-chloropyridazine (55.5 g, 0.428 mol) and 3-(Trifluoromethoxy)phenylacetic acid (1.1 equiv., 0.471 mol, 104 g) were dissolved in DMF (30.0 vol., 1.66 L) in a 3000 mL three neck round-bottom flask. Addition of
- 20 DIEA (1.1 equiv., 0.471 mol, 82 mL) via addition funnel was done over 5 minutes. Propylphosphonic anhydride solution (300 mL of a 50% solution in DMF, 1.1 equiv., 0.471 mol, ) was charged into a 500 mL addition funnel and added dropwise to

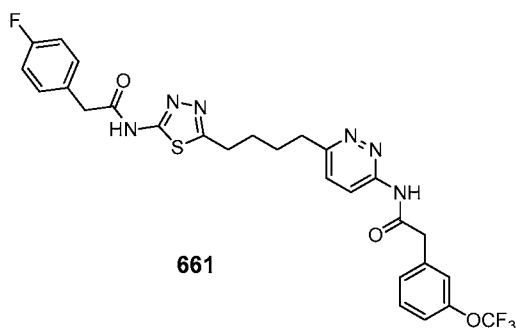
reaction solution (keeping reaction temperature  $\leq +30\text{ }^{\circ}\text{C}$ ). The reaction usually goes to completion after 3 hours (TLC: 6:4 hexanes-ethyl acetate). Reaction mixture was then poured into 7.5% sodium bicarbonate (80.0 vol., 4.4 L) which was chilled in an ice bath. Off-white crystalline powder was filtered through a Büchner funnel, rinsed with water (20.0 vol., 1.1 L). Dried in a  $50\text{ }^{\circ}\text{C}$  vacuum to a constant weight to afford N-(6-chloropyridazin-3-yl)-2-(3-(trifluoromethoxy)phenyl)acetamide **1117**: yield of 119.6 g (77%).  $^1\text{H}$  NMR (300 MHz, DMSO- $d_6$ )  $\delta$  11.63 (s, 1H), 8.38(d,  $J=9.4$  Hz, 1H), 7.88(d,  $J=9.4$  Hz, 1H), 7.52 – 7.27(m, 4H), 3.90(s, 2H).



4-Cyanobutylzinc bromide solution (3.0 equiv., 0.50 mol, 1.0 L) was charged into an argon gas purged 5000 mL 3 neck round bottom flask. Argon<sub>(g)</sub> purge for 5 minutes followed by the addition of **1117** (1.0 equiv., 0.167 mol, 55.3 g) and NiCl<sub>2</sub>(dppp) (0.15 equiv., 0.0251 mol, 13.6 g) under a blanket of argon<sub>(g)</sub>. The reaction usually goes to completion after 4 hours (TLC: 1:1 hexanes-ethyl acetate). EtOAc (15 vol., 832 mL) added to deep red solution. Water (15 vol., 832 mL) was added, thick slurry formed. 1N HCl added until slurry breaks to pale blue layer (~6 vol., 333 mL). Transferred to separatory funnel and organic layer was washed with 1N HCl (2x500 mL), dried (MgSO<sub>4</sub>) and concentrated by rotary evaporation (bath  $\leq 30\text{ }^{\circ}\text{C}$ ) to a solid reddish oil. Oil dissolved in dichloromethane (15 vol., 832 mL), silica gel (100g) was slurried into red solution, this was concentrated by rotary evaporation (bath  $\leq 30\text{ }^{\circ}\text{C}$ ) to a solid reddish powder. Loaded onto a bed of silica gel (5 cm x 11 cm), flushed with 25% hexanes in ethyl Acetate (3 L), combined organics concentrated by rotary evaporation (bath  $\leq 30\text{ }^{\circ}\text{C}$ ). Dried under high vacuum to a constant weight to afford N-(6-(4-cyanobutyl)pyridazin-3-yl)-2-(3-(trifluoromethoxy)phenyl)acetamide **1118**: yield of 58.2 g (92%).  $^1\text{H}$  NMR (300 MHz, DMSO- $d_6$ )  $\delta$  11.41 (s, 1H), 8.28(d,  $J=9.2$  Hz, 1H), 7.65(d,  $J=9.2$  Hz, 1H), 7.52 – 7.27(m, 4H), 3.89(s, 2H), 2.92(t,  $J=7.5$  Hz, 2H), 2.56(t,  $J=7.0$  Hz, 2H), 1.80 (m, 2H), 1.61 (m, 2H).

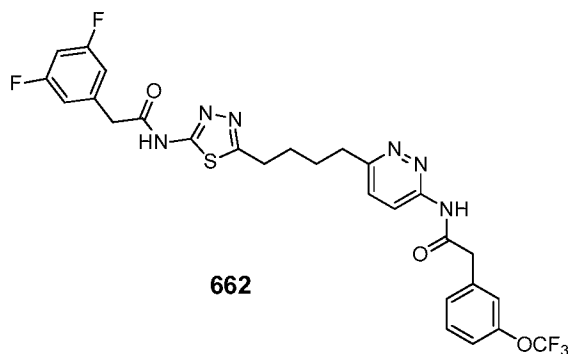


**1118** (1.0 equiv., 0.154 mol, 58.2 g) was charged into a 500 mL round bottom flask along with thiosemicarbazide (1.2 equiv., 0.184 mol, 16.8 g). TFA (5 vol., 291 mL) slowly added to reaction vessel while stirring. The reaction slurry was heated in a 5 65°C bath with an open top reflux condenser. The reaction usually goes to completion after 5 hours (determined by LC/MS). Toluene (10 vol., 582 mL) added to deep red solution, azeotroped by rotary evaporation (bath ≤ 30 °C) to a red oil. Slowly transferred oil to a well stirred 6000 mL Erlenmeyer flask containing 7.5% sodium bicarbonate solution (69 vol., 4.0 L) cooled in a 0°C bath. The crystals were 10 filtered through a Büchner funnel and rinsed twice with diethyl ether (5 vol., 2x250 mL). Dried under high vacuum to a constant weight to afford N-(6-(4-(5-amino-1,3,4-thiadiazol-2-yl)butyl)pyridazin-3-yl)-2-(3-(trifluoromethoxy)phenyl)acetamide **657**; yield of 55.7 g (80%). <sup>1</sup>H NMR (300 MHz, DMSO-d<sub>6</sub>) δ 11.33 (s, 1H), 8.21(d, J=9.2 Hz, 1H), 7.58(d, J=9.2 Hz, 1H), 7.51 – 7.26(m, 4H), 6.99(s, 2H), 3.88(s, 2H), 15 2.87(m, 4H), 1.71 (m, 4H).

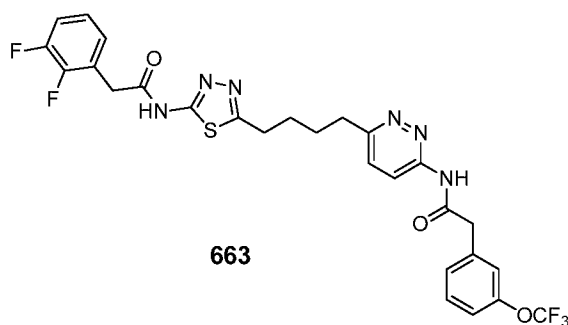


To a solution of **657** (50 mg, 0.11 mmol) in DMF (3 mL) at 0 °C was added 4-fluorophenyl acetic acid (22 mg, 0.14 mmol), HOBt (30 mg, 0.22 mmol) and EDCI (42 mg, 0.22 mmol). The resulting mixture was stirred at room temperature for 1.5 h 20 before it was cooled to 0 °C and quenched with H<sub>2</sub>O. The precipitate was collected by suction filtration and further purified by silica gel chromatography eluting with 1–10% MeOH in DCM to afford **661**. <sup>1</sup>H NMR (300 MHz, DMSO-d<sub>6</sub>) δ 12.65 (bs, 1H),

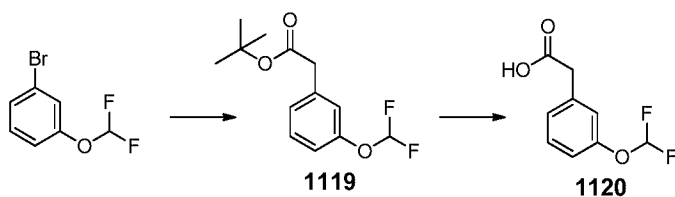
11.31 (s, 1H), 8.20 (d,  $J = 9.1$  Hz, 1H), 7.57 (d,  $J = 9.4$  Hz, 1H), 7.49–7.14 (m, 8H), 3.87 (s, 2H), 3.81 (s, 2H), 3.06–2.86 (m, 4H), 1.77–1.72 (m, 4H).



**662** was prepared by the procedure as described for compound **661**.  $^1\text{H}$  NMR (300 MHz, DMSO- $d_6$ )  $\delta$  12.67 (bs, 1H), 11.31 (s, 1H), 8.20 (d,  $J = 9.1$  Hz, 1H), 7.57 (d,  $J = 9.1$  Hz, 1H), 7.51–7.07 (m, 7H), 3.89 (s, 2H), 3.87 (s, 2H), 3.06–2.86 (m, 4H), 1.77–1.72 (m, 4H).



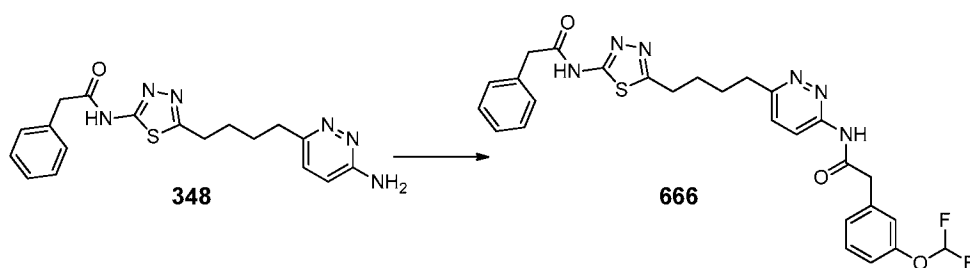
**663** was prepared by the procedure as described for compound **661**.  $^1\text{H}$  NMR (300 MHz, DMSO- $d_6$ )  $\delta$  12.74 (bs, 1H), 11.31 (s, 1H), 8.20 (d,  $J = 9.2$  Hz, 1H), 7.57 (d,  $J = 9.2$  Hz, 1H), 7.51–7.19 (m, 7H), 3.97 (s, 2H), 3.87 (s, 2H), 3.06–2.86 (m, 4H), 1.77–1.72 (m, 4H).



To a mixture of 1-bromo-3-(difluoromethoxy) benzene (1 g, 4.5 mmol), bis(tri-tert-butylphosphine) palladium(0) (460 mg, 0.9 mmol) in 1,4-dioxane (30 ml) under argon

atmosphere was added 0.5 M of 2-tert-butoxy-2-oxoethyl zinc chloride in ether (22.5 ml). The resulting mixture was stirred at room temperature overnight. The mixture was partitioned between saturated  $\text{NH}_4\text{Cl}$  and EtOAc. The organic extract was washed with brine, dried over sodium sulfate, filtered and evaporated. The crude material was purified by silica gel chromatography eluting with 0-10% EtOAc in Hexane to afford **1119**.

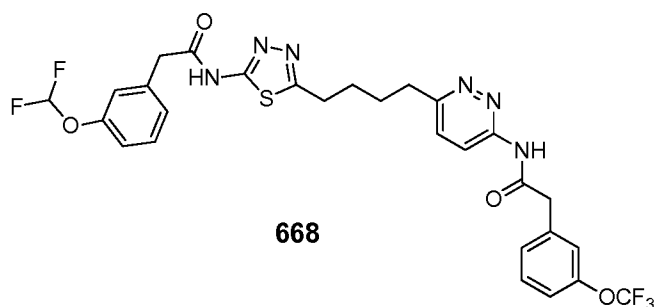
To a solution of **1119** (300 mg, 1.16 mmol) in DCM (5 ml) at 0 °C was added TFA (3 ml) dropwise. The resulting mixture was stirred at room temperature overnight before it was evaporated to dryness then triturated the residue with ether to afford **1120**.



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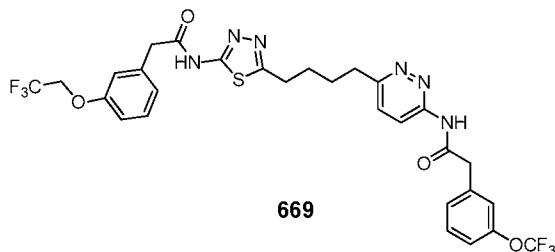
A flask was charged with **348** (50 mg, 0.135 mmol), **1120** (28 mg, 0.142 mmol) in DMF (1 ml) at 0 °C was added HOBT (39 mg, 0.285 mmol) followed by EDCI (68 mg, 0.356 mmol). The resulting mixture was slowly warmed up to room temperature and stirred overnight before it was quenched by addition of ice water (~5 mL). The white precipitate was collected by suction filtration, rinsed with more water. The crude material was purified by silica gel chromatography eluting with 0-6% MeOH in DCM to afford **666**.  $^1\text{H}$  NMR (300 MHz,  $\text{DMSO-d}_6$ )  $\delta$  12.71 (s, 1H), 11.32 (s, 1H), 8.22-8.19 (d,  $J$  = 9.12 Hz, 1H), 7.58-7.54 (d,  $J$  = 9.03 Hz, 1H), 7.48-6.98 (m, 10H), 3.81 (bs, 4H), 3.01 (bs, 2H), 2.90 (bs, 2H), 1.73 (bs, 4H).

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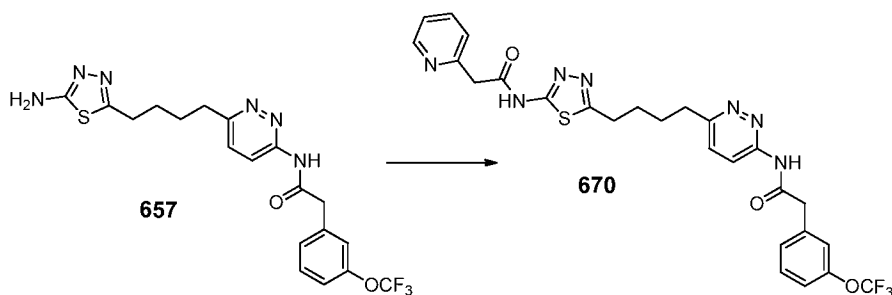


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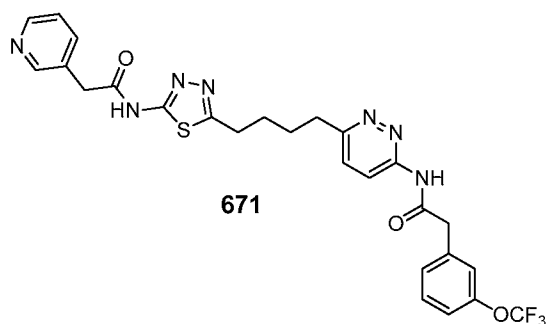
**668** was made using procedure described for compound **675**.  $^1\text{H}$  NMR (300 MHz, DMSO- $d_6$ )  $\delta$  12.71 (s, 1H), 11.32 (s, 1H), 8.22-8.19 (d,  $J = 9.15$  Hz, 1H), 7.58-6.99 (m, 10H), 3.87-3.84 (d, 4H), 3.01 (bs, 2H), 2.90 (bs, 2H), 1.73 (bs, 4H).



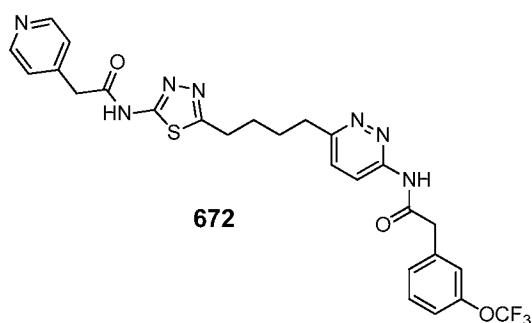
- 5 **669** was made using procedure described for compound **675**.  $^1\text{H}$  NMR (300 MHz, DMSO- $d_6$ )  $\delta$  12.71 (s, 1H), 11.32 (s, 1H), 8.22-8.19 (d,  $J = 9.09$  Hz, 1H), 7.58-7.54 (d,  $J = 9.37$  Hz, 1H), 7.48-7.28 (m, 6H), 7.03-6.97 (m, 2H), 4.77-4.74 (q, 2H), 3.87 (s, 2H), 3.78 (s, 2H), 3.01 (bs, 2H), 2.90 (bs, 2H), 1.73 (bs, 4H).



- 10 A flask was charged with **657** (50 mg, 0.111 mmol), 2-pyridine acetic acid hydrochloride (20 mg, 0.116 mmol) in DMF (1 ml) at 0  $^{\circ}\text{C}$  was treated with propylphosphonic anhydride solution (91  $\mu\text{l}$ ) followed by triethylamine (40  $\mu\text{l}$ , 0.29 mmol). The resulting mixture was slowly warmed up to room temperature and stirred for 1 h before it was quenched by addition of ice water ( $\sim 5$  mL). The yellow
- 15 precipitate was collected by suction filtration, rinsed with more water. The crude material was purified by silica gel chromatography eluting with 0-6% MeOH in DCM to afford **670**.  $^1\text{H}$  NMR (300 MHz, DMSO- $d_6$ )  $\delta$  12.67 (s, 1H), 11.32 (s, 1H), 8.53-8.49 (m, 1H), 8.22-8.19 (d,  $J = 9.12$  Hz, 1H), 7.78-7.76 (t, 1H), 7.58-7.26 (m, 7H), 4.01 (s, 2H), 3.87 (s, 2H), 3.01 (bs, 2H), 2.90 (bs, 2H), 1.73 (bs, 4H).

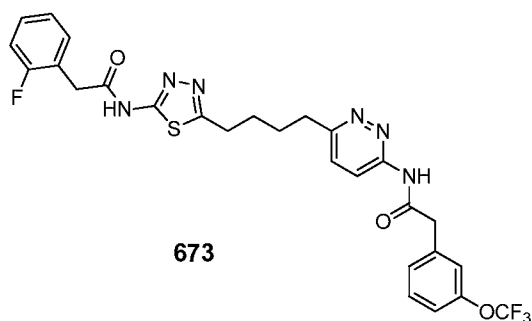


**671** was made using procedure described for compound **670**.  $^1\text{H}$  NMR (300 MHz, DMSO- $d_6$ )  $\delta$  12.70 (s, 1H), 11.32 (s, 1H), 8.53-8.48 (m, 2H), 8.22-8.19 (d,  $J$  = 9.12 Hz, 1H), 7.76-7.26 (m, 7H), 3.87 (s, 4H), 3.01 (bs, 2H), 2.90 (bs, 2H), 1.73 (bs, 4H).

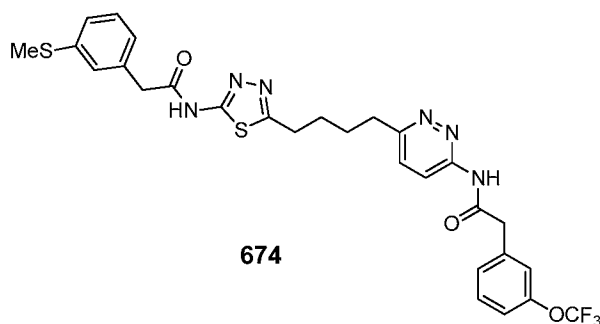


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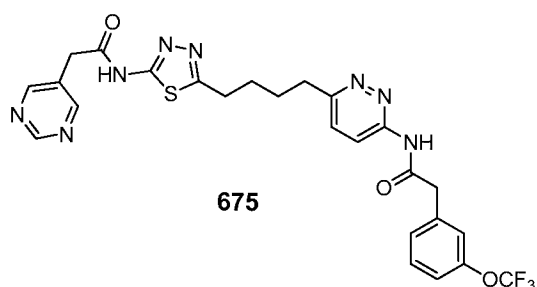
**672** was made using procedure described for compound **670**.  $^1\text{H}$  NMR (300 MHz, DMSO- $d_6$ )  $\delta$  11.32 (s, 1H), 8.53-8.52 (bs, 2H), 8.22-8.19 (d,  $J$  = 9.12 Hz, 1H), 7.58-7.26 (m, 7H), 3.87 (s, 4H), 3.01 (bs, 2H), 2.90 (bs, 2H), 1.73 (bs, 4H).



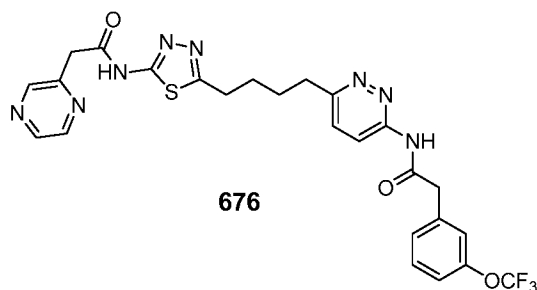
10 **673** was prepared by the procedure as described for compound **661**.  $^1\text{H}$  NMR (300 MHz, DMSO- $d_6$ )  $\delta$  12.69 (bs, 1H), 11.31 (s, 1H), 8.20 (d,  $J$  = 9.1 Hz, 1H), 7.57 (d,  $J$  = 9.1 Hz, 1H), 7.51-7.21 (m, 8H), 3.90 (s, 2H), 3.87 (s, 2H), 3.06-2.86 (m, 4H), 1.77-1.72 (m, 4H).



**674** was prepared by the procedure as described for compound **661**.  $^1\text{H}$  NMR (300 MHz, DMSO- $d_6$ )  $\delta$  12.63 (bs, 1H), 11.32 (s, 1H), 8.20 (d,  $J$  = 9.2 Hz, 1H), 7.57 (d,  $J$  = 9.2 Hz, 1H), 7.51–7.38 (m, 3H), 7.33–7.09 (m, 5H), 3.87 (s, 2H), 3.79 (s, 2H),  
 5 3.06–2.86 (m, 4H), 2.48 (s, 3H), 1.77–1.72 (m, 4H).

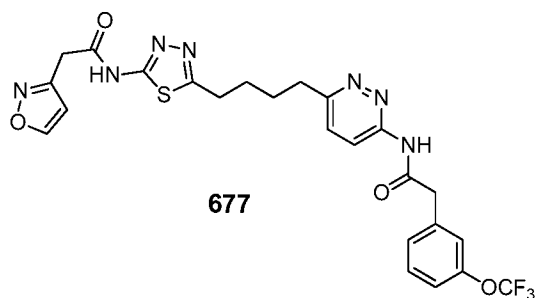


A flask was charged with **657** (70 mg, 0.155 mmol), 5-pyrimidineacetic acid (22 mg, 0.162 mmol) in DMF (1 ml) at 0  $^{\circ}\text{C}$  was added HOBT (44 mg, 0.326 mmol) followed by EDCI (78 mg, 0.408 mmol). The resulting mixture was slowly warmed up to room  
 10 temperature and stirred for overnight before it was quenched by addition of ice water (~5 mL). The white precipitate was collected by suction filtration, rinsed with more water. The crude material was purified by silica gel chromatography eluting with 0–6% MeOH in DCM to afford **675**.  $^1\text{H}$  NMR (300 MHz, DMSO- $d_6$ )  $\delta$  12.75 (s, 1H), 11.32 (s, 1H), 9.11 (s, 1H), 8.76 (s, 1H), 8.22–8.19 (d,  $J$  = 9.12 Hz, 1H), 7.59–7.26 (m, 6H), 3.94 (s, 2H), 3.87 (s, 2H), 3.01 (bs, 2H), 2.90 (bs, 2H), 1.73 (bs, 4H).  
 15



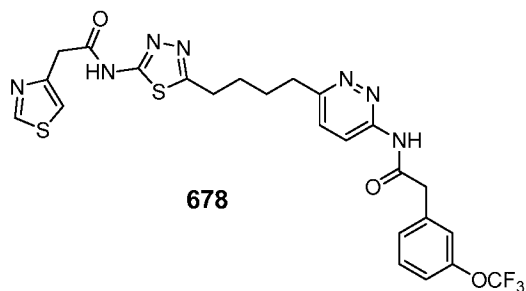


**676** was made using procedure described for compound **675**.  $^1\text{H}$  NMR (300 MHz, DMSO- $d_6$ )  $\delta$  12.75 (s, 1H), 11.32 (s, 1H), 8.70 (s, 1H), 8.61-8.57 (m, 2H), 8.22-8.19 (d,  $J = 9.36$  Hz, 1H), 7.59-7.26 (m, 5H), 4.11 (s, 2H), 3.87 (s, 2H), 3.01 (bs, 2H), 2.90 (bs, 2H), 1.73 (bs, 4H).



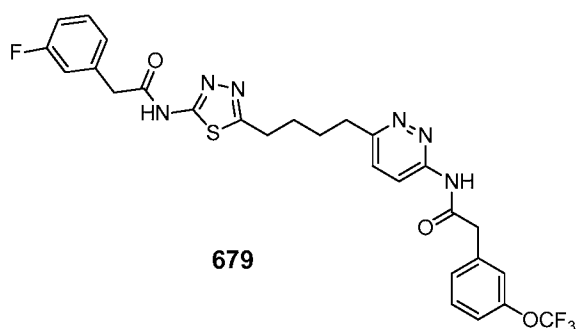
5

**677** was made using procedure described for compound **675**.  $^1\text{H}$  NMR (300 MHz, DMSO- $d_6$ )  $\delta$  12.75 (s, 1H), 11.32 (s, 1H), 8.89 (s, 1H), 8.22-8.19 (d,  $J = 9.15$  Hz, 1H), 7.59-7.26 (m, 5H), 6.62 (s, 1H), 3.99 (s, 2H), 3.87 (s, 2H), 3.01 (bs, 2H), 2.90 (bs, 2H), 1.73 (bs, 4H).



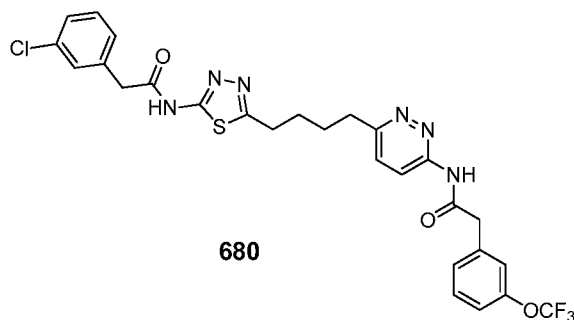
10

**678** was made using procedure described for compound **675**.  $^1\text{H}$  NMR (300 MHz, DMSO- $d_6$ )  $\delta$  12.75 (s, 1H), 11.32 (s, 1H), 9.06 (s, 1H), 8.22-8.19 (d,  $J = 9.21$  Hz, 1H), 7.59-7.26 (m, 6H), 4.03 (s, 2H), 3.87 (s, 2H), 3.01 (bs, 2H), 2.90 (bs, 2H), 1.73 (bs, 4H).



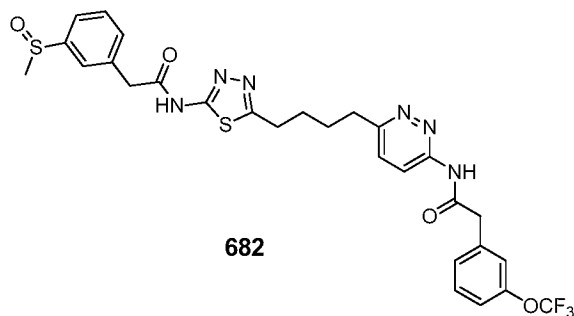
15

**679** was prepared by the procedure as described for compound **661**.  $^1\text{H}$  NMR (300 MHz, DMSO- $d_6$ )  $\delta$  12.67 (bs, 1H), 11.31 (s, 1H), 8.20 (d,  $J = 9.2$  Hz, 1H), 7.57 (d,  $J = 9.2$  Hz, 1H), 7.51–7.36 (m, 4H), 7.29–7.12 (m, 4H), 3.87 (s, 2H), 3.85 (s, 2H), 3.06–2.86 (m, 4H), 1.77–1.72 (m, 4H).



5

**680** was prepared by the procedure as described for compound **661**.  $^1\text{H}$  NMR (300 MHz, DMSO- $d_6$ )  $\delta$  12.67 (bs, 1H), 11.31 (s, 1H), 8.20 (d,  $J = 9.3$  Hz, 1H), 7.57 (d,  $J = 9.0$  Hz, 1H), 7.51–7.28 (m, 8H), 3.87 (s, 2H), 3.84 (s, 2H), 3.06–2.86 (m, 4H), 1.77–1.72 (m, 4H).

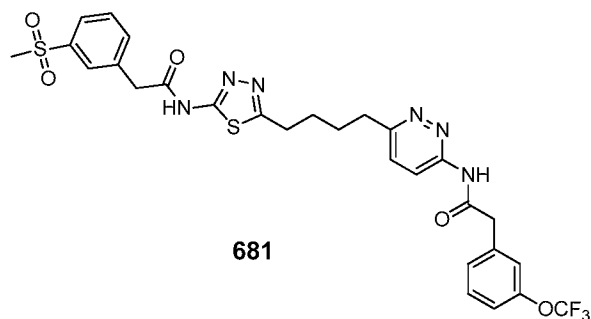


10

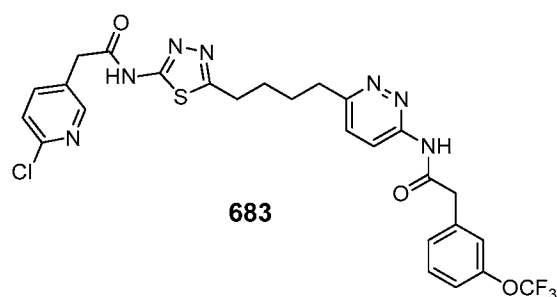
To a solution of **674** (100 mg, 0.16 mmol) in DCM at  $-78$  °C was added *m*-CPBA (60 mg, 0.24 mmol) in 4 portions. The resulting mixture was stirred at that temperature for 1 h before it was slowly warmed up to  $-10$  °C and quenched with 25% aq.

$\text{Na}_2\text{S}_2\text{O}_3$  solution. The reaction was diluted with EtOAc, washed with saturated aq.

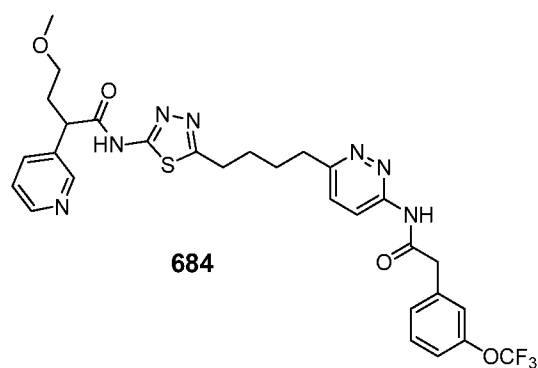
15  $\text{NaHCO}_3$  ( $3 \times 10$  mL). The combined organic layer was separated, washed with brine, dried ( $\text{MgSO}_4$ ) and concentrated. The crude was purified by HPLC to afford **682**.  $^1\text{H}$  NMR (300 MHz, DMSO- $d_6$ )  $\delta$  12.72 (bs, 1H), 11.31 (s, 1H), 8.20 (d,  $J = 9.0$  Hz, 1H), 7.68 (m, 1H), 7.60–7.26 (m, 8H), 3.91 (s, 2H), 3.87 (s, 2H), 3.06–2.86 (m, 4H), 2.76 (s, 3H), 1.77–1.72 (m, 4H).



**681** was prepared from **657** and 3-methylsulphonylphenyl acetic acid by the procedure as described for compound **661**.  $^1\text{H}$  NMR (300 MHz, DMSO- $d_6$ )  $\delta$  12.72 (bs, 1H), 11.31 (s, 1H), 8.20 (d,  $J = 9.0$  Hz, 1H), 7.92 – 7.83 (m, 2H), 7.70–7.26 (m, 7H), 3.93 (s, 2H), 3.87 (s, 2H), 3.23 (s, 3H), 3.06–2.86 (m, 4H), 1.77–1.72 (m, 4H).

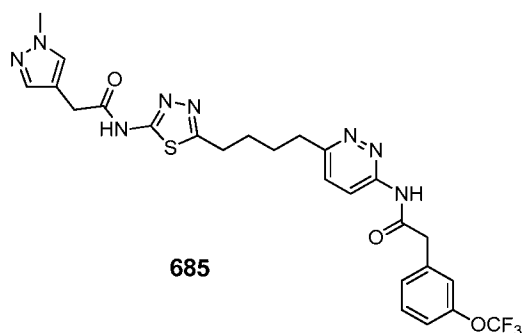


**683** was made using procedure described for compound **675**.  $^1\text{H}$  NMR (300 MHz, DMSO- $d_6$ )  $\delta$  12.75 (s, 1H), 11.32 (s, 1H), 8.36 (s, 1H), 8.21–8.18 (d,  $J = 9.18$  Hz, 1H), 7.84–7.80 (d,  $J = 9.36$  Hz, 1H), 7.59–7.26 (m, 6H), 3.90–3.87 (d, 4H), 3.01 (bs, 2H), 2.90 (bs, 2H), 1.73 (bs, 4H).

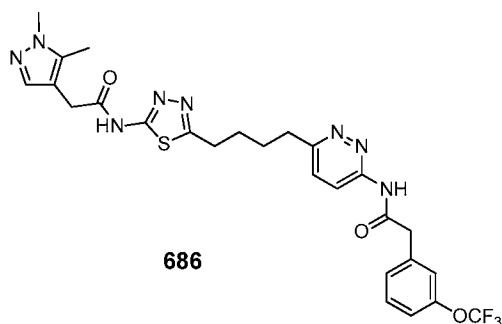


**684** was made using procedure described for compound **675**.  $^1\text{H}$  NMR (300 MHz, DMSO- $d_6$ )  $\delta$  12.75 (s, 1H), 11.32 (s, 1H), 8.57 (s, 1H), 8.51–8.49 (d,  $J = 9.18$  Hz, 1H), 8.21–8.18 (d,  $J = 9.06$  Hz, 1H), 7.79–7.75 (d,  $J = 9.36$  Hz, 1H), 7.59–7.26 (m, 6H),

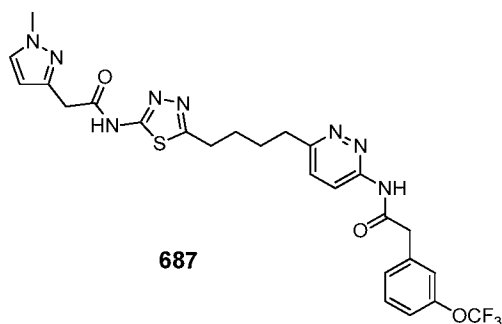
4.07 (t, 2H), 3.87 (s, 2H), 3.30-3.28 (m, 1H), 3.19 (s, 3H), 3.01 (bs, 2H), 2.90 (bs, 2H), 2.3-2.5 (m, 1H), 1.99-1.96 (m, 1H), 1.73 (bs, 4H).



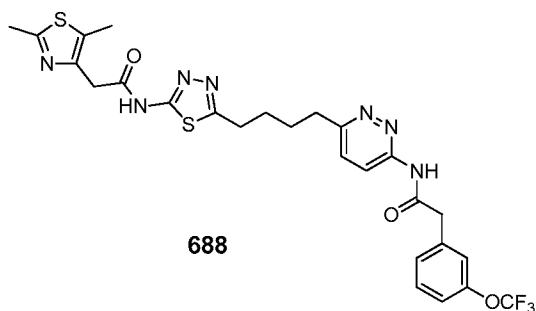
**685** was prepared by the procedure as described for compound **661**. <sup>1</sup>H NMR (300 MHz, DMSO-d<sub>6</sub>) δ 12.52 (bs, 1H), 11.31 (s, 1H), 8.20 (d, *J* = 9.1 Hz, 1H), 7.61–7.25 (m, 7H), 3.87 (s, 2H), 3.80 (s, 3H), 3.62 (s, 2H), 3.06–2.86 (m, 4H), 1.77–1.72 (m, 4H).



**686** was prepared by the procedure as described for compound **661**. <sup>1</sup>H NMR (300 MHz, DMSO-d<sub>6</sub>) δ 12.53 (bs, 1H), 11.32 (s, 1H), 8.20 (d, *J* = 9.1 Hz, 1H), 7.58 (d, *J* = 9.2 Hz, 1H), 7.52–7.26 (m, 4H), 5.96 (s, 1H), 3.87 (s, 2H), 3.67 (s, 2H), 3.64 (s, 3H), 3.06–2.86 (m, 4H), 2.21 (s, 3H), 1.77–1.72 (m, 4H).

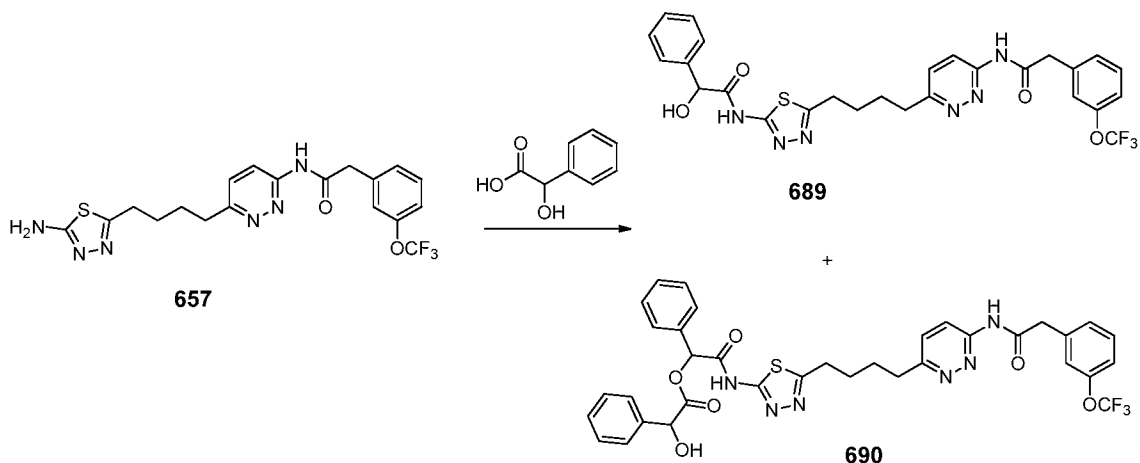


**687** was prepared by the procedure as described for compound **661**.  $^1\text{H}$  NMR (300 MHz, DMSO- $d_6$ )  $\delta$  12.56 (bs, 1H), 11.32 (s, 1H), 8.20 (d,  $J = 9.3$  Hz, 1H), 7.61–7.38 (m, 6H), 6.17 (d,  $J = 2.2$  Hz, 1H), 3.87 (s, 2H), 3.79 (s, 3H), 3.75 (s, 2H), 3.03–2.90 (m, 4H), 1.7–1.72 (m, 4H).



5

**688** was prepared by the procedure as described for compound **661**.  $^1\text{H}$  NMR (300 MHz, DMSO- $d_6$ )  $\delta$  12.61 (bs, 1H), 11.32 (s, 1H), 8.20 (d,  $J = 9.3$  Hz, 1H), 7.58 (d,  $J = 9.3$  Hz, 1H), 7.51–7.26 (m, 4H), 3.87 (s, 2H), 3.84 (s, 2H), 3.07–2.86 (m, 4H), 1.77–1.72 (m, 4H).

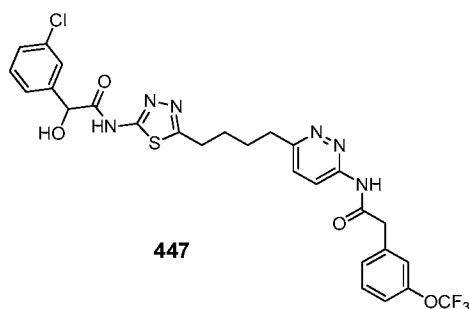


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To a solution of **657** (200 mg, 0.44 mmol) in DMF (4 mL) at 0 °C was added mandelic acid (124 mg, 0.66 mmol), HOBt (119 mg, 0.88 mmol) and EDCI (170 mg, 0.88 mmol). The resulting mixture was stirred at room temperature for 1.5 h before it was cooled to 0 °C and quenched with  $\text{H}_2\text{O}$ . The precipitate was collected by suction filtration and further purified by silica gel chromatography eluting with 1–10% MeOH in DCM to afford **690** and a more polar **689**. **689**:  $^1\text{H}$  NMR (300 MHz, DMSO- $d_6$ )  $\delta$  12.42 (bs, 1H), 11.31 (s, 1H), 8.20 (d,  $J = 9.2$  Hz, 1H), 7.58–7.27 (m, 10H), 6.35 (d,  $J = 4.4$  Hz, 1H), 5.34 (d,  $J = 4.3$  Hz, 1H), 3.87 (s, 2H), 3.03–2.89 (m,

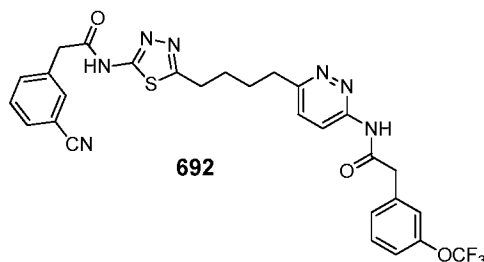
15

4H), 1.77–1.73 (m, 4H). **690**:  $^1\text{H}$  NMR (300 MHz, DMSO- $d_6$ )  $\delta$  13.05 (bs, 1H), 11.31 (s, 1H), 8.20 (d,  $J = 9.0$  Hz, 1H), 7.59–7.26 (m, 15H), 6.26 (d,  $J = 5.5$  Hz, 1H), 6.11 (s, 1H), 5.38 (d,  $J = 5.3$  Hz, 1H), 3.87 (s, 2H), 3.03–2.88 (m, 4H), 1.76–1.73 (m, 4H).



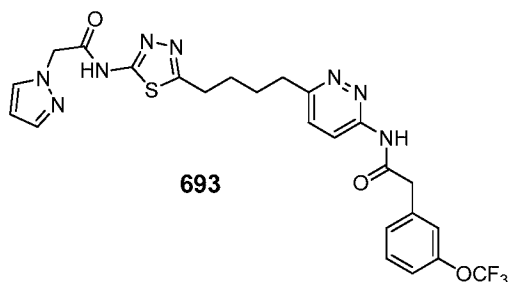
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**447** was prepared from **657** and 3-chloromandelic acid by the procedure as described for compound **689**.  $^1\text{H}$  NMR (300 MHz, DMSO- $d_6$ )  $\delta$  12.48 (bs, 1H), 11.31 (s, 1H), 8.20 (d,  $J = 9.2$  Hz, 1H), 7.59–7.26 (m, 9H), 6.53 (m, 1H), 5.36 (t,  $J = 0.7$  Hz, 1H), 3.87 (s, 2H), 3.03–2.90 (m, 4H), 1.75–1.71 (m, 4H).



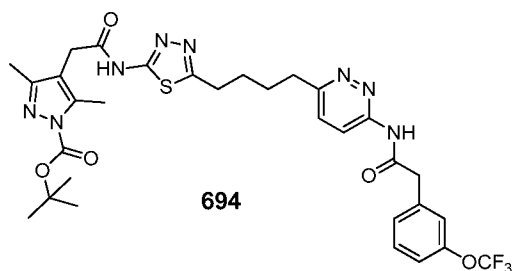
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**692** was made using procedure described for compound **675**.  $^1\text{H}$  NMR (300 MHz, DMSO- $d_6$ )  $\delta$  12.75 (s, 1H), 11.32 (s, 1H), 8.21–8.18 (d,  $J = 9.18$  Hz, 1H), 7.80–7.26 (m, 9H), 3.92 (s, 2H), 3.87 (s, 2H), 3.01 (bs, 2H), 2.90 (bs, 2H), 1.73 (bs, 4H).

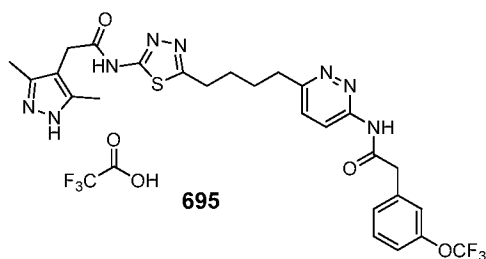


15 **693** was made using procedure described for compound **675**.  $^1\text{H}$  NMR (300 MHz, DMSO- $d_6$ )  $\delta$  12.75 (s, 1H), 11.32 (s, 1H), 8.22–8.19 (d,  $J = 9.06$  Hz, 1H), 7.79 (s, 1H),

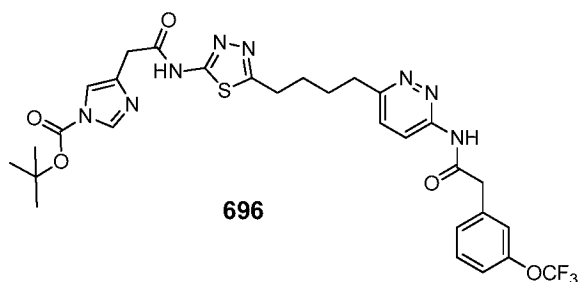
7.59-7.26 (m, 6H), 6.31 (s, 1H), 5.20 (s, 2H), 3.87 (s, 2H), 3.01 (bs, 2H), 2.90 (bs, 2H), 1.73 (bs, 4H).



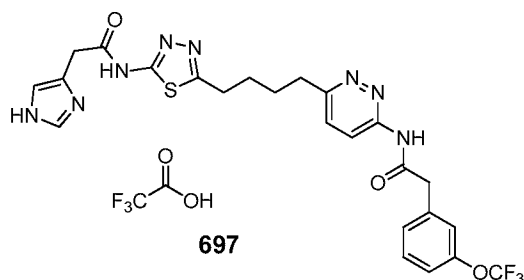
**694** was made using procedure described for compound **675**. <sup>1</sup>H NMR (300 MHz, DMSO-d<sub>6</sub>) δ 12.71 (s, 1H), 11.32 (s, 1H), 8.22-8.18 (d, *J* = 9.15 Hz, 1H), 7.58-7.54 (d, *J* = 9.18 Hz, 1H), 7.48-7.26 (m, 4H), 3.87 (s, 2H), 3.63 (s, 2H), 3.01 (bs, 2H), 2.90 (bs, 2H), 2.39 (s, 3H), 2.13 (s, 3H), 1.73 (bs, 4H), 1.57 (s, 9H).



To a solution of **694** (50 mg, 0.081 mmol) in DCM (2 ml) was added TFA (2 ml) at 0 °C. The resulting mixture was stirred at room temperature for 1 h before it was evaporated under vacuo to dryness. Ether was added and the white precipitate was collected by suction filtration, rinsed with more ether to afford **695**. <sup>1</sup>H NMR (300 MHz, DMSO-d<sub>6</sub>) δ 12.71 (s, 1H), 11.32 (s, 1H), 8.22-8.19 (d, *J* = 9.36 Hz, 1H), 7.60-7.57 (d, *J* = 9.27 Hz, 1H), 7.51-7.28 (m, 4H), 3.88 (s, 2H), 3.57 (s, 2H), 3.01 (bs, 2H), 2.90 (bs, 2H), 2.45 (s, 3H), 2.15 (s, 3H), 1.73 (bs, 4H).

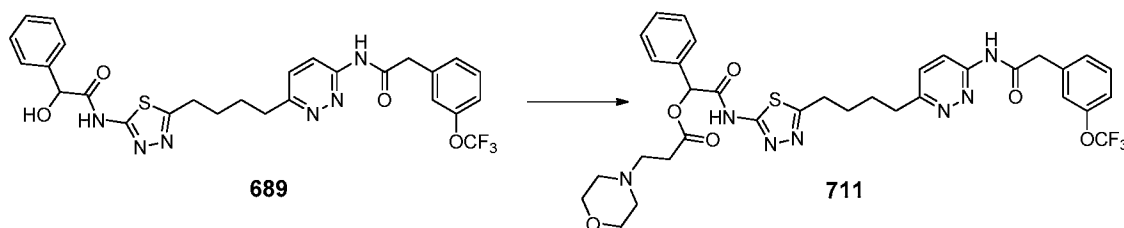


**696** was made using procedure described for compound **695**.  $^1\text{H}$  NMR (300 MHz, DMSO- $d_6$ )  $\delta$  12.71 (s, 1H), 11.32 (s, 1H), 8.22-8.19 (d,  $J = 9.30$  Hz, 1H), 8.15 (s, 1H), 7.58-7.54 (d,  $J = 9.30$  Hz, 1H), 7.48-7.28 (m, 5H), 3.87 (s, 2H), 3.76 (s, 2H), 3.01 (bs, 2H), 2.90 (bs, 2H), 1.73 (bs, 4H), 1.59 (s, 9H).



5

**697** was made using procedure described for compound **695**.  $^1\text{H}$  NMR (300 MHz, DMSO- $d_6$ )  $\delta$  14.22 (s, 1H), 12.71 (s, 1H), 11.32 (s, 1H), 9.01 (s, 1H), 8.22-8.19 (d,  $J = 9.15$  Hz, 1H), 7.59-7.26 (m, 6H), 4.04 (s, 2H), 3.87 (s, 2H), 3.01 (bs, 2H), 2.90 (bs, 2H), 1.73 (bs, 4H).

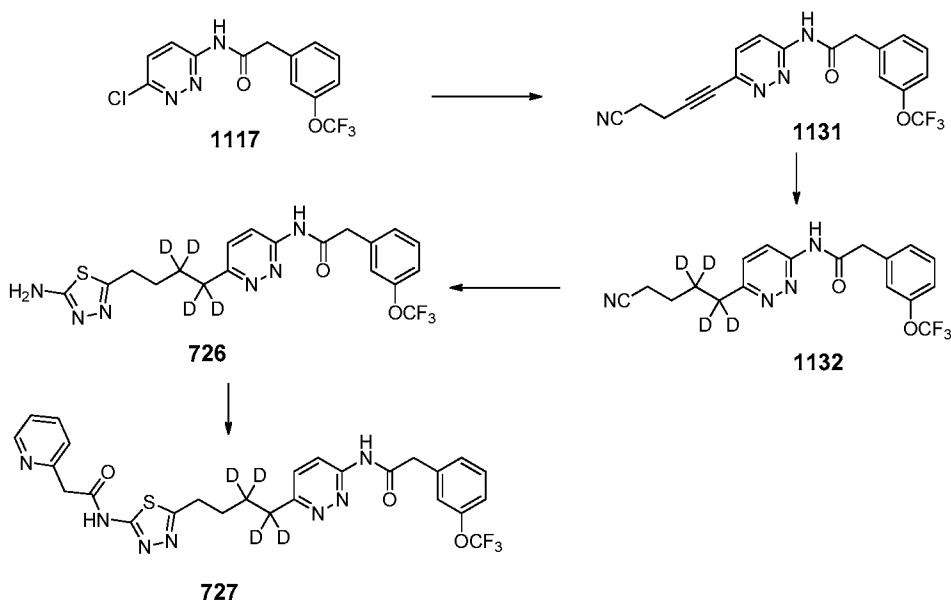


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To a suspension of 3-morpholin-4-yl-propionic acid hydrochloride (113 mg, 0.58 mmol) in DMF (8 mL) at 0 °C was added *N*-(3-dimethylaminopropyl)-*N'*-ethylcarbodiimide hydrochloride (130 mg, 0.67 mmol). The resulting mixture was stirred at 0 °C for 40 min and followed by addition of **689** (300 mg, 0.48 mmol) and 4-DMAP (165 mg, 1.35 mmol). The resulting mixture was stirred from 0 °C to room temperature over a period of 3.5 h before it was diluted with EtOAc and cold water. The organic layer was separated and washed with water (3 $\times$ 15 mL), brine, dried (MgSO<sub>4</sub>) and concentrated. The crude product was purified by silica gel chromatography eluting with 0–15% MeOH in CH<sub>2</sub>Cl<sub>2</sub> to provide **711** (297 mg) as white solid.  $^1\text{H}$  NMR (300 MHz, CDCl<sub>3</sub>)  $\delta$  10.75 (bs, 1H), 8.49 (d,  $J = 9.0$  Hz, 1H), 7.64 (s, 1H), 7.50–7.26 (m, 7H), 7.16–7.15 (m, 1H), 6.51 (s, 1H), 4.04 (s, 2H), 3.80–3.72 (m, 4H), 3.88–2.81 (m, 8H), 2.75–2.71 (m, 5H), 1.89 (m, 4H).

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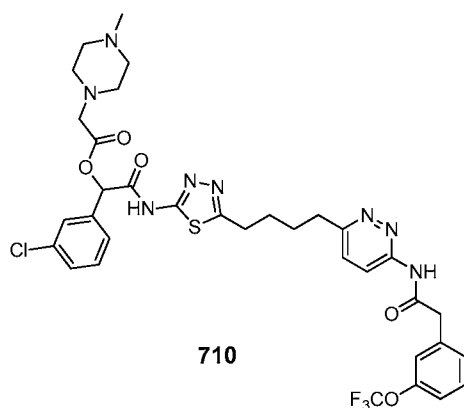
A mixture of **1117** (4.00 g, 12.06 mmol), 4-pentynenitrile (2.11 mL, 24.12 mmol), PdCl<sub>2</sub>(PPh<sub>3</sub>)<sub>2</sub> (847 mg, 1.21 mmol), CuI (184 mg, 0.96 mmol) and Et<sub>3</sub>N (13.44 mL, 96.48 mmol) in DMF (18 mL) was heated at 55 °C for 5 h. The reaction was cooled to room temperature and poured into a mixture of ice-water. The precipitate was collected by suction filtration and air dried. The crude product was further recrystallized from a mixture of i-PrOH-H<sub>2</sub>O first and then from i-PrOH to provide alkyne **1131**.

A mixture of alkyne **1131** (6.00 g) and Pd(OH)<sub>2</sub>/C (1.00 g) in a mixture of EtOAc (150 mL), THF (75 mL) and MeOH (75 mL) was stirred under 1 atm of D<sub>2</sub> at room temperature for 3 h before the catalyst was filtered off a short plug of SiO<sub>2</sub> and rinsed with EtOAc. The filtrate was concentrated to provide the crude product which was further recrystallized from a mixture of EtOAc and ether to give the desired alkane **1132** as off-white solid (6.01 g).

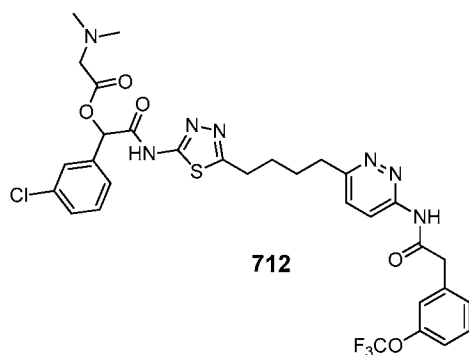
A mixture of nitrile **1132** (5.20 g, 13.61 mmol) and thiosemicarbazide (1.61 g, 17.69 mmol) in TFA (75 mL) was heated at 80 °C for 4 h. The reaction was cooled to room temperature and poured into a mixture of ice-water. The mixture was basified with NaOH pellets (pH 14). The white precipitate was collected by suction filtration, rinsed with water and dried to provide **726** (5.87 g).

To a solution of **726** (1.40 g, 3.07 mmol) and 2-pyridylacetic acid HCl salt (1.49 g, 8.59 mmol) in DMF (20 mL) at 0 °C was added Et<sub>3</sub>N (1.50 mL, 10.73 mmol) and followed by 1-propanephosphonic anhydride (2.73 mL, 50% in DMF, 4.29 mmol). This mixture was stirred for 2.5 h at room temperature before it was cooled back to 0

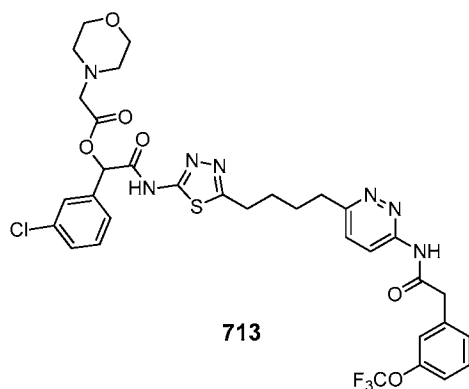
°C and quenched with ice-H<sub>2</sub>O. The precipitate was collected by suction filtration and air dried. This crude product was further purified by silica gel chromatography eluting with 0–15% MeOH in DCM to afford **727** (0.97 g). <sup>1</sup>H NMR (300 MHz, DMSO-d<sub>6</sub>) δ 12.67 (s, 1H), 11.31 (s, 1H), 8.52–8.50 (m, 1H), 8.20 (d, *J* = 9.2 Hz, 1H), 7.78 (dt, *J* = 1.8, 7.6 Hz, 1H), 7.58 (d, *J* = 9.1 Hz, 1H), 7.51–7.26 (m, 6H), 4.02 (s, 2H), 3.87 (s, 2H), 3.03 (t, *J* = 7.4 Hz, 2H), 1.73 (t, *J* = 7.4 Hz, 2H).



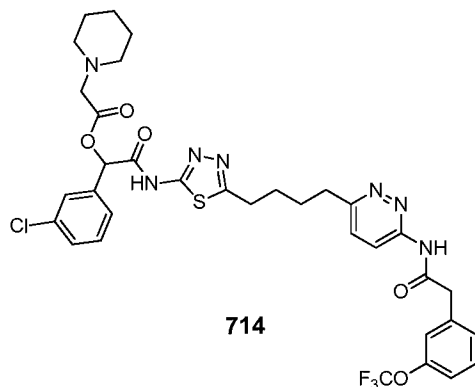
Compound **710** was prepared from compound **447** using a procedure analogous to that employed for the preparation of compound **711**. <sup>1</sup>H NMR (300 MHz, DMSO-d<sub>6</sub>) δ 11.32 (s, 1H), 8.21-8.18 (d, *J* = 9.06 Hz, 1H), 7.62-7.26 (m, 9H), 6.16 (s, 1H), 3.87 (s, 10 2H), 3.52-3.50 (d, 2H), 3.01 (bs, 2H), 2.90 (bs, 2H), 2.80-2.71(m, 11H), 1.73 (bs, 4H).



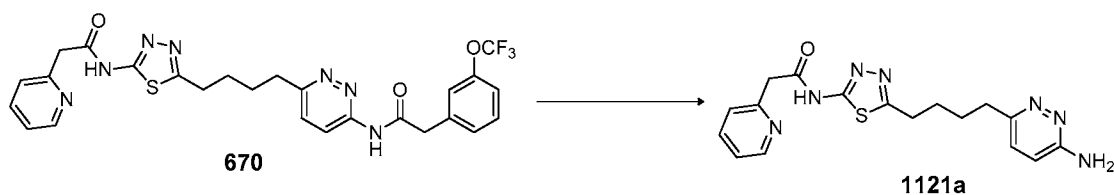
Compound **712** was prepared from compound **447** using a procedure analogous to that employed for the preparation of compound **711**. <sup>1</sup>H NMR (300 MHz, DMSO-d<sub>6</sub>) δ 11.32 (s, 1H), 8.21-8.18 (d, *J* = 9.06 Hz, 1H), 7.62-7.26 (m, 9H), 6.16 (s, 1H), 3.87 (s, 15 2H), 3.38-3.36 (d, 2H), 3.01 (bs, 2H), 2.90 (bs, 2H), 2.29 (s, 6H), 1.73 (bs, 4H).



Compound **713** was prepared from compound **447** using a procedure analogous to that employed for the preparation of compound **711**.  $^1\text{H}$  NMR (300 MHz, DMSO- $d_6$ )  $\delta$  13.11 (bs, 1H), 11.32 (s, 1H), 8.21-8.18 (d,  $J = 9.06$  Hz, 1H), 7.62-7.26 (m, 9H), 6.16 (s, 1H), 3.87 (s, 2H), 3.60-3.57 (m, 4H), 3.44-3.42 (d, 2H), 3.01 (bs, 2H), 2.90 (bs, 2H), 2.55-2.51 (m, 4H), 1.73 (bs, 4H).

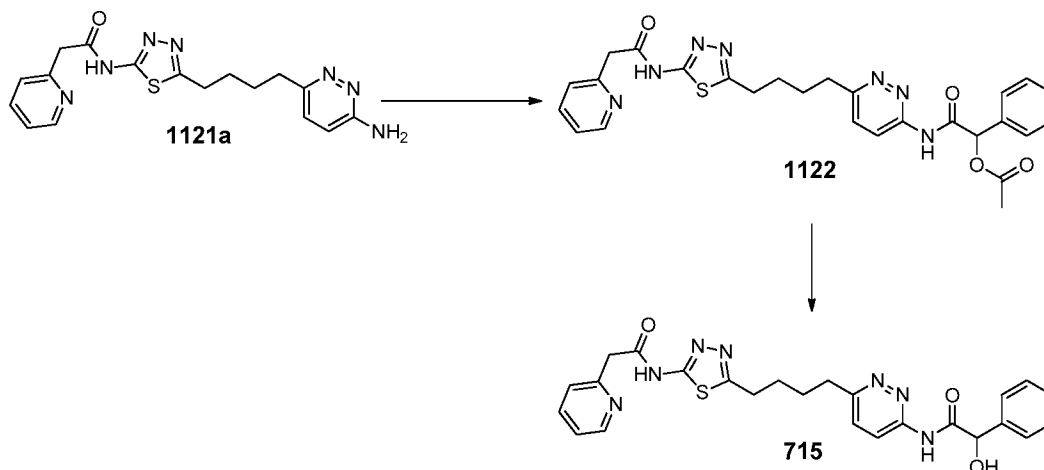


Compound **714** was prepared from compound **447** using a procedure analogous to that employed for the preparation of compound **711**.  $^1\text{H}$  NMR (300 MHz, DMSO- $d_6$ )  $\delta$  11.32 (s, 1H), 8.21-8.18 (d,  $J = 9.06$  Hz, 1H), 7.62-7.26 (m, 9H), 6.16 (s, 1H), 3.87 (s, 2H), 3.38-3.31 (d, 2H), 3.01 (bs, 2H), 2.90 (bs, 2H), 2.49-2.47 (m, 4H), 1.93 (bs, 4H), 1.73 (bs, 4H), 1.72 (bs, 2H).



To a suspension of **670** (3 g, 5.24 mmol) in MeOH (50 ml) at  $0^\circ\text{C}$  was added 2N NaOH (20 ml) solution. The resulting mixture was stirred at room temperature overnight. The solvent was evaporated under vacuo and the mixture was acidified

with 1N HCl to pH 6. The white precipitate was collected by suction filtration, rinsed with more water and dried to afford **1121a**.  $^1\text{H}$  NMR (300 MHz, DMSO- $d_6$ )  $\delta$  12.66 (s, 1H), 8.51-8.50 (m, 1H), 7.81-7.76 (m, 1H), 7.42-7.28 (m, 2H), 7.16-7.13 (d, 1H), 6.73-6.70 (d, 1H), 6.10 (s, 2H), 4.0 (s, 2H), 3.01 (bs, 2H), 2.71 (bs, 2H), 1.70 (bs, 4H).



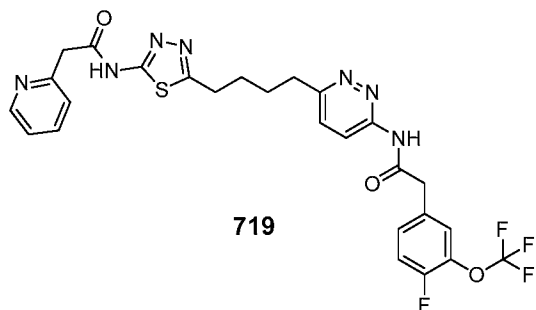
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To a solution of **1121a** (20 mg, 0.054 mmol) in DMF (1 ml) at 0 °C was added triethylamine (11  $\mu$ l, 0.081 mmol) drop wise followed by o-acetylmandelic acid chloride (15  $\mu$ l, 0.065 mmol) drop wise. The resulting mixture was slowly warmed up to room temperature and stirred for 1 h before it was quenched by addition of water (~3 mL) at 0 °C. The mixture was partitioned between water and EtOAc. The organic extract was washed with brine, dried over sodium sulfate, filtered and evaporated. The crude material was purified by silica gel chromatography eluting with 0-5% MeOH in DCM to afford **1122**.

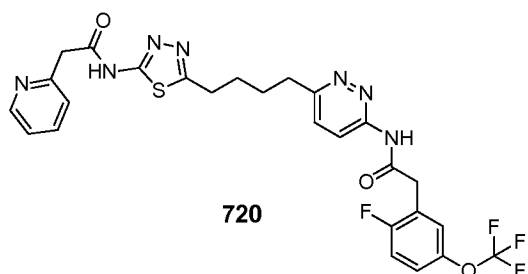
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A flask was charged with **1122** (20 mg, 0.037 mmol) and 2N ammonia in MeOH (5 ml). The mixture was stirred at room temperature for 2 hours. The solvent was evaporated under vacuo and the mixture was triturated with ether. The white precipitate was collected by suction filtration, rinsed with ether and dried to afford **715**.  $^1\text{H}$  NMR (300 MHz, DMSO- $d_6$ )  $\delta$  12.66 (s, 1H), 10.61 (s, 1H), 8.51-8.50 (m, 1H), 8.21-8.18 (d,  $J$  = 9.06 Hz, 1H), 7.81-7.76 (m, 1H), 7.61-7.53 (m, 3H), 7.42-7.28 (m, 5H), 6.49-6.47 (d, 1H), 5.30-5.28 (d, 1H), 4.0 (s, 2H), 3.02 (bs, 2H), 2.91 (bs, 2H), 1.75 (bs, 4H).

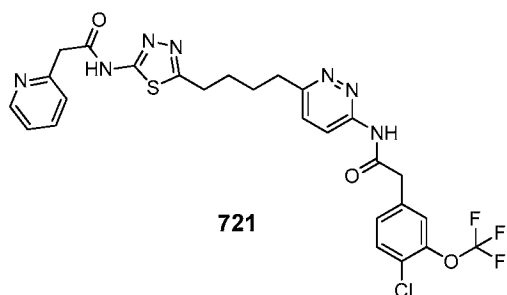
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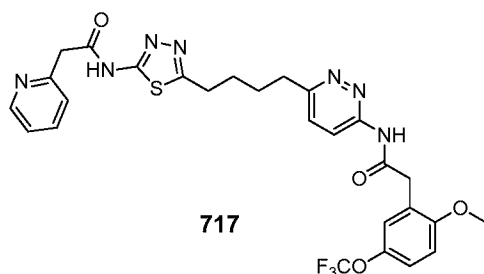
Compound **719** was prepared using a procedure analogous to that employed for the preparation of compound **670**.  $^1\text{H}$  NMR (300 MHz, DMSO- $d_6$ )  $\delta$  12.66 (s, 1H), 11.32 (s, 1H), 8.51-8.50 (m, 1H), 8.21-8.18 (d,  $J = 9.06$  Hz, 1H), 7.79-7.76 (m, 1H), 7.59-7.30 (m, 6H), 4.0 (s, 2H), 3.87 (s, 2H), 3.01 (bs, 2H), 2.90 (bs, 2H), 1.75 (bs, 4H).



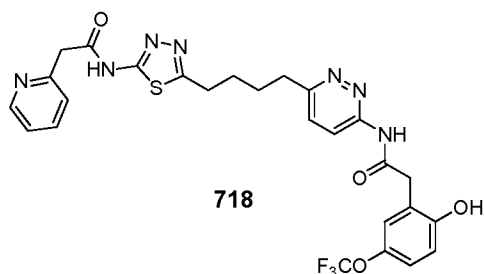
Compound **720** was prepared using a procedure analogous to that employed for the preparation of compound **670**.  $^1\text{H}$  NMR (300 MHz, DMSO- $d_6$ )  $\delta$  12.66 (s, 1H), 11.32 (s, 1H), 8.51-8.50 (m, 1H), 8.19-8.16 (d,  $J = 9.06$  Hz, 1H), 7.79-7.76 (m, 1H), 7.59-7.30 (m, 6H), 4.01 (s, 2H), 3.95 (s, 2H), 3.03 (bs, 2H), 2.91 (bs, 2H), 1.76 (bs, 4H).



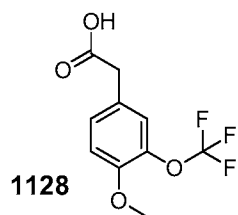
Compound **721** was prepared using a procedure analogous to that employed for the preparation of compound **670**.  $^1\text{H}$  NMR (300 MHz, DMSO- $d_6$ )  $\delta$  12.66 (s, 1H), 11.32 (s, 1H), 8.51-8.50 (m, 1H), 8.21-8.16 (d,  $J = 9.06$  Hz, 1H), 7.81-7.28 (m, 7H), 4.01 (s, 2H), 3.89 (s, 2H), 3.03 (bs, 2H), 2.91 (bs, 2H), 1.76 (bs, 4H).



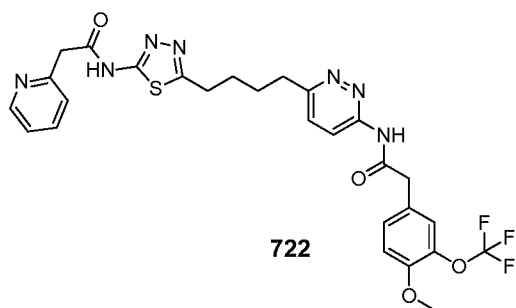
Compound **717** was prepared using a procedure analogous to that employed for the preparation of compound **670**. <sup>1</sup>H NMR (300 MHz, DMSO-d<sub>6</sub>) δ 12.66 (s, 1H), 11.17 (s, 1H), 8.52-8.50 (m, 1H), 8.19-8.16 (d, *J* = 9.06 Hz, 1H), 7.81-7.76 (m, 1H), 7.58-7.55 (d, 1H), 7.42-7.09 (m, 4H), 7.08-7.06 (d, 1H), 4.01 (s, 2H), 3.83 (s, 2H), 3.79 (s, 3H), 3.03 (bs, 2H), 2.91 (bs, 2H), 1.76 (bs, 4H).



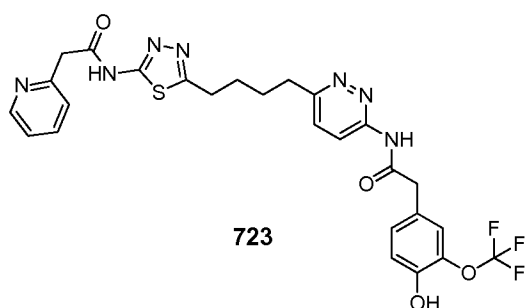
To a solution of **717** (10 mg, 0.017 mmol) in DCM (3 ml) at 0 °C was added boron tribromide solution (1N in DCM) (2 ml) drop wise. The resulting mixture was slowly warmed up to room temperature and stirred for 4.5 h before it was quenched by addition of water (~3 mL). The mixture was then basified with 1N NaOH to pH 8. The mixture was partitioned between water and DCM. The organic extract was washed with brine, dried over sodium sulfate, filtered and evaporated. The crude material was purified by silica gel chromatography eluting with 0-10% MeOH in DCM to afford **718**. <sup>1</sup>H NMR (300 MHz, DMSO-d<sub>6</sub>) δ 11.17 (s, 1H), 8.52-8.50 (m, 1H), 8.21-8.18 (d, *J* = 9.06 Hz, 1H), 7.81-7.76 (m, 1H), 7.58-7.55 (d, 1H), 7.51-7.09 (m, 4H), 6.88-6.85 (d, 1H), 4.0 (s, 2H), 3.79 (s, 2H), 3.03 (bs, 2H), 2.91 (bs, 2H), 1.76 (bs, 4H).



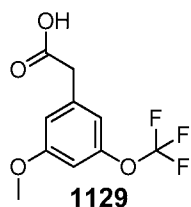
Compound **1128** was prepared from 4-bromo-2-trifluoromethoxyanisole using a procedure analogous to that for compound **1124** below.



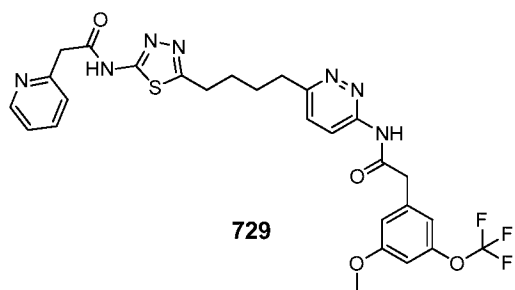
Compound **722** was prepared using compound **1128** with a procedure analogous to that for compound **670**. <sup>1</sup>H NMR (300 MHz, DMSO-d<sub>6</sub>) δ 12.66 (s, 1H), 11.17 (s, 1H), 8.52-8.50 (m, 1H), 8.21-8.18 (d, *J* = 9.06 Hz, 1H), 7.81-7.76 (m, 1H), 7.58-7.55 (d, 1H), 7.42-7.19 (m, 5H), 4.0 (s, 2H), 3.85 (s, 3H), 3.79 (s, 2H), 3.03 (bs, 2H), 2.91 (bs, 2H), 1.76 (bs, 4H).



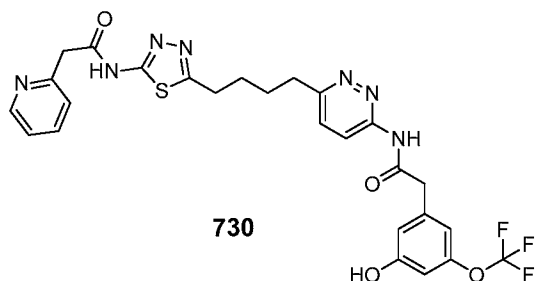
Compound **723** was prepared from compound **722** using a procedure analogous to that for the preparation of compound **718** above. <sup>1</sup>H NMR (300 MHz, DMSO-d<sub>6</sub>) δ 12.66 (s, 1H), 11.17 (s, 1H), 10.06 (s, 1H), 8.52-8.50 (m, 1H), 8.21-8.18 (d, *J* = 9.06 Hz, 1H), 7.81-7.76 (m, 1H), 7.58-7.55 (d, 1H), 7.42-7.19 (m, 4H), 6.99-6.96 (d, 1H), 4.0 (s, 2H), 3.70 (s, 2H), 3.03 (bs, 2H), 2.91 (bs, 2H), 1.76 (bs, 4H).



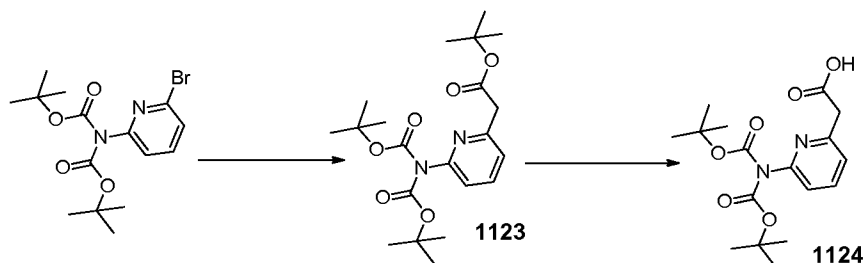
Compound **1129** was prepared from 3-bromo-5-trifluoromethoxyanisole using a procedure analogous to that for compound **1126** below.



Compound **729** was prepared using compound **1129** with a procedure analogous to that for compound **670**. <sup>1</sup>H NMR (300 MHz, DMSO-d<sub>6</sub>) δ 12.66 (s, 1H), 11.28 (s, 1H), 8.52-8.50 (m, 1H), 8.21-8.18 (d, *J* = 9.06 Hz, 1H), 7.81-7.76 (m, 1H), 7.58-7.55 (d, 1H), 7.42-7.29 (m, 2H), 6.99-6.95 (m, 2H), 6.84 (s, 1H), 4.0 (s, 2H), 3.80 (m, 5H), 3.03 (bs, 2H), 2.91 (bs, 2H), 1.76 (bs, 4H).



Compound **730** was prepared from compound **729** using a procedure analogous to that for the preparation of compound **718** above. <sup>1</sup>H NMR (300 MHz, DMSO-d<sub>6</sub>) δ 12.66 (s, 1H), 11.28 (s, 1H), 10.04 (s, 1H), 8.52-8.50 (m, 1H), 8.21-8.18 (d, *J* = 9.06 Hz, 1H), 7.81-7.76 (m, 1H), 7.58-7.55 (d, 1H), 7.42-7.29 (m, 2H), 6.81-6.78 (m, 2H), 6.61 (s, 1H), 4.0 (s, 2H), 3.74 (m, 2H), 3.03 (bs, 2H), 2.91 (bs, 2H), 1.76 (bs, 4H).

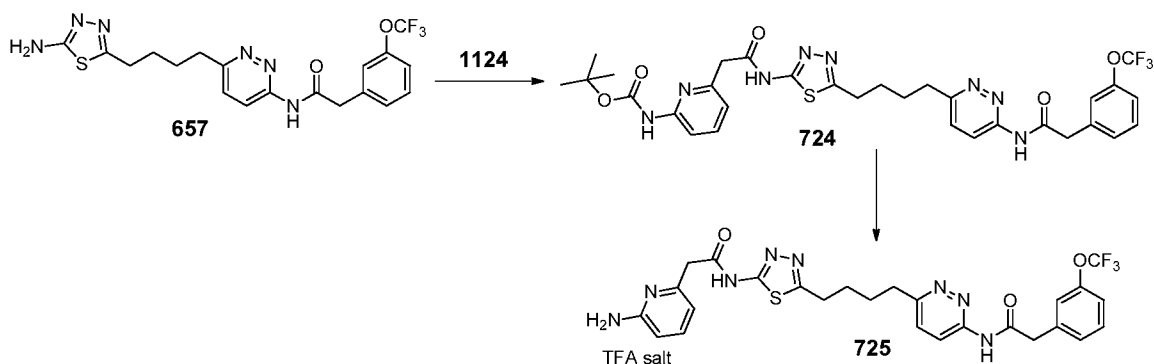


To a mixture of 6-(di-Boc-amino)-2-bromopyridine (1 g, 2.9 mmol), bis(tri-tert-butylphosphine) palladium(0) (300 mg, 0.59 mmol) in 1,4-dioxane (30 ml) under argon atmosphere was added 0.5 M of 2-tert-butoxy-2-oxoethyl zinc chloride in ether (15 ml). The resulting mixture was stirred at room temperature overnight. The mixture was partitioned between saturated NH<sub>4</sub>Cl and EtOAc. The organic extract was washed with brine, dried over sodium sulfate, filtered and evaporated. The crude



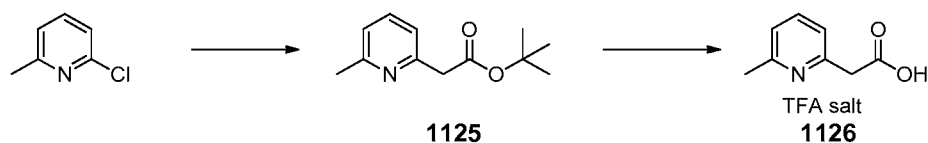
material was purified by silica gel chromatography eluting with 0-20% EtOAc in Hexane to afford **1123**.

To a solution of **1123** (150 mg, 0.37 mmol) in MeOH (6 ml) and water (2 ml) at 0 °C was added Lithium hydroxide monohydrate (100 mg, 2.38 mmol). The resulting mixture was stirred at room temperature for 2 days before it was evaporated to dryness. The mixture was then acidified with 1N HCl (pH 4), and it was partitioned between water and EtOAc. The organic extract was washed with water, dried over sodium sulfate, filtered and evaporated to afford **1124**.



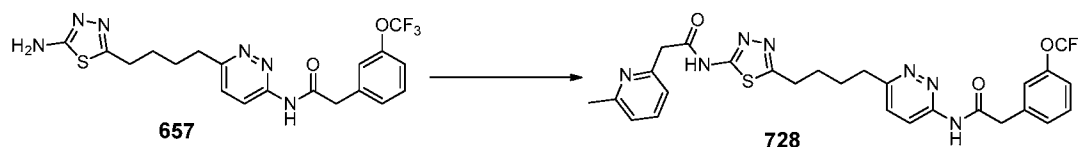
A flask was charged with **657** (105 mg, 0.232 mmol), **1124** (90 mg, 0.255 mmol) in DMF (1 ml) at 0 °C was added propylphosphonic anhydride solution (300 ul) followed by triethylamine (89 ul, 0.64 mmol). The resulting mixture was slowly warmed up to room temperature and stirred for 3 h before it was quenched by addition of ice water (~5 mL). The precipitate was collected by suction filtration, rinsed with more water. The crude material was purified by silica gel chromatography eluting with 0-6% MeOH in DCM to afford **724**. <sup>1</sup>H NMR (300 MHz, DMSO-d<sub>6</sub>) δ 12.67 (s, 1H), 11.32 (s, 1H), 9.69 (s, 1H), 8.22-8.19 (d, *J* = 9.12 Hz, 1H), 7.72-7.01 (m, 8H), 3.91-3.87 (d, 4H), 3.01 (bs, 2H), 2.90 (bs, 2H), 1.75 (bs, 4H) 1.47 (s, 9H).

To a solution of **724** (50 mg, 0.07 mmol) in DCM (3 ml) at 0 °C was added TFA (3 ml) dropwise. The resulting mixture was stirred at room temperature for 3 h before it was evaporated to dryness then triturated the residue with ether to afford **725**. <sup>1</sup>H NMR (300 MHz, DMSO-d<sub>6</sub>) δ 12.67 (s, 1H), 11.32 (s, 1H), 8.22-8.19 (d, *J* = 9.12 Hz, 1H), 7.88-7.77 (m, 3H), 7.59-7.26 (m, 5H), 6.90-6.80 (m, 2H), 4.05 (s, 2H), 3.87 (s, 2H), 3.01 (bs, 2H), 2.90 (bs, 2H), 1.75 (bs, 4H).

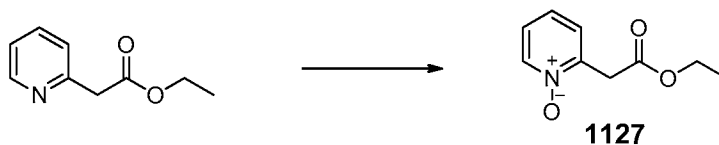


To a stirred solution of tert-butyl acetate (789  $\mu$ l, 5.88 mmol), 2-chloro-6-methylpyridine (428  $\mu$ l, 3.92 mmol), chloro(2-di-*t*-butylphosphino-2',4',6'-tri-1-propyl-1,1'-bi-phenyl)[2-(2-aminoethyl)phenyl]palladium(II) (27 mg, 0.039 mmol) in toluene (10 ml) at 0  $^{\circ}$ C under argon was added a solution of LHMDS (1M in toluene) (12 ml, 12 mmol) pre-cooled to 0  $^{\circ}$ C. The resulting mixture was stirred for 1 h. The mixture was partitioned between saturated  $\text{NH}_4\text{Cl}$  and EtOAc. The organic extract was washed with brine, dried over sodium sulfate, filtered and evaporated. The crude material was purified by silica gel chromatography eluting with 0-15% EtOAc in Hexane to afford **1125**.

To a solution of **1125** (267 mg, 1.29 mmol) in DCM (3 ml) at 0  $^{\circ}$ C was added TFA (1.5 ml) dropwise. The resulting mixture was stirred at room temperature overnight before it was evaporated to dryness then triturated the residue with ether to afford **1126**.

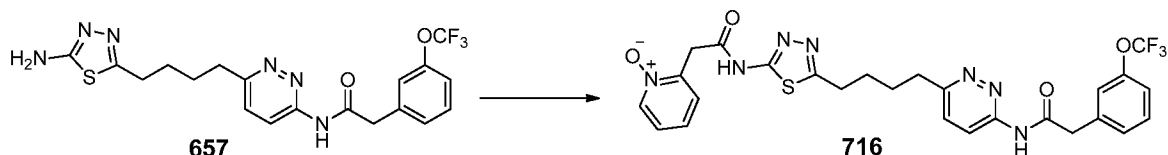


A flask was charged with **657** (50 mg, 0.111 mmol), **1126** (35 mg, 0.133 mmol) in DMF (1 ml) at 0  $^{\circ}$ C was added propylphosphonic anhydride solution (155  $\mu$ l) followed by triethylamine (57  $\mu$ l, 0.4 mmol). The resulting mixture was slowly warmed up to room temperature and stirred for 3 h before it was quenched by addition of ice water (~5 mL). The precipitate was collected by suction filtration, rinsed with more water. The crude material was purified by silica gel chromatography eluting with 0-6% MeOH in DCM to afford **728**.  $^1\text{H}$  NMR (300 MHz,  $\text{DMSO}-d_6$ )  $\delta$  12.67 (s, 1H), 11.32 (s, 1H), 8.22-8.19 (d,  $J$  = 9.12 Hz, 1H), 7.69-7.15 (m, 8H), 3.96 (s, 2H), 3.87 (s, 2H), 3.01 (bs, 2H), 2.90 (bs, 2H), 2.52 (s, 3H), 1.75 (bs, 4H).



To a solution of ethyl 2-pyridyl acetate (1 g, 6.05 mmol) in DCM (20 ml) at 0  $^{\circ}$ C was added MCPBA (77% max) (1.77 g, 10.2 mmol). The resulting mixture was warmed up to room temperature for 3 h before it was partitioned between saturated sodium

bicarbonate and DCM. The organic extract was washed with brine, dried over sodium sulfate, filtered and evaporated. The crude material was purified by silica gel chromatography eluting with 0-12% MeOH in EtOAc to afford **1127**.



5

To a suspension of **657** (331 mg, 0.73 mmol) in toluene was added **1127** (278 mg, 1.53 mmol) followed by trimethylaluminum (2M in toluene) (732  $\mu$ L, 1.46 mmol). The resulting mixture was stirred at 60  $^{\circ}$ C overnight. The reaction mixture was partitioned between water and DCM. The organic extract was washed with brine, dried over sodium sulfate, filtered and evaporated. The crude material was purified by silica gel chromatography eluting with 0-5% MeOH in DCM then 0-15% MeOH in EtOAc to afford **716**.  $^1\text{H}$  NMR (300 MHz, DMSO- $d_6$ )  $\delta$  12.67 (s, 1H), 11.32 (s, 1H), 8.29-8.27 (m, 1H), 8.21-8.19 (d,  $J$  = 9.12 Hz, 1H), 7.61-7.26 (m, 8H), 4.03 (s, 2H), 3.87 (s, 2H), 3.01 (bs, 2H), 2.90 (bs, 2H), 1.75 (bs, 4H).

## 15 Example 2: Compound Assays

Compounds were assayed in both an in vitro biochemical assay and a cell proliferation assay as follows. The IC<sub>50</sub> results are provided in Table 2.

### **Recombinant Enzyme assay**

Compounds were assessed for their ability to inhibit the enzymatic activity of a recombinant form of Glutaminase 1 (GAC) using a biochemical assay that couples the production of glutamate (liberated by GAC) to glutamate dehydrogenase (GDH) and measuring the change in absorbance for the reduction of NAD $^{+}$  to NADH.

Substrate solution was prepared (50 mM Tris-HCl pH 8.0, 0.2 mM EDTA, 150 mM K<sub>2</sub>HPO<sub>4</sub>, 0.1 mg/ml BSA, 1 mM DTT, 20mM L-glutamine, 2 mM NAD $^{+}$ , and 10 ppm antifoam) and 50  $\mu$ L added to a 96-well half area clear plate (Corning #3695).

Compound (2  $\mu$ L) was added to give a final DMSO concentration of 2% at 2X the desired concentration of compound. Enzymatic reaction was started with the addition of 50  $\mu$ L of enzyme solution (50 mM Tris-HCl pH 8.0, 0.2 mM EDTA, 150 mM K<sub>2</sub>HPO<sub>4</sub>, 0.1 mg/ml BSA, 1 mM DTT, 10 ppm antifoam, 4 units/ml GDH, 4 mM adenosine diphosphate, and 4 nM GAC) and read in a Molecular Devices M5 plate

reader at 20°C. The plate reader was configured to read absorbance ( $\lambda=340$  nm) in kinetic mode for 15 minutes. Data was recorded as milli-absorbance units per minute and slopes were compared to a control compound and a DMSO-only control on the same plate. Compounds with slopes less than the DMSO control were considered

5 inhibitors and plate variability was assessed using the control compound.

Results from this assay for several compounds of the invention are shown in Table 2, expressed as IC<sub>50</sub>, or half maximal inhibitory concentration, wherein IC<sub>50</sub> is a quantitative measure indicating how much compound is needed to inhibit a given biological activity by half.

#### 10 **Recombinant Enzyme assay – Time Dependence**

Compounds were assessed for their ability to inhibit the enzymatic activity of a recombinant form of Glutaminase 1 (GAC) using a biochemical assay that couples the production of glutamate (liberated by GAC) to glutamate dehydrogenase (GDH) and measuring the change in absorbance for the reduction of NAD<sup>+</sup> to NADH.

15 Enzyme solution was prepared (50 mM Tris-HCl pH 8.0, 0.2 mM EDTA, 150 mM K<sub>2</sub>HPO<sub>4</sub>, 0.1 mg/ml BSA, 1 mM DTT, 10 ppm antifoam, 4 units/ml GDH, 4 mM adenosine diphosphate, and 4 nM GAC) and 50  $\mu$ L added to a 96-well half area clear plate (Corning #3695). Compound (2  $\mu$ L) was added to give a final DMSO concentration of 2% at 2X the desired concentration of compound. The  
20 enzyme/compound mix was sealed with sealing foil (USA Scientific) and allowed to incubate, with mild agitation, for 60 minutes at 20°C. Enzymatic reaction was started with the addition of 50  $\mu$ L of substrate solution (50 mM Tris-HCl pH 8.0, 0.2 mM EDTA, 150 mM K<sub>2</sub>HPO<sub>4</sub>, 0.1 mg/ml BSA, 1 mM DTT, 20mM L-glutamine, 2 mM NAD<sup>+</sup>, and 10 ppm antifoam) and read in a Molecular Devices M5 plate reader at  
25 20°C. The plate reader was configured to read absorbance ( $\lambda=340$  nm) in kinetic mode for 15 minutes. Data was recorded as milli-absorbance units per minute and slopes were compared to a control compound and a DMSO-only control on the same plate. Compounds with slopes less than the DMSO control were considered inhibitors and plate variability was assessed using the control compound.

30 Results from this assay for several compounds are shown in Table 2, expressed as IC<sub>50</sub>, or half maximal inhibitory concentration, wherein IC<sub>50</sub> is a quantitative measure indicating how much compound is needed to inhibit a given biological activity by half.

**Cell proliferation assay**

P493-6 (myc “on”) cells were maintained in growth media (RPMI-1640, 10%FBS, 2mM glutamine, 100 units/ml Penicillin and 100µg/ml streptomycin) at 37°C with 5% CO<sub>2</sub>. For compound assay, P493-6 cells were plated in 96-well V-bottom plates on the day of compound addition in 50 µl of growth media at a cell density of 200,000 cells/ml (10,000 cells/well). Compounds were serially diluted in 100% DMSO at 200-times the final concentration. Compounds were diluted 100-fold into growth media and then 50 µl of this mixture was added to cell plates making the final concentration of DMSO 0.5%. Cells were incubated with compound for 72 hrs at 37°C with 5% CO<sub>2</sub> and analyzed for antiproliferative effects either by Cell Titer Glo (Promega) or FACS analysis using the Viacount (Millipore) kit on the Guava instrument.

Results from this assay for several compounds are shown in Table 2, expressed as IC<sub>50</sub>, or half maximal inhibitory concentration, wherein IC<sub>50</sub> is a quantitative measure indicating how much compound is needed to inhibit a given biological activity by half.

**Modified Recombinant Enzyme assay – Time Dependence**

Compounds were assessed for their ability to inhibit the enzymatic activity of a recombinant form of glutaminase using a biochemical assay that couples the production of Glu (liberated by glutaminase) to GDH and measures the increase in fluorescence due to the reduction of NADP<sup>+</sup> to NADPH.

Assay Set-up: Glutaminase reaction buffer was prepared [50 mM Tris-HCl pH 8.8, 150 mM K<sub>2</sub>HPO<sub>4</sub>, 0.25 mM EDTA, 0.1 mg/ml BSA (Calbiochem no. 2960), 1 mM DTT, 2 mM NADP<sup>+</sup> (Sigma Aldrich no. N5755), and 0.01% TX-100] and used to make 3x-enzyme-containing solution, 3x-substrate-containing solution, and 3x-inhibitor-containing solution (see below). Inhibitor-containing solution was made by diluting DMSO stocks of compounds into the glutaminase reaction buffer to create a 3x inhibitor solution containing 6% DMSO. 3x-enzyme-containing solution was made by diluting recombinant glutaminase and GDH from *Proteus* species (Sigma Aldrich no. G4387) into glutaminase buffer to create a 6 nM glutaminase plus 18 units/mL GDH solution. A 3x substrate solution containing either Gln, Glu, or

NADPH was made by diluting a stock of Gln (Sigma Aldrich no. 49419), Glu (Sigma Aldrich no. 49449), or NADPH (Sigma Aldrich no. N1630) into glutaminase reaction buffer to create a 3x-substrate solution. Reactions were assembled in a 384-well low-volume black microtiter plates (Molecular Devices no. 0200-5202) by mixing 5  $\mu$ L of inhibitor-containing solution with 5  $\mu$ L of substrate-containing solution followed by 5  $\mu$ L of enzyme-containing solution when no preincubation was required. When time-dependent effects of compound inhibition were tested, enzyme-containing solution was treated with inhibitor-containing solution for the indicated time prior to addition of substrate-containing solution.

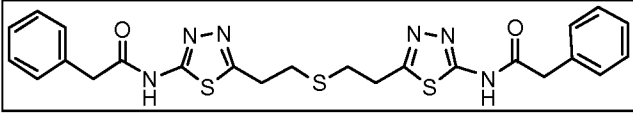
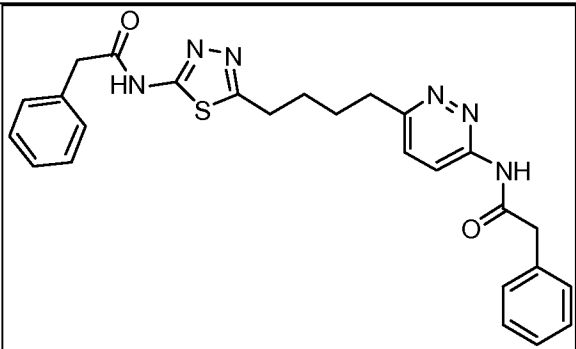
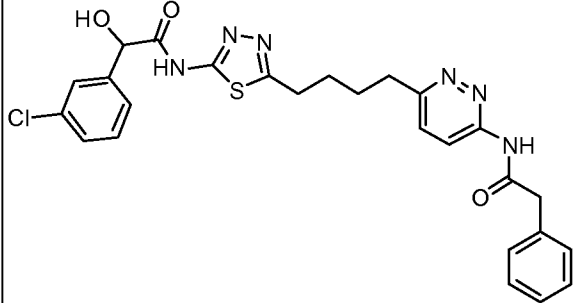
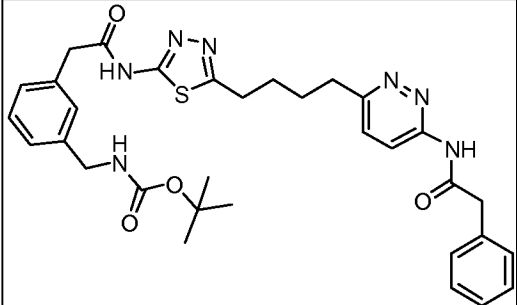
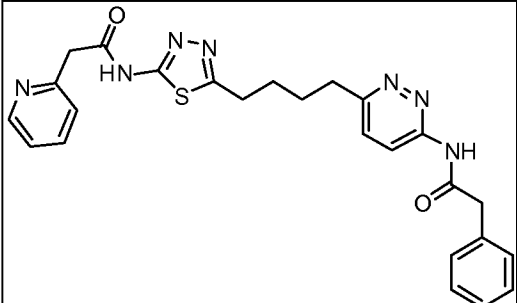
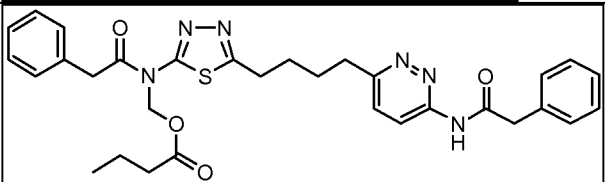
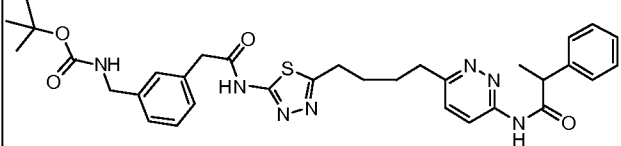
Measurement of glutaminase activity: Following the mixture of all three components, fluorescence increase (Ex: 340 nm, Em:460 nm) was recorded for 15 min at room temperature using the Spectromax M5e (Molecular Devices).

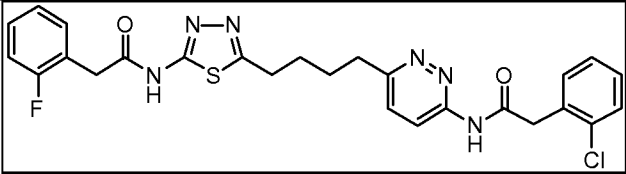
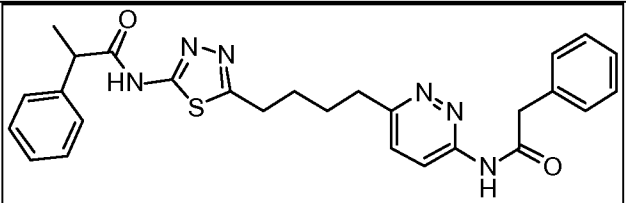
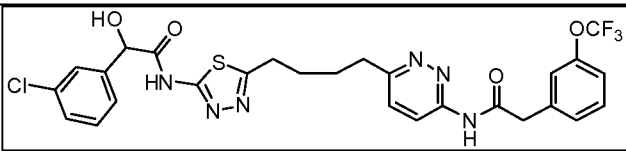
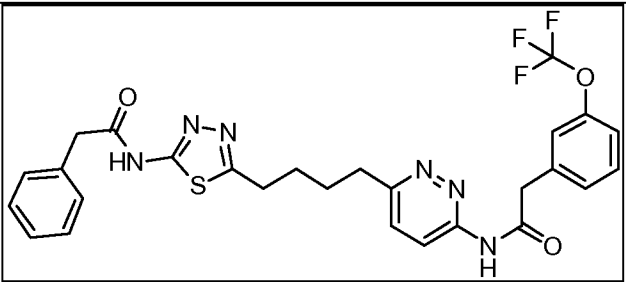
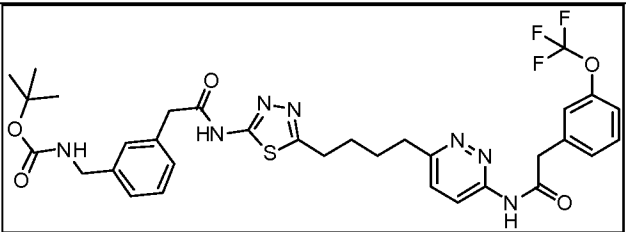
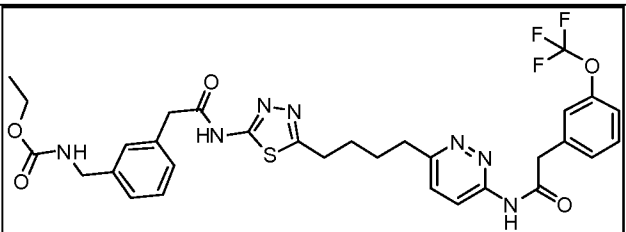
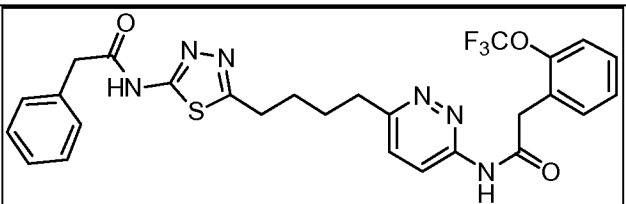
IC50 Determination: The initial velocities of each progress curve were calculated using a straight line equation ( $Y=Y_{\text{intercept}} + (\text{slope}) * X$ ). Initial velocity values were plotted against compound concentration and fit to a four parameter dose response equation ( $\% \text{ activity} = \text{Bottom} + (\text{Top}-\text{Bottom})/(1+10^{((\text{LogIC}_{50}-X)*\text{HillSlope}))})$ ) to calculate an IC50 value.

Results from this assay for several compounds are shown in Table 2, expressed as IC50, or half maximal inhibitory concentration, wherein IC50 is a quantitative measure indicating how much compound is needed to inhibit a given biological activity by half.

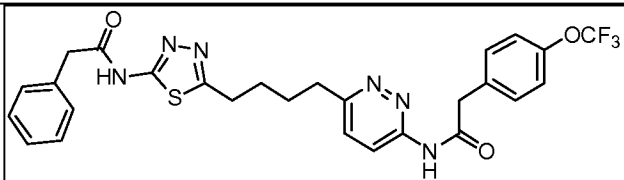
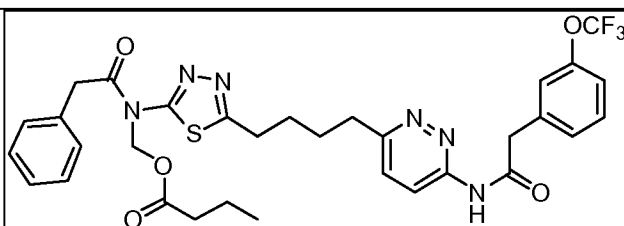
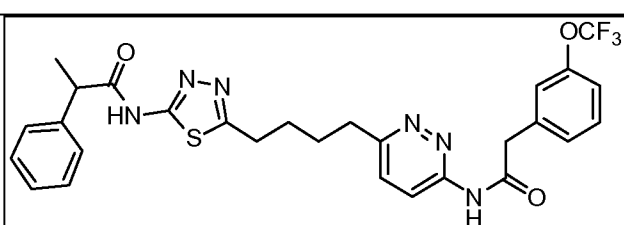
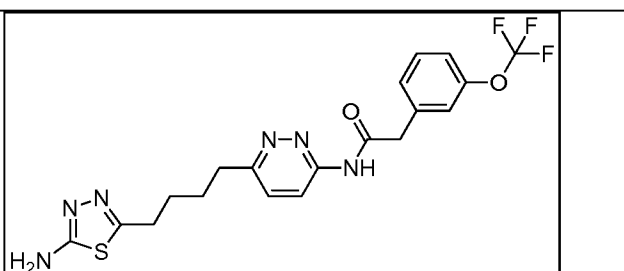
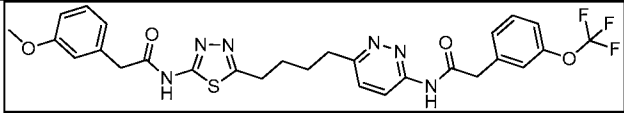
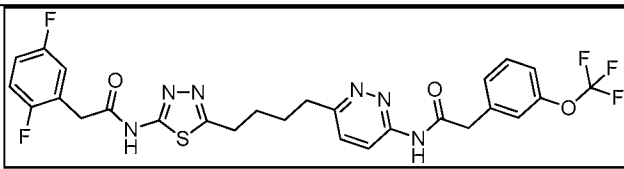
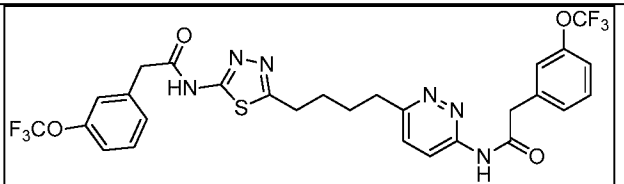
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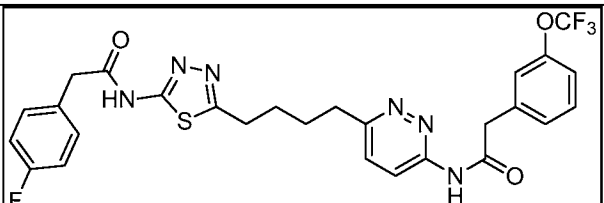
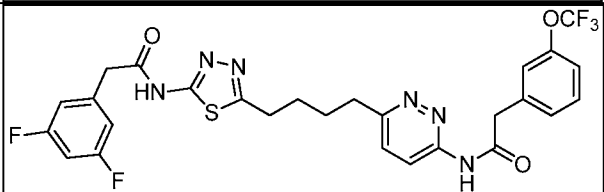
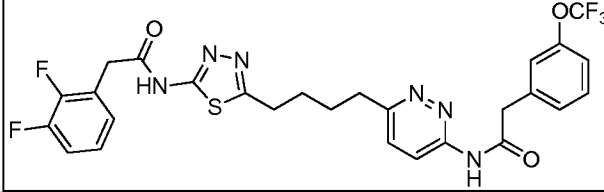
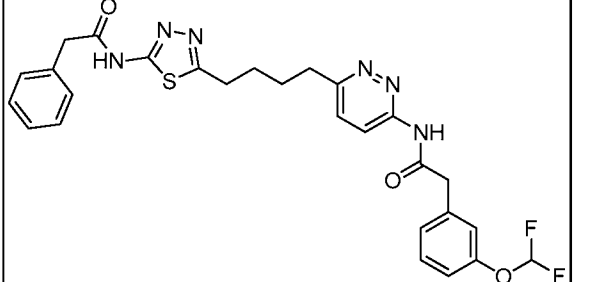
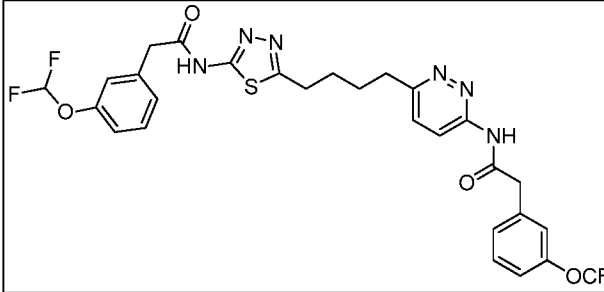
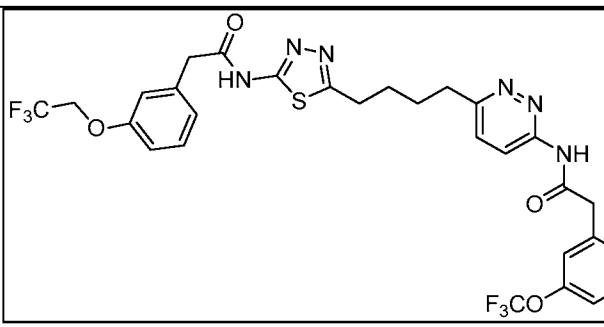
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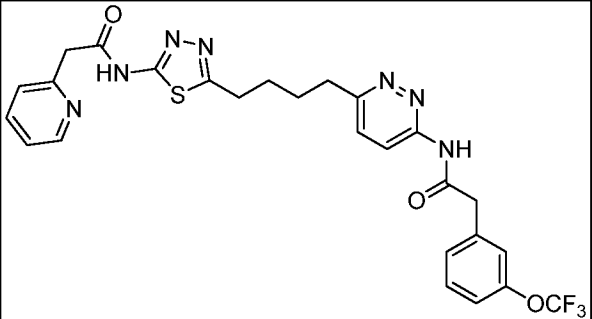
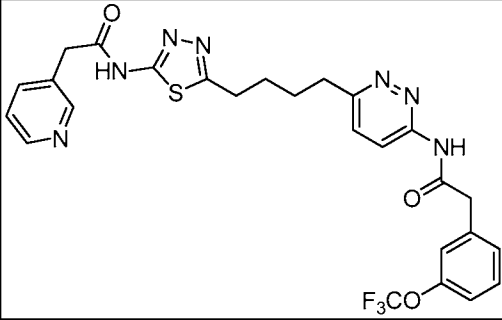
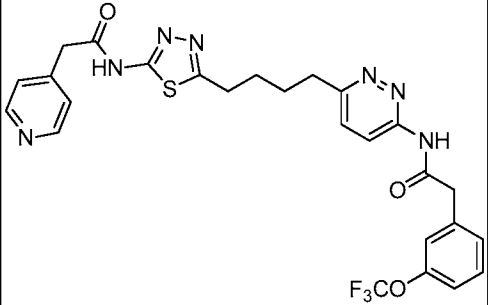
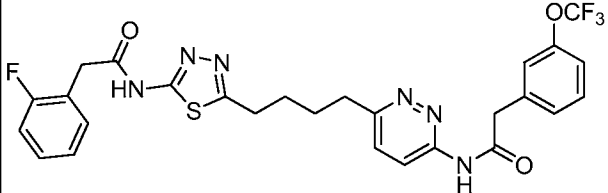
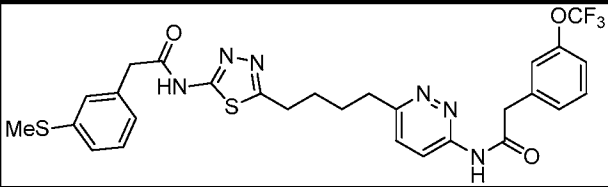
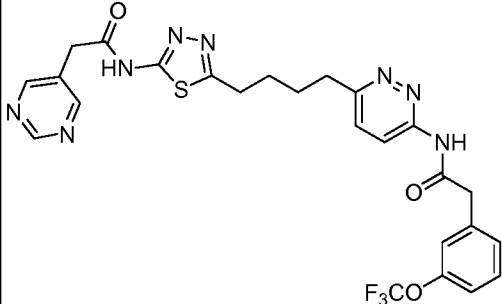
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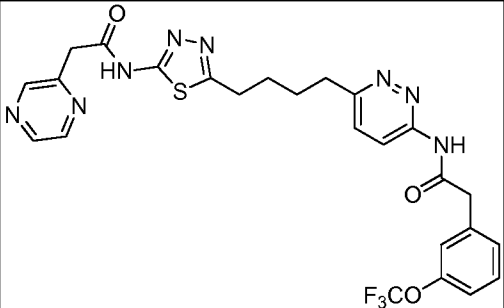
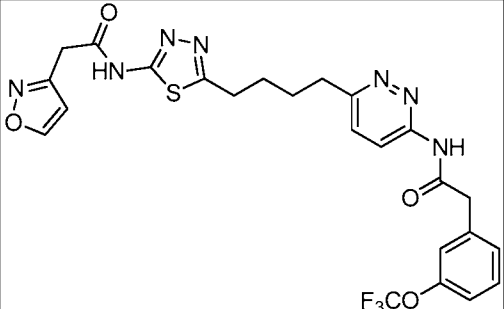
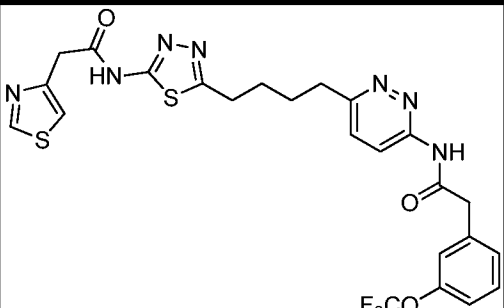
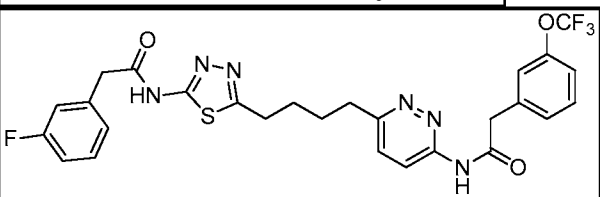
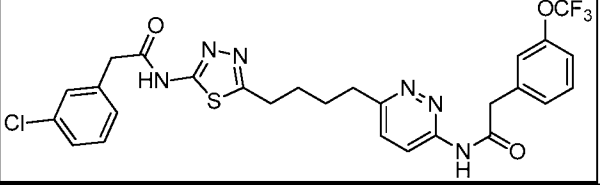
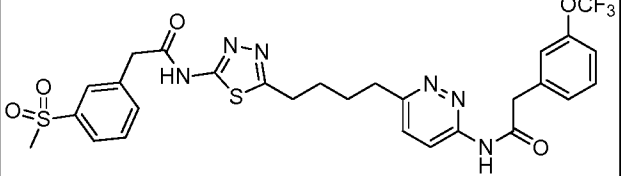
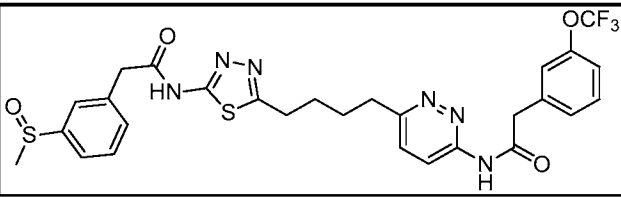
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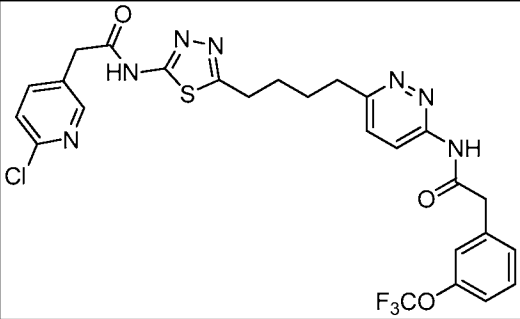
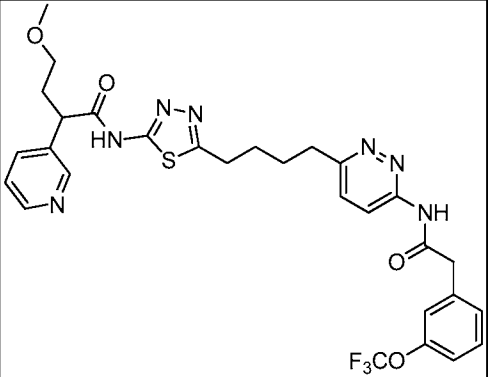
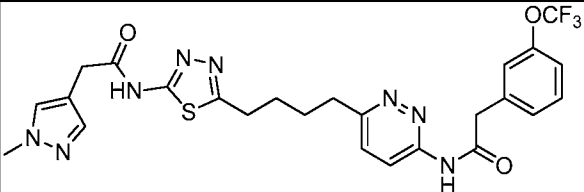
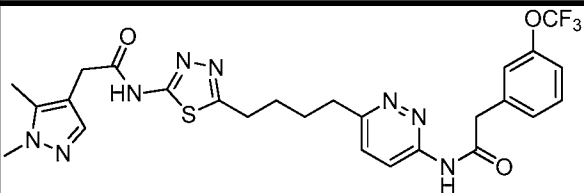
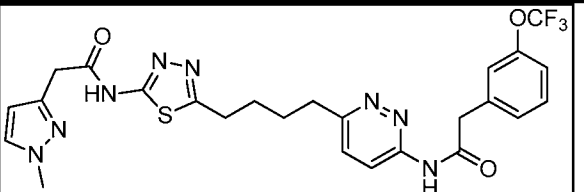
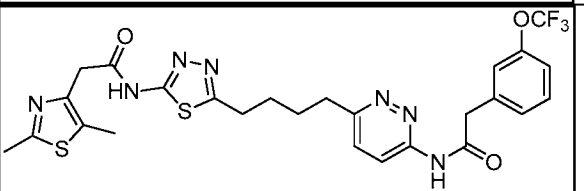
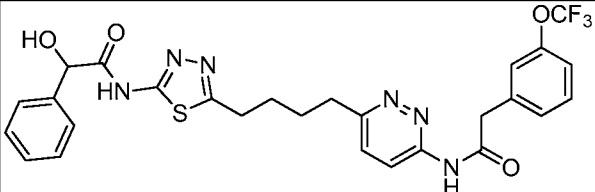


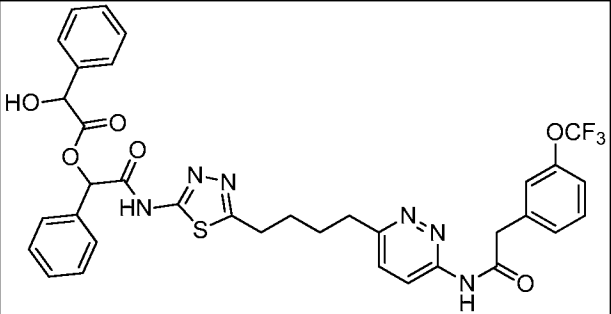
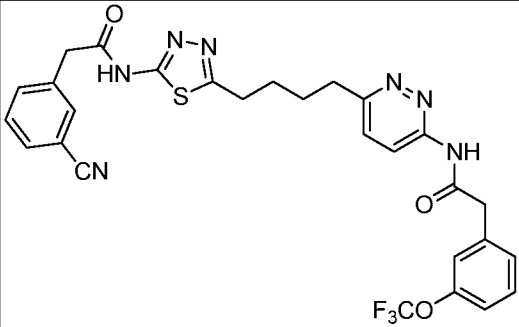
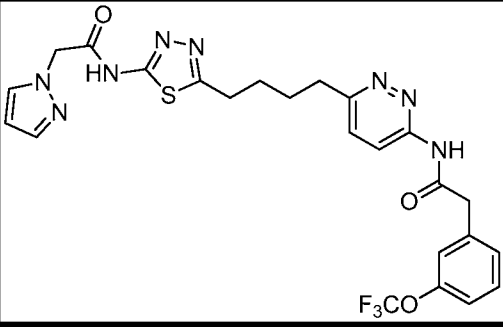
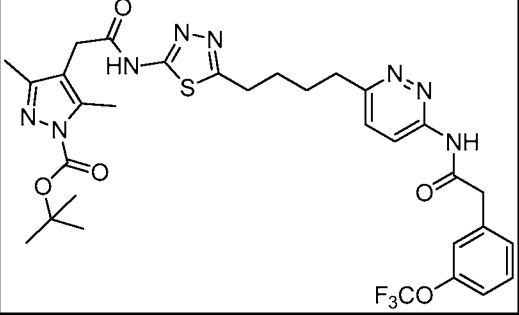
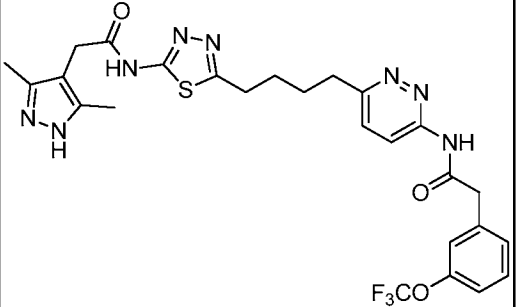
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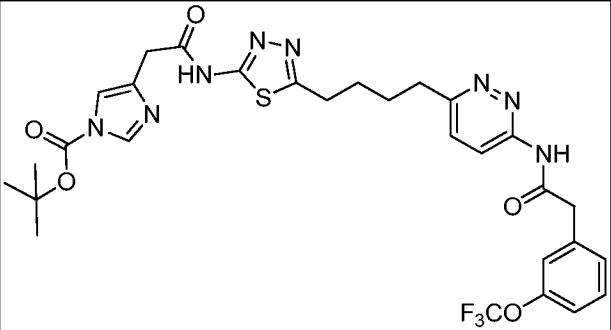
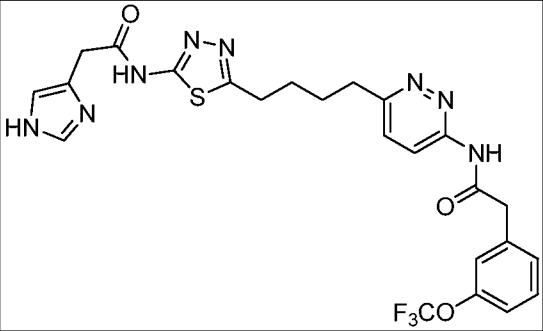
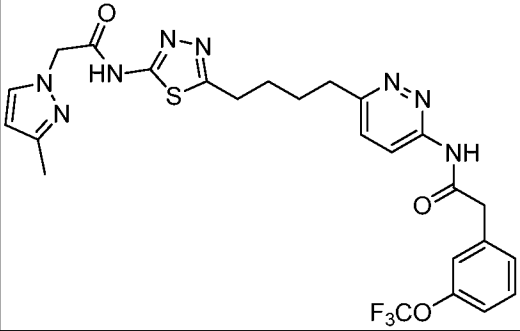
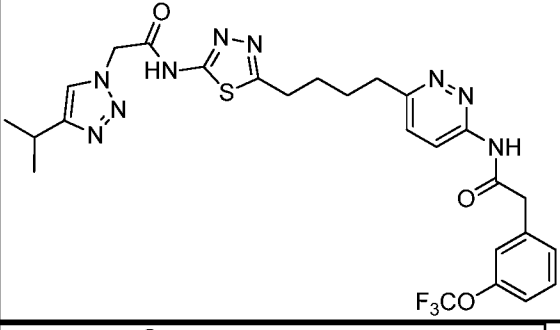
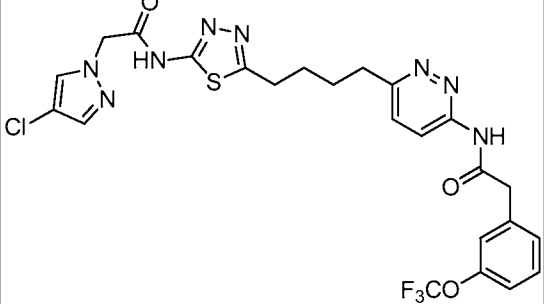
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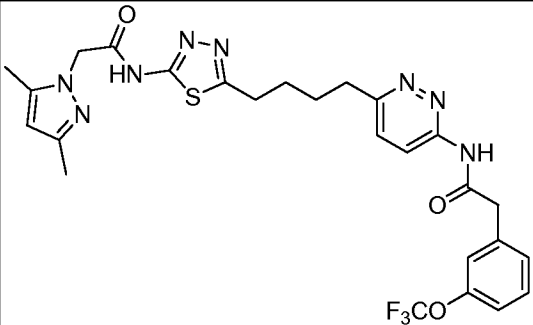
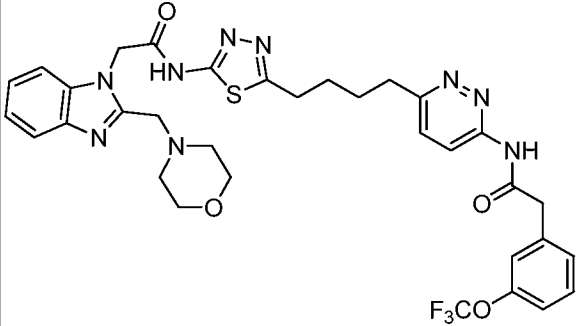
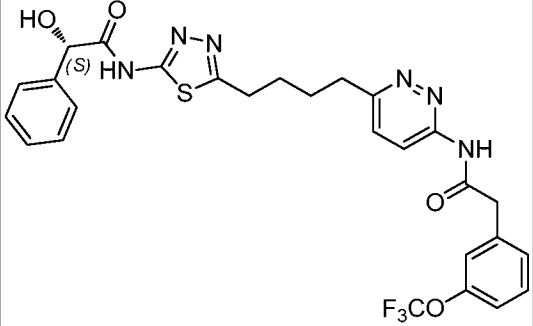
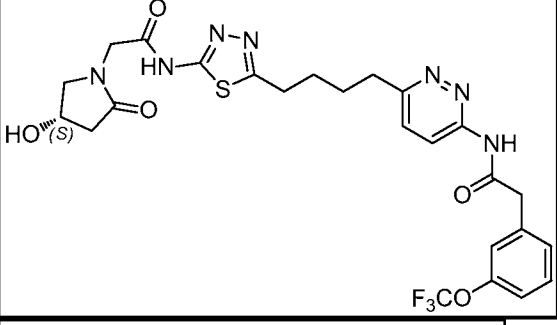
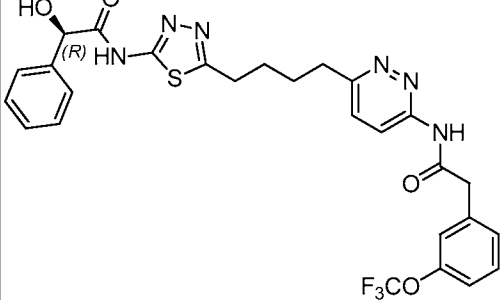
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675						0.040

676						0.030
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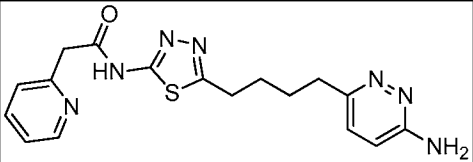
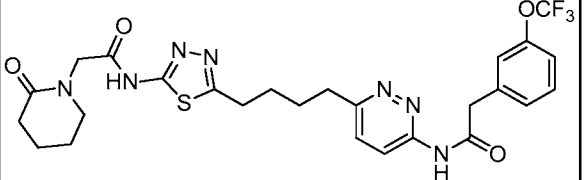
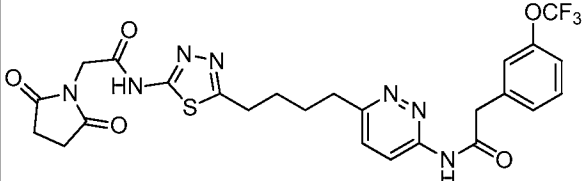
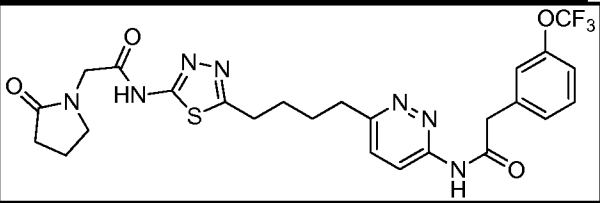
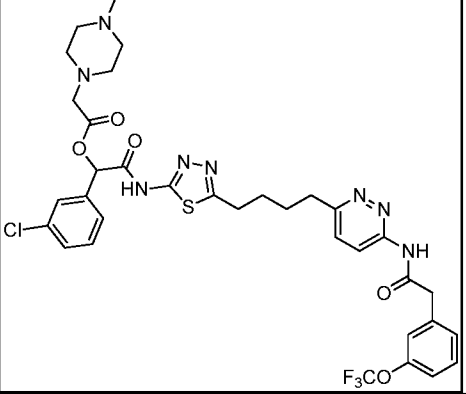
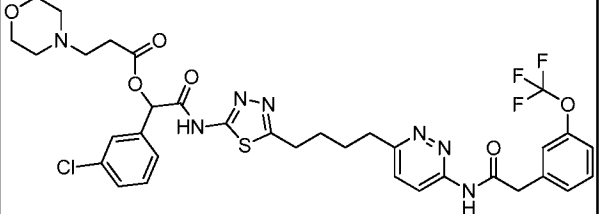
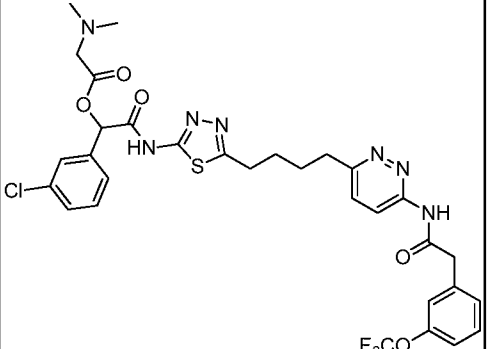
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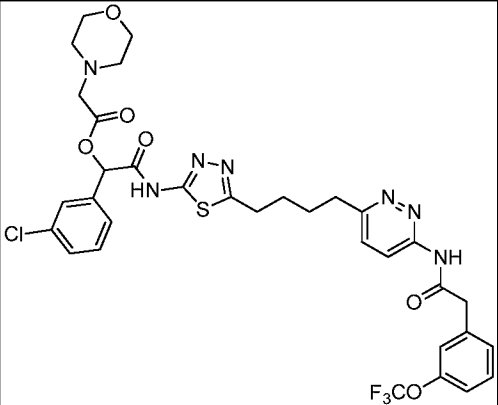
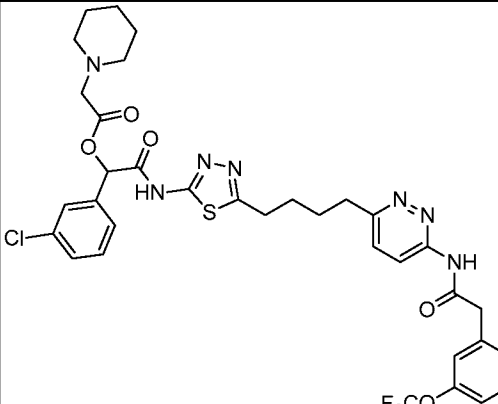
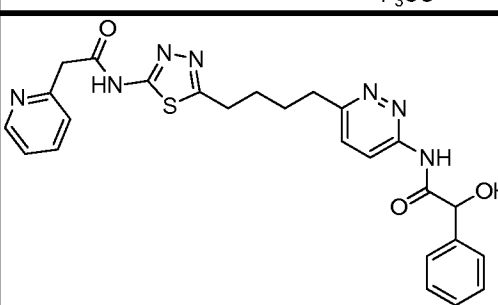
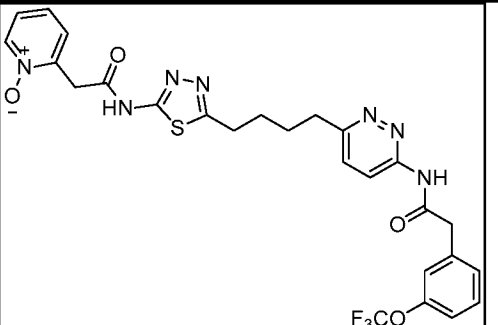
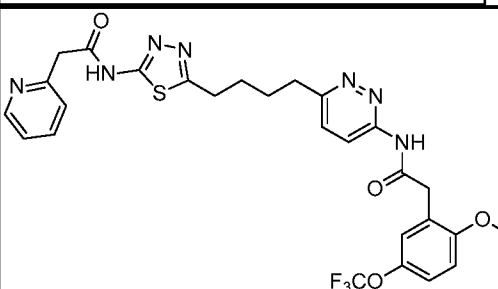
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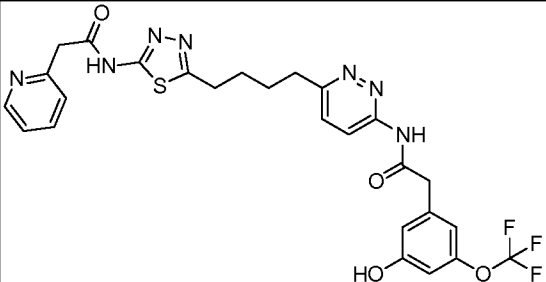


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708						2.8
709						0.14
710						
711						
712						

713						
714						
715			0.19			0.39
716						0.18
717			0.034			0.019

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721	 <chem>Clc1ccc(OC(F)(F)F)cc1NC(=O)c2ccnnc2CCCCC3S=C4N=NC(=S4)NC(=O)c5ccncc5</chem>		0.016			0.022
722	 <chem>COc1ccc(OC(F)(F)F)cc1NC(=O)c2ccnnc2CCCCC3S=C4N=NC(=S4)NC(=O)c5ccncc5</chem>		0.024			0.016
723	 <chem>Oc1ccc(OC(F)(F)F)cc1NC(=O)c2ccnnc2CCCCC3S=C4N=NC(=S4)NC(=O)c5ccncc5</chem>		0.042			0.02

724		0.14			0.034
725		0.050			0.15
726		0.54			0.61
727		0.023			0.012
728		0.012			0.018
729		0.016			0.026

730			0.013			0.025
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### Example 3: Caco-2 Permeability Assay

Caco-2 cells are commonly used in a confluent monolayer on a cell culture insert filter. When cultured in this format and under specific conditions, the cells become differentiated and polarized such that their phenotype, morphologically and functionally resembles the enterocytes lining the small intestine. The cell monolayer provides a physical and biochemical barrier to the passage of small molecules, and is widely used across the pharmaceutical industry as an in vitro model of the human small intestinal mucosa to predict the absorption of orally administered drugs (Hidalgo et al., Gastroenterology, 1989; Artursson, J. Pharm. Sci., 1990). The correlation between the in vitro apparent permeability ( $P_{app}$ ) across Caco-2 monolayers and the in vivo absorption is well established (Artursson et al., Biochem. Biophys. Res. Comm., 1991).

The present assay was used to determine the bidirectional permeability of the compounds of the invention through Caco-2 cell monolayers. Caco-2 cells were grown in confluent monolayers where the media of both the apical (A) and basolateral (B) sides were at pH 7.4. Compounds were dosed at  $1\mu\text{M}$  in the presence of  $200\mu\text{M}$  Lucifer Yellow, on the apical side (A $\rightarrow$ B) or the basolateral side (B $\rightarrow$ A) for assessment, in duplicate. Samples from both A and B sides were taken after 120 minutes exposure, and compound concentration (reported as percent recovery) was determined using a generic LC-MS/MS method with a minimum four-point calibration curve.

The absorption potential of compounds were classified as either Low ( $P_{app} < 1 \times 10^{-6} \text{ cm/s}$ ) or High ( $P_{app} > 1 \times 10^{-6} \text{ cm/s}$ ). The efflux ratio was calculated as ( $P_{app} \text{ B} \rightarrow \text{A}$ )/( $P_{app} \text{ A} \rightarrow \text{B}$ ), with efflux ratios being significant when greater than or equal to 3 when the  $P_{app} \text{ (B} \rightarrow \text{A)}$  was greater than or equal to  $1 \times 10^{-6} \text{ cm/s}$ . Results for certain compounds of the invention are shown in Table 3.

Table 3: Caco-2 Permeability Results

Cmpd	Direction	Recovery (%)	Papp (avg.)	Efflux Ratio	Permeability Classification	Significant Efflux
533	A→B	41	4.94	7.6	High	Yes
	B→A	52	37.5			
585	A→B	42	7.52	3.1	High	Yes
	B→A	53	23.4			
616	A→B	65	8.23	6.0	High	Yes
	B→A	76	49.5			
295	A→B	89	8.17	7.3	High	Yes
	B→A	96	59.8			
318	A→B	73	2.45	18	High	Yes
	B→A	82	44.5			
339	A→B	73	2.39	17	High	Yes
	B→A	80	41.6			
354	A→B	117	1.38	33	High	Yes
	B→A	101	45.0			
436	A→B	44	3.75	6.6	High	Yes
	B→A	57	24.7			
660	A→B	56	0.61	3.9	Low	Yes
	B→A	68	2.37			
670	A→B	70	9.64	6.2	High	Yes
	B→A	72	59.6			
679	A→B	34	7.59	2.6	High	No
	B→A	42	19.6			
447	A→B	71	7.76	3.5	High	Yes
	B→A	56	27.2			
703	A→B	51	6.26	6.6	High	Yes
	B→A	66	41.0			
705	A→B	60	8.52	6.0	High	Yes
	B→A	67	51.0			

Example 4: Solubility

Ca. 1 mg portions of test article were combined with 120  $\mu$ L solvent in wells of a 96 x 2 mL polypropylene plate. The plate was vigorously vortex mixed at room temperature (*ca.* 20 C) for 18 hr and each well checked visually for undissolved solid; wells containing no visible solid were charged with additional solid test article and vortex mixed another 6 hr at room temperature after which all wells showed visible solid. The contents of all wells were then filtered through a 0.45  $\mu$ m GHP filter plate to yield clear filtrates. 5  $\mu$ L of each filtrate was diluted into 100  $\mu$ L DMF and vortex mixed to yield HPLC samples. Duplicate quantitation standards for each test article were prepared by diluting weighed portions of solid test article in measured volumes

of DMF. 2  $\mu$ L of each HPLC sample and quantitation standard were analyzed by HPLC using the method outlined in Table 4. Dissolved test article concentrations were calculated by peak area ratio against the appropriate quantitation standards. Solubility results are presented in Table 5.

5 Table 4: Outline of HPLC Method

<b>Instrument</b>	Shimadzu Prominence UFLC with Diode Array UV/Vis Detector	
<b>Column</b>	VWR Sonoma C8(2), 3.5 $\mu$ m, 2.1 x 50 mm	
<b>Column Temp</b>	40° C	
<b>Mobile Phase A</b>	0.1% (v/v) formic acid in water	
<b>Mobile Phase B</b>	0.1% (v/v) formic acid in acetonitrile	
<b>Flow Rate</b>	0.4 mL/min	
<b>Gradient</b>	<i>Time (min)</i>	<i>% Mobile Phase B</i>
	0	20
	8	100
	8.5	100
	8.6	20
	9.6	END

Table 5: Measured Solubilities

<b>Solvent</b>	<b>Solubility (mg/mL)</b>			
	<b>1</b>	<b>295</b>	<b>402</b>	<b>585</b>
water	< 0.002	< 0.002	< 0.004	< 0.002
0.9% NaCl	< 0.002	< 0.002	< 0.004	< 0.002
0.1 M HCl	< 0.002	0.003	< 0.004	< 0.002
50 mM Cit pH 2.3	< 0.002	< 0.002	< 0.004	< 0.002
50 mM Cit pH 3.3	< 0.002	< 0.002	< 0.004	< 0.002
50 mM Cit	< 0.002	< 0.002	< 0.004	< 0.002

pH 4.4				
50 mM Cit pH 5.4	< 0.002	< 0.002	< 0.004	< 0.002
PBS	< 0.002	< 0.002	< 0.004	< 0.002
0.1 M NaOH	14.420	0.268	< 0.004	0.192
10% PS80 / 50 mM cit	0.050	0.027	0.153	0.261
10% CrEL / 50 mM cit	0.076	0.055	0.157	0.228
20% SBECD / 50 mM cit	0.046	0.090	0.019	0.125
20% HPBCD / 50 mM cit	0.042	0.167	0.056	0.327
Labrasol	0.258	0.918	31.032	5.004
Capryol PGMC	0.042	1.540	11.210	1.780
Capryol 90	0.081	0.215	13.676	1.744
canola oil	< 0.002	< 0.002	0.529	0.072
PEG400	0.451	1.644	30.179	3.944
PG	0.048	0.234	1.365	1.422
EtOH	0.040	0.083	2.958	1.991
<b>Solvent</b>	<b>Solubility (mg/mL)</b>			
	<b>670</b>	<b>447</b>	<b>703</b>	
water	0.007	< 0.004	< 0.004	
0.9% NaCl	< 0.002	0.005	< 0.004	
0.1 M HCl	0.005	< 0.004	< 0.004	
50 mM Cit pH 2.3	0.066	< 0.004	< 0.004	
50 mM Cit pH 3.3	0.003	< 0.004	< 0.004	
50 mM Cit pH 4.4	< 0.002	< 0.004	< 0.004	
50 mM Cit pH 5.4	< 0.002	< 0.004	< 0.004	
PBS	< 0.002	< 0.004	< 0.004	
0.1 M NaOH	0.227	0.192	0.656	
10% PS80 / 50 mM cit	1.204	0.851	0.378	
10% CrEL / 50 mM cit	0.458	0.732	0.309	
20% SBECD /	5.256	2.718	0.476	



50 mM cit				
20% HPBCD / 50 mM cit	9.685	2.177	0.651	
Labrasol	5.042	77.164	20.727	
Capryol PGMC	1.519	7.916	3.683	
Capryol 90	1.974	11.114	7.409	
canola oil	0.012	0.071	0.014	
PEG400	9.901	57.334	22.419	
PG	2.569	8.265	4.698	
EtOH	0.964	3.921	2.645	

#### Example 5: Pharmacokinetic Studies

For PK studies performed in mice, female CD-1 mice, age 5-8 weeks, were dosed orally by gavage (10 mL/kg volume) with test compounds. At pre-determined time-points (e.g. 1, 3, and 6 hrs) post-dosing, groups of three mice were sacrificed by CO<sub>2</sub> inhalation and blood collected via cardiac puncture. Blood samples were placed into K2 EDTA coated tubes and kept on ice. Samples were centrifuged at 2000 x g for 10 minutes at 4°C and plasma isolated. Plasma was stored at -70°C until bioanalytical analysis. Figures 1 and 2 show the plasma concentration of compounds 585, 295, 447 and 318 over time following oral dosing of 50 mg/kg to female CD-1 mice.

For PK studies performed in rats, groups of three female Sprague-Dawley Rats, age 7-10 weeks, with jugular vein cannulae were dosed orally by gavage (5-10 mL/kg) with test compounds. Serial blood samples were collected via the jugular vein cannulae at multiple time-points pre and post-dose. Blood samples were placed into K2 EDTA coated tubes on kept on ice. Samples were centrifuged at 2500 x g for 10 minutes at 4°C and plasma isolated. Plasma was stored at -70°C until bioanalytical analysis. Figure 3 shows the plasma concentration of compound 670 over time following oral dosing of 500, 250, 80 and 25 mg/kg in 25% Hydroxypropyl- $\beta$ -cyclodextrin (HPBCD formulation), to female Sprague Dawley rats.

Results from several studies are shown in Table 6. The plasma samples were analyzed using Liquid chromatography tandem mass spectrometry (LC/MS/MS) methods. Frozen plasma samples were thawed on ice or room temperature. Aliquotes of study plasma samples and calibration samples prepared in the same matrix as the study

samples were quenched in an organic solvent (methanol, acetonitrile or DMF) containing an internal standard. The mixtures were then centrifuged and filtered and the filtrates were injected to an LC/MS/MS system to determine concentrations of test compounds.

5 Table 6: Pharmacokinetics studies and results

Cmpd	Dose (mg/kg)	Species	Vehicle	Solution/ Suspension	Timepoints (h)	Cmax (uM)	Tmax (h)
295	50	Mouse	Eudragit L100-55 solid dispersion	Suspension	1, 6	0.02	6
585	50	Mouse	Eudragit L100-55 solid dispersion	Suspension	0.5, 1, 3, 6	0.93	3
585	50	Mouse	1%NMP/99% Gelucire	Solution	0.5, 1, 3, 6	5.16	1
585	50	Rat	Eudragit L100-55 solid dispersion	Suspension	0.5, 1, 2, 4, 8, 24	1.15	2
670	25	Rat	20% HPBCD / 10mM Citrate pH 2.0	Solution	pre, 0.5, 1, 2, 4, 8, 24	4.4	1
670	80	Rat	65% HPBCD/10mM Citrate pH 2.6	Solution	pre, 0.5, 1, 2, 4, 8, 24	12.5	1
670	250	Rat	40% HPBCD/10mM Citrate pH 2.2	Solution	pre, 0.5, 1, 2, 4, 8, 24	9.9	24
670	500	Rat	40% HPBCD/10mM Citrate pH 2.2	Solution	pre, 0.5, 1, 2, 4, 8, 24	15.3	2
670	100	Mouse	25% HPBCD/10mM Citrate pH 2.2	Solution	1, 2, 4, 8, 24	5.75	1
670	200	Mouse	25% HPBCD/10	Solution	1, 2, 4, 8, 24	5.05	1

			mM Citrate pH 2.2				
447	50	Mouse	2% NMP/ 98% Gelucire	Solution	1, 3, 6	1.13	1
318	50	Mouse	0.5% CMC/0.1% PS80	Suspension	0.5, 1, 3, 6	0.01	1
318	50	Mouse	Capryol PGMC	Suspension	0.5, 1, 3, 6	0.08	3

Example 6: Lung adenocarcinoma xenograft efficacy study.

Female scid/beige mice (n=20) age 6-8 weeks were implanted subcutaneously with  $1 \times 10^7$  H2122 lung adenocarcinoma cells per mouse suspended in PBS. Mice were  
5 randomized into the following two groups of n=10 mice/group: 1) Vehicle control (25% Hydroxypropyl- $\beta$ -cyclodextrin) and 2) Compound 670 dosed orally at 200 mg/kg (formulated at 20 mg/mL in 25% HP- $\beta$ -CD). For both groups, dosing was initiated 24 hours post-implant and continued orally BID for 23 days. Tumors were measured with calipers three times per week and tumor volume calculated using the  
10 formula tumor volume ( $\text{mm}^3$ ) =  $(a \times b^2/2)$  where 'b' is the smallest diameter and 'a' is the largest perpendicular diameter. \*\*P-value < 0.01 (Two-sided T-test). Results are shown in Figure 4.

Example 7: Triple negative breast cancer xenograft study.

Female CB.17 SCID mice (n=40) age 8-12 weeks were implanted subcutaneously  
15 with  $1 \times 10^7$  JIMT-1 triple negative breast cancer cells per mouse mixed 1:1 with Matrigel. When tumor volumes reached 100-150 $\text{mm}^3$  mice were randomized into the following four groups of n=10 mice/group: 1) Vehicle control (25% Hydroxypropyl- $\beta$ -cyclodextrin) dosed orally BID for 35 days; 2) Compound 670 dosed orally at 200 mg/kg BID for 35 days (formulated at 20 mg/mL in 25% HP- $\beta$ -  
20 CD); 3) Paclitaxel dosed intravenously at 10 mg/kg every other day for a total of 5 doses; and 4) Compound 670 (200 mg/kg orally BID x 35 days) and Paclitaxel (10 mg/kg IV qod x 5). Tumors were measured with calipers two times per week and tumor volume calculated using the formula tumor volume ( $\text{mm}^3$ ) =  $(a \times b^2/2)$  where 'b' is the smallest diameter and 'a' is the largest perpendicular diameter. \*\*P-value <

0.01 (One-way ANOVA vs. vehicle). ## P-value < 0.01 (Two-sided T-test vs. paclitaxel alone). Results are shown in Figure 5.

Example 8: Multiple Myeloma xenograft study.

Female CB.17 SCID mice (n=20) age 8-12 weeks were implanted subcutaneously with  $1 \times 10^7$  RPMI-8226 myeloma cells per mouse mixed 1:1 with Matrigel. Mice were randomized into the following two groups of n=10 mice/group: 1) Vehicle control (25% Hydroxypropyl- $\beta$ -cyclodextrin) and 2) Compound 670 dosed orally at 200 mg/kg (formulated at 20 mg/mL in 25% HP- $\beta$ -CD). For both groups, dosing was initiated when tumors reached a volume of 100-150mm<sup>3</sup> and continued orally BID for 28 days. Tumors were measured with calipers two times per week and tumor volume calculated using the formula tumor volume (mm<sup>3</sup>) = (a x b<sup>2</sup>/2) where 'b' is the smallest diameter and 'a' is the largest perpendicular diameter. \*\*P-value < 0.01 (Two-sided T-test). Results are shown in Figure 6.

Example 9: Treatment of Multiple Myeloma cells with a combination of drugs.

As shown in Figure 7, MM1S cells (panels A & B) and RPMI-8226 cells (panels C & D) were treated with a dose titration of either compound 670, pomalidomide or a mixture thereof (panels A & C) or compound 670, dexamethsone or a mixture thereof (panels B & D) for 72 hours in growth media. At the end of the incubation, cell viability was measured using Cell Titer Glo as per manufacturer's protocol (Promega, Madison, WI). Measured values for compound-treated cells were normalized to DMSO-treated cells and data is reported as a cell survival ratio with a value of 1 (one) corresponding to maximum cell survival and a value of 0 (zero) corresponding to no cell survival. Cell survival ratios for all compound treatments are represented as bar graphs. Combination indices were calculated using the Calcsyn program (biosoft.com) and reported for individual mixtures of compound 670 and pomalidomide [POM] (panels A & C) and individual mixtures of compound 670 and dexamethasone [DEX] (panels B & D). Compound mixtures that produced a synergistic anti-tumor activity are highlighted.

Incorporation by Reference

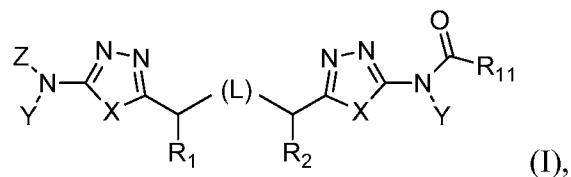
All publications and patents mentioned herein are hereby incorporated by reference in their entirety as if each individual publication or patent was specifically and individually indicated to be incorporated by reference. In case of conflict, the present application, including any definitions herein, will control.

5    Equivalents

While specific embodiments of the subject invention have been discussed, the above specification is illustrative and not restrictive. Many variations of the invention will become apparent to those skilled in the art upon review of this specification and the claims below. The full scope of the invention should be determined by reference  
10    to the claims, along with their full scope of equivalents, and the specification, along with such variations.


**Claims:**

1. A method of treating cancer or immunological or neurological diseases comprising administering a compound of formula I,



5 or a pharmaceutically acceptable salt thereof, wherein:

L represents CH<sub>2</sub>SCH<sub>2</sub>, CH<sub>2</sub>CH<sub>2</sub>, CH<sub>2</sub>CH<sub>2</sub>CH<sub>2</sub>, CH<sub>2</sub>, CH<sub>2</sub>S, SCH<sub>2</sub>, CH<sub>2</sub>NHCH<sub>2</sub>,

CH=CH, or , wherein any hydrogen atom of a CH or CH<sub>2</sub> unit may be replaced by alkyl or alkoxy, any hydrogen of an NH unit may be replaced by alkyl, and any hydrogen atom of a CH<sub>2</sub> unit of CH<sub>2</sub>CH<sub>2</sub>, CH<sub>2</sub>CH<sub>2</sub>CH<sub>2</sub> or

10 CH<sub>2</sub> may be replaced by hydroxy;

X, independently for each occurrence, represents S, O or CH=CH, wherein any hydrogen atom of a CH unit may be replaced by alkyl;

Y, independently for each occurrence, represents H or CH<sub>2</sub>O(CO)R<sub>7</sub>;

15 R<sub>7</sub>, independently for each occurrence, represents H or substituted or unsubstituted alkyl, alkoxy, aminoalkyl, alkylaminoalkyl, heterocyclalkyl, arylalkyl, or heterocyclalkoxy;

Z represents H or R<sub>3</sub>(CO);

R<sub>1</sub> and R<sub>2</sub> each independently represent H, alkyl, alkoxy or hydroxy;

20 R<sub>3</sub> represents substituted or unsubstituted alkyl, hydroxyalkyl, aminoalkyl, acylaminoalkyl, alkenyl, alkoxy, alkoxyalkyl, aryl, arylalkyl, aryloxy, aryloxyalkyl, cycloalkyl, cycloalkylalkyl, heterocycl, heterocyclalkyl, heteroaryl, heteroarylalkyl, heteroaryloxy, heteroaryloxyalkyl or C(R<sub>8</sub>)(R<sub>9</sub>)(R<sub>10</sub>), N(R<sub>4</sub>)(R<sub>5</sub>) or OR<sub>6</sub>, wherein any free hydroxyl group may be acylated to form C(O)R<sub>7</sub>;

25 R<sub>4</sub> and R<sub>5</sub> each independently for each occurrence represent H or substituted or unsubstituted alkyl, hydroxyalkyl, acyl, aminoalkyl, acylaminoalkyl, alkenyl, alkoxyalkyl, aryl, arylalkyl, aryloxy, aryloxyalkyl, cycloalkyl, cycloalkylalkyl, heterocycl, heterocyclalkyl, heteroaryl, heteroarylalkyl, heteroaryloxy, or

heteroaryloxyalkyl, wherein any free hydroxyl group may be acylated to form C(O)R<sub>7</sub>;

R<sub>6</sub> represents substituted or unsubstituted alkyl, hydroxyalkyl, aminoalkyl, acylaminoalkyl, alkenyl, alkoxyalkyl, aryl, arylalkyl, aryloxy, aryloxyalkyl, cycloalkyl, cycloalkylalkyl, heterocyclyl, heterocyclalkyl, heteroaryl, heteroarylalkyl, heteroaryloxy, or heteroaryloxyalkyl, wherein any free hydroxyl group may be acylated to form C(O)R<sub>7</sub>;

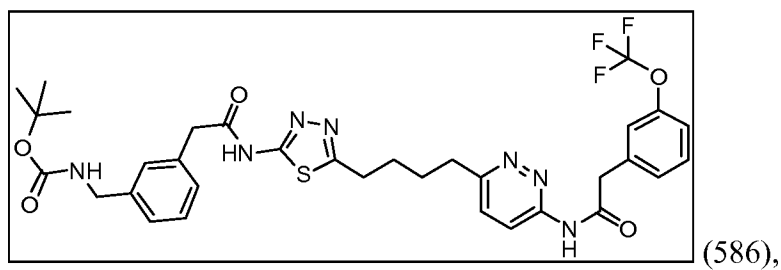
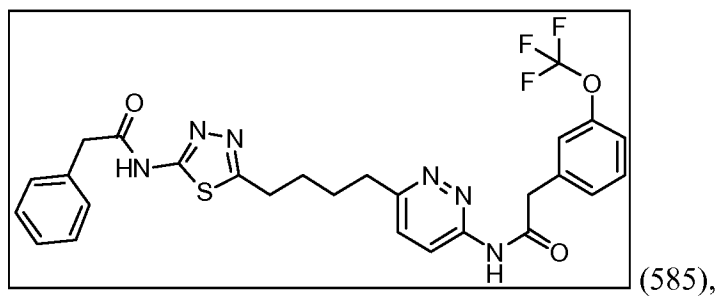
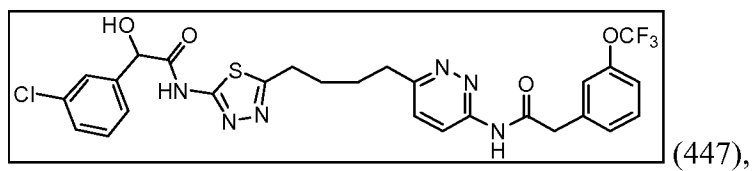
R<sub>8</sub>, R<sub>9</sub> and R<sub>10</sub> each independently for each occurrence represent H or substituted or unsubstituted alkyl, hydroxy, hydroxyalkyl, amino, acylamino, aminoalkyl, acylaminoalkyl, alkoxy, alkoxyalkyl, aryl, arylalkyl, aryloxy, aryloxyalkyl, cycloalkyl, cycloalkylalkyl, heterocyclyl, heterocyclalkyl, heteroaryl, heteroarylalkyl, heteroaryloxy, or heteroaryloxyalkyl, or R<sub>8</sub> and R<sub>9</sub> together with the carbon to which they are attached, form a carbocyclic or heterocyclic ring system, wherein any free hydroxyl group may be acylated to form C(O)R<sub>7</sub>, and wherein at least two of R<sub>8</sub>, R<sub>9</sub> and R<sub>10</sub> are not H;

R<sub>11</sub> represents aryl, arylalkyl, aryloxy, aryloxyalkyl, heteroaryl, heteroarylalkyl, heteroaryloxy, or heteroaryloxyalkyl, wherein the aryl or heteroaryl ring is substituted with either -OCHF<sub>2</sub> or -OCF<sub>3</sub> and is optionally further substituted, or R<sub>11</sub> represents C(R<sub>12</sub>)(R<sub>13</sub>)(R<sub>14</sub>), N(R<sub>4</sub>)(R<sub>14</sub>) or OR<sub>14</sub>, wherein any free hydroxyl group may be acylated to form C(O)R<sub>7</sub>;

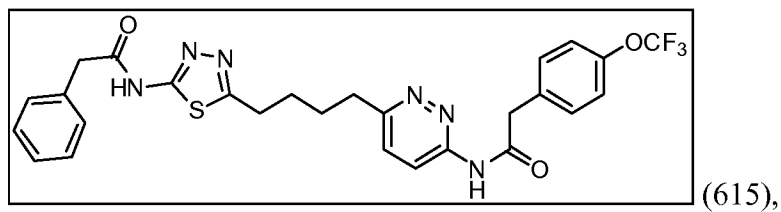
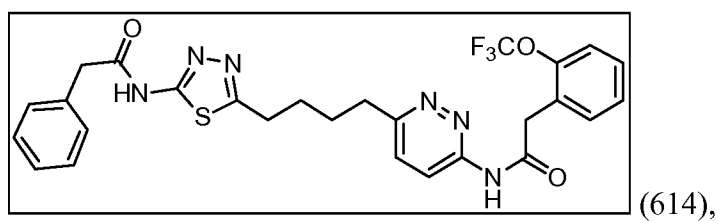
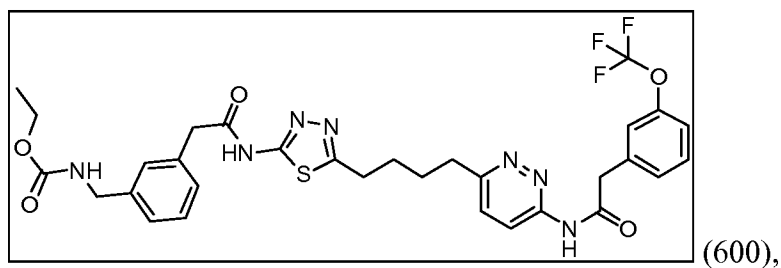
R<sub>12</sub> and R<sub>13</sub> each independently represent H or substituted or unsubstituted alkyl, hydroxy, hydroxyalkyl, amino, acylamino, aminoalkyl, acylaminoalkyl, alkoxy, alkoxyalkyl, aryl, arylalkyl, aryloxy, aryloxyalkyl, cycloalkyl, cycloalkylalkyl, heterocyclyl, heterocyclalkyl, heteroaryl, heteroarylalkyl, heteroaryloxy, or heteroaryloxyalkyl, wherein any free hydroxyl group may be acylated to form C(O)R<sub>7</sub>, and wherein both of R<sub>12</sub> and R<sub>13</sub> are not H; and

R<sub>14</sub> represents aryl, arylalkyl, aryloxy, aryloxyalkyl, heteroaryl, heteroarylalkyl, heteroaryloxy, or heteroaryloxyalkyl, wherein the aryl or heteroaryl ring is substituted with either -OCHF<sub>2</sub> or -OCF<sub>3</sub> and is optionally further substituted.

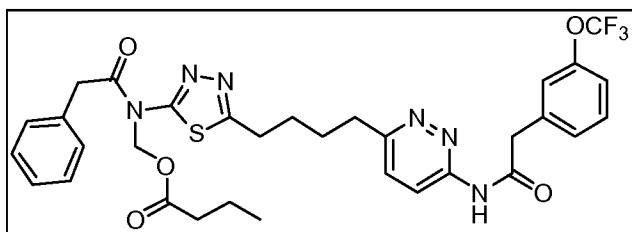
2. The method of claim 1, wherein the compound is not one of the following:



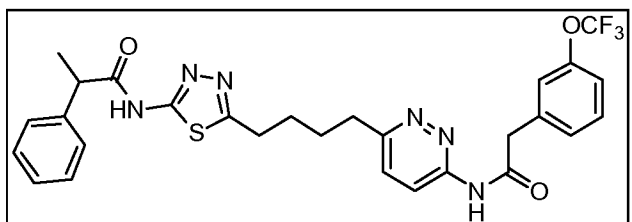
5







(629), or

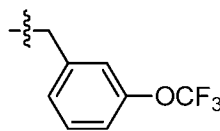


(636).

3. The method of claim 1 or 2, wherein  $R_{11}$  represents arylalkyl, wherein the aryl ring is substituted with  $-OCF_3$ .

5 4. The method of claim 3, wherein  $R_{11}$  represents trifluoromethoxybenzyl.

5. The method of claim 4, wherein  $R_{11}$  represents



6. The method of any preceding claim, wherein L represents  $CH_2SCH_2$ ,  $CH_2CH_2$ ,  $CH_2S$  or  $SCH_2$ .

7. The method of any preceding claim, wherein L represents  $CH_2CH_2$ .

10 8. The method of any preceding claim, wherein each Y represents H.

9. The method of any preceding claim, wherein X represents S or  $CH=CH$ , wherein any hydrogen atom of a CH unit may be replaced by alkyl.

10. The method of any preceding claim, wherein Z represents  $R_3(CO)$ .

11. The method of claim 10, wherein  $R_3$  and  $R_{11}$  are not identical.

15 12. The method of any preceding claim, wherein  $R_1$  and  $R_2$  each represent H.

13. The method of any preceding claim, wherein Z represents  $R_3(CO)$  and  $R_3$  represents substituted or unsubstituted arylalkyl, heteroarylalkyl, cycloalkyl or heterocycloalkyl.
14. The method of claim 13, wherein Z represents  $R_3(CO)$  and  $R_3$  represents substituted or unsubstituted heteroarylalkyl.
15. The method of claim 14, wherein Z represents  $R_3(CO)$  and  $R_3$  represents substituted or unsubstituted pyridylalkyl.
16. The method of any of claims 1-12, wherein Z represents  $R_3(CO)$  and  $R_3$  represents  $C(R_8)(R_9)(R_{10})$ , wherein  $R_8$  represents substituted or unsubstituted aryl, arylalkyl, heteroaryl or heteroaralkyl,  $R_9$  represents H, and  $R_{10}$  represents hydroxy, hydroxyalkyl, alkoxy or alkoxyalkyl.
17. The method of claim 16, wherein  $R_8$  represents substituted or unsubstituted aryl, arylalkyl, or heteroaryl.
18. The method of claim 16 or 17, wherein  $R_{10}$  represents hydroxy, hydroxyalkyl, or alkoxy.
19. The method of any of claims 1-5, wherein L represents  $CH_2SCH_2$ ,  $CH_2CH_2$ ,  $CH_2S$  or  $SCH_2$ , each Y represents H, X represents S, Z represents  $R_3(CO)$ ,  $R_1$  and  $R_2$  each represent H, and  $R_3$  represents substituted or unsubstituted arylalkyl, heteroarylalkyl, cycloalkyl or heterocycloalkyl.
20. The method of any of claims 1-5, wherein L represents  $CH_2SCH_2$ ,  $CH_2CH_2$ ,  $CH_2S$  or  $SCH_2$ , each Y represents H, X represents S, Z represents  $R_3(CO)$ ,  $R_1$  and  $R_2$  each represent H, and  $R_3$  represents  $C(R_8)(R_9)(R_{10})$ , wherein  $R_8$  represents substituted or unsubstituted aryl, arylalkyl, heteroaryl or heteroaralkyl,  $R_9$  represents H, and  $R_{10}$  represents hydroxy, hydroxyalkyl, alkoxy or alkoxyalkyl.
21. The method of claim 20, wherein L represents  $CH_2CH_2$ .

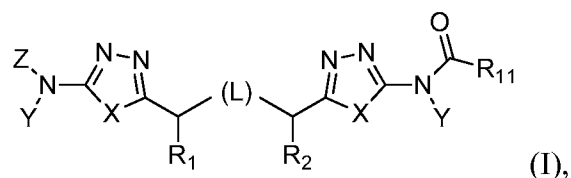
22. The method of claim 20 or 21, wherein  $R_8$  represents substituted or unsubstituted aryl, arylalkyl or heteroaryl.
23. The method of claim 22, wherein  $R_8$  represents substituted or unsubstituted aryl.
24. The method of any of claims 20-23, wherein  $R_{10}$  represents hydroxy, hydroxyalkyl or alkoxy.

25. The method of claim 24, wherein  $R_{10}$  represents hydroxyalkyl.

26. The method of any of claims 1-5, wherein L represents  $CH_2CH_2$ , each Y represents H, X represents S, Z represents  $R_3(CO)$ ,  $R_1$  and  $R_2$  each represent H, and  $R_3$  represents arylalkyl, heteroarylalkyl, cycloalkyl or heterocycloalkyl.


27. The method of claim 26, wherein  $R_3$  represents heteroarylalkyl.

28. A pharmaceutical composition comprising one or more pharmaceutically acceptable excipients and a compound of formula I,



- or a pharmaceutically acceptable salt thereof, wherein:

L represents  $CH_2SCH_2$ ,  $CH_2CH_2$ ,  $CH_2CH_2CH_2$ ,  $CH_2$ ,  $CH_2S$ ,  $SCH_2$ ,  $CH_2NHCH_2$ ,

$CH=CH$ , or , wherein any hydrogen atom of a CH or  $CH_2$  unit may be replaced by alkyl or alkoxy, any hydrogen of an NH unit may be replaced by alkyl, and any hydrogen atom of a  $CH_2$  unit of  $CH_2CH_2$ ,  $CH_2CH_2CH_2$  or  $CH_2$  may be replaced by hydroxy;

X, independently for each occurrence, represents S, O or  $CH=CH$ , wherein any hydrogen atom of a CH unit may be replaced by alkyl;

Y, independently for each occurrence, represents H or  $CH_2O(CO)R_7$ ;

R<sub>7</sub>, independently for each occurrence, represents H or substituted or unsubstituted alkyl, alkoxy, aminoalkyl, alkylaminoalkyl, heterocyclalkyl, arylalkyl, or heterocyclalkoxy;

Z represents H or R<sub>3</sub>(CO);

5 R<sub>1</sub> and R<sub>2</sub> each independently represent H, alkyl, alkoxy or hydroxy;

R<sub>3</sub> represents substituted or unsubstituted alkyl, hydroxyalkyl, aminoalkyl, acylaminoalkyl, alkenyl, alkoxy, alkoxyalkyl, aryl, arylalkyl, aryloxy, aryloxyalkyl, cycloalkyl, cycloalkylalkyl, heterocycl, heterocyclalkyl, heteroaryl, heteroarylalkyl, heteroaryloxy, heteroaryloxyalkyl or

10 C(R<sub>8</sub>)(R<sub>9</sub>)(R<sub>10</sub>), N(R<sub>4</sub>)(R<sub>5</sub>) or OR<sub>6</sub>, wherein any free hydroxyl group may be acylated to form C(O)R<sub>7</sub>;

R<sub>4</sub> and R<sub>5</sub> each independently for each occurrence represent H or substituted or unsubstituted alkyl, hydroxyalkyl, acyl, aminoalkyl, acylaminoalkyl, alkenyl, alkoxyalkyl, aryl, arylalkyl, aryloxy, aryloxyalkyl, cycloalkyl, cycloalkylalkyl, heterocycl, heterocyclalkyl, heteroaryl, heteroarylalkyl, heteroaryloxy, or heteroaryloxyalkyl, wherein any free hydroxyl group may be acylated to form C(O)R<sub>7</sub>;

15 R<sub>6</sub> represents substituted or unsubstituted alkyl, hydroxyalkyl, aminoalkyl, acylaminoalkyl, alkenyl, alkoxyalkyl, aryl, arylalkyl, aryloxy, aryloxyalkyl, cycloalkyl, cycloalkylalkyl, heterocycl, heterocyclalkyl, heteroaryl, heteroarylalkyl, heteroaryloxy, or heteroaryloxyalkyl, wherein any free hydroxyl group may be acylated to form C(O)R<sub>7</sub>;

20 R<sub>8</sub>, R<sub>9</sub> and R<sub>10</sub> each independently for each occurrence represent H or substituted or unsubstituted alkyl, hydroxy, hydroxyalkyl, amino, acylamino, aminoalkyl, acylaminoalkyl, alkoxycarbonyl, alkoxycarbonylamino, alkenyl, alkoxy, alkoxyalkyl, aryl, arylalkyl, aryloxy, aryloxyalkyl, cycloalkyl, cycloalkylalkyl, heterocycl, heterocyclalkyl, heteroaryl, heteroarylalkyl, heteroaryloxy, or heteroaryloxyalkyl, or R<sub>8</sub> and R<sub>9</sub> together with the carbon to which they are attached, form a carbocyclic or heterocyclic ring system, wherein any free hydroxyl group may be acylated to form C(O)R<sub>7</sub>, and wherein at least two of R<sub>8</sub>, R<sub>9</sub> and R<sub>10</sub> are not H;

25 R<sub>11</sub> represents aryl, arylalkyl, aryloxy, aryloxyalkyl, heteroaryl, heteroarylalkyl, heteroaryloxy, or heteroaryloxyalkyl, wherein the aryl or heteroaryl ring is

substituted with either  $-\text{OCHF}_2$  or  $-\text{OCF}_3$  and is optionally further substituted, or  $\text{R}_{11}$  represents  $\text{C}(\text{R}_{12})(\text{R}_{13})(\text{R}_{14})$ ,  $\text{N}(\text{R}_4)(\text{R}_{14})$  or  $\text{OR}_{14}$ , wherein any free hydroxyl group may be acylated to form  $\text{C}(\text{O})\text{R}_7$ ;

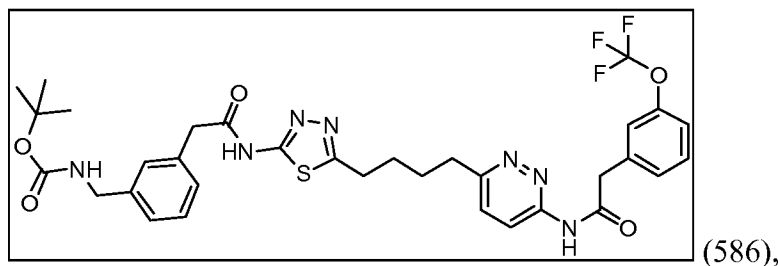
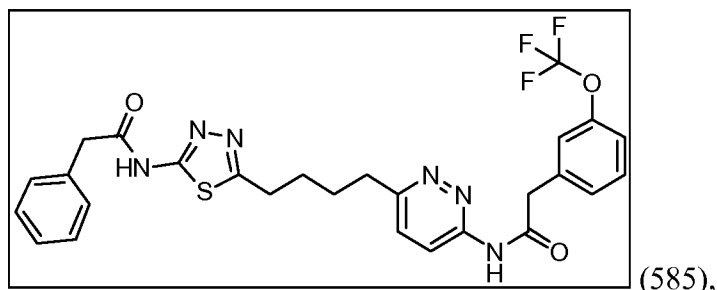
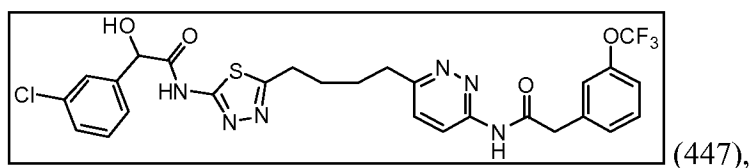
$\text{R}_{12}$  and  $\text{R}_{13}$  each independently represent H or substituted or unsubstituted alkyl,

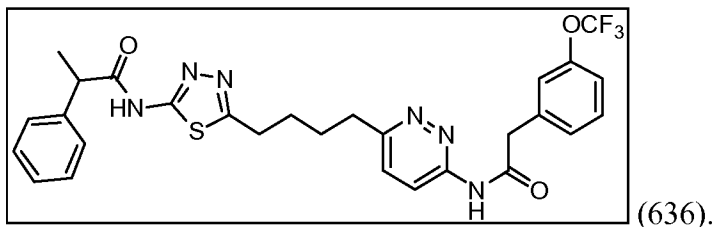
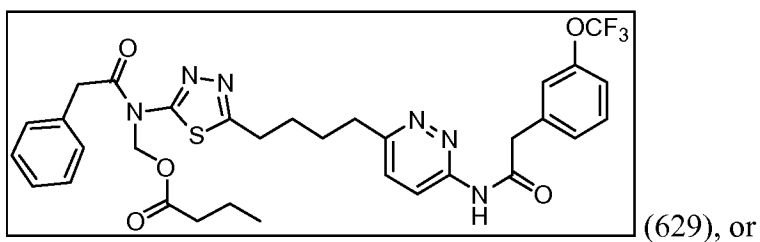
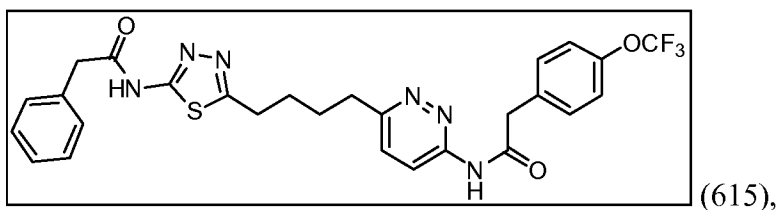
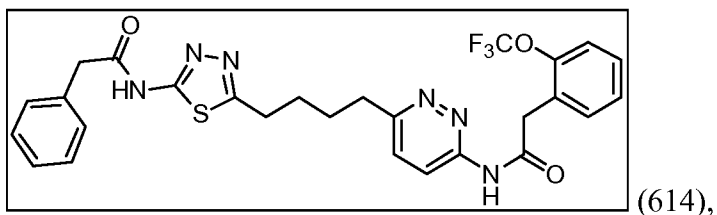
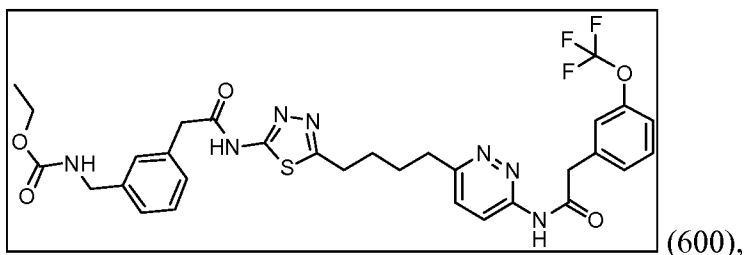
5 hydroxy, hydroxyalkyl, amino, acylamino, aminoalkyl, acylaminoalkyl, alkoxy, alkoxyalkyl, aryl, arylalkyl, aryloxy, aryloxyalkyl, cycloalkyl, cycloalkylalkyl, heterocycl, heterocyclalkyl, heteroaryl, heteroarylalkyl, heteroaryloxy, or heteroaryloxyalkyl, wherein any free hydroxyl group may be acylated to form  $\text{C}(\text{O})\text{R}_7$ , and wherein both of  $\text{R}_{12}$  and  $\text{R}_{13}$  are not H; and

$\text{R}_{14}$  represents aryl, arylalkyl, aryloxy, aryloxyalkyl, heteroaryl, heteroarylalkyl, heteroaryloxy, or heteroaryloxyalkyl, wherein the aryl or heteroaryl ring is substituted with either  $-\text{OCHF}_2$  or  $-\text{OCF}_3$  and is optionally further substituted.

29. The pharmaceutical composition of claim 28, wherein the compound is not

15 one of the following:



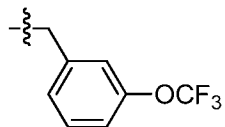


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30. The pharmaceutical composition of claim 28 or 29, wherein  $R_{11}$  represents arylalkyl, wherein the aryl ring is substituted with  $-OCF_3$ .

31. The pharmaceutical composition of claim 30, wherein  $R_{11}$  represents trifluoromethoxybenzyl.

10 32. The pharmaceutical composition of claim 31, wherein  $R_{11}$  represents



33. The pharmaceutical composition of any of claims 28-32, wherein L represents  $\text{CH}_2\text{SCH}_2$ ,  $\text{CH}_2\text{CH}_2$ ,  $\text{CH}_2\text{S}$  or  $\text{SCH}_2$ .
34. The pharmaceutical composition of any of claims 28-32, wherein L represents  $\text{CH}_2\text{CH}_2$ .
- 5 35. The pharmaceutical composition of any of claims 28-34, wherein each Y represents H.
36. The pharmaceutical composition of any of claims 28-35, wherein X represents S or  $\text{CH}=\text{CH}$ , wherein any hydrogen atom of a CH unit may be replaced by alkyl.
37. The pharmaceutical composition of any of claims 28-36, wherein Z represents  
10  $\text{R}_3(\text{CO})$ .
38. The pharmaceutical composition of claim 37, wherein  $\text{R}_3$  and  $\text{R}_{11}$  are not identical.
39. The pharmaceutical composition of any of claims 28-38, wherein  $\text{R}_1$  and  $\text{R}_2$  each represent H.
- 15 40. The pharmaceutical composition of any of claims 28-39, wherein Z represents  $\text{R}_3(\text{CO})$  and  $\text{R}_3$  represents substituted or unsubstituted arylalkyl, heteroarylalkyl, cycloalkyl or heterocycloalkyl.
41. The pharmaceutical composition of claim 40, wherein Z represents  $\text{R}_3(\text{CO})$  and  $\text{R}_3$  represents substituted or unsubstituted heteroarylalkyl.
- 20 42. The pharmaceutical composition of claim 41, wherein Z represents  $\text{R}_3(\text{CO})$  and  $\text{R}_3$  represents substituted or unsubstituted pyridylalkyl.
43. The pharmaceutical composition of any of claims 28-39, wherein Z represents  $\text{R}_3(\text{CO})$  and  $\text{R}_3$  represents  $\text{C}(\text{R}_8)(\text{R}_9)(\text{R}_{10})$ , wherein  $\text{R}_8$  represents substituted or

unsubstituted aryl, arylalkyl, heteroaryl or heteroaralkyl,  $R_9$  represents H, and  $R_{10}$  represents hydroxy, hydroxyalkyl, alkoxy or alkoxyalkyl.

44. The pharmaceutical composition of claim 43, wherein  $R_8$  represents substituted or unsubstituted aryl, arylalkyl, or heteroaryl.

5 45. The pharmaceutical composition of 43 or 44, wherein  $R_{10}$  represents hydroxy, hydroxyalkyl, or alkoxy.

46. The pharmaceutical composition of any of claims 28-32, wherein L represents  $CH_2SCH_2$ ,  $CH_2CH_2$ ,  $CH_2S$  or  $SCH_2$ , each Y represents H, X represents S, Z represents  $R_3(CO)$ ,  $R_1$  and  $R_2$  each represent H, and  $R_3$  represents substituted or  
10 unsubstituted arylalkyl, heteroarylalkyl, cycloalkyl or heterocycloalkyl.

47. The pharmaceutical composition of any of claims 28-32, wherein L represents  $CH_2SCH_2$ ,  $CH_2CH_2$ ,  $CH_2S$  or  $SCH_2$ , each Y represents H, X represents S, Z represents  $R_3(CO)$ ,  $R_1$  and  $R_2$  each represent H, and  $R_3$  represents  $C(R_8)(R_9)(R_{10})$ , wherein  $R_8$  represents substituted or unsubstituted aryl, arylalkyl, heteroaryl or  
15 heteroaralkyl,  $R_9$  represents H, and  $R_{10}$  represents hydroxy, hydroxyalkyl, alkoxy or alkoxyalkyl.

48. The pharmaceutical composition of claim 47, wherein L represents  $CH_2CH_2$ .

49. The pharmaceutical composition of claim 47 or 48, wherein  $R_8$  represents substituted or unsubstituted aryl, arylalkyl or heteroaryl.

20 50. The pharmaceutical composition of claim 49, wherein  $R_8$  represents substituted or unsubstituted aryl.

51. The pharmaceutical composition of any of claims 47-50, wherein  $R_{10}$  represents hydroxy, hydroxyalkyl or alkoxy.

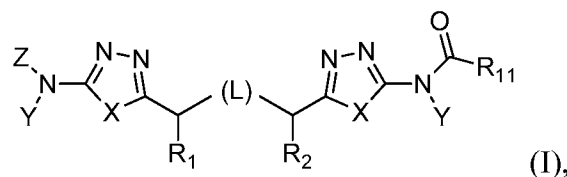
52. The pharmaceutical composition of claim 51, wherein  $R_{10}$  represents  
25 hydroxyalkyl.



53. The pharmaceutical composition of any of claims 28-32, wherein L represents  $\text{CH}_2\text{CH}_2$ , Y represents H, X represents S, Z represents  $\text{R}_3(\text{CO})$ ,  $\text{R}_1$  and  $\text{R}_2$  each represent H, and each  $\text{R}_3$  represents arylalkyl, heteroarylalkyl, cycloalkyl or heterocycloalkyl.


54. The pharmaceutical composition of claim 53, wherein  $\text{R}_3$  represents heteroarylalkyl.

55. A compound of formula I,



or a pharmaceutically acceptable salt thereof, wherein:

10 L represents  $\text{CH}_2\text{SCH}_2$ ,  $\text{CH}_2\text{CH}_2$ ,  $\text{CH}_2\text{CH}_2\text{CH}_2$ ,  $\text{CH}_2$ ,  $\text{CH}_2\text{S}$ ,  $\text{SCH}_2$ ,  $\text{CH}_2\text{NHCH}_2$ ,

$\text{CH}=\text{CH}$ , or , wherein any hydrogen atom of a CH or  $\text{CH}_2$  unit may be replaced by alkyl or alkoxy, any hydrogen of an NH unit may be replaced by alkyl, and any hydrogen atom of a  $\text{CH}_2$  unit of  $\text{CH}_2\text{CH}_2$ ,  $\text{CH}_2\text{CH}_2\text{CH}_2$  or  $\text{CH}_2$  may be replaced by hydroxy;

15 X, independently for each occurrence, represents S, O or  $\text{CH}=\text{CH}$ , wherein any hydrogen atom of a CH unit may be replaced by alkyl;

Y, independently for each occurrence, represents H or  $\text{CH}_2\text{O}(\text{CO})\text{R}_7$ ;

$\text{R}_7$ , independently for each occurrence, represents H or substituted or unsubstituted alkyl, alkoxy, aminoalkyl, alkylaminoalkyl, heterocyclalkyl, arylalkyl, or  
20 heterocyclalkoxy;

Z represents H or  $\text{R}_3(\text{CO})$ ;

$\text{R}_1$  and  $\text{R}_2$  each independently represent H, alkyl, alkoxy or hydroxy;

$\text{R}_3$  represents substituted or unsubstituted alkyl, hydroxyalkyl, aminoalkyl, acylaminoalkyl, alkenyl, alkoxy, alkoxyalkyl, aryl, arylalkyl, aryloxy,  
25 aryloxyalkyl, cycloalkyl, cycloalkylalkyl, heterocycl, heterocyclalkyl, heteroaryl, heteroarylalkyl, heteroaryloxy, heteroaryloxyalkyl or  $\text{C}(\text{R}_8)(\text{R}_9)(\text{R}_{10})$ ,  $\text{N}(\text{R}_4)(\text{R}_5)$  or  $\text{OR}_6$ , wherein any free hydroxyl group may be acylated to form  $\text{C}(\text{O})\text{R}_7$ ;

R<sub>4</sub> and R<sub>5</sub> each independently for each occurrence represent H or substituted or unsubstituted alkyl, hydroxyalkyl, acyl, aminoalkyl, acylaminoalkyl, alkenyl, alkoxyalkyl, aryl, arylalkyl, aryloxy, aryloxyalkyl, cycloalkyl, cycloalkylalkyl, heterocyclyl, heterocyclylalkyl, heteroaryl, heteroarylalkyl, heteroaryloxy, or heteroaryloxyalkyl, wherein any free hydroxyl group may be acylated to form C(O)R<sub>7</sub>;

R<sub>6</sub> represents substituted or unsubstituted alkyl, hydroxyalkyl, aminoalkyl, acylaminoalkyl, alkenyl, alkoxyalkyl, aryl, arylalkyl, aryloxy, aryloxyalkyl, cycloalkyl, cycloalkylalkyl, heterocyclyl, heterocyclylalkyl, heteroaryl, heteroarylalkyl, heteroaryloxy, or heteroaryloxyalkyl, wherein any free hydroxyl group may be acylated to form C(O)R<sub>7</sub>;

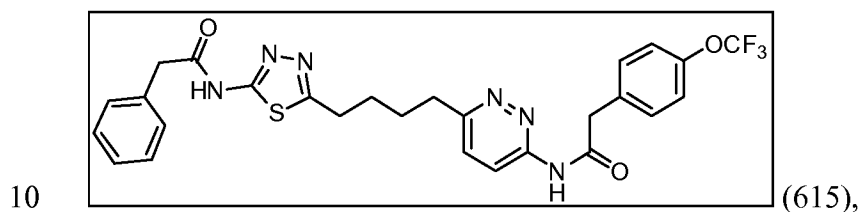
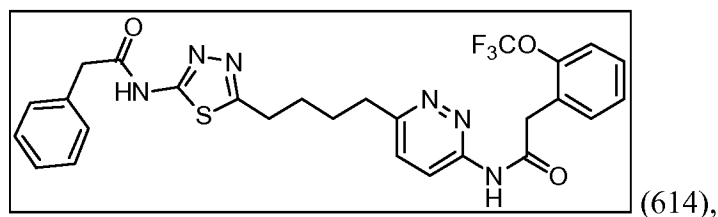
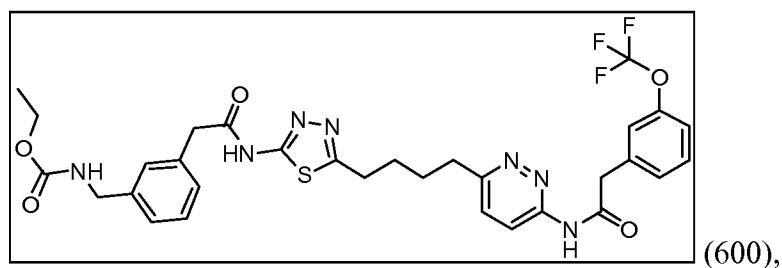
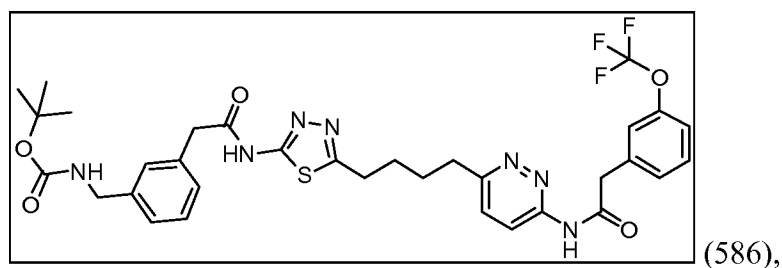
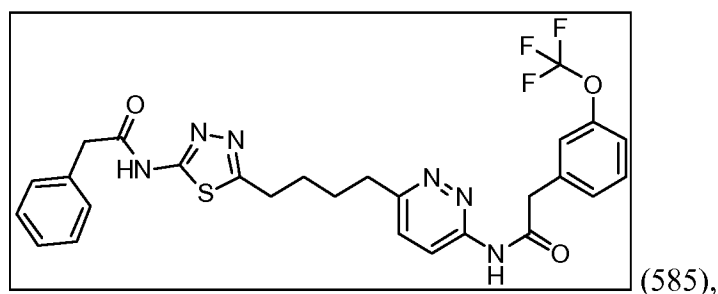
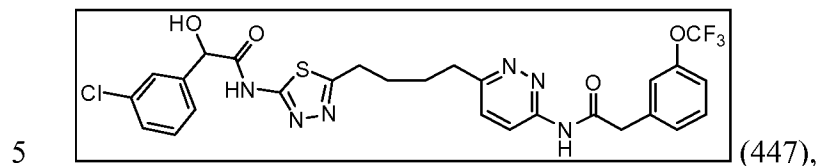
R<sub>8</sub>, R<sub>9</sub> and R<sub>10</sub> each independently for each occurrence represent H or substituted or unsubstituted alkyl, hydroxy, hydroxyalkyl, amino, acylamino, aminoalkyl, acylaminoalkyl, alkoxy, alkoxyalkyl, aryl, arylalkyl, aryloxy, aryloxyalkyl, cycloalkyl, cycloalkylalkyl, heterocyclyl, heterocyclylalkyl, heteroaryl, heteroarylalkyl, heteroaryloxy, or heteroaryloxyalkyl, or R<sub>8</sub> and R<sub>9</sub> together with the carbon to which they are attached, form a carbocyclic or heterocyclic ring system, wherein any free hydroxyl group may be acylated to form C(O)R<sub>7</sub>, and wherein at least two of R<sub>8</sub>, R<sub>9</sub> and R<sub>10</sub> are not H;

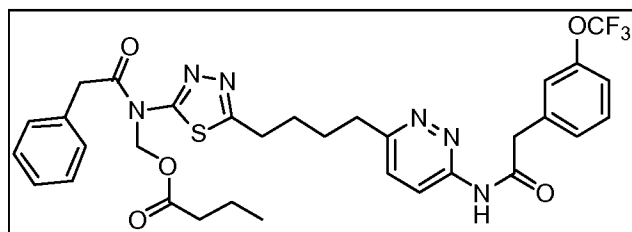
R<sub>11</sub> represents aryl, arylalkyl, aryloxy, aryloxyalkyl, heteroaryl, heteroarylalkyl, heteroaryloxy, or heteroaryloxyalkyl, wherein the aryl or heteroaryl ring is substituted with either -OCHF<sub>2</sub> or -OCF<sub>3</sub> and is optionally further substituted, or R<sub>11</sub> represents C(R<sub>12</sub>)(R<sub>13</sub>)(R<sub>14</sub>), N(R<sub>4</sub>)(R<sub>14</sub>) or OR<sub>14</sub>, wherein any free hydroxyl group may be acylated to form C(O)R<sub>7</sub>;

R<sub>12</sub> and R<sub>13</sub> each independently represent H or substituted or unsubstituted alkyl, hydroxy, hydroxyalkyl, amino, acylamino, aminoalkyl, acylaminoalkyl, alkoxy, alkoxyalkyl, aryl, arylalkyl, aryloxy, aryloxyalkyl, cycloalkyl, cycloalkylalkyl, heterocyclyl, heterocyclylalkyl, heteroaryl, heteroarylalkyl, heteroaryloxy, or heteroaryloxyalkyl, wherein any free hydroxyl group may be acylated to form C(O)R<sub>7</sub>, and wherein both of R<sub>12</sub> and R<sub>13</sub> are not H; and

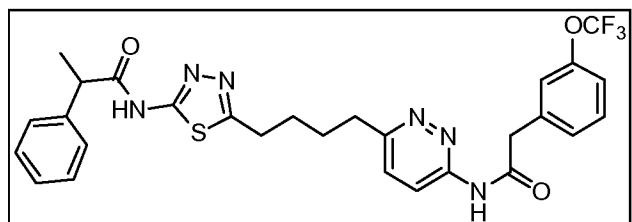
R<sub>14</sub> represents aryl, arylalkyl, aryloxy, aryloxyalkyl, heteroaryl, heteroarylalkyl, heteroaryloxy, or heteroaryloxyalkyl, wherein the aryl or heteroaryl ring is substituted with either -OCHF<sub>2</sub> or -OCF<sub>3</sub> and is optionally further substituted.

56. The compound of claim 55, wherein the compound is not one of the following:





(629), or

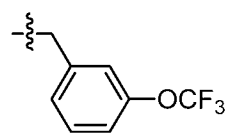


(636).

57. The compound of claim 55 or 56, wherein  $R_{11}$  represents arylalkyl, wherein the aryl ring is substituted with  $-OCF_3$ .

5 58. The compound of claim 57, wherein  $R_{11}$  represents trifluoromethoxybenzyl.

59. The compound of claim 58, wherein  $R_{11}$  represents



60. The compound of any of claims 55-59, wherein L represents  $CH_2SCH_2$ ,  $CH_2CH_2$ ,  $CH_2S$  or  $SCH_2$ .

61. The compound of any of claims 55-60, wherein L represents  $CH_2CH_2$ .

10 62. The compound of any of claims 55-61, wherein each Y represents H.

63. The compound of any of claims 55-62, wherein X represents S or  $CH=CH$ , wherein any hydrogen atom of a CH unit may be replaced by alkyl.

64. The compound of any of claims 55-63, wherein Z represents  $R_3(CO)$ .

65. The compound of claim 64, wherein  $R_3$  and  $R_{11}$  are not identical.

15 66. The compound of any of claims 55-65, wherein  $R_1$  and  $R_2$  each represent H.

67. The compound of any of claims 55-66, wherein Z represents  $R_3(CO)$  and  $R_3$  represents substituted or unsubstituted arylalkyl, heteroarylalkyl, cycloalkyl or heterocycloalkyl.
68. The compound of claim 67, wherein Z represents  $R_3(CO)$  and  $R_3$  represents substituted or unsubstituted heteroarylalkyl.
69. The compound of claim 68, wherein Z represents  $R_3(CO)$  and  $R_3$  represents substituted or unsubstituted pyridylalkyl.
70. The compound of any of claims 55-66, wherein Z represents  $R_3(CO)$  and  $R_3$  represents  $C(R_8)(R_9)(R_{10})$ , wherein  $R_8$  represents substituted or unsubstituted aryl, arylalkyl, heteroaryl or heteroaralkyl,  $R_9$  represents H, and  $R_{10}$  represents hydroxy, hydroxyalkyl, alkoxy or alkoxyalkyl.
71. The compound of claim 70, wherein  $R_8$  represents substituted or unsubstituted aryl, arylalkyl, or heteroaryl.
72. The compound of claim 70 or 71, wherein  $R_{10}$  represents hydroxy, hydroxyalkyl, or alkoxy.
73. The compound of any of claims 55-59, wherein L represents  $CH_2SCH_2$ ,  $CH_2CH_2$ ,  $CH_2S$  or  $SCH_2$ , each Y represents H, X represents S, Z represents  $R_3(CO)$ ,  $R_1$  and  $R_2$  each represent H, and  $R_3$  represents substituted or unsubstituted arylalkyl, heteroarylalkyl, cycloalkyl or heterocycloalkyl.
74. The compound of any of claims 55-59, wherein L represents  $CH_2SCH_2$ ,  $CH_2CH_2$ ,  $CH_2S$  or  $SCH_2$ , each Y represents H, X represents S, Z represents  $R_3(CO)$ ,  $R_1$  and  $R_2$  each represent H, and  $R_3$  represents  $C(R_8)(R_9)(R_{10})$ , wherein  $R_8$  represents substituted or unsubstituted aryl, arylalkyl, heteroaryl or heteroaralkyl,  $R_9$  represents H, and  $R_{10}$  represents hydroxy, hydroxyalkyl, alkoxy or alkoxyalkyl.
75. The compound of claim 74, wherein L represents  $CH_2CH_2$ .

76. The compound of claim 74 or 75, wherein  $R_8$  represents substituted or unsubstituted aryl, arylalkyl or heteroaryl.

77. The compound of claim 76, wherein  $R_8$  represents substituted or unsubstituted aryl.

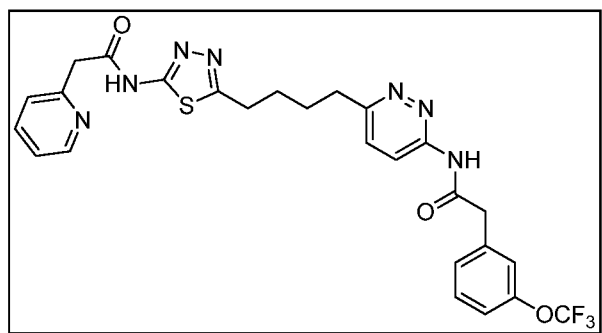
5 78. The compound of any of claims 74-77, wherein  $R_{10}$  represents hydroxy, hydroxyalkyl or alkoxy.

79. The compound of claim 78, wherein  $R_{10}$  represents hydroxyalkyl.

80. The compound of any of claims 55-59, wherein L represents  $CH_2CH_2$ , Y represents H, X represents S, Z represents  $R_3(CO)$ ,  $R_1$  and  $R_2$  each represent H, and  $R_3$  represents arylalkyl, heteroarylalkyl, cycloalkyl or heterocycloalkyl.

81. The compound of claim 80, wherein  $R_3$  represents heteroarylalkyl.

15 82. A compound having the structure



or a pharmaceutically acceptable salt thereof.

Figure 1

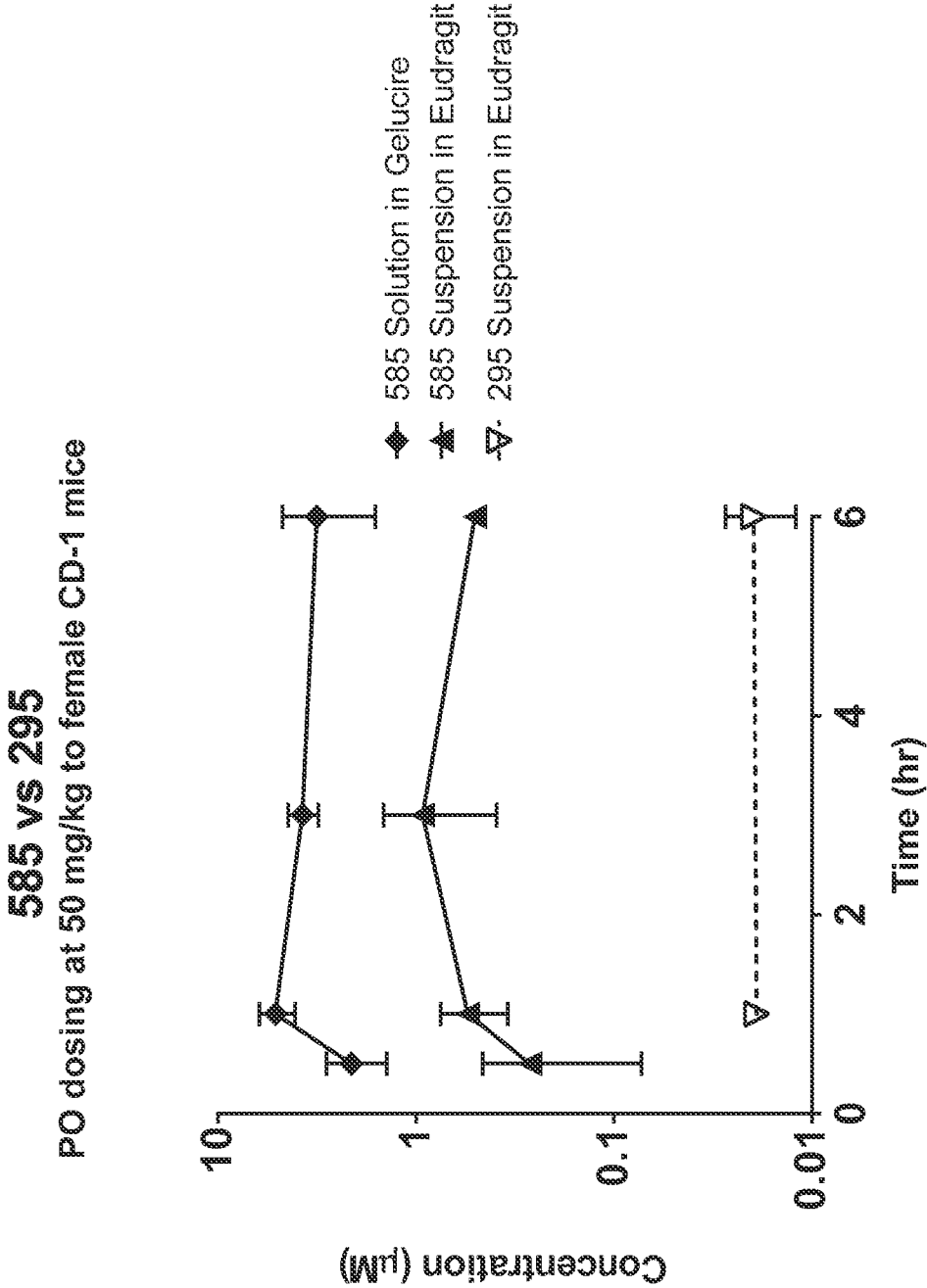


Figure 2

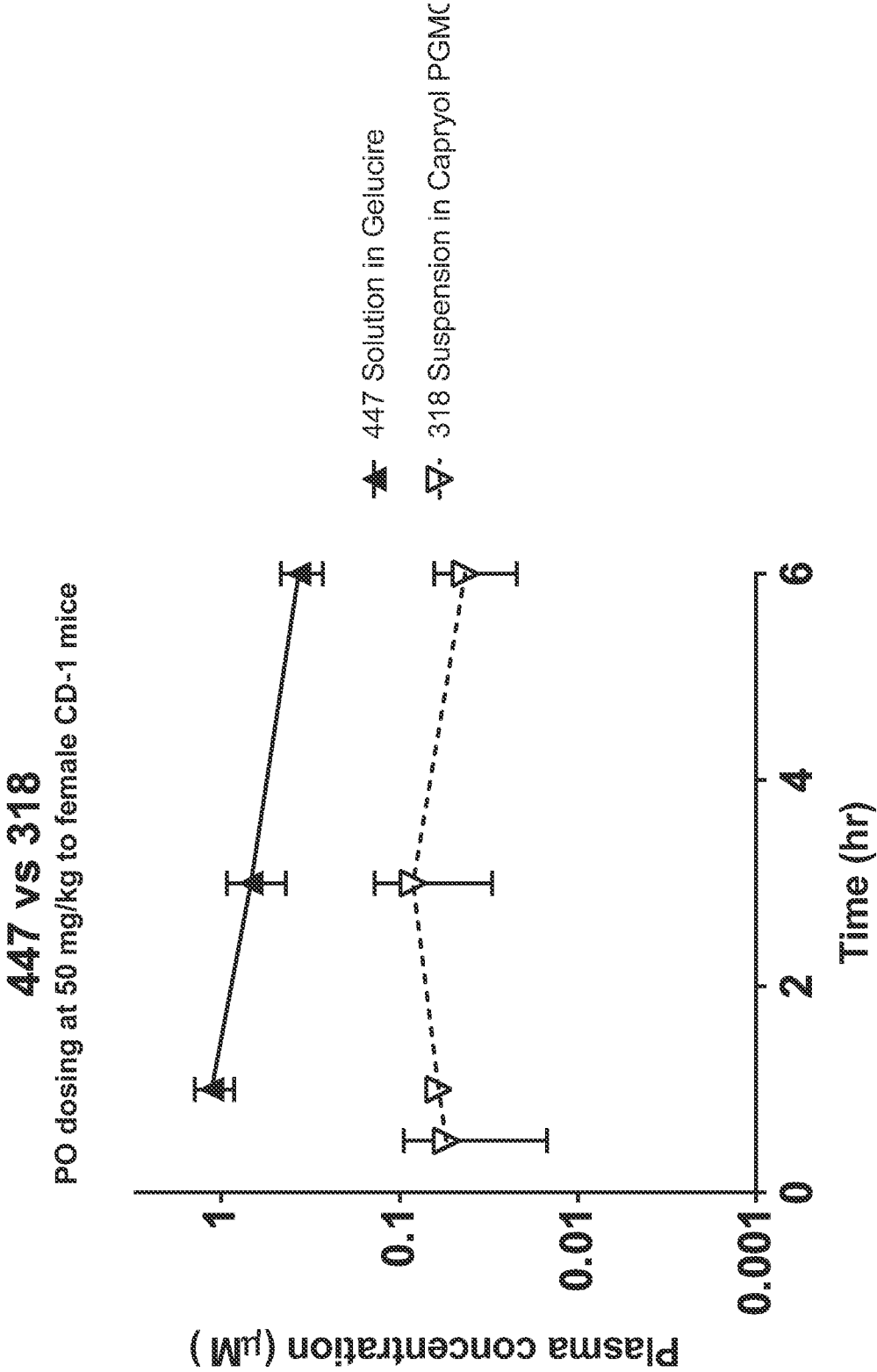
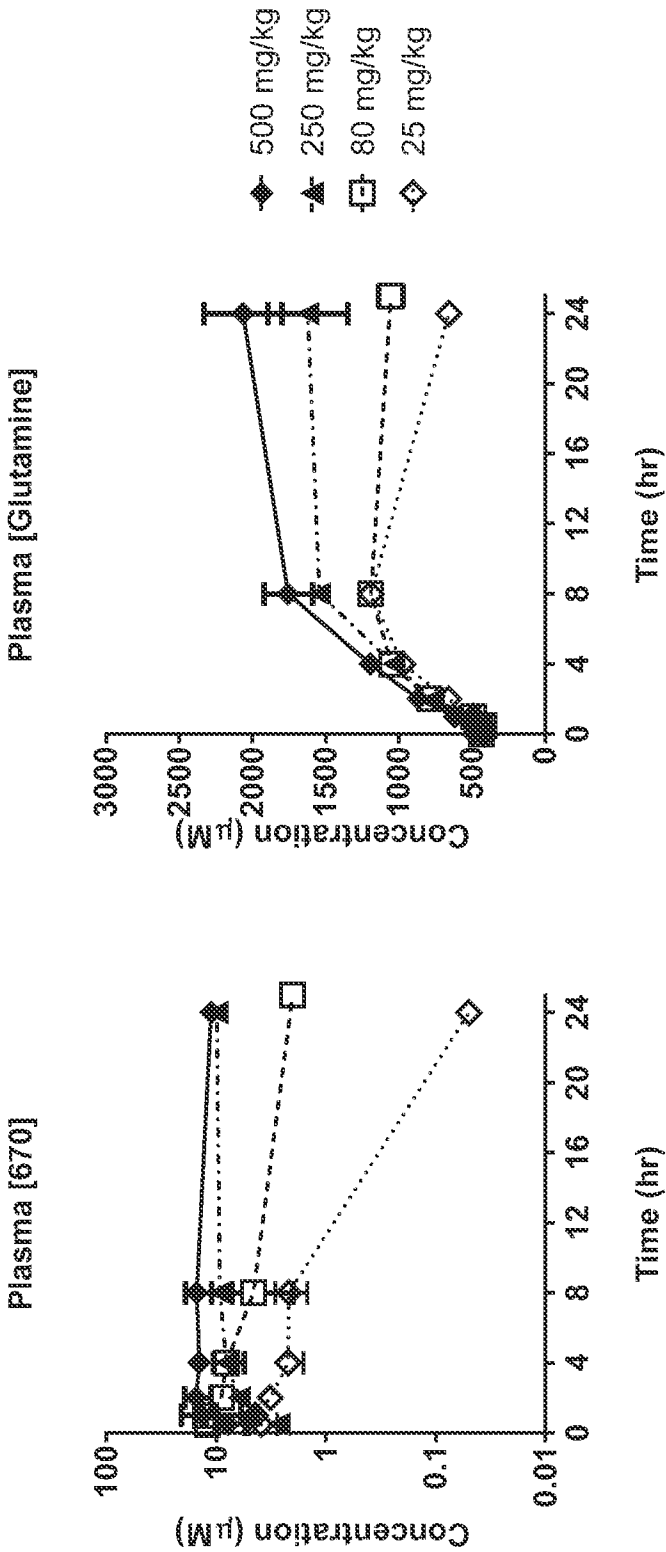




Figure 3

**670**  
PO dosing to female Sprague Dawley rats  
(HPBCD formulation)



H2122 Lung Adenocarcinoma Xenograft

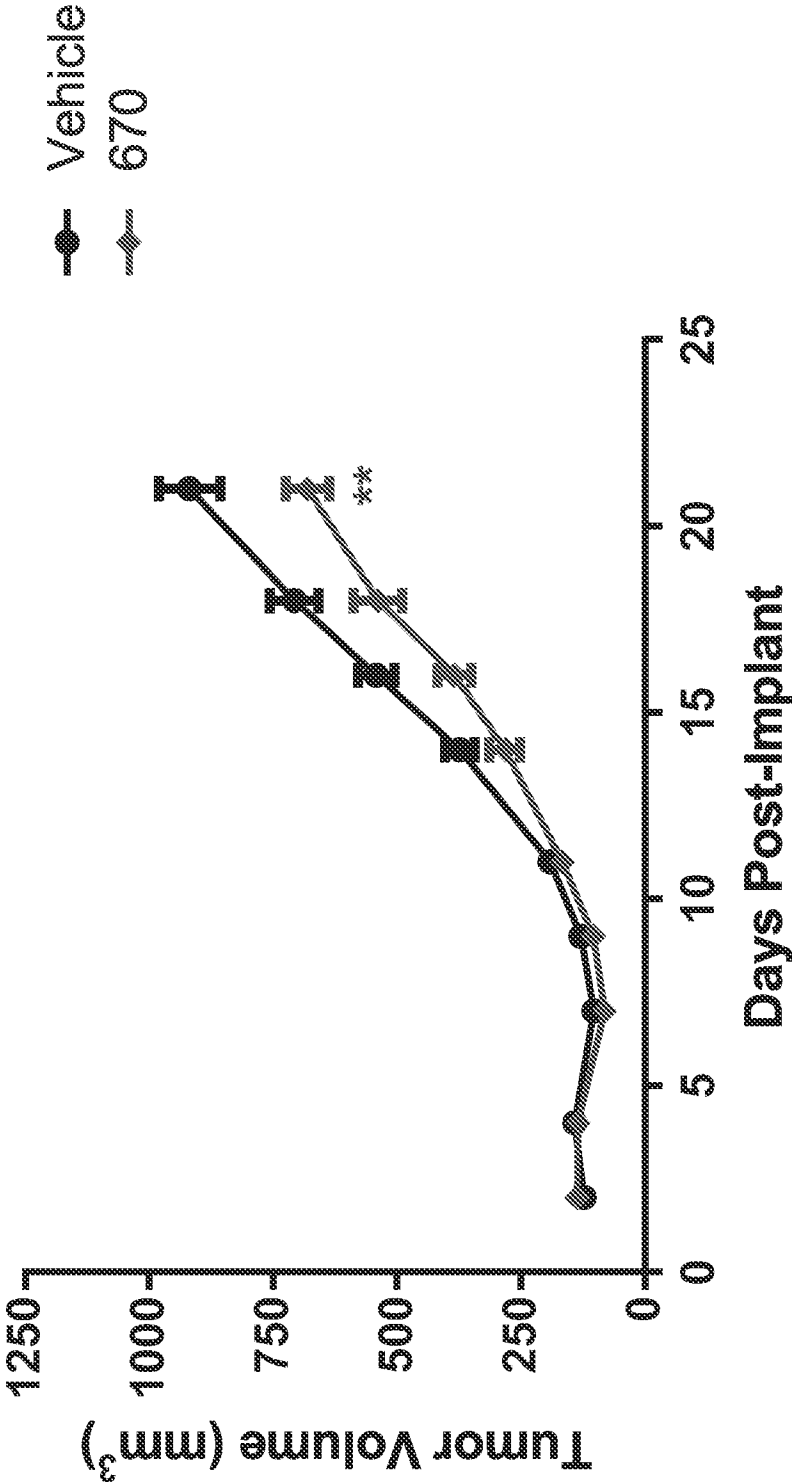
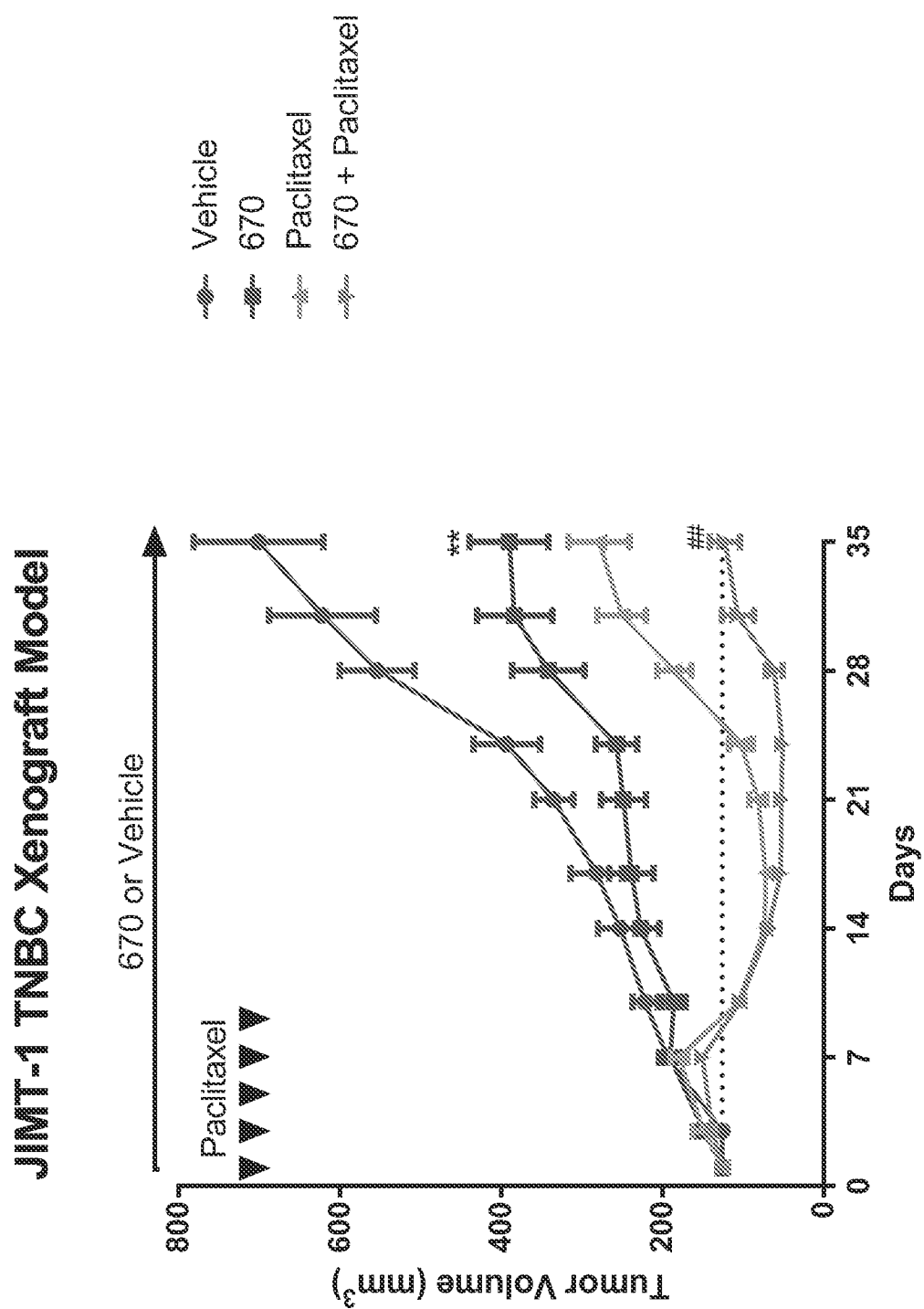


Figure 4

Figure 5



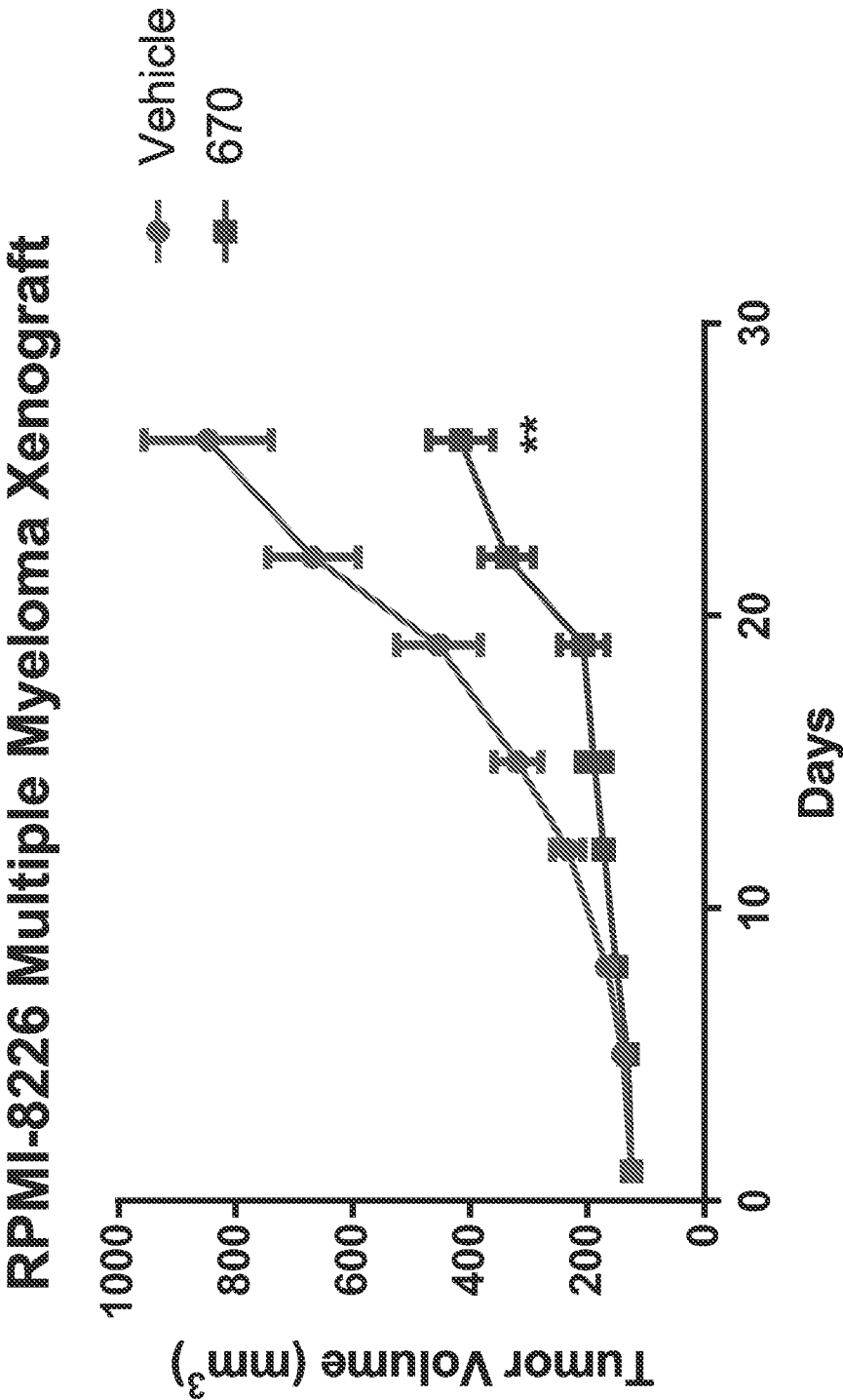
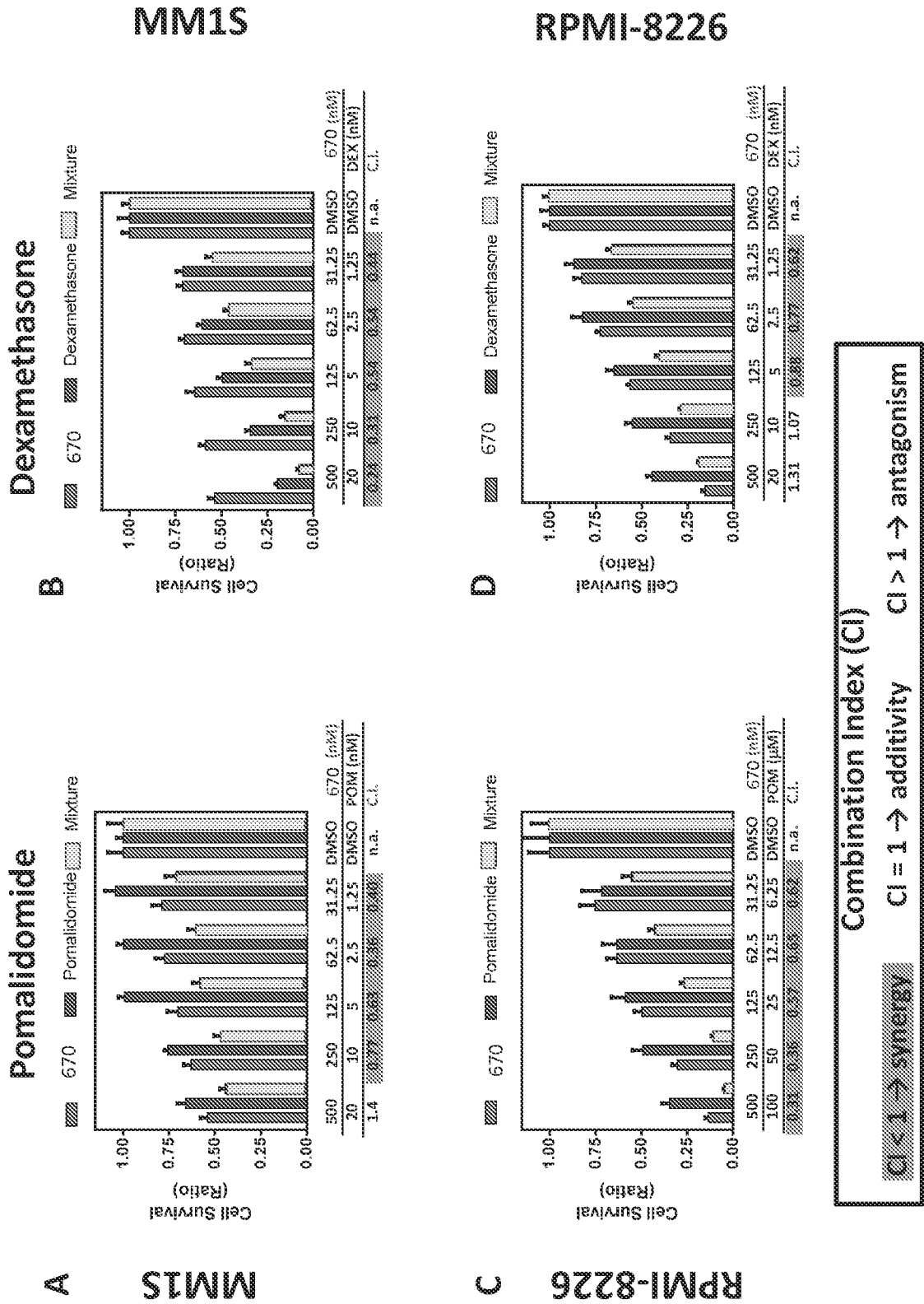


Figure 6

Figure 7



## INTERNATIONAL SEARCH REPORT

International application No.  
**PCT/US2013/070277**

## A. CLASSIFICATION OF SUBJECT MATTER

**C07D 417/06 (2006.01) C07D 417/14 (2006.01) A61K 31/501 (2006.01) A61P 35/00 (2006.01) A61P 37/00 (2006.01)  
A61P 25/28 (2006.01)**

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)

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

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

STN: databases Registry and CPlus; structure search based on formula I

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	Documents are listed in the continuation of Box C	



Further documents are listed in the continuation of Box C



See patent family annex

* "A"	Special categories of cited documents: document defining the general state of the art which is not considered to be of particular relevance	"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
"E"	earlier application or patent but published on or after the international filing date	"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
"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)	"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
"O"	document referring to an oral disclosure, use, exhibition or other means	"&"	document member of the same patent family
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search  
13 February 2014

Date of mailing of the international search report  
13 February 2014

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INTERNATIONAL SEARCH REPORT		International application No.
C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		PCT/US2013/070277
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2012/006506 A1 (MASSACHUSETTS INSTITUTE OF TECHNOLOGY) 12 January 2012 See claims 1, 4, 23	1, 2, 6, 8–10, 12, 13, 19, 28, 29, 33, 35–37, 39, 40, 46, 55, 56, 60, 62–64, 66, 67, 73
X	Shukla, K., <i>et al.</i> , “Design, Synthesis and Pharmacological Evaluation of Bis-2-(5-phenylacetamido-1,2,4-thiadiazol-2-yl)ethyl sulphide 3 (BPTES) Analogs as Glutaminase Inhibitors”, <i>Journal of Medicinal Chemistry</i> , 2012, <b>55</b> (23), 10551-10563 See compounds 3, 6, 11a, 11b, 15a, 15b, 15d to 15f, 20 and 27 in table 1 on page 10554, table 1, page 10562	28, 29, 33–36, 38, 39, 55, 56, 60–63, 65, 66, 73
X	Thangavelu, K., <i>et al.</i> , “Structural basis for the allosteric inhibitory mechanism of human kidney-type glutaminase (KGA) and its regulation by Raf-Mek-Erk signaling in cancer cell metabolism”, <i>Proceedings of the National Academy of Sciences of the United States of America</i> , 2012, <b>109</b> (20), 7705-7710, S7705/1-S7705/13 See compound 5 on page 6 of 12 of the Supporting Information	55, 56, 60, 62–64, 66, 67, 73
X	US 2002/0115698 A1 (NEWCOMB <i>et al.</i> ) 22 August 2002 See title, abstract, compounds 1770, 1830, 1855, 1831, 1832, 1836, 1837 and 1853 in table 1 on page 4, example 2, paragraph 0086, claim 1	1, 2, 6, 8–10, 12–15, 19, 28, 29, 33, 35–37, 39–42, 46, 55, 56, 60, 62–64, 66–69, 73
X	Shimano, Y., <i>et al.</i> , “Syntheses of Poly(diacylthiosemicarbazide)s from Diacylthiocyanates and Dihydrazides, and Their Thermal Cyclodehydration”, <i>Kobunshi Ronbunshu</i> , 1980, <b>37</b> (2), 131-7 See compound V on page 131	55, 56, 60, 62–64, 66, 73
X	Gehlen, H., <i>et al.</i> , “Über die Einwirkung von Isocyanaten auf substituierte 2-Amino-1,3,4-oxdiazole”, <i>Justus Liebigs Annalen der Chemie</i> , 1966, <b>692</b> , 151-65 See the first compound of table 2c on page 157	55, 56, 60–64, 66, 73
X	CAS RN 331234-76-5, STN Entry Date 13 April 2001 N,N'-[thiobis(2,1-ethanediyl-1,3,4-thiadiazole-5,2-diyl)]bis-1H-1,2,4-triazole-3-carboxamide	55, 56, 60, 62–64, 66, 73
X	CAS RN 1400068-83-8, STN Entry Date 08 October 2012 N,N'-(5,5'-(pentane-1,5-diyl)bis(1,3,4-thiadiazole-5,2-diyl))bis(2-methoxybenzamide)	55, 56, 62–64, 66, 73
P,X	WO 2013/078123 A1 (CALITHERA BIOSCIENCES INC.) 30 May 2013 See compounds in table 3 from page 169 onwards, eg compounds 1, 25, 354, 395 and 636 <i>inter alia</i> , claims	1–82
Form PCT/ISA/210 (fifth sheet) (July 2009)		

<b>INTERNATIONAL SEARCH REPORT</b> Information on patent family members		International application No. <b>PCT/US2013/070277</b>	
This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.			
Patent Document/s Cited in Search Report		Patent Family Member/s	
Publication Number	Publication Date	Publication Number	Publication Date
WO 2012/006506 A1	12 Jan 2012	WO 2012006506 A1	12 Jan 2012
US 2002/0115698 A1	22 Aug 2002	US 6451828 B1	17 Sep 2002
WO 2013/078123 A1	30 May 2013	US 2013157998 A1	20 Jun 2013
		US 8604016 B2	10 Dec 2013
		WO 2013078123 A1	30 May 2013
<b>End of Annex</b>			
<p>Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.          Form PCT/ISA/210 (Family Annex)(July 2009)</p>			