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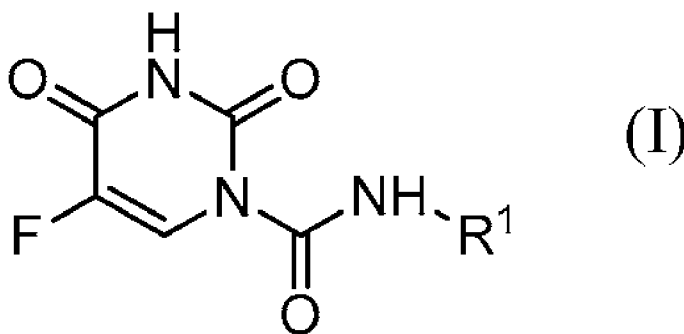
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(54) Title: FLUOROURACIL DERIVATIVES



(57) Abstract: This invention relates to novel fluorouracil derivatives of Formula I or pharmaceutically acceptable salts thereof. This invention also provides compositions comprising a compound of this invention and the use of such compositions in methods of treating diseases and conditions that are beneficially treated by administering a thymidylate synthase inhibitor.

FLUOROURACIL DERIVATIVES**Cross-Reference To Related Applications**

5 This application claims priority under 35 U.S.C. § 119(e) to U.S. Provisional Application No. 61/309,204, filed March 1, 2010, which is incorporated by reference herein in its entirety.

Background of the Invention

10 [1] Many current medicines suffer from poor absorption, distribution, metabolism and/or excretion (ADME) properties that prevent their wider use or limit their use in certain indications. Poor ADME properties are also a major reason for the failure of drug candidates in clinical trials. While formulation technologies and prodrug strategies can be employed in some cases to improve certain ADME properties, these approaches often fail to address the underlying ADME problems that exist for many
15 drugs and drug candidates. One such problem is rapid metabolism that causes a number of drugs, which otherwise would be highly effective in treating a disease, to be cleared too rapidly from the body. A possible solution to rapid drug clearance is frequent or high dosing to attain a sufficiently high plasma level of drug. This, however, introduces a number of potential treatment problems such as poor patient
20 compliance with the dosing regimen, side effects that become more acute with higher doses, and increased cost of treatment. A rapidly metabolized drug may also expose patients to undesirable toxic or reactive metabolites.

[2] Another ADME limitation that affects many medicines is the formation of toxic or biologically reactive metabolites. As a result, some patients receiving the
25 drug may experience toxicities, or the safe dosing of such drugs may be limited such that patients receive a suboptimal amount of the active agent. In certain cases, modifying dosing intervals or formulation approaches can help to reduce clinical adverse effects, but often the formation of such undesirable metabolites is intrinsic to the metabolism of the compound.

30 [3] In some select cases, a metabolic inhibitor will be co-administered with a drug that is cleared too rapidly. Such is the case with the protease inhibitor class of drugs that are used to treat HIV infection. The FDA recommends that these drugs be co-dosed with ritonavir, an inhibitor of cytochrome P450 enzyme 3A4 (CYP3A4), the

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enzyme typically responsible for their metabolism (see Kempf, D.J. et al., Antimicrobial agents and chemotherapy, 1997, 41(3): 654-60). Ritonavir, however, causes adverse effects and adds to the pill burden for HIV patients who must already take a combination of different drugs. Similarly, the CYP2D6 inhibitor quinidine has
5 been added to dextromethorphan for the purpose of reducing rapid CYP2D6 metabolism of dextromethorphan in a treatment of pseudobulbar affect. Quinidine, however, has unwanted side effects that greatly limit its use in potential combination therapy (see Wang, L et al., Clinical Pharmacology and Therapeutics, 1994, 56(6 Pt 1): 659-67; and FDA label for quinidine at www.accessdata.fda.gov).

10 [4] In general, combining drugs with cytochrome P450 inhibitors is not a satisfactory strategy for decreasing drug clearance. The inhibition of a CYP enzyme's activity can affect the metabolism and clearance of other drugs metabolized by that same enzyme. CYP inhibition can cause other drugs to accumulate in the body to toxic levels.

15 [5] A potentially attractive strategy for improving a drug's metabolic properties is deuterium modification. In this approach, one attempts to slow the CYP-mediated metabolism of a drug or to reduce the formation of undesirable metabolites by replacing one or more hydrogen atoms with deuterium atoms. Deuterium is a safe, stable, non-radioactive isotope of hydrogen. Compared to hydrogen, deuterium forms
20 stronger bonds with carbon. In select cases, the increased bond strength imparted by deuterium can positively impact the ADME properties of a drug, creating the potential for improved drug efficacy, safety, and/or tolerability. At the same time, because the size and shape of deuterium are essentially identical to those of hydrogen, replacement of hydrogen by deuterium would not be expected to affect the
25 biochemical potency and selectivity of the drug as compared to the original chemical entity that contains only hydrogen.

[6] Over the past 35 years, the effects of deuterium substitution on the rate of metabolism have been reported for a very small percentage of approved drugs (see, e.g., Blake, MI et al, J Pharm Sci, 1975, 64:367-91; Foster, AB, Adv Drug Res 1985,
30 14:1-40 ("Foster"); Kushner, DJ et al, Can J Physiol Pharmacol 1999, 79-88; Fisher, MB et al, Curr Opin Drug Discov Devel, 2006, 9:101-09 ("Fisher")). The results have been variable and unpredictable. For some compounds deuteration caused decreased metabolic clearance *in vivo*. For others, there was no change in

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metabolism. Still others demonstrated increased metabolic clearance. The variability in deuterium effects has also led experts to question or dismiss deuterium modification as a viable drug design strategy for inhibiting adverse metabolism (see Foster at p. 35 and Fisher at p. 101).

5 [7] The effects of deuterium modification on a drug's metabolic properties are not predictable even when deuterium atoms are incorporated at known sites of metabolism. Only by actually preparing and testing a deuterated drug can one determine if and how the rate of metabolism will differ from that of its non-deuterated counterpart. *See*, for example, Fukuto et al. (J. Med. Chem. 1991, 34, 2871-76).

10 Many drugs have multiple sites where metabolism is possible. The site(s) where deuterium substitution is required and the extent of deuteration necessary to see an effect on metabolism, if any, will be different for each drug.

[8] Carmofur, also known as 5-fluoro-*N*-hexyl-2,4-dioxo-pyrimidine-1-carboxamide and as 1-hexylcarbamoyl-5-fluorouracil, is a pyrimidine analogue which
15 acts as an antineoplastic agent through inhibition of thymidylate synthase. Thymidylate synthase methylates deoxyuridine monophosphate into thymidine monophosphate. Inhibiting this enzyme blocks the synthesis of thymidine, which is required for DNA replication.

[9] Carmofur is approved in Japan for the treatment of cancer. Recent clinical
20 trials, 2001 to 2005, have focused on the use of carmofur for treatment of breast cancer (Morimoto, K. et al., Osaka City Med. J., 2003, 49: 77-83), hepatocellular carcinoma (Ono, T. et al., Cancer, 2001, 91(12): 2378-85) and colorectal cancer (Sakamoto, J. et al., Japanese Journal of Clinical Oncology Advance, 2005, 35(9): 536-44).

25 [10] Carmofur is a prodrug which has some anticancer activity of its own, and is ultimately transformed *in vivo* to 5-fluorouracil (5-FU). 5-FU has been in use as an anti-cancer agent for about 40 years and principally acts as a thymidylate synthase inhibitor. 5-FU has systemic effects but acts most significantly upon rapidly-dividing cells that rely heavily on their nucleotide synthesis machinery, such as cancer cells.

30 [11] Currently there are several drugs on the market that attempt to prolong the presence of active 5-FU by dosing a precursor molecule with a longer residence time in the plasma/relevant tissues. Carmofur is a member of this class. The time required for degradation of carmofur's urea side chain prolongs the drug's presence in the

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body and allows more time for tissue distribution. The predominant metabolic pathway in humans involves initial ω -oxidation of the hexyl chain followed by sequential β -oxidation to finally release 5-FU. There is evidence that carmofur and its intermediary carboxylic acid metabolites have anticancer activity themselves, in addition to the strong anticancer activity of 5-FU.

[12] Infrequent cases of leukoencephalopathy (0.026% reported by Mixutani, T. in Brain Nerve, Feb. 2008, 60(2): 137-41) have been noted in patients treated with carmofur or with 5-fluorouracil (Matsumoto, S. et al., Neuroradiology, November, 1995, 37(8): 649-652; Baehring, JM, et al., Neurol Neurosurg Psychiatry, 2008, 79:535-539).

[13] Despite the beneficial activities of carmofur, there is a continuing need for new compounds to treat the aforementioned diseases and conditions.

Definitions

[14] The term "treat" means decrease, suppress, attenuate, diminish, arrest, or stabilize the development or progression of a disease (e.g., a disease or disorder delineated herein), lessen the severity of the disease or improve the symptoms associated with the disease.

[15] "Disease" means any condition or disorder that damages or interferes with the normal function of a cell, tissue, or organ.

[16] It will be recognized that some variation of natural isotopic abundance occurs in a synthesized compound depending upon the origin of chemical materials used in the synthesis. Thus, a preparation of carmofur will inherently contain small amounts of deuterated isotopologues. The concentration of naturally abundant stable hydrogen and carbon isotopes, notwithstanding this variation, is small and immaterial as compared to the degree of stable isotopic substitution of compounds of this invention. See, for instance, Wada, E et al., Seikagaku, 1994, 66:15; Gannes, LZ et al., Comp Biochem Physiol Mol Integr Physiol, 1998, 119:725.

[17] In the compounds of this invention any atom not specifically designated as a particular isotope is meant to represent any stable isotope of that atom. Unless otherwise stated, when a position is designated specifically as "H" or "hydrogen", the position is understood to have hydrogen at its natural abundance isotopic composition. Also unless otherwise stated, when a position is designated specifically as "D" or

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“deuterium”, the position is understood to have deuterium at an abundance that is at least 3340 times greater than the natural abundance of deuterium, which is 0.015% (i.e., at least 50.1% incorporation of deuterium).

5 [18] The term “isotopic enrichment factor” as used herein means the ratio between the isotopic abundance and the natural abundance of a specified isotope.

[19] In other embodiments, a compound of this invention has an isotopic enrichment factor for each designated deuterium atom of at least 3500 (52.5% deuterium incorporation at each designated deuterium atom), at least 4000 (60% deuterium incorporation), at least 4500 (67.5% deuterium incorporation), at least 5000
10 (75% deuterium), at least 5500 (82.5% deuterium incorporation), at least 6000 (90% deuterium incorporation), at least 6333.3 (95% deuterium incorporation), at least 6466.7 (97% deuterium incorporation), at least 6600 (99% deuterium incorporation), or at least 6633.3 (99.5% deuterium incorporation).

[20] The term “isotopologue” refers to a species in which the chemical structure
15 differs from a specific compound of this invention only in the isotopic composition thereof.

[21] The term “compound,” when referring to a compound of this invention, refers to a collection of molecules having an identical chemical structure, except that there may be isotopic variation among the constituent atoms of the molecules. Thus, it will
20 be clear to those of skill in the art that a compound represented by a particular chemical structure containing indicated deuterium atoms, will also contain lesser amounts of isotopologues having hydrogen atoms at one or more of the designated deuterium positions in that structure. The relative amount of such isotopologues in a compound of this invention will depend upon a number of factors including the
25 isotopic purity of deuterated reagents used to make the compound and the efficiency of incorporation of deuterium in the various synthesis steps used to prepare the compound. However, as set forth above the relative amount of such isotopologues *in toto* will be less than 49.9% of the compound. In other embodiments, the relative amount of such isotopologues *in toto* will be less than 47.5%, less than 40%, less than
30 32.5%, less than 25%, less than 17.5%, less than 10%, less than 5%, less than 3%, less than 1%, or less than 0.5% of the compound.

[22] The invention also provides salts of the compounds of the invention.

[23] A salt of a compound of this invention is formed between an acid and a basic

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group of the compound, such as an amino functional group, or a base and an acidic group of the compound, such as a carboxyl functional group. According to another embodiment, the compound is a pharmaceutically acceptable acid addition salt.

[24] The term “pharmaceutically acceptable,” as used herein, refers to a component that is, within the scope of sound medical judgment, suitable for use in contact with the tissues of humans and other mammals without undue toxicity, irritation, allergic response and the like, and are commensurate with a reasonable benefit/risk ratio. A “pharmaceutically acceptable salt” means any non-toxic salt that, upon administration to a recipient, is capable of providing, either directly or indirectly, a compound of this invention. A “pharmaceutically acceptable counterion” is an ionic portion of a salt that is not toxic when released from the salt upon administration to a recipient.

[25] Acids commonly employed to form pharmaceutically acceptable salts include inorganic acids such as hydrogen bisulfide, hydrochloric acid, hydrobromic acid, hydroiodic acid, sulfuric acid and phosphoric acid, as well as organic acids such as para-toluenesulfonic acid, salicylic acid, tartaric acid, bitartaric acid, ascorbic acid, maleic acid, besylic acid, fumaric acid, gluconic acid, glucuronic acid, formic acid, glutamic acid, methanesulfonic acid, ethanesulfonic acid, benzenesulfonic acid, lactic acid, oxalic acid, para-bromophenylsulfonic acid, carbonic acid, succinic acid, citric acid, benzoic acid and acetic acid, as well as related inorganic and organic acids.

Such pharmaceutically acceptable salts thus include sulfate, pyrosulfate, bisulfate, sulfite, bisulfite, phosphate, monohydrogenphosphate, dihydrogenphosphate, metaphosphate, pyrophosphate, chloride, bromide, iodide, acetate, propionate, decanoate, caprylate, acrylate, formate, isobutyrate, caprate, heptanoate, propiolate, oxalate, malonate, succinate, suberate, sebacate, fumarate, maleate, butyne-1,4-dioate, hexyne-1,6-dioate, benzoate, chlorobenzoate, methylbenzoate, dinitrobenzoate, hydroxybenzoate, methoxybenzoate, phthalate, terephthalate, sulfonate, xylene sulfonate, phenylacetate, phenylpropionate, phenylbutyrate, citrate, lactate, β -hydroxybutyrate, glycolate, maleate, tartrate, methanesulfonate, propanesulfonate, naphthalene-1-sulfonate, naphthalene-2-sulfonate, mandelate and other salts. In one embodiment, pharmaceutically acceptable acid addition salts include those formed with mineral acids such as hydrochloric acid and hydrobromic acid, and especially those formed with organic acids such as maleic acid.

[26] The pharmaceutically acceptable salt may also be a salt of a compound of the

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present invention having an acidic functional group, such as a carboxylic acid functional group, and a base. Exemplary bases include, but are not limited to, hydroxide of alkali metals including sodium, potassium, and lithium; hydroxides of alkaline earth metals such as calcium and magnesium; hydroxides of other metals, such as aluminum and zinc; ammonia, organic amines such as unsubstituted or hydroxyl-substituted mono-, di-, or tri-alkylamines, dicyclohexylamine; tributyl amine; pyridine; N-methyl, N-ethylamine; diethylamine; triethylamine; mono-, bis-, or tris-(2-OH-(C₁-C₆)-alkylamine), such as N,N-dimethyl-N-(2-hydroxyethyl)amine or tri-(2-hydroxyethyl)amine; N-methyl-D-glucamine; morpholine; thiomorpholine; piperidine; pyrrolidine; and amino acids such as arginine, lysine, and the like.

[27] The compounds of the present invention (e.g., compounds of Formula I), may contain an asymmetric carbon atom, for example, as the result of deuterium substitution or otherwise. As such, compounds of this invention can exist as either individual enantiomers, or mixtures of the two enantiomers. Accordingly, a compound of the present invention may exist as either a racemic mixture or a scalemic mixture, or as individual respective stereoisomers that are substantially free from another possible stereoisomer. The term “substantially free of other stereoisomers” as used herein means less than 25% of other stereoisomers, preferably less than 10% of other stereoisomers, more preferably less than 5% of other stereoisomers and most preferably less than 2% of other stereoisomers are present. Methods of obtaining or synthesizing an individual enantiomer for a given compound are known in the art and may be applied as practicable to final compounds or to starting material or intermediates.

[28] Unless otherwise indicated, when a disclosed compound is named or depicted by a structure without specifying the stereochemistry and has one or more chiral centers, it is understood to represent all possible stereoisomers of the compound.

[29] The term “stable compounds,” as used herein, refers to compounds which possess stability sufficient to allow for their manufacture and which maintain the integrity of the compound for a sufficient period of time to be useful for the purposes detailed herein (e.g., formulation into therapeutic products, intermediates for use in production of therapeutic compounds, isolatable or storable intermediate compounds, treating a disease or condition responsive to therapeutic agents).

[30] “D” and “d” both refer to deuterium. “Stereoisomer” refers to both

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enantiomers and diastereomers. "Tert" and "t-" each refer to tertiary. "US" refers to the United States of America.

[31] "Substituted with deuterium" refers to the replacement of one or more hydrogen atoms with a corresponding number of deuterium atoms.

5 [32] "Alkyl" by itself or as part of another substituent refers to a saturated branched or straight-chain monovalent hydrocarbon radical having the stated number of carbon atoms (i.e., C₁-C₆ means one to six carbon atoms).

[33] Unless otherwise specified, "alkylene" by itself or as part of another substituent refers to a saturated straight-chain or branched divalent group having the
10 stated number of carbon atoms and derived from the removal of two hydrogen atoms from the corresponding alkane. Examples of straight chained and branched alkylene groups include -CH₂- (methylene), -CH₂-CH₂- (ethylene), -CH₂-CH₂-CH₂- (propylene), -C(CH₃)₂-, -CH₂-CH(CH₃)-, -CH₂-CH₂-CH₂-CH₂- (butylene), -CH₂-CH₂-CH₂-CH₂-CH₂- (pentylene), -CH₂-CH(CH₃)-CH₂-, and -CH₂-C(CH₃)₂-CH₂-.

15 [34] "Aryl" by itself or as part of another substituent refers to a monovalent aromatic hydrocarbon group having the stated number of carbon atoms (i.e., C₅-C₁₄ means from 5 to 14 carbon atoms). Typical aryl groups include, but are not limited to, phenyl or naphthyl.

[35] "Arylalkyl" by itself or as part of another substituent refers to an acyclic alkyl
20 group in which one of the hydrogen atoms bonded to a carbon atom, typically a terminal or sp₃ carbon atom, is replaced with an aryl group. Typical arylalkyl groups include, but are not limited to, benzyl, phenylmethyl, phenylethyl, phenylpropyl, naphthylmethyl, and naphthylethyl. In one embodiment, the alkyl moiety of the arylalkyl group is (C₁-C₆) and the aryl moiety is (C₅-C₁₄). In a more specific
25 embodiment the alkyl group is (C₁-C₃) and the aryl moiety is (C₅-C₁₀), such as (C₆-C₁₀).

[36] "Heteroaryl" by itself or as part of another substituent refers to a monovalent heteroaromatic group having the stated number of ring atoms (e.g., "5-14 membered" means from 5 to 14 ring atoms) derived by the removal of one hydrogen atom from a
30 single atom of a parent heteroaromatic ring system. Typical heteroaryl groups include, but are not limited to, groups derived from acridine, arsindole, benzodioxan, benzofuran, carbazole, β-carboline, chromane, chromene, cinnoline, furan, imidazole, indazole, indole, indoline, indolizine, isobenzofuran, isochromene, isoindole,

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isoindoline, isoquinoline, isothiazole, isoxazole, naphthyridine, oxadiazole, oxazole, perimidine, phenanthridine, phenanthroline, phenazine, phthalazine, pteridine, purine, pyran, pyrazine, pyrazole, pyridazine, pyridine, pyrimidine, pyrrole, pyrrolizine, quinazoline, quinoline, quinolizine, quinoxaline, tetrazole, thiadiazole, thiazole, thiophene, triazole, xanthene, and the like.

[37] "Heteroarylalkyl" by itself or as part of another substituent refers to an acyclic alkyl group in which one of the hydrogen atoms bonded to a carbon atom, typically a terminal or sp^3 carbon atom, is replaced with a heteroaryl group. In one embodiment, the alkyl moiety of the heteroarylalkyl is (C_1 - C_6) alkyl and the heteroaryl moiety is a 5-14-membered heteroaryl. In a more specific embodiment, the alkyl moiety is (C_1 - C_3) alkyl and the heteroaryl moiety is a 5-10 membered heteroaryl.

[38] "Halogen" or "Halo" by themselves or as part of another substituent refers to fluorine, chlorine, bromine and iodine, or fluoro, chloro, bromo and iodo.

[39] As used herein, the term "terminal carbon" in a straight chain alkyl substituted with deuterium refers to the carbon at the end of the chain. For example, in the chain $-CD_2-CD_2-CD_2-CH_3$, the carbon of the $-CH_3$ group is the terminal carbon. As another example, in the $^1CH_2-CH_2-CH_2-CD_3$, the carbon of the $-CD_3$ group is the terminal carbon.

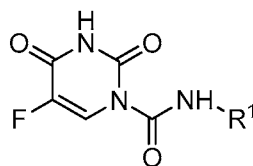
[40] As used herein, the term "internal carbon" in a straight chain alkyl substituted with deuterium refers to any carbon other than the carbon at the end of the chain. For example, in the chain $-CD_2-CD_2-CD_2-CH_3$, any carbon other than the carbon of the $-CH_3$ group is an internal carbon. As another example, in the chain $^1CH_2-CH_2-CH_2-CD_3$, any carbon other than the carbon of the $-CD_3$ group is an internal carbon.

[41] Throughout this specification, a variable may be referred to generally (e.g., "each R") or may be referred to specifically (e.g., R^1 , R^2 , R^3 , etc.). Unless otherwise indicated, when a variable is referred to generally, it is meant to include all specific embodiments of that particular variable.

Therapeutic Compounds

[42] The present invention provides a compound of Formula I:

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(I),

or a pharmaceutically acceptable salt thereof, wherein:

R¹ is a C₁-C₆ straight chain alkyl substituted with deuterium or a (C₁-C₅ straight chain alkylene)-COOR² wherein the straight chain alkylene is substituted with deuterium; and,

R² is selected from hydrogen, (C₁-C₆) alkyl, (C₅-C₁₄) aryl, (C₆-C₁₆) arylalkyl, 5-14 membered heteroaryl and 6-16 membered heteroarylalkyl, wherein when R² is other than hydrogen, R² is optionally substituted with one or more substituents independently selected from R^a, =O, -OR^a, halo-substituted -OR^a, =S, -SR^a, =NR^a, -NONR^a, -NR^cR^c, halogen, -CF₃, -CN, -NC, -OCN, -SCN, -NO, -NO₂, =N₂, -N₃, -S(O)R^a, -S(O)₂R^a, -S(O)₂OR^a, -S(O)₂NR^cR^c, -OS(O)R^a, -OS(O)₂R^a, -OS(O)₂OR^a, -OS(O)₂NR^cR^c, -C(O)R^a, -C(O)OR^a, -C(O)NR^cR^c, -C(NH)NR^cR^c, -OC(O)R^a, -OC(O)OR^a, -OC(O)NR^cR^c, -OC(NH)NR^cR^c, -NHC(O)R^a, -NHC(O)OR^a, -NHC(O)NR^cR^c and -NHC(NH)NR^cR^c, wherein

each R^a is independently selected from hydrogen, deuterium and (C₁-C₄) alkyl optionally substituted with deuterium; and

each R^c is independently an R^a or, alternatively, two R^c taken together with the nitrogen atom to which they are bound to form a 5 or 6 membered ring.

[43] In one embodiment, R¹ is a C₁-C₆ straight chain alkyl substituted with deuterium or a (C₁-C₅ straight chain alkylene)-COOR² wherein the straight chain alkylene is substituted with deuterium; and R² is selected from hydrogen, (C₁-C₆) alkyl, (C₅-C₁₄) aryl, (C₆-C₁₆) arylalkyl, 5-14 membered heteroaryl and 6-16 membered heteroarylalkyl, wherein when R² is other than hydrogen, R² is optionally substituted with deuterium.

[44] In one embodiment, R¹ is a C₁-C₆ straight chain alkyl wherein each internal carbon of R¹ has zero or two deuterium and the terminal carbon of R¹ has zero or three deuterium.

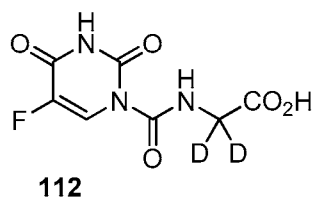
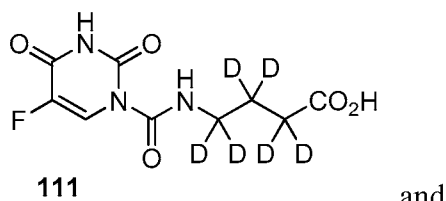
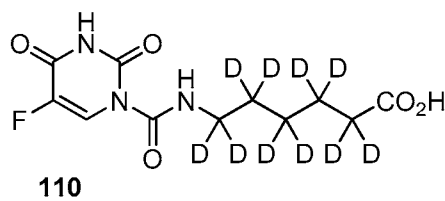
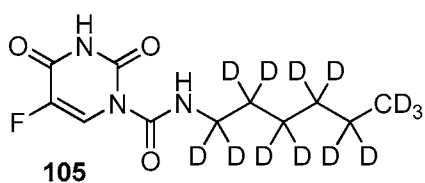
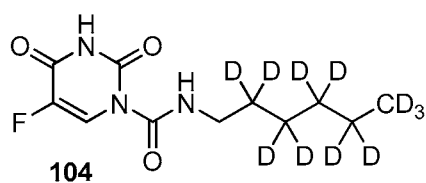
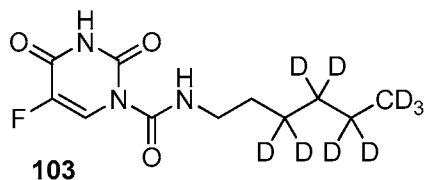
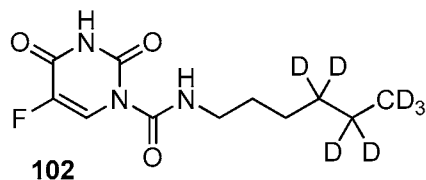
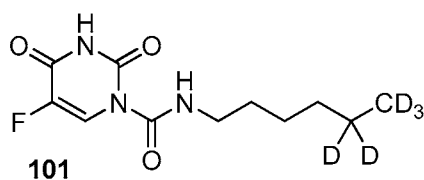
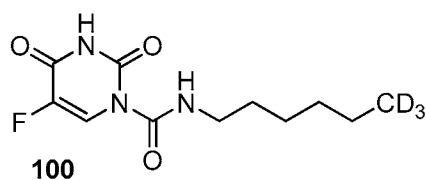
[45] In one embodiment, the terminal carbon of R¹ has three deuterium.

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[46] In one aspect of this embodiment, R^1 is selected from $-(CH_2)_5-CD_3$, $-(CH_2)_4-CD_2-CD_3$, $-(CH_2)_3-(CD_2)_2-CD_3$, $-(CH_2)_2-(CD_2)_3-CD_3$, $-CH_2-(CD_2)_4-CD_3$, and $-(CD_2)_5-CD_3$

[47] In one embodiment, R^1 is $(C_1-C_5 \text{ straight chain alkylene})-COOR^2$, and each carbon atom of the R^1 alkylene is independently substituted with 0 or 2 deuterium. In one aspect of this embodiment, R^2 is hydrogen. In another aspect of this embodiment, R^1 alkylene is selected from methylene, propylene and pentylene. In a more particular aspect, R^1 alkylene is selected from methylene, propylene and pentylene and R^2 is hydrogen. In still another aspect of this embodiment, R^1 alkylene is selected from $-CD_2-\ddagger$, $-(CD_2)_3-\ddagger$, and $-(CD_2)_5-\ddagger$ wherein “ $\ddagger$ ” represents the point of attachment of R^1 to $COOR^2$.

[48] Examples of a compound of Formula I include the following:



, or pharmaceutically acceptable salts thereof.

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[49] In another set of embodiments, any atom not designated as deuterium in any of the embodiments set forth above is present at its natural isotopic abundance.

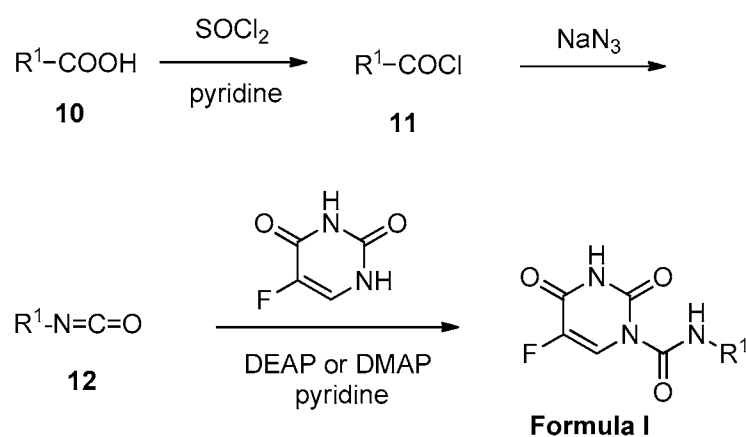
[50] The synthesis of compounds of Formula I may be readily achieved by synthetic chemists of ordinary skill by reference to the Exemplary Synthesis and Examples disclosed herein. Relevant procedures analogous to those of use for the preparation of compounds of Formula I and intermediates thereof are disclosed, for instance in Wang, Y. et al., *Jingxi Yu Zhuanyong Huaxuepin*, 2005, 13(10): 11-13; Wei, R. et al., *Zhongguo Yaowu Huaxue Zazhi*, 2001, 11(1): 49-50; US Patent No. 4,071,519; and Ozaki, S. et al., *Chem. Pharm. Bull.*, 1986, 34(2): 893-896 .

[51] Such methods can be carried out utilizing corresponding deuterated and optionally, other isotope-containing reagents and/or intermediates to synthesize the compounds delineated herein, or invoking standard synthetic protocols known in the art for introducing isotopic atoms to a chemical structure.

Exemplary Synthesis

[52] A convenient method for synthesizing compounds of Formula I is depicted in Scheme 1.

[53] Scheme 1. General Route to Compounds of Formula I.



[54] Scheme 1 depicts a general route to preparing compounds of Formula I. In a manner analogous to that described by Wang, Y. et al., *Jingxi Yu Zhuanyong Huaxuepin*, 2005, 13(10): 11-13, and by Wei, R. et al., *Zhongguo Yaowu Huaxue Zazhi*, 2001, 11(1): 49-50, carboxylic acid **10** is treated with thionyl chloride to afford acyl chloride **11**. Treatment with sodium azide generates isocyanate **12**.

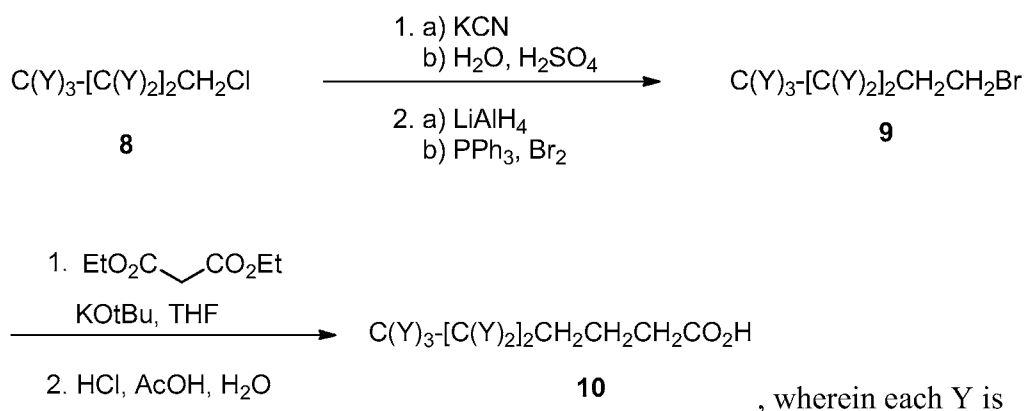
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Reaction of **12** with 5-fluorouracil in the presence of 4-(dimethylamino)pyridine (DMAP) or of 4-(diethylamino)pyridine (DEAP) provides compounds of Formula I. This last step may also be conducted in a manner analogous to the one described in US Patent No. 4,071,519, example 5.

- 5 **[55]** Examples of acids **10** include commercially available 7,7,7-d₃-heptanoic acid (**10a**) and heptanoic-d₁₃ acid (**10b**). The use of **10a** and **10b** in Scheme 1 ultimately provides compounds of Formula I wherein -R¹ is -(CH₂)₅CD₃ (compound **100**) and -R¹ is -(CD₂)₅CD₃ (compound **105**), respectively. Other deuterated acids **10** may be obtained as shown in Schemes 2 and 3 below.

10

[56] Scheme 2. Preparation of Intermediates 10.



- 15 independently hydrogen or deuterium, provided that at least one Y is deuterium.

- [57]** Commercially available examples of deuterated alkyl chlorides **8** include CD₃CD₂(CH₂)₂Cl and CD₃(CD₂)₂CH₂Cl. A commercially available example of alkyl bromide **9** is CD₃(CD₂)₃CH₂Br. Treatment of **8** with KCN and subsequent hydrolysis with aqueous H₂SO₄, followed by LiAlH₄ reduction and subsequent treatment of the alcohol with triphenylphosphine and Br₂ yield the appropriately deuterated intermediates **9** in a manner analogous to that described by Vitale, A. et al., J. Organometallic Chem., 1985, 286(1): 91-101. Reaction of alkyl bromide **9** with diethyl malonate in the presence of potassium tert-butoxide followed by treatment with HCl and AcOH in H₂O in a manner analogous to that described by Owen, C.P.; et al. Journal of Steroid Biochemistry and Molecular Biology (2008), 111(1-2), 117-127, affords acids CD₃CD₂(CH₂)₄CO₂H (**10c**), CD₃(CD₂)₂(CH₂)₃CO₂H (**10d**), and CD₃(CD₂)₃(CH₂)₂CO₂H (**10e**). Alternatively, bromide **9** is reacted with diethyl malonate in the presence of sodium hydride followed by treatment with aqueous HCl

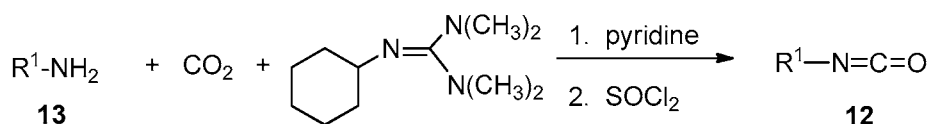
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in a manner analogous to that described by Darley, D.J.; et al. *Organic & Biomolecular Chemistry* (2009), 7(3), 543-552 to afford acids **10c**, **10d** and **10e**.

The use of **10c**, **10d** and **10e** in Scheme 1 ultimately provides compounds of Formula I wherein $-R^1$ is $-(CH_2)_4CD_2CD_3$ (compound **101**), $-R^1$ is $-(CH_2)_3(CD_2)_2CD_3$

5 (compound **102**) and $-R^1$ is $-(CH_2)_2(CD_2)_3CD_3$ (compound **103**) respectively.

[58] Scheme 3. Alternate Pathway to Intermediates 12.



10 [59] Alternatively, an appropriately deuterated isocyanate **12** may be prepared from an appropriately deuterated amine **13** as shown in Scheme 3 above in a manner analogous to that described by Dean, D. et al., *Tetrahedron Letters*, 1997, 38(6): 919-922. Addition of CO_2 to an appropriately deuterated amine **13** in the presence of N-cyclohexyl-N',N',N'',N''-tetramethyl guanidine (CyTMG) and pyridine, followed by

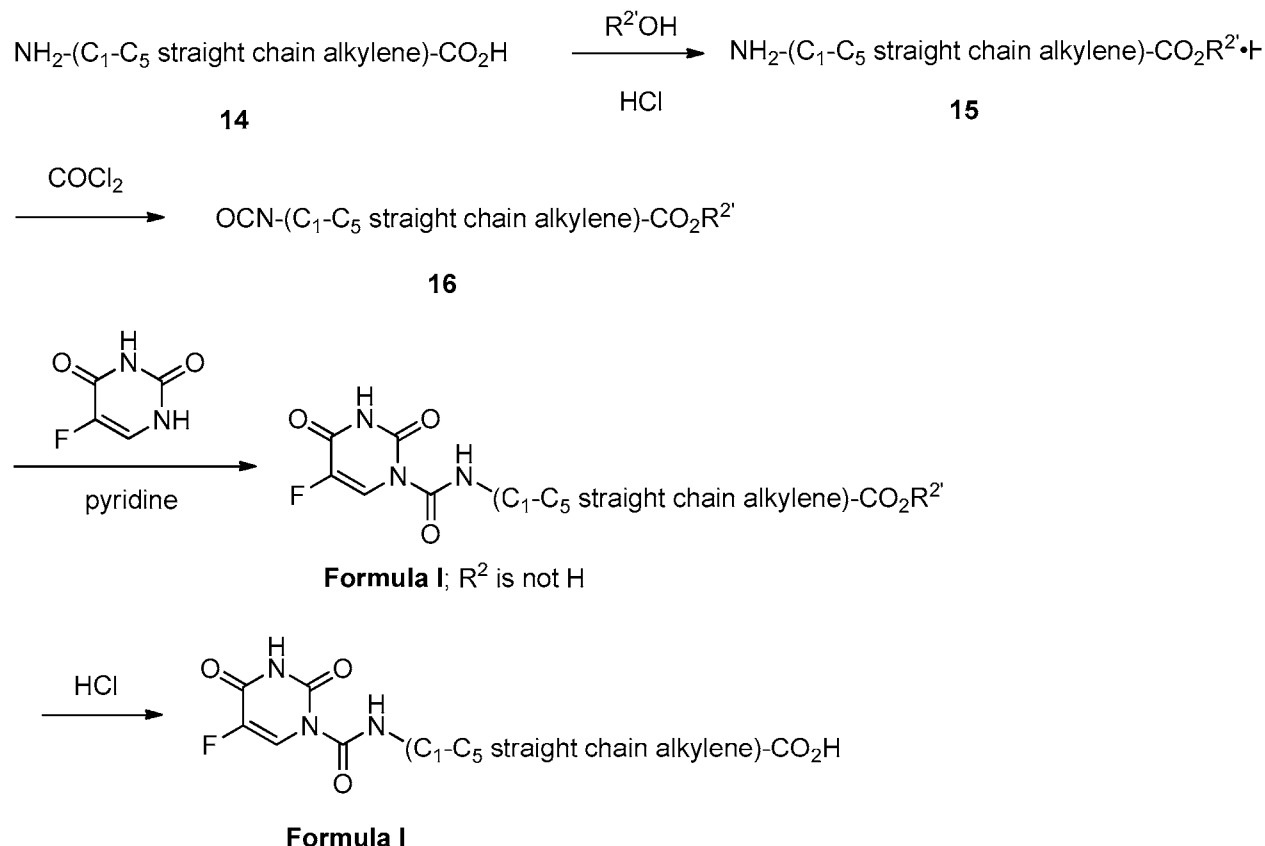
15 treatment with thionyl chloride as dehydrating agent, affords **12**.

[60] One example of a deuterated amine **13** includes commercially available hexylamine- d_{13} (**13a**). Other deuterated amines may be prepared by methods known in the art from their corresponding alcohols. Commercially available examples of such alcohols include $CD_3(CD_2)_4CH_2OH$ and $CD_3CD_2(CH_2)_4OH$ which may be

20 converted to $CD_3(CD_2)_4CH_2NH_2$ (**13b**) and $CD_3CD_2(CH_2)_4NH_2$ (**13c**) respectively. Conversion of **13a**, **13b** and **13c** to their corresponding isocyanates **12** for use in Scheme I ultimately provides compounds of Formula I wherein $-R^1$ is $-(CD_2)_5CD_3$ (compound **105**), $-R^1$ is $-CH_2(CD_2)_4CD_3$ (compound **104**), and $-R^1$ is $-(CH_2)_4CD_2CD_3$ (compound **101**), respectively.

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[61] Scheme 4. Preparation of Compounds of Formula I where R¹ is -(C₁-C₅ straight chain alkylene)-COOR².



- 5 **[62]** Compounds of Formula I where R¹ is -(C₁-C₅ straight chain alkylene)-COOR² may be prepared as depicted in Scheme 4 in a manner analogous to that described by Ozaki, S. et al., Chem. Pharm. Bull., 1986, 34(2): 893-896. Conversion of the appropriately deuterated aminoalkyl carboxylic acid **14** to the corresponding ester **15** (R² in Scheme 4 represents any R² other than hydrogen) in the presence of ethanol and HCl is followed by reaction with phosgene to afford the isocyanate carboxylic acid **16**. Reaction of intermediate **16** with 5-fluorouracil (5-FU) in the presence of a base such as pyridine yields a compound of Formula I, wherein R¹ is -(C₁-C₅ straight chain alkylene)-COOR² and R² is other than hydrogen, which upon hydrolysis with aqueous HCl affords the corresponding compound of Formula I wherein R¹ is -(C₁-C₅ straight chain alkylene)-COOH.
- 10
- 15

[63] Examples of aminoalkyl carboxylic acids **14** include commercially available NH₂CD₂CO₂H (**14a**), NH₂CD₂(CH₂)₂CO₂H (**14b**), NH₂(CH₂)₂CD₂CO₂H (**14c**) and NH₂(CD₂)₃CO₂H (**14d**). Other examples of **14**, where C₁-C₅ straight chain alkylene is n-pentylene substituted with deuterium, may be prepared by known methods. For

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example $\text{NH}_2(\text{CD}_2)_5\text{CO}_2\text{H}$ (**14e**) may be prepared from commercially available cyclohexanone- d_{10} as described by Anastasiadis, A. et al., Australian Journal of Chemistry, 2001, 54(12): 747-750. Additionally, $\text{NH}_2(\text{CH}_2)_4\text{CD}_2\text{CO}_2\text{H}$ (**14f**) and $\text{NH}_2\text{CD}_2(\text{CH}_2)_4\text{CO}_2\text{H}$ (**14g**) may be prepared as described by Heidemann, G. et al.,
5 Faserforschung und Textiltechnik, 1967, 18(4): 183-189.

[64] The specific approaches and compounds shown above are not intended to be limiting. The chemical structures in the schemes herein depict variables that are hereby defined commensurately with chemical group definitions (moieties, atoms, etc.) of the corresponding position in the compound formulae herein, whether
10 identified by the same variable name (i.e., R^1 , R^2 , R^3 , etc.) or not. The suitability of a chemical group in a compound structure for use in the synthesis of another compound is within the knowledge of one of ordinary skill in the art.

[65] Additional methods of synthesizing compounds of Formula I and their synthetic precursors, including those within routes not explicitly shown in schemes
15 herein, are within the means of chemists of ordinary skill in the art. Synthetic chemistry transformations and protecting group methodologies (protection and deprotection) useful in synthesizing the applicable compounds are known in the art and include, for example, those described in Larock R, *Comprehensive Organic Transformations*, VCH Publishers (1989); Greene, TW et al., *Protective Groups in Organic Synthesis*, 3rd Ed., John Wiley and Sons (1999); Fieser, L et al., *Fieser and Fieser's Reagents for Organic Synthesis*, John Wiley and Sons (1994); and Paquette, L, ed., *Encyclopedia of Reagents for Organic Synthesis*, John Wiley and Sons (1995) and subsequent editions thereof.
20

[66] Combinations of substituents and variables envisioned by this invention are
25 only those that result in the formation of stable compounds.

Compositions

[67] The invention also provides pyrogen-free pharmaceutical compositions comprising an effective amount of a compound of Formula I (e.g., including any of
30 the formulae herein), or a pharmaceutically acceptable salt of said compound; and a pharmaceutically acceptable carrier. The carrier(s) are "acceptable" in the sense of being compatible with the other ingredients of the formulation and, in the case of a

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pharmaceutically acceptable carrier, not deleterious to the recipient thereof in an amount used in the medicament.

[68] Pharmaceutically acceptable carriers, adjuvants and vehicles that may be used in the pharmaceutical compositions of this invention include, but are not limited to, ion exchangers, alumina, aluminum stearate, lecithin, serum proteins, such as human serum albumin, buffer substances such as phosphates, glycine, sorbic acid, potassium sorbate, partial glyceride mixtures of saturated vegetable fatty acids, water, salts or electrolytes, such as protamine sulfate, disodium hydrogen phosphate, potassium hydrogen phosphate, sodium chloride, zinc salts, colloidal silica, magnesium trisilicate, polyvinyl pyrrolidone, cellulose-based substances, polyethylene glycol, sodium carboxymethylcellulose, polyacrylates, waxes, polyethylene-polyoxypropylene-block polymers, polyethylene glycol and wool fat.

[69] If required, the solubility and bioavailability of the compounds of the present invention in pharmaceutical compositions may be enhanced by methods well-known in the art. One method includes the use of lipid excipients in the formulation. See “Oral Lipid-Based Formulations: Enhancing the Bioavailability of Poorly Water-Soluble Drugs (Drugs and the Pharmaceutical Sciences),” David J. Hauss, ed. Informa Healthcare, 2007; and “Role of Lipid Excipients in Modifying Oral and Parenteral Drug Delivery: Basic Principles and Biological Examples,” Kishor M. Wasan, ed. Wiley-Interscience, 2006.

[70] Another known method of enhancing bioavailability is the use of an amorphous form of a compound of this invention optionally formulated with a poloxamer, such as LUTROLTM and PLURONICTM (BASF Corporation), or block copolymers of ethylene oxide and propylene oxide. See United States patent 7,014,866; and United States patent publications 20060094744 and 20060079502.

[71] The pharmaceutical compositions of the invention include those suitable for oral, rectal, nasal, topical (including buccal and sublingual), vaginal or parenteral (including subcutaneous, intramuscular, intravenous and intradermal) administration. In certain embodiments, the compound of the invention is administered transdermally (e.g., using a transdermal patch or iontophoretic techniques). Other formulations may conveniently be presented in unit dosage form, e.g., tablets, sustained release capsules, and in liposomes, and may be prepared by any methods well known in the

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art of pharmacy. See, for example, Remington: The Science and Practice of Pharmacy, Lippincott Williams & Wilkins, Baltimore, MD (20th ed. 2000).

[72] Such preparative methods include the step of bringing into association with the molecule to be administered ingredients such as the carrier that constitutes one or more accessory ingredients. In general, the compositions are prepared by uniformly and intimately bringing into association the active ingredients with liquid carriers, liposomes or finely divided solid carriers, or both, and then, if necessary, shaping the product.

[73] In certain embodiments, the compound is administered orally. Compositions of the present invention suitable for oral administration may be presented as discrete units such as capsules, sachets, or tablets each containing a predetermined amount of the active ingredient; a powder or granules; a solution or a suspension in an aqueous liquid or a non-aqueous liquid; an oil-in-water liquid emulsion; a water-in-oil liquid emulsion; packed in liposomes; or as a bolus, etc. Soft gelatin capsules can be useful for containing such suspensions, which may beneficially increase the rate of compound absorption.

[74] In the case of tablets for oral use, carriers that are commonly used include lactose and corn starch. Lubricating agents, such as magnesium stearate, are also typically added. For oral administration in a capsule form, useful diluents include lactose and dried cornstarch. When aqueous suspensions are administered orally, the active ingredient is combined with emulsifying and suspending agents. If desired, certain sweetening and/or flavoring and/or coloring agents may be added.

[75] Compositions suitable for oral administration include lozenges comprising the ingredients in a flavored basis, usually sucrose and acacia or tragacanth; and pastilles comprising the active ingredient in an inert basis such as gelatin and glycerin, or sucrose and acacia.

[76] Compositions suitable for parenteral administration include aqueous and non-aqueous sterile injection solutions which may contain anti-oxidants, buffers, bacteriostats and solutes which render the formulation isotonic with the blood of the intended recipient; and aqueous and non-aqueous sterile suspensions which may include suspending agents and thickening agents. The formulations may be presented in unit-dose or multi-dose containers, for example, sealed ampules and vials, and may be stored in a freeze dried (lyophilized) condition requiring only the addition of the

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sterile liquid carrier, for example water for injections, immediately prior to use. Extemporaneous injection solutions and suspensions may be prepared from sterile powders, granules and tablets.

[77] Such injection solutions may be in the form, for example, of a sterile injectable aqueous or oleaginous suspension. This suspension may be formulated according to techniques known in the art using suitable dispersing or wetting agents (such as, for example, Tween 80) and suspending agents. The sterile injectable preparation may also be a sterile injectable solution or suspension in a non-toxic parenterally-acceptable diluent or solvent, for example, as a solution in 1,3-butanediol. Among the acceptable vehicles and solvents that may be employed are mannitol, water, Ringer's solution and isotonic sodium chloride solution. In addition, sterile, fixed oils are conventionally employed as a solvent or suspending medium. For this purpose, any bland fixed oil may be employed including synthetic mono- or diglycerides. Fatty acids, such as oleic acid and its glyceride derivatives are useful in the preparation of injectables, as are natural pharmaceutically-acceptable oils, such as olive oil or castor oil, especially in their polyoxyethylated versions. These oil solutions or suspensions may also contain a long-chain alcohol diluent or dispersant.

[78] The pharmaceutical compositions of this invention may be administered in the form of suppositories for rectal administration. These compositions can be prepared by mixing a compound of this invention with a suitable non-irritating excipient which is solid at room temperature but liquid at the rectal temperature and therefore will melt in the rectum to release the active components. Such materials include, but are not limited to, cocoa butter, beeswax and polyethylene glycols.

[79] The pharmaceutical compositions of this invention may be administered by nasal aerosol or inhalation. Such compositions are prepared according to techniques well-known in the art of pharmaceutical formulation and may be prepared as solutions in saline, employing benzyl alcohol or other suitable preservatives, absorption promoters to enhance bioavailability, fluorocarbons, and/or other solubilizing or dispersing agents known in the art. See, e.g.: Rabinowitz JD and Zaffaroni AC, US Patent 6,803,031, assigned to Alexza Molecular Delivery Corporation.

[80] Topical administration of the pharmaceutical compositions of this invention is especially useful when the desired treatment involves areas or organs readily accessible by topical application. For topical application topically to the skin, the

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pharmaceutical composition should be formulated with a suitable ointment containing the active components suspended or dissolved in a carrier. Carriers for topical administration of the compounds of this invention include, but are not limited to, mineral oil, liquid petroleum, white petroleum, propylene glycol, polyoxyethylene polyoxypropylene compound, emulsifying wax, and water. Alternatively, the pharmaceutical composition can be formulated with a suitable lotion or cream containing the active compound suspended or dissolved in a carrier. Suitable carriers include, but are not limited to, mineral oil, sorbitan monostearate, polysorbate 60, cetyl esters wax, cetaryl alcohol, 2-octyldodecanol, benzyl alcohol, and water. The pharmaceutical compositions of this invention may also be topically applied to the lower intestinal tract by rectal suppository formulation or in a suitable enema formulation. Topically-transdermal patches and iontophoretic administration are also included in this invention.

[81] Application of the subject therapeutics may be local, so as to be administered at the site of interest. Various techniques can be used for providing the subject compositions at the site of interest, such as injection, use of catheters, trocars, projectiles, pluronic gel, stents, sustained drug release polymers or other device which provides for internal access.

[82] Thus, according to yet another embodiment, the compounds of this invention may be incorporated into compositions for coating an implantable medical device, such as prostheses, artificial valves, vascular grafts, stents, or catheters. Suitable coatings and the general preparation of coated implantable devices are known in the art and are exemplified in US Patents 6,099,562; 5,886,026; and 5,304,121. The coatings are typically biocompatible polymeric materials such as a hydrogel polymer, polymethylsiloxane, polycaprolactone, polyethylene glycol, polylactic acid, ethylene vinyl acetate, and mixtures thereof. The coatings may optionally be further covered by a suitable topcoat of fluorosilicone, polysaccharides, polyethylene glycol, phospholipids or combinations thereof to impart controlled release characteristics in the composition. Coatings for invasive devices are to be included within the definition of pharmaceutically acceptable carrier, adjuvant or vehicle, as those terms are used herein.

[83] According to another embodiment, the invention provides a method of coating an implantable medical device comprising the step of contacting said device with the

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coating composition described above. It will be obvious to those skilled in the art that the coating of the device will occur prior to implantation into a mammal.

[84] According to another embodiment, the invention provides a method of impregnating an implantable drug release device comprising the step of contacting
5 said drug release device with a compound or composition of this invention.

Implantable drug release devices include, but are not limited to, biodegradable polymer capsules or bullets, non-degradable, diffusible polymer capsules and biodegradable polymer wafers.

[85] According to another embodiment, the invention provides an implantable
10 medical device coated with a compound or a composition comprising a compound of this invention, such that said compound is therapeutically active.

[86] According to another embodiment, the invention provides an implantable drug release device impregnated with or containing a compound or a composition comprising a compound of this invention, such that said compound is released from
15 said device and is therapeutically active.

[87] Where an organ or tissue is accessible because of removal from the subject, such organ or tissue may be bathed in a medium containing a composition of this invention, a composition of this invention may be painted onto the organ, or a composition of this invention may be applied in any other convenient way.

20 [88] In another embodiment, a composition of this invention further comprises a second therapeutic agent. The second therapeutic agent may be selected from any compound or therapeutic agent known to have or that demonstrates advantageous properties when administered with a compound having the same mechanism of action as carmofur.

25 [89] Preferably, the second therapeutic agent is an agent useful in the treatment or prevention of cancer, such as a chemotherapeutic agent, or an antimetabolite.

[90] In one embodiment, the second therapeutic agent is 5-fluorouracil or mitomycin C.

[91] In another embodiment, the invention provides separate dosage forms of a
30 compound of this invention and one or more of any of the above-described second therapeutic agents, wherein the compound and second therapeutic agent are associated with one another. The term "associated with one another" as used herein means that the separate dosage forms are packaged together or otherwise attached to one another

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such that it is readily apparent that the separate dosage forms are intended to be sold and administered together (within less than 24 hours of one another, consecutively or simultaneously).

5 [92] In the pharmaceutical compositions of the invention, the compound of the present invention is present in an effective amount. As used herein, the term “effective amount” refers to an amount which, when administered in a proper dosing regimen, is sufficient to treat the target disorder.

10 [93] The interrelationship of dosages for animals and humans (based on milligrams per meter squared of body surface) is described in Freireich et al., Cancer Chemother. Rep, 1966, 50: 219. Body surface area may be approximately determined from height and weight of the subject. See, e.g., Scientific Tables, Geigy Pharmaceuticals, Ardsley, N.Y., 1970, 537.

15 [94] In one embodiment, an effective amount of a compound of this invention can range from about 0.1 to 10 mg/kg body weight/day or from about 10 to 1000 mg/m²/day. In a more specific aspect, an effective amount of a compound of this invention can range from about 50 to 1000 mg/m²/day, more specifically from about 50 to 600 mg/m²/day.

20 [95] Effective doses will also vary, as recognized by those skilled in the art, depending on the diseases treated, the severity of the disease, the route of administration, the sex, age and general health condition of the subject, excipient usage, the possibility of co-usage with other therapeutic treatments such as use of other agents and the judgment of the treating physician. For example, guidance for selecting an effective dose can be determined by reference to the prescribing information for carmofur.

25 [96] For pharmaceutical compositions that comprise a second therapeutic agent, an effective amount of the second therapeutic agent is between about 20% and 100% of the dosage normally utilized in a monotherapy regime using just that agent. Preferably, an effective amount is between about 70% and 100% of the normal monotherapeutic dose. The normal monotherapeutic dosages of these second
30 therapeutic agents are well known in the art. See, e.g., Wells et al., eds., Pharmacotherapy Handbook, 2nd Edition, Appleton and Lange, Stamford, Conn. (2000); PDR Pharmacopoeia, Tarascon Pocket Pharmacopoeia 2000, Deluxe Edition,

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Tarascon Publishing, Loma Linda, Calif. (2000), each of which references are incorporated herein by reference in their entirety.

[97] It is expected that some of the second therapeutic agents referenced above will act synergistically with the compounds of this invention. When this occurs, it will allow the effective dosage of the second therapeutic agent and/or the compound of this invention to be reduced from that required in a monotherapy. This has the advantage of minimizing toxic side effects of either the second therapeutic agent of a compound of this invention, synergistic improvements in efficacy, improved ease of administration or use and/or reduced overall expense of compound preparation or formulation.

Methods of Treatment

[98] In another embodiment, the invention provides a method of inhibiting the activity of thymidylate synthase in a cell, comprising contacting a cell with one or more compounds of Formula I, or a pharmaceutically acceptable salt thereof.

[99] According to another embodiment, the invention provides a method of treating a cancer in a subject, comprising the step of administering to the subject an effective amount of a compound of Formula I, or a pharmaceutically acceptable salt thereof or a composition of this invention.

[100] In one particular embodiment, the method of this invention is used to treat breast cancer, hepatocellular carcinoma or colorectal cancer in a subject in need thereof.

[101] Other cancers which can be treated with the disclosed compounds include cancer of the stomach, gastroesophageal junction, ovaries, pancreas, urogenital tract and basal cell carcinoma.

[102] In another particular embodiment, the method of this invention is used to treat colorectal cancer in a subject in need thereof.

[103] Identifying a subject in need of such treatment can be in the judgment of a subject or a health care professional and can be subjective (e.g. opinion) or objective (e.g. measurable by a test or diagnostic method).

[104] In another embodiment, any of the above methods of treatment comprises the further step of co-administering to the subject in need thereof one or more second therapeutic agents. The choice of second therapeutic agent may be made from any

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second therapeutic agent known to be useful for co-administration with carmofur.

The choice of second therapeutic agent is also dependent upon the particular disease or condition to be treated. Examples of second therapeutic agents that may be employed in the methods of this invention are those set forth above for use in

5 combination compositions comprising a compound of this invention and a second therapeutic agent.

[105] In particular, the combination therapies of this invention include co-administering a compound of Formula I or a pharmaceutically acceptable salt thereof and a second therapeutic agent selected from mitomycin or fluorouracil to a subject in
10 need thereof for treatment of colon cancer or colorectal cancer.

[106] The term “co-administered” as used herein means that the second therapeutic agent may be administered together with a compound of this invention as part of a single dosage form (such as a composition of this invention comprising a compound of the invention and an second therapeutic agent as described above) or as separate,
15 multiple dosage forms. Alternatively, the additional agent may be administered prior to, consecutively with, or following the administration of a compound of this invention. In such combination therapy treatment, both the compounds of this invention and the second therapeutic agent(s) are administered by conventional methods. The administration of a composition of this invention, comprising both a
20 compound of the invention and a second therapeutic agent, to a subject does not preclude the separate administration of that same therapeutic agent, any other second therapeutic agent or any compound of this invention to said subject at another time during a course of treatment.

[107] Effective amounts of these second therapeutic agents are well known to those
25 skilled in the art and guidance for dosing may be found in patents and published patent applications referenced herein, as well as in Wells et al., eds., Pharmacotherapy Handbook, 2nd Edition, Appleton and Lange, Stamford, Conn. (2000); PDR Pharmacopoeia, Tarascon Pocket Pharmacopoeia 2000, Deluxe Edition, Tarascon Publishing, Loma Linda, Calif. (2000), and other medical texts. However, it is well
30 within the skilled artisan’s purview to determine the second therapeutic agent’s optimal effective-amount range.

[108] In one embodiment of the invention, where a second therapeutic agent is administered to a subject, the effective amount of the compound of this invention is

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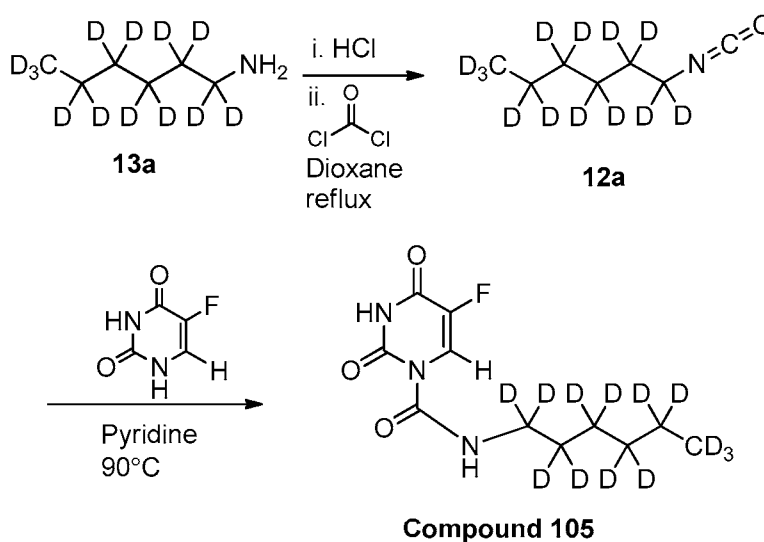
less than its effective amount would be where the second therapeutic agent is not administered. In another embodiment, the effective amount of the second therapeutic agent is less than its effective amount would be where the compound of this invention is not administered. In this way, undesired side effects associated with high doses of either agent may be minimized. Other potential advantages (including without limitation improved dosing regimens and/or reduced drug cost) will be apparent to those of skill in the art.

[109] In yet another aspect, the invention provides the use of a compound of Formula I or a pharmaceutically acceptable salt thereof alone or together with one or more of the above-described second therapeutic agents in the manufacture of a medicament, either as a single composition or as separate dosage forms, for treatment or prevention in a subject of a disease, disorder or symptom set forth above. Another aspect of the invention is a compound of Formula I or a pharmaceutically acceptable salt thereof for use in the treatment or prevention in a subject of a disease, disorder or symptom thereof delineated herein.

Examples

[110] Example 1. Synthesis of 5-Fluoro-2,4-dioxo-N-(hexyl-d₁₃)-3,4-dihydropyrimidine-1(2H)-carboxamide (Compound **105).**

[111] Scheme 5. Synthesis of Compound **105.**



[112] Step 1. 1,1,1,2,2,3,3,4,4,5,5,6,6-d₁₃-6-Isocyanatohexane (12a**).** A solution of 1,1,2,2,3,3,4,4,5,5,6,6,6-tridecadeuterohexan-1-amine (200 mg, 1.75 mmol, 98 atom % D CDN Isotopes) in 1,4-dioxane (3.5 mL, 0.5 M) was prepared in a 25 mL round bottom flask. A hydrochloric acid solution in 1,4-dioxane (0.952 mL) was added to

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this solution under an atmosphere of nitrogen. Immediate gas evolution was observed along with precipitation of a white solid. Next a 20% by weight solution of phosgene in toluene (0.483 mL) was added to the reaction. The resulting mixture was heated at reflux for three hours. The reaction was cooled, diluted with heptanes (10 mL), and poured in to a separatory funnel containing ice water. The phases were separated and the organic layer was dried over sodium sulfate. The suspension was filtered and the resulting solution of isocyanate **12a** was used without further manipulation in the next step.

[113] Step 2. 5-Fluoro-2,4-dioxo-N-(hexyl-d₁₃)-3,4-dihydropyrimidine-1(2H)-carboxamide (Compound **105**). Pyridine (0.708 mL) and 5-fluorouracil were added directly to the isocyanate solution prepared in Step 1. Precipitation of a white solid was observed immediately. The suspension was heated to 90 °C for twelve hours. The reaction was then cooled, concentrated to near dryness and re-dissolved in dichloromethane. The organic layer was washed with aqueous HCl (1 M), aqueous copper sulfate (saturated) and brine. The organic layer was then dried over sodium sulfate, filtered and concentrated to give Compound **105** as a white solid (48 mg, 0.178 mmol, 11% yield). MS [(M-H)]: 269.2.

[114] **Example 2. Evaluation of Metabolic Stability**

[115] *A. Microsomal Assay:* Human liver microsomes (20 mg/mL) are obtained from Xenotech, LLC (Lenexa, KS). β-nicotinamide adenine dinucleotide phosphate, reduced form (NADPH), magnesium chloride (MgCl₂), and dimethyl sulfoxide (DMSO) are purchased from Sigma-Aldrich.

[116] *Determination of Metabolic Stability:* 7.5 mM stock solutions of test compounds are prepared in DMSO. The 7.5 mM stock solutions are diluted to 12.5-50 μM in acetonitrile (ACN). The 20 mg/mL human liver microsomes are diluted to 0.625 mg/mL in 0.1 M potassium phosphate buffer, pH 7.4, containing 3 mM MgCl₂. The diluted microsomes are added to wells of a 96-well deep-well polypropylene plate in triplicate. A 10 μL aliquot of the 12.5-50 μM test compound is added to the microsomes and the mixture is pre-warmed for 10 minutes. Reactions are initiated by addition of pre-warmed NADPH solution. The final reaction volume is 0.5 mL and contains 0.5 mg/mL human liver microsomes, 0.25-1.0 μM test compound, and 2 mM NADPH in 0.1 M potassium phosphate buffer, pH 7.4, and 3 mM MgCl₂. The

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reaction mixtures are incubated at 37 °C, and 50 µL aliquots are removed at 0, 5, 10, 20, and 30 minutes and added to shallow-well 96-well plates which contain 50 µL of ice-cold ACN with internal standard to stop the reactions. The plates are stored at 4 °C for 20 minutes after which 100 µL of water is added to the wells of the plate

5 before centrifugation to pellet precipitated proteins. Supernatants are transferred to another 96-well plate and analyzed for amounts of parent remaining by LC-MS/MS using an Applied Bio-systems API 4000 mass spectrometer. The same procedure is followed for the non-deuterated counterpart of the compound of Formula I and the positive control, 7-ethoxycoumarin (1 µM). Testing is done in triplicate.

10 [117] **Data analysis:** The *in vitro* $t_{1/2}$ s for test compounds are calculated from the slopes of the linear regression of % parent remaining (ln) vs incubation time relationship.

$$\text{in vitro } t_{1/2} = 0.693/k$$

$$k = -[\text{slope of linear regression of \% parent remaining}(\ln) \text{ vs incubation time}]$$

15 [118] Data analysis is performed using Microsoft Excel Software.

[119] **B. *In vivo* determination of metabolic stability:**

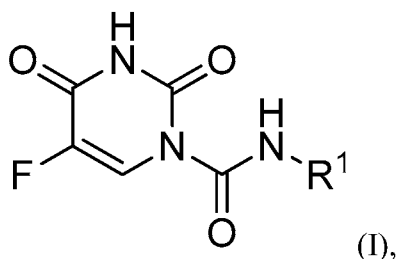
Male Sprague-Dawley rats are dosed intravenously or orally at 10 mg/kg, in an appropriate dosing vehicle, with carmofur or an exemplary compound of the invention (4 rats/compd/dose). Blood samples are drawn predose and at approximately 8 time-
20 points post-dose from each rat. Whole blood or plasma are analyzed by LC-MS/MS to determine the concentration of the dosed compound at each time point.

Pharmacokinetic parameters for carmofur and the exemplary compound of the invention are determined by non-compartmental analysis using the WinNonlin program.

25 [120] Without further description, it is believed that one of ordinary skill in the art can, using the preceding description and the illustrative examples, make and utilize the compounds of the present invention and practice the claimed methods. It should be understood that the foregoing discussion and examples merely present a detailed description of certain preferred embodiments. It will be apparent to those of ordinary
30 skill in the art that various modifications and equivalents can be made without departing from the spirit and scope of the invention.

We claim:

1. A compound of Formula I:



or a pharmaceutically acceptable salt thereof, wherein:

R^1 is a C_1 - C_6 straight chain alkyl substituted with deuterium or (C_1 - C_5 straight chain alkylene)- $COOR^2$ wherein the straight chain alkylene is substituted with deuterium; and

- R^2 is selected from hydrogen, (C_1 - C_6) alkyl, (C_5 - C_{14}) aryl, (C_6 - C_{16}) arylalkyl, 5-14 membered heteroaryl and 6-16 membered heteroarylalkyl, wherein when R^2 is other than hydrogen, R^2 is optionally substituted with deuterium.

2. The compound of claim 1, wherein R^1 is a C_1 - C_6 straight chain alkyl wherein each internal carbon of R^1 has zero or two deuterium and the terminal carbon of R^1 has zero or three deuterium.

3. The compound of claim 2, wherein the terminal carbon of R^1 has three deuterium.

4. The compound of claim 2 wherein R^1 is selected from $-(CH_2)_5-CD_3$, $-(CH_2)_4-CD_2-CD_3$, $-(CH_2)_3-(CD_2)_2-CD_3$, $-(CH_2)_2-(CD_2)_3-CD_3$, $-CH_2-(CD_2)_4-CD_3$, and $-(CD_2)_5-CD_3$.

5. The compound of claim 1, wherein R^1 is (C_1 - C_5 straight chain alkylene)- $COOR^2$ and each carbon atom in the R^1 alkylene is independently substituted with zero or two deuterium.

6. The compound of claim 5, wherein R^2 is hydrogen.

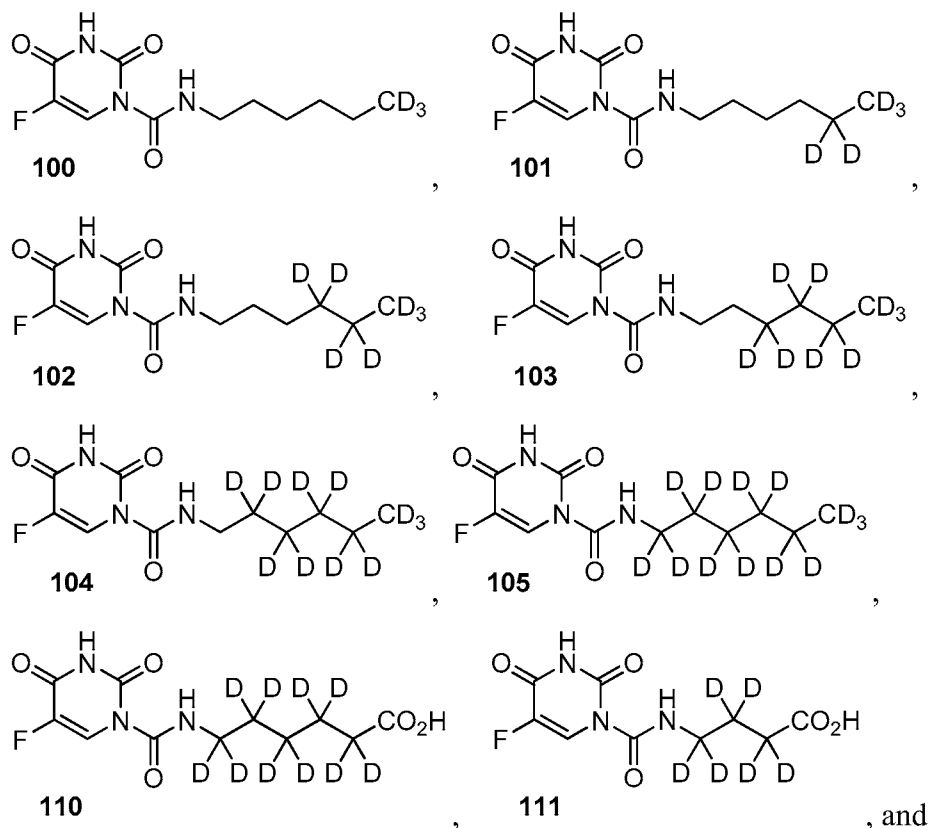
7. The compound of claim 5 or 6, wherein R^1 alkylene is selected from methylene, propylene and pentylene.

8. The compound of claim 7, wherein R^1 is selected from $-\text{CD}_2\text{COOR}^2$, $-(\text{CD}_2)_3\text{COOR}^2$, and $-(\text{CD}_2)_5\text{COOR}^2$.

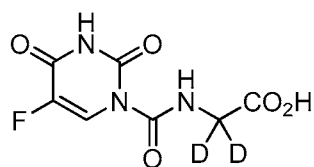
9. The compound of any one of claims 1-8, wherein any atom not designated as deuterium is present at its natural isotopic abundance.

10. The compound of claim 1, wherein the compound is selected from any one of the following:

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**112**

, wherein any atom not designated as deuterium in

compounds 100, 101, 102, 103, 104, 105, 110, 111, and 112 is present at its natural isotopic abundance;

or a pharmaceutically acceptable salt thereof.

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11. The compound of claim 10, wherein the compound is compound **105**, wherein any atom not designated as deuterium in compound **105** is present at its natural isotopic abundance; or a pharmaceutically acceptable salt thereof.

10 12. A pyrogen-free pharmaceutical composition comprising a compound of claim 1 or a pharmaceutically acceptable salt thereof and a pharmaceutically acceptable carrier.

13. The composition of claim 12, further comprising 5-fluorouracil or mitomycin
15 C.

14. A method of treating cancer in a subject in need thereof comprising the step of administering to the subject a composition of claim 12.

20 15. The method of claim 14, wherein the cancer is selected from breast cancer, colon cancer or colorectal cancer.

16. The method of claim 14 or 15, comprising the additional step of administering to the subject in need thereof a second therapeutic agent useful in the treatment of
25 cancer.

17. The method of claim 16, wherein the cancer is colon cancer or colorectal cancer and the second therapeutic agent is mitomycin C or fluorouracil.

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 11/26436

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - A01N 43/04 (2011.01)

USPC - 514/50

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC(8) - A01N 43/04 (2011.01)

USPC - 514/50

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
USPC - 514/256;536/285,285.2,285.4;544/316,336Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
PubWest (PGPB,USPT,USOC,EPAB,JPAB); Google. Search Terms Used:
deuterated fluorouracil, 1-carbamoyl-5-fluorouracil deuterated, carmofur, uracil, mitomycin, colorectal, colon, breast cancer**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 4,071,519 A (OZAKI et al.), 31 January 1978 (31.01.1978), col 2	1-17
Y	US 2009/0022706 A1 (GANT et al.), 22 January 2009 (22.01.2009), para [0006-0007]	1-17
Y	US 2007/0154972 A1 (SALAMONE et al.) 05 July 2007 (05.07.2007), para [0020-0059]	5-9, 14-17

☐ Further documents are listed in the continuation of Box C.


* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

18 April 2011 (18.04.2011)

Date of mailing of the international search report

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Name and mailing address of the ISA/US

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