Stilbene Analogs and Methods of Treating Cancer

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Recommended Citation
Watt, David; Liu, Chunming; Sviripa, Vitaliy M.; and Zhang, Wen, "Stilbene Analogs and Methods of Treating Cancer" (2015). Pharmaceutical Sciences Faculty Patents. 39.
https://uknowledge.uky.edu/ps_patents/39
(54) STILBENE ANALOGS AND METHODS OF TREATING CANCER

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(* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: 14/192,616
(22) Filed: Feb. 27, 2014

Prior Publication Data

Related U.S. Application Data
(62) Division of application No. 13/360,109, filed on Jan. 27, 2012, now Pat. No. 8,664,273.
(60) Provisional application No. 61/437,341, filed on Jan. 28, 2011, provisional application No. 61/439,118, filed on Feb. 3, 2011.

(51) Int. Cl.
A61K 31/03 (2006.01)
A61K 31/44 (2006.01)
C07C 211/48 (2006.01)
C07C 211/52 (2006.01)
C07C 291/04 (2006.01)
C07D 233/64 (2006.01)
C07D 295/073 (2006.01)
C07D 495/04 (2006.01)
G01N 33/574 (2006.01)
G01N 33/58 (2006.01)
C07C 39/21 (2006.01)
C07C 43/23 (2006.01)

(52) U.S. Cl.
CPC .................. A61K 31/03 (2013.01); A61K 31/44 (2013.01); C07C 39/21 (2013.01); C07C 43/23 (2013.01); C07C 211/48 (2013.01); C07C 211/52 (2013.01); C07C 291/04 (2013.01); C07D 233/64 (2013.01); C07D 295/073 (2013.01); C07D 495/04 (2013.01); G01N 33/574 (2013.01); G01N 33/58 (2013.01); G01N 2800/52 (2013.01)

(58) Field of Classification Search
CPC .... C07C 211/52; C07C 291/04; C07C 39/21; C07C 43/23; C07D 233/64; C07D 295/073; C07D 495/04; A61K 31/03; A61K 31/44
See application file for complete search history.

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ABSTRACT

Stilbene analogs and pharmaceutical compositions that are useful for the treatment of various cancers, including without limitation, colorectal cancer (CRC) and breast cancer are disclosed. The halogenated stilbene analogs include nitrogen heteroaryl groups and/or amino groups on the stilbene ring.

7 Claims, 18 Drawing Sheets


* cited by examiner
FIG. 3

FIG. 4
A

4a
4b
4c
4d
4e
4f
4g
4h
4i
4j
4k
4l

B

C

FIG. 5
FIG. 5 Continued
FIG 6. continued
FIG. 7
FIG. 8
FIG. 9
MAT2A  + - + - +
MAT2B  - + - + +
FIDAS-13 - - + + +

Binding

Input

FIG. 10
A. MAT 2A Activity Assay

B. SAM Levels in Colon Cancer Cells

C. SAH Levels in Colon Cancer Cells

FIG. 11
FIG. 13
4-Day Cellular Proliferation Assay: Cell Line 174

FIG. 14

Hep3B - 6 days Cell proliferation

FIG. 15
FIG. 16

Tumor Volume

- Vehicle
- 4dd

Tumor Volume (mm³)

Days

0 5 10 15 20
A

MCF7 Cells Proliferation

B

H460 Cell proliferation

FIG. 17
A549 Cell proliferation

- DMSO
- 4dd-10uM

Days

BON Cell proliferation

- DMSO
- 4r-10uM
- 4dd-10uM

Cell Growth (10^6/ml)

Days

FIG. 17 Continued
E

**PC3 Cell Proliferation**

- **DMSO**
- **4r-10uM**

![Graph showing cell proliferation over days](image)

FIG. 17 Continued

A

- **MAT2A**
- **MAT2A-K265L**
- **MAT2A-short**

B

- **Beads**
- **MAT2A**
- **MAT2A-short**

- **Binding**
- **Input**

Anti-MAT2A

C

- **MAT1A**
- **MAT2A**
- **MAT2A-K265L**

- **Binding**
- **Input**

Anti-His-Tag

FIG 18
1

STILBENE ANALOGS AND METHODS OF TREATING CANCER

CROSS-REFERENCE TO RELATED APPLICATION

This application is a Divisional of U.S. application Ser. No. 13/360,109, filed on Jan. 27, 2012, which claims the benefit of both U.S. Provisional Application No. 61/437,341 filed Jan. 28, 2011 and U.S. Provisional Application No. 61/439,118, filed Feb. 3, 2011, the entire disclosures of which are incorporated by reference herein.

SEQUENCE LISTING

The application contains a Sequence Listing which has been submitted in ASCII format via EFS-Web and is hereby incorporated by reference in its entirety. The Sequence Listing was previously submitted in parent application Ser. No. 13/360,109. Said ASCII copy, created on May 14, 2014, is named SequenceListing_050229_0626.txt, and it is 5,375 bytes in size.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH

This invention was made with government support under 2P20 RR020171 awarded by The National Institutes of Health. The government has certain rights in the invention.

TECHNICAL FIELD

The present disclosure is directed to compounds having antineoplastic activity. In particular, the disclosure is directed to halogenated stilbene analogs and methods of detecting the levels of MAT2A in a complex protein mixture.

BACKGROUND

Resveratrol (trans- or (E)-3,5,4’-trihydroxy stilbene (I)) (FIG. 1) is a phytoalexin produced in plants and popularized as a beneficial ingredient of red wine. Resveratrol, its cis- or (Z)-isomer (2), and another stilbene derivative, pterostilbene (3), exhibit some anti-cancer activity. (FIG. 1) Recently, we found that resveratrol and pterostilbene, a stilbene found in blueberries, inhibit colon cancer cells at least partially through inhibiting Wnt/β-catenin signaling. Zhang, W. et al., J Med Chem 2011, 54, 1288-97.

Wnt/β-catenin signaling plays an important role in development and tumorigenesis, and the deregulation of Wnt signaling results in formation of tumors. Over 90% of colorectal cancers contain a mutation in APC or β-catenin, and these mutations stabilize β-catenin and activate Wnt signaling. Cells containing these mutations constitutively activate Wnt signaling and undergo strong proliferation that ultimately leads to cancer. Intercepting and blocking the Wnt/β-catenin pathway at various points in the signaling cascade is an attractive target for colon cancer chemoprevention and therapeutics.

Several Wnt inhibitors have been identified that target the upstream signaling of β-catenin and promote β-catenin degradation. Although these agents inhibit Wnt signaling in normal cells and some APC-mutated colon cancer cells, they may not be effective in colon cancer cells containing β-catenin mutations. Several other Wnt inhibitors have also been reported. However, side effects limit their potential use in humans. Natural products found in foods are potentially ideal chemopreventive and therapeutic agents for cancer if they possess sufficient potency and minimal toxicity.

Therefore, there is an ongoing need for compounds that are more potent than resveratrol and pterostilbene and that can be used to treat cancer and other ailments. There is also a particular need for compounds that do not exhibit deleterious side effects.

SUMMARY OF THE DISCLOSURE

Advantages of the present disclosure include halogenated stilbene analogs and compositions having antineoplastic activity and methods of inhibiting cancer cell growth and/or treating cancer in a patient by administering one or more of the halogenated stilbene analogs or compositions.

One aspect of the present disclosure is directed to halogenated stilbene analogs that are useful for killing hyperproliferating cells such as cancer cells for the treatment of human malignant and benign cancers, including without limitation, colorectal cancer (CRC), liver and breast cancer. In this aspect of the disclosure, there are provided certain halogenated stilbene analogs having anti-neoplastic activity against cancerous cells. The halogenated stilbene analogs of the present disclosure include compounds according to formula (I):

$$X-Ar_1 - CR^1 - CR^2 - Ar_2$$

(II)

wherein R’ and R” are independently H, alkyl, halo, alkoxy, cyano; X represents at least one halogen, e.g., a fluorine, chlorine, bromine, or iodine substituent, on Ar1; each of Ar1 and Ar2 are aryl, e.g., phenyl, naphthyl, and heteroaryl, e.g., pyridyl, pyrididy1, piperidyl, pyrimidyl, indolyl, thieryl, which can be further substituted with halo, amino, alky- lamino, dialkylamino, aryalkylamino, N-oxides of dialkyl- lamino, trialkylammonium, mercapto, alkylthio, alkylamino, nitro, nitrosyl, cyano, alkox, alkenylox, ary1, heteroaryl, sulfanyl, sulfonylamide, CONR11R12, NR11CO(AR13), NR11CONR12AR13 where R11, R12, R13 are independently H, alkyl, heteroaryl or a fluorine; provided that Ar2 contains at least one nitrogen atom in the aryl ring or at least one nitrogen substituent on the aryl ring; e.g., an NR’R’’Z substituent where R’ is H, alkyl, alkox, ary1, heteroaryl, R’’ is an alkyl group, and R is an unshared pair of electrons, H, alkyl, oxygen; or a pharmaceutically acceptable salt thereof.

In another embodiment of the present disclosure, the halogenated stilbene analogs include compounds of formula (II):

$$\begin{align*}
\text{II)}
\end{align*}$$

or a pharmaceutically acceptable salt thereof, wherein each of R’ and R’’ are as defined above.
R₁ to R₁₀ are independently H, halo, amino, alkylamino, dialkylamino, N-oxides of dialkylamino, aryalkylamino, dialkylaminoamino, trialkylammonium, mercapto, alkylthio, alkane, nitro, nitroso, alkoxy, alkenyloxy, aryl, heteroaryl, sulfonyl, sulfonamide, CONR₁, NR₁₂, NR₁₃CO(R₁₄), NR₁₅COO(R₁₆), NR₁, CONR₁₁R₁₂, where R₁, R₁₁, R₁₂, R₁₃, are independently, H, alkyl, ary, heteroaryl or a fluorine; provided at least one of R₁ to R₅ is a halogen, e.g., a fluorine and/or chlorine; and at least one of R₆ to R₁₀ is a nitrogen containing substituent, e.g., an NR₁₂R₁₃Z substitution where R¹² is H, alkyl, alkoxy, ary, heteroaryl, R² is an alkyl group, Z is an unshared pair of electrons, H, alkyl, oxygen.

In another embodiment of the present disclosure, the halogenated stilbene analogs include compounds according to formula (III):

![Chemical Structure](image)

or a pharmaceutically acceptable salt thereof, where, R₂, R₃, R₆, R₉, R₁₀, R₁₁, R₁₂, R₁₃, R¹⁰, R², R° and NR'R²Z are the same as defined above.

The present disclosure also encompasses biotinylated derivatives of the halogenated stilbene analogs and metabolites of the halogenated stilbene analogs.

The present disclosure further encompasses pharmaceutical compositions of the halogenated stilbene analogs, e.g., one or more compounds of formula (I), formula (II) and/or formula (III) and/or one or more pharmaceutically acceptable salts of compounds according to formulas (I), (II) and/or (III), in combination with a pharmaceutical carrier. In one aspect of the present disclosure, the pharmaceutical compositions comprise an effective amount of at least one halogenated stilbene analog.

The present disclosure is further directed to methods of treating cancer, e.g., inhibiting cancer cell growth and/or inhibiting tumor growth in a mammal, such as a human, or treating diseases associated with hyperproliferating cells. In one embodiment of this aspect of the disclosure, a therapeutically effective amount of one or more halogenated stilbene analogs, pharmaceutical salts and/or compositions thereof is administered to a patient in need of treatment of cancer sufficient to treat/inhibit cancer cell growth in the patient.

In another embodiment of this aspect of the disclosure, a therapeutically effective amount of one or more halogenated stilbene analogs, pharmaceutical salts and/or compositions thereof sufficient to inhibit the cancer cell growth in a patient is administered to a patient suffering from colorectal cancer. In another embodiment, a therapeutically effective amount of one or more halogenated stilbene analogs, pharmaceutical salts and/or compositions thereof sufficient to inhibit or treat breast cancer.

In yet another embodiment, a therapeutically effective amount of one or more halogenated stilbene analogs, pharmaceutical salts and/or compositions thereof sufficient to inhibit the cancer cell growth in a patient is administered to a patient suffering from age-related cancer. Non-limiting examples of age-related cancers include prostate, breast, lung and colorectal cancers, which tend to occur more in older individuals, e.g., 65 years or older.

In another aspect of the present disclosure, there is provided a method for disrupting Wnt signaling and/or other pathways using inhibitors of the enzyme, methionine S-adenosyltransferase (MAT2A), in a cell by treating the cell with an effective amount of a halogenated stilbene analog. These analogs can inhibit methionine S-adenosyltransferase 2A (MAT2A) and reduce cellular S-adenosyl-methionine (SAM), which is a major donor of DNA methylation and protein methylation that regulate gene expression and tumor growth. SAM is also a key factor in metabolic pathways. Thus, the halogenated stilbene analogs described in the present disclosure are also drug candidates for treatment of metabolic diseases, such as diabetes.

The present disclosure further encompasses a pharmaceutical composition including one or more compounds of formula (I), formula (II) and/or formula (III) and/or one or more pharmaceutically acceptable salt, solvate, hydrate, prodrug or metabolite thereof, for treatment of a disorder associated with an increased MAT2A biological activity or levels. In a related embodiment, the disorder associated with an increased MAT2A biological activity or levels is cancer. In another embodiment, the cancer is colon cancer, breast cancer, lung cancer, prostate cancer or liver cancer.

The present disclosure is also directed to a method of treating a disorder associated with an increased methionine adenosyltransferase 2A (MAT2A) biological activity or levels in a subject including administering to the subject an effective amount of one or more compounds of formula (I)-(III) and/or one or more pharmaceutically acceptable salt, solvate, hydrate, prodrug or metabolite thereof. In another embodiment, the present disclosure is directed to a method of treating a disorder associated with an increased MAT2A biological activity or levels in a subject including administering to the subject an effective amount of a composition including one or more compounds of formula (I)-(II) and/or one or more pharmaceutically acceptable salt, solvate, hydrate, prodrug or metabolite thereof. In another embodiment, the modulation of MAT2A activity includes decreasing MAT2A biological activity or levels in a subject. In another related embodiment, the modulation of MAT2A activity includes decreasing SAM and/or S-adenosylhomocysteine (SAH) synthesis.

The present disclosure is also directed to a method of detecting the levels of MAT2A in a complex protein sample, said method includes contacting a detectably labeled compound of formula (I)-(III) to said complex protein mixture under conditions whereby said labeled compound binds to MAT2A present in the sample; isolating the bound MAT2A; removing any unbound proteins and detecting the level of the MAT2A bound to the detectably labeled compound in the sample. In a related embodiment, the isolation of the bound MAT2A is carried out by an affinity-based separation method. In another related embodiment, the compound of (I)-(III) is biotinylated. In another related embodiment, the detection is conducted by western blot, HPLC, FPLC, ion...
BRIEF DESCRIPTION OF THE DRAWINGS

Reference is made to the attached drawings, wherein elements having the same reference numeral designations represent similar elements throughout and wherein:

FIG. 1 shows the structures of naturally occurring stilbenes with antineoplastic activity. Structure 1 is trans-resveratrol, 2 is cis-resveratrol and 3 is pterostilbene.

FIG. 2 is a schematic drawing of the general synthesis of certain stilbene analogs and 1,2-diarylethenes. Legend: a, (1) n-BuLi, THF; (2) ArCHO; b, (1) NaH, DMF; (2) ArCHO; c, H₂, Pd—C, THF.

FIG. 3 shows the chemical structures of several potential metabolites of fluorinated and/or chlorinated stilbene analogs of the present disclosure.

FIG. 4 is a schematic drawing of the synthesis of biotin derivatives of the halogenated stilbene analogs. Legend: a, SnCl₂, HCl, HOAc; b, CNBr; c, biotinyl chloride, Et₃N, THF; d, biotin, HOBt, EDC, Et₃N, DMF; e, (1-biotinyl-iodoacetamidy1)-3,6-dioxaoctanediamine, K₂CO₃, EIOH.

FIG. 5(A) provides the chemical structures of various monofluorinated stilbenes of the present disclosure. FIG. 5(B) is a Western blot showing 4-aminostilbene (4c) represses Wnt target genes at 30 μM. FIG. 5(C) is a Western blot showing 4-styryl-N,N-dimethylaniline (4d) is more active than 4-methoxystilbene (4b) at 30 μM. FIG. 5(D) is a Western blot showing 4-(2-fluorostyryl)-N,N-dimethylaniline (4e) and 4-(3-fluorostyrlyl)-N,N-dimethylaniline (40) represses Wnt target genes at 10 μM. FIG. 5(E) is a Western blot showing the effect of the dimethylaminophenyl group within 4e. FIG. 5(F) is a graph showing the potency of (4e) in comparison to that of resveratrol and pterostilbene in inhibiting the proliferation of CRC cells.

FIG. 6(A) provides the chemical structures of several dihalogenated N,N-dialkylaminostilbene analogs 4 and a saturated analog 5 of the disclosure. FIG. 6(B) is a Western blot showing that dihalogenated N,N-dimethylaminostilbenes 4o, 4m and 4r repress Wnt target genes at 10 μM. FIG. 6(C) is a Western blot showing that the ortho- and meta-isomers of N,N-dimethylamino analogs (4p and 4q) are not as active as the para-isomer (4r). FIG. 6(D) is a Western blot showing that trihalogenated N,N-dimethylaminostilbene analogs (4v and 4w) are active Wnt inhibitors. FIG. 6(E) is a Western blot demonstrating that compound 4r represses Wnt target genes at 0.5 μM.

FIG. 7 demonstrates the effects of halogenated analogs of the present disclosure on CRC cell proliferation in vitro and in vivo. FIG. 7(A) is a graph showing inhibition of CRC cell proliferation at 0.1, 0.3 and 1 μM of various compounds of the disclosure. FIG. 7(B) shows representative nude mice treated with compound 4r or corn oil after injection with LS174 CRC cells (2x10⁶) subcutaneously into both flanks. FIG. 7(C) is a graph of the body weights of nude mice treated with compound 4r and corn oil. FIG. 7(D) is a graph of tumor volume in mice treated with compound 4r or corn oil. Statistical significance was calculated by the student’s t test (*p<0.05).

FIG. 8(A) is a bar graph showing fluorescence at 365 nM detected by Promega GloMax® Luminometer. FIG. 8(B) is a Western blot showing compound 4s is an active Wnt inhibitor.

FIG. 9 relates to affinity purification of stilbene analog target. FIG. 9(A) shows a biotinylated derivative 13 of a halogenated stilbene analog of the present disclosure.
9(B) shows silver staining of protein markers (1), elutions from Biotin-stilbene analog-beads (2), Streptavidin beads alone (3) and unrelated biotin-labeled beads (4).

FIG. 10 shows halogenated stilbene analogs of the present disclosure directly interacted with MAT2A, GST-MAT2A and GST-MAT2B fusion proteins were expressed and purified from *E. coli*. These proteins were incubated with streptavidin beads with or without biotinylated derivative 13. The binding proteins were eluted by 2.5 mM D-biotin and analyzed by Western blot with an anti-GST-Ab.

FIG. 11 shows that halogenated stilbenes are more potent than resveratrol in inhibiting the MAT2A activity in producing SAM and SAH. FIG. 11A shows the effects of 10 μM of compound 4r versus 30 μM of resveratrol on SAM levels in LS174 colon cancer cells. FIG. 11B shows the effects of 3 μM of compound 4dd and 10 μM of compound 4r versus 30 μM of resveratrol on SAM levels in colon cancer cells. FIG. 11C shows the effects of 3 μM of compound 4dd and 10 μM of compound 4r versus 30 μM of resveratrol on SAH levels in colon cancer cells.

FIG. 12 shows that MAT2A and MAT2B are essential for cancer cell proliferation and their inhibition at a transcription level represses cancer cell proliferation. Knocking down MAT2A gene (12A) and MAT2B gene (12B) with shRNAs are shown to inhibit proliferation of liver cancer cell line Hep3B (12C).

FIG. 13 shows a time-course study for the effects of the MAT2A and MAT2B genes inhibition on the proliferation of colon cancer cells. FIG. 13A shows inhibition of the HT29 cell proliferation by MAT2A and MAT2B shRNAs. FIG. 13B shows inhibition of the LS174T cell proliferation by MAT2A and MAT2B shRNAs.

FIG. 14 is a chart showing that the halogenated stilbene analogs of the present disclosure inhibit proliferation of colon cancer cells.

FIG. 15 is a chart illustrating that the halogenated stilbene analogs of the present disclosure inhibit proliferation of liver cancer cells.

FIG. 16 is a chart showing the effect of the halogenated stilbene 4dd toward inhibition of xenograft tumors in nude mice.

FIG. 17 shows the inhibitory effects of selected halogenated stilbene analogs on proliferation of breast cancer (17A), lung cancer (17B and 17C), carcinosarcoma tumor (17D) and prostate cancer (17E) cell lines.

FIG. 18A shows a mutant MAT2A (K265L) that was prepared to conduct binding studies for the halogenated stilbene analogs. FIG. 18B shows that a terminal deletion of MAT2A (MAT2A-short) does not affect the binding of the halogenated stilbene analogs to MAT2A. FIG. 18C shows that mutant MAT2A (MAT2A-K265L) partially loses its ability to bind to halogenated stilbene analogs.

**DETAILED DESCRIPTION OF THE DISCLOSURE**

The present disclosure relates to novel inhibitors of the enzyme methionine adenosyltransferase 2A (MAT2A) (GeneID: 4144; nucleotide NM_005911; amino acid ID: NP_005902). These compounds are useful for treating or preventing any disease and/or condition, wherein modulation of MAT2A levels, and/or its enzymatic products (i.e., S-adenosyl-methionine (SAM or AdoMet)), is effective in ameliorating symptoms or diseases. Inhibition of MAT2A can lead to decrease in SAM levels and a reduction in the methylation reactions or methylated products downstream of SAM. Thus, the disclosure provides compounds, compositions and methods for the treatment or prevention of disorders associated with MAT2A. Such diseases or disorders include, but not limited to, proliferative disorders such as cancer or metabolic disorders such as diabetes, heart disease, aging, obesity, and neurodegenerative disorders such as Alzheimer and Parkinson diseases. Definitions

The term “alkyl” is art-recognized, and includes saturated aliphatic groups, including straight-chain alkyl groups, branched-chain alkyl groups, cycloalkyl (cyclic) groups, alkyl substituted cycloalkyl groups, and cycloalkyl substituted alkyl groups. In certain embodiments, a straight chain or branched chain alkyl has about 30 or fewer carbon atoms in its backbone (e.g., C1-C30 for straight chain, C3-C60 for branched chain), and alternatively, about 20 or fewer. Likewise, cycloalkyls have from about 3 to about 10 carbon atoms in their ring structure, and alternatively about 5, for 7 carbons in the ring structure. The term “alkyl” as used herein also includes halosubstituted alkyls.

The term “alkenyl” is art-recognized and refers to an alkyl group substituted with an aryl group (e.g., an aromatic or heterocyclic group). The terms “alkynyl” and “alkynyl” are art-recognized and refer to 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.

Unless the number of carbons is otherwise specified, “lower alkyl” refers to an alkyl group, as defined above, but having from one to about ten carbons (C1-C10), e.g., from one to about six carbon atoms (C1-C6) in its backbone structure. Likewise, “lower alkenyl” (loweralkynyl, “lower amino”, “lower alkylnyl”, etc. have similar chain lengths.

The term “unit dose” or “dosage” refers to physically discrete units suitable for use in a subject, each unit containing a predetermined-quantity of the therapeutic composition calculated to produce the desired responses discussed above in association with its administration, i.e., the appropriate route and treatment regimen. The quantity to be administered, both according to number of treatments and unit dose, depends on the protection or effect desired.

The term “treat” and “treatment” refer to both therapeutic treatment and prophylactic or preventative measures, wherein the object is to prevent or slow down (lessen) an undesired pathological change or disorder, such as the development or spread of cancer. For purpose of this disclosure, beneficial or desired clinical results include, but are not limited to, alleviation of symptoms, diminishment of extent of disease, stabilized (i.e., not worsening) state of disease, delay or slowing of disease progression, amelioration or palliation of the disease state, and remission (whether partial or total), whether detectable or undetectable. For example, “treatment” can include a qualitative or quantitative reduction (e.g., by at least 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, 95%, or more) in the tumor or metastases size or reduce or prevent metastatic growth. “Treatment” can also mean prolonging survival as compared to expected survival if not receiving treatment.

Those in need of treatment include those already with the condition or disorder as well as those prone to have the condition or disorder or those in which the condition or disorder is to be prevented.

The phrase “therapeutically effective amount” means an amount of a compound of the present disclosure that (i) treats or prevents the particular disease, condition, or disorder, (ii) attenuates, ameliorates, or eliminates one or more symptoms of the particular disease, condition, or disorder, or (iii) prevents or delays the onset of one or more symptoms of the particular disease, condition, or disorder described herein. In
the case of cancer, the therapeutically effective amount of
the drug may be reduce the number of cancer cells; reduce
the tumor size; inhibit (i.e., slow to some extent and preferably
stop) cancer cell infiltration into peripheral organs; inhibit
(i.e., slow to some extent and preferably stop) tumor meta-
stasis; inhibit, to some extent, tumor growth; and/or relieve to
some extent one or more of the symptoms associated with
the cancer. To the extent the drug may prevent growth and/or kill
existing cancer cells, it may be cytostatic and/or cytotoxic.
For cancer therapy, efficacy can be measured, for example, by
assessing the time to disease progression (TTP) and/or deter-
mining the response rate (RR).

The terms “cancer” and “cancerous” refer to or describe the
physiological condition in mammals that is typically charac-
terized by unregulated cell growth. A “tumor” comprises one
or more cancerous cells. Examples of cancer include, but are
not limited to, carcinoma, lymphoma, blastoma, sarcoma,
and leukemia or lymphoid malignancies. More particular
examples of such cancers include squamous cell cancer (e.g.,
epithelial squamous cell cancer), lung cancer including small-cell lung cancer, non-small cell lung cancer (“NSCLC”), adenocarcinoma of the lung and squamous car-
icinoma of the lung, cancer of the peritoneum, hepatocellular
cancer, gastric or stomach cancer including gastrointestinal
cancer, pancreatic cancer, glioblastoma, cervical cancer, ova-
rion cancer, liver cancer, bladder cancer, hepatome, breast
cancer, colon cancer, rectal cancer, colorectal cancer,
endometrial or uterine carcinoma, salivary gland carcinoma,
kidney or renal cancer, prostate cancer, vulval cancer, thyroid
cancer, hepatic carcinoma, anal carcinoma, penile carcinoma,
as well as head and neck cancer.

The term “prodrug” as used in this application refers to a precurso-
or derivative form of a compound of the disclosure that may be less
cytotoxic to cells compared to the parent compound or drug and is capable of being enzymatically or hydrolytically activated or converted into the more active
parent form. The prodrugs of this disclosure include, but are
not limited to, phosphate-containing prodrugs, thiosulfate-
containing prodrugs, sulfate-containing prodrugs, pep-
tide-containing prodrugs, D-amino acid-modified prodrugs,
glycosylated prodrugs, ß-lactam-containing prodrugs,
optionally substituted phenoxycetamide-containing pro-
drugs, optionally substituted phencetamide-containing pro-
drugs, 5-fluorocytosine and other 5-fluorouridine pro-
drugs which can be converted into the more active cytotoxic
free drug.

A “metabolite” is a product produced through metabolism
in the body of a specified compound or salt thereof. Metabo-
lites of a compound may be identified using routine tech-
niques known in the art and their activities determined using
tests such as those described herein. Such products may result
for example from the oxidation, reduction, hydrolysis, ami-
dation, deamidation, esterification, deesterification, enzym-
ic cleavage, and the like, of the administered compound.

The term “complex protein sample” is used to distinguish
a sample from a purified protein sample. A complex protein
sample contains multiple proteins, and may additionally con-
tain other contaminants. Non-limiting examples of a complex
protein samples include tumor tissues, biopsy samples, serum
or cell extracts.

By “reference sample” is meant any sample, standard, or
level that is used for comparison purposes. A “normal refer-
ce sample” can be a prior sample taken from the same
subject, a sample from a subject not having cancer, a subject
that is diagnosed with cancer but not a metastatic disease, a
subject that has been treated for either cancer, metastatic
disease, or both, a subject that has a benign tumor, or a sample
of particular tissues from one or more healthy subjects, or a
pooled sample of tissues from one or more healthy subjects.

The phrase “biological activity of MAT2A” or “MAT2A
biological activity” as used herein, refers to all inherent bio-
logical properties of methionine adenosyltransferase 2A
(MAT2A) enzyme. Biological properties of MAT2A include
but are not limited to catalyzing the transfer of the adenosyl
group of ATP to the sulfur atom of methionine and producing
S-adenosyl-methionine (SAM or AdoMet); involving in an
abnormal cell growth and proliferation in cancer cells; facili-
tating intracellular methylation reactions through the action
of SAM as a methyl group donor.

The term “labeled” or “detectably labeled” as used herein
means joining, either covalently or non-covalently to the
compounds of the present disclosure, a substance which elicits
a physical or chemical response that can be observed or
detected by a binding partner such as biotin/streptavidin,
antigen/antibody or by means of instrumentation such as,
without limitation, UV/Vis spectrophotometers, flow cytome-
ters, fluorescence detection instruments and the like, by the
naked eye. A wide variety of labels and labeling techniques
are well known in the art. Suitable labels include biotin,
radiomulcides, e.g., 32P, 35S, 3H, enzymes, substrates, cofac-
tors, inhibitors, fluorescent moieties, chemiluminescent moi-
eties, magnetic particles, and the like.

The phrase “binds to” when referring to the binding of the
labeled compounds of the present disclosure to MAT2A for
detection purposes, refers to a binding reaction which is
determinative of the presence of the MAT2A in the presence
of a heterogeneous population of proteins and other biologies.
Thus, under binding assay conditions, for example, a labeled
compound of the present disclosure binds to MAT2A and
does not bind in a significant amount to other proteins present
in the sample. A variety of conventional detection means can
be used for detecting the binding of the labeled compounds to
MAT2A, such as western blot, flow cytometry and FACS
analysis, immunohistochemistry and the like. See, e.g., Har-
low and Lane Antibodies, A Laboratory Manual, Cold Spring
Harbor Publications, NY (1988) for a description of, e.g.,
western blot or immunoassay. Typically, a specific
or selective binding reaction will be at least twice the
background signal or noise and more typically more than 10
to 100 times background.

Accordingly, the disclosure includes metabolites of com-
ponds of the disclosure, including compounds produced by
a process comprising contacting a compound of this disclo-
sure with a mammal for a period of time sufficient to yield a
metabolic product thereof.

Therapeutic Agents

Disclosed herein are halogenated stilbene analogs and their
use in mitigating hyperproliferating cells or treating diseases
or disorders associated with MAT2A activity. The haloge-
nated stilbene analogs of the present disclosure display anti-
tumor activity, i.e., cancer cells that are exposed to the com-
ponds are killed, damaged and/or tumor growth is inhibited.
The analogs are useful for treatment of human cancers includ-
ing colorectal cancer, liver, breast cancer, among others.

The halogenated stilbene analogs of the present disclosure
include compounds according to formula (I):
lamin, dialkylamino, aryalkylamino, N-oxides of dialkylamino, trialkylammonium, mercapto, alkylthio, alkanoyl, nitro, nitrosoyl, cyano, alkoxy, alkenoxy, aryl, heteroaryl, sulfonyl, sulfonamide, CONR_{11}R_{12}, NR_{11}CO(R_{13}), NR_{11}COO(R_{13}), NR_{11}CONR_{13}R_{13} where R_{11}, R_{12}, R_{13}, are independently, H, alkyl, aryl, heteroaryl or a fluorine; provided that Ar_{2} contains at least one nitrogen atom in the aryl ring or at least one nitrogen substituent on the aryl ring; e.g., an NR'R''Z substituent on Ar_{2} where R' is H, alkyl, aryl, heteroaryl, R'' is an alkyl group, Z is an unshared pair of electrons, H, alkyl, oxygen. Preferably, the heteroaryl group is a monocyclic ring, wherein the ring comprises 2 to 5 carbon atoms and 1 to 3 heteroatoms, referred to herein as "(C_{2}-C_{5}) heteroaryl". This embodiment also includes a pharmaceutically acceptable salt of formula (I) and a biotinylated derivative of formula (I). The substituents on the carbon-carbon double bond, R', in either the cis- or trans-configuration. In one aspect of the present disclosure, X is one, two or three fluorine substituents and/or X is one, two or three chlorine substituents and/or X represents at least one fluorine and at least one chlorine on Ar_{1}. In another aspect of the present disclosure, X is one or more fluorine and/or chlorine and R' is H or a lower alkyl and R'' is a lower alkyl, or a pharmaceutically acceptable salt thereof, or a biotinylated derivative thereof.

In another embodiment, the present disclosure includes compounds of formula (II):

where R^{2} and R^{6} are as defined above. R_{1} to R_{10} are independently H, halo, amino, dialkylamino, dialkylamino, N-oxides of dialkylamino, arylalkylamino, dialkylamino, trialkylammonium, mercapto, alkylthio, alkanoyl, nitro, nitrosoyl, cyano, alkoxy, alkenoxy, aryl, heteroaryl, sulfonyl, sulfonamide, CONR_{11}R_{12}, NR_{11}CO(R_{13}), NR_{11}COO(R_{13}), NR_{11}CONR_{13}R_{13} where R_{11}, R_{12}, R_{13}, are independently, H, alkyl, aryl, heteroaryl or a fluorine; provided at least one of R_{1} to R_{5} is a halogen, e.g. a fluorine and/or chlorine; and at least one of R_{6} to R_{10} is a nitrogen containing substituent, e.g., an NR'R''Z substituent where R' is H, alkyl, e.g., a lower alkyl, alkoxy, aryl, heteroaryl, R'' is an alkyl group, Z is an unshared pair of electrons, H, alkyl, oxygen, or a pharmaceutically acceptable salt thereof, or a biotinylated derivative thereof.

In another embodiments of the present disclosure, at least one of R_{1} to R_{3} is a chloro-, N-substituent or chlorine substituent; at least one of R_{6} to R_{10} is an NR'R''Z substituent where R' is H or lower alkyl and R'' is a lower alkyl. In certain embodiments, one, two or three of R_{1} to R_{5} is a fluorine or a chlorine group; while in certain embodiments R_{1} and R_{5} are each fluorine and/or chlorine group, e.g., R_{1} and R_{5} are either two fluorine, two chlorine or one each of fluorine and chlorine groups. In another embodiment R_{1} and R_{3} are each fluorine and/or chlorine groups, e.g., R_{1} and R_{3} are either two fluorine, two chlorine or one each of fluorine and chlorine groups.

In another embodiments, the present disclosure includes compounds according to formula (III):

where R_{1}, R_{2}, R_{3}, R_{4}, R_{5}, R_{6}, R_{7}, R_{8}, R_{9}, are fluorine and/or chlorine groups, e.g., R_{1} and R_{5} are either two fluorine, two chlorine or one each of fluorine and chlorine groups. In another aspect of the present disclosure, R^{4} and NR'R''Z are the same as defined above, or pharmaceutically acceptable salts thereof, or a biotinylated derivative thereof. In one aspect of the present disclosure, R^{4}, R^{6} are both H, one or more of R_{1}, R_{2}, R_{3}, or R_{4}, are fluorine or chlorine and R'' is H or lower alkyl, such as a methyl, ethyl, propyl group, and R'' is a lower alkyl, such as a methyl, ethyl, propyl group. In another aspect of the present disclosure, R^{4}, R'' are both H, and at least two of R_{1}, R_{2}, R_{3}, or R_{4}, are fluorine and/or chlorine, or a pharmaceutically acceptable salt thereof, or a biotinylated derivative thereof.

In another embodiment of the present disclosure, the halogenated stilbene analog is a dihalogenated N,N-dimethylamino styrene having at least one fluorine or chlorine is in the 2' or 3' position of the aryl ring. In another embodiment, the stilbene analog has a fluorine in the 2' position and another fluorine in the 6' position. In another embodiment, the stilbene analog has a fluorine in the 2' position and a chlorine in the 6' position. In another embodiment, chlorine in the 2' position and another chlorine in the 6' position. In another embodiment, the stilbene analog has a chlorine in the 2' position and another chlorine in the 3' position.

Particular halogenated stilbene analogs of the present disclosure include (E)-4-(2-Fluorostyryl)-N,N-dimethylaniline; (E)-4-(2,3-Difluorostyryl)-N,N-dimethylaniline; (E)-4-(2,6-Difluorostyryl)-N,N-dimethylaniline; (E)-4-(2-Fluorostyryl)-N,N-diphenyl aniline; (E)-4-(2-Chlorostyryl)-N,N-dimethylaniline; (E)-4-(2-Chlorostyryl)-N,N-diphenyl aniline; (E)-4-(2-Chlorostyryl)-phenyl)-4-methyliperazene; (E)-4-(2-Chlorostyryl)-N,N-dimethylpyridazin-1-amine; (E)-4-(2-Chlorostyryl)-phenyl-1-methyl-1H-imidazole; (E)-4-(2-Chlorostyryl)-N,N-dimethylaniline.

Synthesis

The compounds of the present disclosure, including compounds of Formula (I) to Formula (III), may be prepared by methods disclosed herein or any other method known in the art. One of ordinary skill in the art will know how to modify procedures to obtain the analogs of the present disclosure. In
addition, compounds may be prepared using the methods described below and in Examples 1 through 3 or modified versions thereof.

FIG. 2 is a schematic of the general synthesis of certain halogenated stilbene analogs of the present disclosure. Additional halogenated stilbene analogs of the present disclosure can be made by similar methods or known synthetic procedures known in the art in light of the present disclosure. For example, as shown in FIG. 2 either Wittig or Wadsworth-Emmons reactions using phosphonium salts or diethyl phosphonates, respectively, with aldehydes provided the (E)-stilbenes (4) in good yield. The phosphonium salts were prepared from the corresponding benzyl bromides and triphenylphosphine, and the diethyl phosphonates were prepared from the corresponding benzyl bromides and triethyl phosphite using the Arbusov reaction according to standard literature procedures. Compounds were characterized fully and purity (>95%) established through combustion analyses.

The terms ortho, meta and para are art-recognized term and refer to 1,2-, 1,3- and 1,4-disubstituted benzenes, respectively. For example, the names 1,2-dimethylbenzene and ortho-dimethylbenzene are synonymous.

The present disclosure also encompasses potential metabolites of the halogenated stilbene analogs. These include stilbene analogs, e.g., general formulae (I), (II) or (III), having a dialkylamino substituent which has undergone an oxidation to an N-oxide. In one embodiment, the compound is the N-oxide of the dihalogenated N,N-dimethylaminostyrene having at least one fluorine or chlorine is in the 2' or 3' position. These potential metabolites also include halogenated stilbene analogs having a N,N-dialkylamino group which has undergone a methylation or a demethylation. In one embodiment, the stilbene analog is a dihalogenated N,N,N-trimethylammoniumstyrene having at least one fluorine or chlorine is in the 2' or 6' position. In one embodiment, the analog is a dihalogenated N,N,N-methylaminostyrene having at least one fluorine or chlorine is in the 2' or 3' position. In another embodiment, the analog is a dihalogenated N,N,N-methylhydroxymiaminostyrene having at least one fluorine or chlorine in the 2' or 3' position.

The present disclosure also encompasses biotinylated derivatives of the halogenated stilbene analogs. Such biotinylated derivatives are useful in identifying the molecular target for these agents. Stilbene analogs encompassed by formulas (I), (II) and (III) were synthesized and converted to biotinylated derivatives. The biotinylated derivatives that retain biological activity were used to identify a molecular enzyme target for these compounds, methionine S-adenosyltransferase.

In certain embodiments of the present disclosure, the halogenated stilbene analogs of the disclosure, or a pharmaceutically acceptable salt, solvate, hydrate or prodrug thereof, inhibit the growth of hyperproliferative cells. In certain embodiments of the present disclosure, the halogenated stilbene analogs of the disclosure, or a pharmaceutically acceptable salt, solvate, hydrate or prodrug thereof, inhibit methionine S-adenosyltransferase 2A (MAT2A) activity and are useful in treating diseases or conditions associated with MAT2A, e.g., diseases and conditions whose maintenance and/or spread require MAT2A.

Metabolites of Compounds of the Disclosure

Also falling within the scope of this disclosure are the in vivo metabolic products of formulas (I) to (III) described herein. Such products may result for example from the oxidation, reduction, hydrolysis, amidation, deamination, esterification, deesterification, enzymatic cleavage, and the like, of the administered compound.

Accordingly, the disclosure includes metabolites of compounds of formulas (I) to (III), including compounds produced by a process comprising contacting a compound of this disclosure with a mammal for a period of time sufficient to yield a metabolic product thereof.

Metabolite products typically are identified by preparing a detectably labeled, for example a radiolabeled (e.g., C or H isotope) compound of the disclosure, administering it parenterally in a detectable dose (e.g., greater than about 0.5 mg/kg) to an animal such as rat, mouse, guinea pig, monkey, or to man, allowing sufficient time for metabolism to occur (typically about 30 seconds to 30 hours) and isolating its conversion products from the urine, blood or other biological samples. These products are easily isolated since they are detectably labeled (others are isolated by the use of antibodies capable of binding epitopes surviving in the metabolite). The metabolite structures are determined in conventional fashion, e.g., by MS, 1C/MS or NMR analysis. In general, analysis of metabolites is done in the same way as conventional drug metabolism studies, which are well known to those skilled in the art. The metabolite products, so long as they are not otherwise found in vivo, are useful in diagnostic assays for therapeutic dosing of the compounds of the disclosure. Examples of likely metabolites of compounds of formulas (I) to (III) are shown in FIG. 3 and synthesized according to Example 2.

Prodrugs of the Compounds of the Disclosure

In addition to compounds of the disclosure, the disclosure also includes pharmaceutically acceptable prodrugs of such compounds. Prodrugs include compounds wherein an amino acid residue, or a polypeptide chain of two or more (e.g., two, three or four) amino acid residues, is covalently joined through an amide or ester bond to a free amino, hydroxy or carboxylic acid group of a compound of the present disclosure. The amino acid residues include but are not limited to the 20 naturally occurring amino acids commonly designated by three letter symbols and also includes phosphoserine, phosphothreonine, phosphophytosine, 4-hydroxyproline, hydroxyxynine, demosine, isodemosine, gamma-carboxyglutamate, hippuric acid, octahydroindole-2-carboxylic acid, statine, 1,2,3,4-tetrahydroisoquinoline-3-carboxylic acid, penicillamine, ornithine, 3-methylhistidine, norvaline, beta-alanine, gamma-aminobutyric acid, citrulline, homocysteine, homoserine, methyl-alanine, para-benzoylphenylalanine, phenylglycine, propargylglycine, sarcosine, methionine sulfoxide and tert-butylglycine.

Additional types of prodrugs are also encompassed. For instance, a free carboxyl group of a compound of the disclosure can be derivatized as an amide or alkyl ester. As another example, compounds of this disclosure comprising free hydroxy groups may be derivatized as prodrugs by converting the hydroxyl group into a group such as, but not limited to, a phosphate ester, hemisuccinate, dimethylamineacetate, or phosphoryloxymethyloxycarbonyl group, as outlined in Advanced Drug Delivery Reviews, (1996) 19:1-15. Carbamate prodrugs of hydroxy and amino groups are also included, as are carbonate prodrugs, sulfonate esters and sulfate esters of hydroxy groups. Derivatization of hydroxy groups as (acylloxymethyl) and (acyl氧yethyl) ethers, wherein the acyl group may be an alkyl ester optionally substituted with groups including, but not limited to, ether, amine and carboxylic acid functionalities, or where the acyl group is an amino acid ester as described above, are also encompassed. Prodrugs of this type are described in J. Med. Chem., (1996), 39:10. More specific examples include replacement of the hydrogen atom with a group such as (C1-C6)alkanoyloxyethyl, 1-((C1-C6)alkanoyloxy)ethyl, 1-methyl-1-((C1-C6)
tories, suitable carriers and additives including starches, tablets, capsules, and for solid preparations such as suppositories. Varieties of forms depending on the form of preparation desired. The formulation and not deleterious to the recipient thereof. 45 metabolite thereof, together with one or more pharmaceutical acceptable salts, solvate, hydrate, prodrug or metabolite thereof, in a therapeutically effective amount for killing cancer cells, or cancer stem cells, may act to kill cancer cells, or cancer stem cells or to control or suppress tumor growth or metastasis, among other functions.

Methods of preparation well known by those of ordinary skill may also be used in this aspect of the present disclosure.

In an embodiment, the composition of the present disclosure enables sustained, continuous delivery of a compound of Formula (I) to Formula (III) or a pharmaceutically acceptable carrier. The pharmaceutically acceptable carrier may take a wide variety of forms, depending on the route desired for administration, for example, oral or parenteral (including intravenous). Carriers such as starches, sugars, microcrystalline cellulose, diluents, granulating agents, lubricants, binders and disintegrating agents may be used. For example, preferred solid oral preparations are tablets or capsules, because of their ease of administration. If desired, tablets may be coated by standard aqueous or nonaqueous techniques. Oral and parenteral sustained release dosage forms may also be used.

Liposomal suspensions may also be pharmaceutically acceptable carriers. These may be prepared according to methods known to those skilled in the art. For example, liposomal formulations may be prepared by dissolving appropriate lipid(s) in an organic solvent that is then evaporated, leaving behind a thin film of dried lipid on the surface of the container. An aqueous solution of the active compound is then introduced into the container. The container is then swirled by hand to free lipid material from the sides of the container and to disperse lipid aggregates, thereby forming the liposomal suspension. Other methods of preparation well known by those of ordinary skill may also be used in this aspect of the present disclosure.

In an embodiment, the compositions are prepared with carriers that will protect the active compound(s) against rapid elimination from the body, such as a controlled release formulation, including implants and microencapsulated delivery systems. Biodegradable, biocompatible polymers can be used, such as ethylene vinyl acetate, polyanhydrides, polylactic acid, collagen, polyorthoesters, and polylactic acid. Methods for preparation of such formulations will be apparent to those skilled in the art.

The pharmaceutically acceptable carrier may take a wide variety of forms, depending on the route desired for administration, for example, oral or parenteral (including intravenous). Carriers such as starches, sugars, microcrystalline cellulose, diluents, granulating agents, lubricants, binders and disintegrating agents may be used. For example, preferred solid oral preparations are tablets or capsules, because of their ease of administration. If desired, tablets may be coated by standard aqueous or nonaqueous techniques. Oral and parenteral sustained release dosage forms may also be used.

Liposomal suspensions may also be pharmaceutically acceptable carriers. These may be prepared according to methods known to those skilled in the art. For example, liposomal formulations may be prepared by dissolving appropriate lipid(s) in an organic solvent that is then evaporated, leaving behind a thin film of dried lipid on the surface of the container. An aqueous solution of the active compound is then introduced into the container. The container is then swirled by hand to free lipid material from the sides of the container and to disperse lipid aggregates, thereby forming the liposomal suspension. Other methods of preparation well known by those of ordinary skill may also be used in this aspect of the present disclosure.

In an embodiment, the composition of the present disclosure enables sustained, continuous delivery of a compound of Formula (I) to Formula (III) or a pharmaceutically acceptable carrier. The pharmaceutically acceptable carrier may take a wide variety of forms, depending on the route desired for administration, for example, oral or parenteral (including intravenous). Carriers such as starches, sugars, microcrystalline cellulose, diluents, granulating agents, lubricants, binders and disintegrating agents may be used. For example, preferred solid oral preparations are tablets or capsules, because of their ease of administration. If desired, tablets may be coated by standard aqueous or nonaqueous techniques. Oral and parenteral sustained release dosage forms may also be used.

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In an embodiment, the composition of the present disclosure enables sustained, continuous delivery of a compound of Formula (I) to Formula (III) or a pharmaceutically acceptable carrier. The pharmaceutically acceptable carrier may take a wide variety of forms, depending on the route desired for administration, for example, oral or parenteral (including intravenous). Carriers such as starches, sugars, microcrystalline cellulose, diluents, granulating agents, lubricants, binders and disintegrating agents may be used. For example, preferred solid oral preparations are tablets or capsules, because of their ease of administration. If desired, tablets may be coated by standard aqueous or nonaqueous techniques. Oral and parenteral sustained release dosage forms may also be used.

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In an embodiment, the composition of the present disclosure enables sustained, continuous delivery of a compound of Formula (I) to Formula (III) or a pharmaceutically acceptable carrier. The pharmaceutically acceptable carrier may take a wide variety of forms, depending on the route desired for administration, for example, oral or parenteral (including intravenous). Carriers such as starches, sugars, microcrystalline cellulose, diluents, granulating agents, lubricants, binders and disintegrating agents may be used. For example, preferred solid oral preparations are tablets or capsules, because of their ease of administration. If desired, tablets may be coated by standard aqueous or nonaqueous techniques. Oral and parenteral sustained release dosage forms may also be used.
The formulations of the present disclosure include those suitable for oral, parenteral (including subcutaneous, intradermal, intramuscular, intravenous, intratracheal and intraarticu lar), rectal and topical (including dermal, buccal, sublingual and intraocular) administration, as well as those for administration by inhalation. The most suitable route may depend upon the condition and disorder of the recipient. Exemplary formulations are well known to those skilled in the art, and general methods for preparing them are found in any standard pharmacy school textbook, for example, Remington: THE SCIENCE AND PRACTICE OF PHARMACY, 21st Ed., Lippincott. The formulations of the present disclosure may conveniently be presented in unit dosage form and may be prepared by any of the methods well known in the art of pharmacy. All methods include the step of bringing into association a compound or a pharmaceutically acceptable salt or solvate thereof ("active ingredient") with the carrier which constitutes one or more of the necessary ingredients. In general, the formulations are prepared by uniformly and intimately bringing into association the active ingredient with liquid carriers or finely divided solid carriers or both and then, if necessary, shaping the product into the desired formulation. Oral formulations are well known to those skilled in the art, and general methods for preparing them are found in any standard pharmacy school textbook, for example, Remington: THE SCIENCE AND PRACTICE OF PHARMACY, 21st Ed., the entire disclosure of which is incorporated herein by reference.

The concentration of active compound of the present disclosure, i.e., at least one of the compounds of Formula (I) to Formula (III) or a pharmaceutically acceptable salt, solvate, hydrate, prodrug or metabolite thereof, in the drug composition will depend on absorption, distribution, inactivation, and excretion rates of the drug as well as other factors known to those of skill in the art. It is to be noted that dosage values will also vary with the severity of the condition to be alleviated. The composition may be administered at once, or may be divided into a number of smaller doses to be administered at varying intervals of time.

Oral compositions will generally include an inert diluent or an edible carrier. They may be enclosed in gelatin capsules or compressed into tablets. For the purpose of oral therapeutic administration, the active compound or its prodrug derivative can be incorporated with excipients and used in the form of tablets, troches, or capsules. Pharmaceutically compatible binding agents, and/or adjuvant materials can be included as part of the composition.

The tablets, pills, capsules, troches and the like can contain any of the following non-limiting ingredients, or compounds of a similar nature: a binder such as microcrystalline cellulose; gum tragacanth or gelatin; an excipient such as starch or lactose; a dispersing agent such as glidant; a lubricant such as magnesium stearate; a sweetening agent such as sucrose or saccharin; or a flavoring agent such as peppermint, methyl salicylate, or fruit flavoring. When the dosage unit form is a capsule, it can contain, in addition to any of the above, a liquid carrier such as a fatty oil. In addition, dosage unit forms can contain various other materials which modify the physical form of the dosage unit, for example, coatings of sugar, shellac, or enteric agents.

The tablets, for example, may optionally be coated or scored and may be formulated so as to provide sustained, delayed or controlled release of the active ingredient therein. Oral and parenteral sustained release drug delivery systems are well known to those skilled in the art, and general methods of achieving sustained release of orally or parenterally administered drugs are found, for example, in Remington: THE SCIENCE AND PRACTICE OF PHARMACY, 21st Ed.

The active compound may also be administered as a component of an elixir, suspension, syrup, wafer or the like. A syrup may contain, in addition to the active compounds, sucrose or fructose as a sweetening agent and certain preservatives, dyes and colorings and flavors.

In certain embodiments of the present disclosure, the halogenated stilbene analog is formulated as admixture with a pharmaceutically acceptable carrier, excipient or additive. In general, the pharmaceutical composition is administered in orally-administrable form, but for treatment of a number of conditions, a number of other formulations may be administered via a topical, parenteral, intravenous, intramuscular, transdermal, buccal, subcutaneous, suppository or other route, including an eye or ocular route. Intravenous and intramuscular formulations are generally administered in sterile saline. Of course, one of ordinary skill in the art may modify the formulations within the teachings of the specification to provide numerous formulations for a particular route of administration without rendering the pharmaceutical compositions unstable or compromising their therapeutic activity. It is also well within the routine skill to modify the route of administration and dosage regimen of a particular compound in order to manage the pharmacokinetics of the present compounds for maximum beneficial effect to the patient.

In certain pharmaceutical dosage forms, the pro-drug form of the compounds may be preferred. One of ordinary skill in the art will recognize how to readily modify the present compounds to pro-drug forms to facilitate delivery of active compounds to a targeted site within the host organism or patient. The routine skill will also take advantage of favorable pharmacokinetic parameters of the pro-drug forms, where applicable, in delivering the present compounds to a targeted site within the host organism or patient to maximize the intended effect of the compound.

Pharmaceutical compositions containing any of the compounds of Formula (I) to Formula (III) or a pharmaceutically acceptable salt, solvate, hydrate, prodrug or metabolite thereof, may be conveniently presented in unit dosage form and prepared by any of the methods well known in the art of pharmacy. Preferred unit dosage formulations are those containing an effective dose, or an appropriate fraction thereof, of the active ingredient, or a pharmaceutically acceptable salt thereof. The magnitude of a prophylactic or therapeutic dose typically varies with the nature and severity of the condition to be treated and the route of administration. The dose, and perhaps the dose frequency, will also vary according to the age, body weight and response of the individual patient. In general, the total daily dose (in single or divided doses) ranges from about 0.1 mg per day to about 7000 mg per day, or about 0.1 mg per day to about 100 mg per day, or from about 10 mg per day to about 100 mg per day, or from about 20 mg to about 100 mg, to about 80 mg or to about 60 mg. In some embodiments, the total daily dose may range from about 10 mg to about 500 mg per day, or about 100 mg to about 500 mg per day. It is further recommended that children, patients over 65 years old, and those with impaired renal or hepatic function, initially receive low doses and that the dosage be titrated based on individual responses and/or blood levels. It may be necessary to use dosages outside these ranges in some cases, as will be apparent to those in the art. Further, it is noted that the clinician or treating physician knows how and when to interrupt, adjust or terminate therapy in conjunction with individual patient's response.

Alternatively, the maximum safe starting dose of the compounds of the present disclosure for use in initial clinical trials...
in adults may be determined by following, for example, the FDA guidelines for estimating maximum safe dosage. These guidelines provide guidance for using the dosages used in animal studies to extrapolate safe dosage for use in human trials. See Guidance for Industry, Estimating the Maximum Safe Starting Dose in Initial Clinical Trials for Therapeutics in Adult Healthy Volunteers, Food and Drug Administration, Center for Drug Evaluation and Research (CDER), July 2005.

In an embodiment, the amount of compound included within therapeutically effective formulations of the present disclosure is an effective amount for treating the conditions associated with MAT2A activity. In general, a therapeutically effective amount of the present preferred compound in dosage form usually ranges from slightly less than about 0.025 mg/kg to about 2.5 mg/kg, and in certain embodiments about 2.5 to about 5 mg/kg or about 2.5 to about 100 mg/kg of the patient or considerably more, depending upon the compound used, the condition being treated and the route of administration, although exceptions to this dosage range may be contemplated by the present disclosure. In some embodiments, halogenated stilbene analogs of the present disclosure are administered in amounts ranging from about 0.1 mg/kg to about 100 mg/kg.

The active compound of the present disclosure, i.e., at least one of the compounds of Formula (I) to Formula (III) or a pharmaceutically acceptable salt, solvate, hydrate, prodrug or metabolite thereof, is included in the pharmaceutically acceptable carrier or diluent in an amount sufficient to deliver to a patient a therapeutically effective amount for the desired indication, without causing serious toxic effects in the patient treated.

In certain embodiments, the active compound is conveniently administered in any suitable unit dosage form, including but not limited to one containing 1 to 3000 mg, preferably 5 to 500 mg of active ingredient per unit dosage form. An oral dosage of 10-250 mg is usually convenient.

The actual dosage amount of a composition of the present disclosure administered to a patient or subject can be determined by physical and physiological factors such as body weight, severity of condition, the type of disease being treated, previous or concurrent therapeutic interventions, idiosyncrasy of the patient and on the route of administration. The practitioner responsible for administration will, in any event, determine the concentration of active ingredient(s) in a composition and appropriate dose(s) for the individual subject.

In certain embodiments, pharmaceutical compositions may comprise, for example, at least about 0.1% of an active compound, i.e., at least one of the compounds of Formula (I) to Formula (III) or a pharmaceutically acceptable salt, solvate, hydrate, prodrug or metabolite thereof. In other embodiments, the active compound may comprise about 1% to about 75% of the weight of the unit, or between about 5% to about 50%, for example, and any range derivable therein. In other non-limiting examples, a dose may also comprise about 1 microgram/kg/body weight, about 5 microgram/kg/body weight, about 10 microgram/kg/body weight, about 50 microgram/kg/body weight, about 100 milligram/kg/body weight, about 150 milligram/kg/body weight, about 200 milligram/kg/body weight, about 300 milligram/kg/body weight, about 400 milligram/kg/body weight or more per administration, and any range derivable therein. In non-limiting examples of a derivable range from the numbers listed herein, a range of about 50 microgram/kg/body weight to about 50 milligram/kg/body weight, or from about 50 microgram/kg/body weight to about 50 milligram/kg/body weight, etc., can be administered.

Route of Administration

In accordance with the methods of the present disclosure, the described halogenated stilbene analogs of the present disclosure or a pharmaceutically acceptable salt, solvate, hydrate or prodrug thereof, may be administered to a subject in a variety of forms depending on the selected route of administration, as will be understood by those skilled in the art. The active compound of the disclosure may be administered, for example, by oral, parenteral, buccal, sublingual, nasal, rectal, patch, pump, or transdermal administration and the pharmaceutical compositions formulated accordingly. Parenteral administration includes intravenous, intraperitoneal, subcutaneous, intramuscular, intratamural, transperitoneal, nasal, intrapulmonary, intrathecal, rectal and topical modes of administration. Parenteral administration may be by continuous infusion over a selected period of time.

Alternatively, the compounds of this disclosure may be incorporated into formulations for any route of administration including for example, oral, topical and parenteral including intravenous, intramuscular, eye or ocular, intraperitoneal, intrabuccal, transdermal and in suppository form.

Methods of Treatment

In an embodiment, the present disclosure is directed to methods for treating a disorder associated with MAT2A biological activity in a subject comprising administering to the subject an effective amount of a compound or composition of one or more compounds of formula (I), formula (II) and/or formula (III) and/or one or more pharmaceutically acceptable salt, solvate, hydrate, prodrug or metabolite thereof. In one embodiment, a MAT2A associated disorder is tumors and/or cancer. Therefore, in an embodiment, the present disclosure is also directed to methods for the treatment of tumors and/or cancer comprising administering an effective amount of one or more halogenated stilbene analogs of the present disclosure and/or a pharmaceutically acceptable salt, solvate, hydrate, prodrug or metabolite thereof to a patient in need of such therapy. For example, the present disclosure contemplates methods of treating various cancers and complications thereof. More particularly, the present disclosure relates to methods for inhibiting the growth of benign and malignant cancer, including a malignant tumor or cancer comprising exposing the tumor to an inhibitory or therapeutically effective amount or concentration of at least one of the halogenated stilbene analogs or pharmaceutically acceptable salts or pharmaceutically acceptable composition thereof.

Treatment of internal malignancies such as eye or ocular cancer, rectal cancer, colon cancer, cervical cancer, prostate cancer, breast cancer, liver cancer and bladder cancer, and age-related cancer among numerous others are contemplated by the present disclosure.

Accordingly, the compounds and/or compositions of the present disclosure are useful for treating animals, and in particular, mammals, including humans, as patients. Thus, humans and other animals, and in particular, mammals, suffering from hyperproliferative disorders, and in particular, cancer, or other diseases as disclosed herein, can be treated by administering to the patient an effective amount of one or more of the halogenated stilbene analogs according to the present disclosure, its derivative or a pharmaceutically acceptable salt thereof, optionally in a pharmaceutically acceptable carrier or diluent, either alone, or in combination with other known pharmaceutical agents (depending upon the disease to be treated). Treatment according to the present disclosure can also be by administration of the compounds and/or compositions of the present disclosure in conjunction
with other conventional cancer therapies, such as radiation treatment or surgery or administration of other anti-cancer agents.

In certain embodiments, the present disclosure can find application in the treatment of any disease for which delivery of a therapeutic halogenated stilbene analog or a pharmaceutically acceptable salt, solvate, hydrate, prodrug or metabolite thereof to a cell or tissue of a subject is believed to be of therapeutic benefit. Examples of such diseases include hyperproliferative diseases and quiescent malignant diseases. In particular embodiments, the disease is a hyperproliferative disease, such as cancer of solid tissues or blood cells. Quiescent malignant diseases that can be treated by a halogenated stilbene analog of the present disclosure or a pharmaceutically acceptable salt, solvate, hydrate, prodrug or metabolite thereof include, for example, chronic lymphocytic leukemia.

For example, a compound or composition of a halogenated stilbene analog of the present disclosure or a pharmaceutically acceptable salt, solvate, hydrate, prodrug or metabolite thereof can be administered to treat a hyperproliferative disease. The hyperproliferative disease may be cancer, leiomyomas, adenosomas, lipomas, hemangiomas, fibromas, pre-neoplastic lesions (such as adenomatous hyperplasia and prostatic intraepithelial neoplasia), carcinoma in situ, oral hairy leukoplakia, or psoriasis.

The cancer may be a solid tumor, metastatic cancer, or non-metastatic cancer. In certain embodiments, the cancer may originate in the bladder, blood, bone, bone marrow, brain, breast, colon, esophagus, duodenum, small intestine, large intestine, colon, rectum, anus, gum, head, kidney, liver, lung, nasopharynx, neck, ovary, prostate, skin, stomach, testis, tongue, or uterus. In certain embodiments, the cancer is ovarian cancer. In particular aspects, the cancer may be a chemo-resistant cancer, i.e., refractive forms of cancer.

Diseases other than cancer involving altered physiological status are also encompassed by the present disclosure. For example, it has been shown that diabetes involves underlying signaling changes, namely resistance to insulin and failure to activate downstream signaling through IRS proteins (Burks D J, White M F. Diabetes 2001 February; 50 Suppl 1:S140-5). Similarly, cardiovascular disease has been shown to involve hypertrophy of the cardiac cells involving multiple pathways such as the PKC family (Malhotra A. Mol Cell Biochem 2001 September; 225 (1-2):97-107). Inflammatory diseases, such as rheumatoid arthritis, are known to involve the chemokine receptors and disrupted downstream signaling (D’Ambrosio D J Immunol Methods 2003 February; 273 (1-2):3-13).

In another aspect of the disclosure, there is provided a method for disrupting Wnt signaling in a cell by contacting the cell with an effective amount of a halogenated stilbene analog of the disclosure. The Wnt signaling pathway describes a complex network of proteins most well known for their roles in embryogenesis and cancer, but also involved in normal physiological processes in adult animals. The canonical Wnt pathway involves a series of events that occur when Wnt proteins bind to cell-surface receptors of the Fizzled family, causing the receptors to activate Dishevelled family proteins and ultimately resulting in a change in the amount of β-catenin that reaches the nucleus. Dishevelled (DSH) is a key component of a membrane-associated Wnt receptor complex which, when activated by Wnt binding, inhibits a second complex of proteins that includes axin, GSK-3, and the protein APC. The axin/GSK-3/APC complex normally promotes the proteolytic degradation of the β-catenin intracellular signaling molecule. After this β-catenin destruction complex is inhibited, a pool of cytoplasmic β-catenin stabilizes, and some β-catenin is able to enter the nucleus and interact with TCF/LEF family transcription factors to promote specific gene expression. In this aspect of the disclosure, cells are brought into contact with an amount of one or more compounds of the disclosure sufficient to disrupt Wnt signaling in the cells.

Combination Therapy

The active compounds of the present disclosure, i.e., one or more compounds of formula (I), formula (II) and/or formula (III) and/or one or more pharmaceutically acceptable salt, solvate, hydrate, prodrug or metabolite thereof can also be mixed with other active materials that do not impair the desired action, or with materials that supplement the desired action, such as other anticancer agents, and in certain instances depending upon the desired therapy or target, antibiotics, antifungals, antiinflammatories, antiviral compounds or other agents having a distinct pharmacological effect.

The methods and compositions of the present disclosure further provide combination therapies which can enhance the therapeutic or protective effect of the compounds of the present disclosure, and/or increase the therapeutic effect of another anti-cancer or anti-hyperproliferative therapy. Therapeutic and prophylactic methods and compositions can be provided in a combined amount effective to achieve the desired effect, such as the killing of a cancer cell and/or the inhibition of cellular hyperproliferation. This process may involve contacting the cells with, for example, a therapeutic nucleic acid, such as a chemotherapeutic agent or an inhibitor of gene expression, as a second therapy. A tissue, tumor, or cell can be contacted with the compounds or compositions of the present disclosure and one or more additional anti-cancer treatment. For example, an additional anticancer treatment may include a chemotherapeutic agent, an anti-hormonal agent, radiotherapy, surgical therapy, or immunotherapy.

Examples of chemotherapeutic agents include alkylating agents such as thiota and cyclophosphamide; alkyl sulfonates such as busulfan, imropustan and pippusulfan; aziridines such as benzodopa, carboquone, meturedopa, and ure­dopa; ethylamines and methylamino­methylamino­methylamino­metilmelamine, triethylen­metilmelamine, triethylenet­etilmelamine and trimethyl­etilmelamine; acetogenins (especially bullatalc and bullatacinone); a camptothecin (including the synthetic analogue topotecan); bryostatin; calystatin; CC-1065 (including its adozelesin, carzelesin and bizeslesin synthetic analogues); cryptophycins (particularly cryptophycin 1 and cryptophycin 8); dolastatin; duocarmycin (including the synthetic analogues, KW-2189 and CB1-1M1); eleutherobin; pancratistatin; a sascodictyin; spingostatin; nitrogen mustards such as chlorambucil, chlor­naphazine, chokophosphamide, estramustine, ifosfamide, melphorethamine, melphorethamine oxide hydrochloride, melphene, novemibicin, phenesterine, prednimustine, trofositamide, uracil; nitrosoureas such as carmustine, chlorozotocin, fotemustine, lomustine, nimustine, and ranimustine; antibiotics such as the enediyne antibiotics (e.g., calicheamicin, especially calicheamicin gammall and calicheamicin omegall); dynemicin, including dynemicin A; bis­phosphonates, such as clotribonate; an esperamicin; as well as neocarzinostatin chromophore and related chromoprotein enediyl antibiotic chromophores, aclacinomycins, actino­mycin, autharancin, azaserine, bleomycins, cactinomycin, carabine, caminomycin, carzinophilin, chromomycins, dactinomycin, daunorubicin, detorubicin, 6-diaza-5-oxo-1-nor­leucine, doxorubicin (including morpholino-doxorubicin, cyanomorpholino-doxorubicin, 2-pyrroline-doxorubicin and deoxy doxorubicin), epirubicin, esorubicin, idarubicin, mar­cellomycin, mitomycins such as mitomycin C, mycophenolic acid, nogalarnycin, olivomycin, peplomycin, poti­romycin,
puromycin, queimycin, rodorubicin, streptogin, strepto- 
zocin, tubecidine, ubenimex, zinostat, zorubicin; anti-me- 
tabolites such as methotrexate and 5-fluorouracil (5-FU); 
folic acid analogues such as denopterin, methotrexate, 
pieropetin, trimetrexate; purine analogues such as fludara- 
bine, 6-mercaptopurine, thiopurine, thioguanine; pyrim- 
idine analogues such as azaindine; acizidine, 6-azauridine, 
carmofur, cytarabine, dideoxyuridine, dioxiluridine, exocit- 
abine, fluridexine; androgens such as calusterone, droso- 
stanolone propionate, epitostanol, methyltestost, testola- 
tone; anti-adenals such as aminoglutethimide, mitotane, 
trilostane; folic acid replenisher such as frolinic acid; acegla- 
tone; alephosphamide glycolide; aminolevulinic acid; eni- 
mechlorethamine, cyclophosphamide, camptothecin, ifosfa- 
tabolites such as methotrexate and 5-fluorouracil (5-FU); 
nomycin, daunorubicin, doxorubicin, bleomycin, plicomy- 
platinum; etoposide (VP-16); ifosfamide; mitoxantrone; vin-
bazine; PSK polysaccharide complex); razoxane; rhizoxin; 
puyreka; lentinan, lonidainine; maytansinoids such as may- 
toxin; verracurin; gacytosine; arabinoside

Also included in the formulations may be anti-hormonal 
agents that act to regulate or inhibit hormone action on 
tumors such as anti-estrogens and selective estrogen 
receptor modulators (SERMs), including, for example, tamoxi- 
en, raloxifene, droloxifene, A-hydroxytamoxifen, trioxifene, 
keoxifene, LY1 70181, onapristone, and toremifene; aromatase 
inhibitors that inhibit the enzyme aromatase which regulates 
estrogen production in the adrenal glands, such as, for 
example, 4(5)-imidazoles, aminoglutethimide, megestrol 
acetae, exemestane, fadrozole, fadrozole, lestro- 
ze, and anastrozole; and anti-androgens such as flutamide, 
niltumidine, bicalutamide, leuprolide, and goserelin; as well 
as troxicitbine (a 1,3-dioxolane nucic acid cytokine ana-
logue); antiensoligonucleotides, particularly those which 
hierbly express genes in signaling pathways implicated in 
abherent cell proliferation, such as, for example, PKC-
alpha, Ralp and H-Ras; ribozymes such as a VEGF expression 
inhibitor and a HER2 expression inhibitor; vaccines such as 
gene therapy vaccines and pharmaceutically acceptable salts, 
acids or derivatives of any of the above.

In an embodiment, a therapeutic formulation or com- 
position set forth herein, which comprises one or more com-
ounds of formula (I), formula (II) and/or formula (III) and/or 
one or more pharmaceutically acceptable salt, solvate, 
hydrate, prodrug or metabolite thereof, may be administered 
before, during, after or in various combinations relative to a 
second anti-cancer treatment. The administrations may be in 
intervals ranging from concurrently to minutes to days to 
weeks. In embodiments where the halogenated stilbene 
containing composition is provided to a patient separately from 
an additional anti-cancer agent, one would generally ensure 
that a significant period of time did not expire between the 
time of each delivery, such that the two agents would still be 
able to exert an advantageously combined effect on the 
patient. In such instances, it is contemplated that one may 
provide a patient with the inhibitor of gene expression therapy 
and the anti-cancer therapy within about 12 to 24 or 72 h of 
each other and, more preferably, within about 6-12 h of each 
other. In some situations it may be desirable to extend the time 
period for treatment significantly where several days (2, 3, 
5, 6 or 7) to several weeks (1, 2, 3, 4, 5, 6, 7 or 8) lapse between 
respective administrations.

Within a single day (24-hour period), the patient may be 
given one or multiple administrations of the agent(s). More-
over, after a course of treatment, it is contemplated that there 
is a period of time at which no anti-cancer treatment is admin-
istered. This time period may last 1, 2, 3, 4, 5, 6, 7 days, and/or 
1, 2, 3, 4, 5 weeks, and/or 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 
months or more, depending on the condition of the patient, 
such as their prognosis, strength, health, etc.

Administration of any compound or therapy of the present 
disclosure to a patient will follow general protocols for the 
administration of such compounds, taking into account the 
toxicity, if any, of the agents. Therefore, in some embodiment 
there is a step of monitoring toxicity that is attributable 
to combination therapy. It is expected that the treatment 
periods would be repeated as necessary. It also is contemplated 
that various standard therapies, as well as radiation and 
surgical intervention, may be applied in combination with the 
desired therapy.

In specific aspects, it is contemplated that a standard 
therapy will include chemotherapy, radiotherapy, immuno-
therapy, surgical therapy or gene therapy and may be 
employed in combination with the combination therapy 
described herein.

Articles of Manufacture

In another embodiment of the disclosure, an article of 
manufacture, or "kit", containing materials useful for the 
treatment of the diseases and disorders described above is 
provided. In one embodiment, the kit comprises a container 
comprising at least one compound of formula (I)-(III), and/or 
one or more pharmaceutically acceptable salt, solvate, 
hydrate, prodrug or metabolite thereof.

The kit may further comprise a label or package insert on or 
associated with the container. The term "package insert" is 
used to refer to instructions customarily included in commer-
cial packages of therapeutic products, that contain information 
about the indications, usage, dosage, administration, 
contraindications and/or warnings concerning the use of such 
therapeutic products. Suitable containers include, for 
example, bottles, vials, syringes, blister pack, etc. The con-
tainer may be formed from a variety of materials such as glass 
or plastic. The container may hold a compound of formula 
(1)-(III) or a formulation thereof which is effective for treating 
the condition and may have a sterile access port (for example, 
the container may be an intravenous solution bag or a vial 
having a stopper pierceable by a hypodermic injection 
needle). At least one active agent in the composition is a
compound of formula (I)-(III). The label or package insert indicates that the composition is used for treating the condition of choice, such as cancer.

In an embodiment, the kit includes two separate pharmaceutical compositions: one containing a compound of the present disclosure, and a second pharmaceutical compound. In another embodiment, an assay or diagnostic kit includes a labeled compound of the present disclosure and one or more reagents necessary for detecting the labeled compound upon binding to its target in-vivo or in-vitro. In a related embodiment, the kit includes a package insert that describes the steps necessary for carrying out the detection assay.

In another embodiment, a kit of the disclosure further comprises a needle or syringe, preferably packaged in sterile form, for injecting the composition, and/or a packaged alcohol pad. Instructions are optionally included for administration of tagged stibene compounds by a clinician or by the patient.

Diagnostic Methods and Diagnostic Probes

Another aspect of the present disclosure provides compounds having general formulas (I)-(III) with a linker moiety (hydrophobic linkers, hydrophilic linkers, photo- cleavable linkers, redox reaction -cleavable linkers), wherein the linker moiety is covalently bonded to a label molecule (a label could be a fluorophor, biotin, different polymer beads and different reactive groups). Exemplary biotinylated analogs have been depicted in FIG. 4 and synthesized according to Example 3, below.

The compounds of the present disclosure when biotinylated provide suitable means for non-radioactive detection and quantitation of MAT2A from complex samples, which offer a useful alternative approach to the routinely used radiometric assays. Therefore, another aspect of the present disclosure relates to the use of biotinylated stibene analogs as a diagnostic reagent for detecting or monitoring the presence or levels of MAT2A in a complex protein sample. A complex protein sample contains multiple proteins, and may additionally contain other contaminants. Non-limiting examples of a complex protein sample include tumor tissues, biopsy, serum and cell extracts.

In one embodiment, the present disclosure relates to a method of detecting, monitoring or analyzing the levels of MAT2A in a complex protein sample, said method comprising adding a labeled compound of formula (I)-(III) to said complex protein mixture under conditions whereby said labeled compound covalently conjugates to MAT2A; isolating the conjugated MAT2A by a suitable affinity-based separation method, removing unbound proteins, detecting the level of MAT2A following the separation. In a related embodiment, the detection can be accomplished by measuring a fluorescence signal emitted from the compound of formula (I)-(III). In another related embodiment, the detection can be accomplished by measuring a fluorescence signal emitted from a label bound via a linker to the compound of formula (I)-(III). The detection step can be accomplished using various analytical procedures that known to the artisan for separating and analyzing complex protein mixtures. These analytical procedures include chromatographic methods such as HPLC, FPLC, ion exchange, size exclusion, mass spectrometry, and the like.

The linker moiety that can be used to attach a detectable label to the compounds of the present disclosure can be any of the linkers shown in FIG. 4. Alternatively, the linker moiety can a linker moiety comprising a repeating alkyleneoxy structure (polyethylene glycols, or "PEG"). Thus, one of skill in the art can select the linker moiety of the compounds of the present disclosure in order to provide additional specificity of them for MAT2A.

Linker moieties include among others, ethers, polyethers, diamines, other diamines, amides, polyamides, polyalcohols, disulfides, silylethers, alkyl or alkenyl chains (straight chain or branched and portions of which may be cyclic) aryl, diaryl or alkaryl groups, having from 0 to 3 sites of aliphatic unsaturation. While normally amino acids and oligopeptides are not preferred, when used they will normally employ amino acids of from 2-3 carbon atoms, i.e. glycine and alanine. Aryl groups in linker moieties can contain one or more heteroatoms (e.g., N, O, or S atoms). The number of atoms referred to above are exclusive of hydrogen in referring to the number of atoms in a group, unless indicated otherwise. The linker moieties, when other than a bond, will have from about 1 to 60 atoms, usually 1 to 30 atoms, where the atoms include C, N, O, S, P, etc., particularly C, N and O, and will generally have from about 1 to 12 carbon atoms and from about 0 to 8, usually 0 to 6 heteroatoms.

In an embodiment, it is desirable to have a detectable label associated with a compound of the present disclosure to allow the compound-MAT2A complex to be captured and washed free of other components of the reaction mixture. The label will generally be under about 1 kDa. Biotin is a conventional label or ligand, particularly analogs such as dethiobiotin and deimino-biotin, which can be readily displaced from streptavidin by biotin. However, any small molecule will suffice that can be captured and released under convenient conditions.

Affinity purification of biological molecules, for example proteins, is known in the art and allows the purification of molecules by exploiting the binding affinity of the target molecule for a molecular binding partner. Examples of affinity purification methods are fusion tag protein purification, avidin-biotin system, pull-down assay and the like.

In another embodiment, the present disclosure relates to a method of diagnosing cancer in a subject, comprising: (1) contacting a labeled compound of formula (I)-(III) with protein in a complex protein sample obtained from the patient to bind the compound to and detect MAT2A protein in the sample; and (2) comparing the level of MAT2A in the sample to that in a normal reference sample, whereupon if the level of MAT2A in the sample is statistically higher than that in the normal reference sample, a diagnosis of cancer is indicated.

In a related embodiment, the sample is a biopsy sample containing, for example, cancer cells selected from breast, prostate, colorectal, lung, colon, bladder, head and neck, intestine, ovarian, or skin cancer cells.

In another embodiment, the present disclosure relates to a method of identifying a subject who is a candidate for receiving treatment with the compounds of the present disclosure; such method comprises (1) obtaining a protein sample from the subject, (2) contacting a detectably labeled compound of formula (I)-(III) with protein present in a complex protein sample to bind to and detect MAT2A in said sample; and (3) comparing the level of MAT2A in the sample to that present in a normal reference sample, whereupon if the level of MAT2A in the sample is statistically higher than that in the normal reference, the subject's candidacy for treatment with one or more compounds of the present disclosure is indicated.

In a related embodiment, the protein sample is a biopsy sample, tissue sample, serum sample, urine sample and the like. If necessary, conventional tools such as protein isolation kits can be used to obtain protein samples from raw biopsy, tissue, blood or urine samples. In another related embodiment, the labeled compound is a biotinylated compound of formula (I)-(III).
**EXAMPLES**

The following examples are intended to further illustrate certain preferred embodiments of the disclosure and are not limiting in nature. Those skilled in the art will recognize, or be able to ascertain, using no more than routine experimentation, numerous equivalents to the specific substances and procedures described herein.

**Example 1**

**Synthesis of Stilbene Analogs**

**Materials and Methods:**

Chemicals were purchased from Sigma Aldrich, MP Biomedical (4e) or TCI (4d) or were synthesized according to literature procedures. Solvents were used from commercial vendors without further purification unless otherwise noted. Nuclear magnetic resonance spectra were determined using a Varian instrument (1H, 400 MHz; 13C, 100 MHz unless otherwise noted). LRMS electron-impact (EI) ionization mass spectra were obtained on a Bruker Utraflexstreme time-of-flight mass spectrometer (Billerica, Mass.), using DHB (2,5-dihydroxybenzoic acid) matrix. Purity of compounds was determined by Atlantic Microlabs, Inc., Norcross, Ga. Compounds were chromatographed on preparative layer Merck silica gel F254 unless otherwise indicated.

**General Procedure A.**

To 1.5 mmol of triprenylphosphonium bromide suspended in 4 mL of anhydrous THF at 78°C was added 2.25 mmol (1.5 eq) of n-ButLi (1.6M in hexane). See FIG. 2 for a general schematic diagram of this reaction. The mixture was warmed to 25°C for 30 min, and 2.25 mmol of an aldehyde in 1 mL of anhydrous THF was added. The mixture was stirred for 24 h, diluted with CH2Cl2, washed with saturated NH4Cl solution, and dried over anhydrous MgSO4. The product was chromatographed using 1:10 CH3OH:CH2Cl2 to afford 85 mg (43%) of 4a. mp 184-185°C.

**Synthesis of (E)-4-Methoxystilbene (4b)**

Procedure B. Yield 87%. Colorless crystals: mp 136-137°C.

**Synthesis of (E)-4-(2-Fluorostyryl)-N,N-dimethylamine (4e)**

Procedure B. Yield 84%. Light yellow crystals from acetonitrile. mp 124-126°C. 1H NMR (acetone-d6): δ 7.73-7.68 (m, 1H), 7.46 (d, 2H, J=8.8 Hz), 7.26-7.09 (m, 4H), 7.08 (d, 1H, J=16.8 Hz), 6.75 (d, 2H, J=9.2 Hz), 2.98 (s, 6H). 13C NMR (acetone-d6): δ 162.84, 131.67 (d, J=4.6 Hz), 128.08 (d, J=8.4 Hz), 127.93 (two C), 126.8 (d, J=4.5 Hz), 126.14 (d, J=12.1 Hz), 125.46, 124.59 (d, J=3.1 Hz), 115.64 (d, J=22.0 Hz), 115.49 (d, J=4.6 Hz), 112.44 (two C), 39.69 (two C). MS: m/z (%): 241 (100), 240 (74), 225 (32), 197 (20), 196 (20), 177 (18), 176 (13). Anal. Caled for C13H12F2N: C, 79.64; H, 6.68. Found: C, 79.77; H, 6.80.

**Synthesis of (E)-4-(3-Fluorostyryl)-N,N-dimethylamine (4f)**

Procedure B. Yield 65%. Light yellow crystals from acetonitrile. mp 147-148°C. 1H NMR (acetone-d6): δ 7.42 (d, 2H, J=8.4 Hz), 7.35-7.25 (m, 3H), 7.17 (d, 1H, J=16.4 Hz), 6.96 (d, 1H, J=16.8 Hz), 6.93-6.88 (m, 1H), 6.72 (d, 2H, J=8.8 Hz), 2.95 (s, 6H). 13C NMR (acetone-d6): δ 163.47 (d, J=241.4 Hz), 150.82, 141.36 (d, J=7.6 Hz), 130.66, 130.42 (d, J=8.4 Hz), 127.97 (two C), 125.22, 122.63 (d, J=2.2 Hz), 122.24 (d, J=2.2 Hz), 113.12 (d, J=21.3 Hz), 112.43 (two C), 111.96 (d, J=22.0 Hz), 39.69 (two C). MS: m/z (%): 241 (100), 240 (69), 225 (25), 197 (20), 196 (18), 177 (16), 176 (10). Anal. Caled for C13H12F2N: C, 79.64; H, 6.68. Found: C, 79.86; H, 6.67.

**Synthesis of (E)-4-(4-Fluorostyryl)-N,N-dimethylamine (4g)**


**Synthesis of (E)-4-(2-Fluorostyryl)-N,N-diyethylamine (4h)**

Procedure B. Yield 51%. Light yellow crystals from hexane. mp 78-79°C. 1H NMR (acetone-d6): δ 7.69-7.65 (m, 1H), 7.40 (d, 2H, J=8.8 Hz), 7.24-7.08 (m, 4I), 7.04 (d, 1H, J=16.4 Hz), 6.71 (d, 2H, J=8.8 Hz), 3.42 (q, 4H, J=7.2 Hz), 1.16 (t, 6H, J=7.2 Hz). 13C NMR (acetone-d6): δ 160.13 (d, J=242.2 Hz), 148.04, 131.73 (d, J=4.5 Hz), 128.24 (two C), 127.91 (d, J=7.6 Hz), 126.70 (d, J=4.5 Hz), 126.27 (d, J=11.4 Hz), 124.57 (d, J=3.8 Hz), 124.49, 115.62 (d, J=22.0 Hz), 114.82 (d, J=3.8 Hz), 111.76 (two C), 44.19 (two C), 12.21 (two C). MS: m/z (%): 269 (34), 255 (19), 254 (100), 226 (22), 225 (20), 197 (16), 196 (17). Anal. Caled for C13H12F2NO2: C, 80.26; H, 7.48. Found: C, 80.07; H, 7.61.

**Synthesis of (E)-4-(2-Fluorostyryl)-N,N-diphenylamine (4i)**

Procedure B. Yield 60%. Light yellow crystals from hexane. mp 114-115°C. 1H NMR (acetone-d6): δ 7.77-7.73 (m, 1H), 7.54 (d, 2H, J=8.4 Hz), 7.34-7.06 (m, 15H), 7.02 (d, 2H, J=8.4 Hz).
J = 8.8 Hz). $^{13}$C NMR (acetone-d$_6$): $\delta$ 160.39 (d, J = 245.9 Hz), 148.00, 147.73, 131.58, 130.87 (d, J = 4.5 Hz), 129.63, 128.90 (d, J = 8.3 Hz), 127.88, 127.23 (d, J = 3.8 Hz), 125.58 (d, J = 12.0 Hz), 124.75, 124.71, 123.53, 123.25, 118.78 (d, J = 3.8 Hz), 115.76 (d, J = 22.0 Hz). MS: m/z (%) 365 (100), 364 (12), 254 (13). Anal. Caled for C$_{20}$H$_{21}$FN$_2$: C, 85.45; H, 5.52. Found: C, 85.59; H, 5.69.

Synthesis of (E)-1-(4-(2-Fluorostyryl)phenyl)-4-methylpipеразин (4K)

Procedure B. Yield 65%. Light yellow crystals from acetonitrile. mp 142-144°C. $^1$H NMR (acetone-d$_6$): $\delta$ 7.72-7.69 (m, 1H), 7.48 (d, 2H, J = 8.8 Hz), 7.28-7.09 (m, 5H), 6.96 (d, 2H, J = 8.8 Hz), 3.22 (t, 4H, J = 5.2 Hz), 2.48 (t, 4H, J = 5.2 Hz), 2.54 (s, 3H). $^{13}$C NMR (acetone-d$_6$): $\delta$ 160.27 (d, J = 245.2 Hz), 151.59, 151.34 (d, J = 5.3 Hz), 128.42 (d, J = 8.4 Hz), 127.97, 127.81 (two C), 126.21 (d, J = 8.3 Hz), 125.90 (d, J = 12.1 Hz), 126.62 (d, J = 3.8 Hz), 118.85 (d, J = 3.8 Hz), 115.69 (d, J = 22.0 Hz), 115.46 (two C), 55.09 (two C), 48.34 (two C), 45.70. MS: m/z (%) 296 (100), 281 (42), 226 (24), 211 (46), 197 (28), 196 (42), 177 (30). Anal. Caled for C$_{22}$H$_{21}$F$_2$N$_2$: C, 77.02; H, 7.14. Found: C, 77.22; H, 7.49.

Synthesis of (E)-4-(2-Fluorostyryl)-N,N-dimethyl-naphthalen-1-amine (4K)

Procedure B. Yield 18%. Yellow crystals from hexane: Et$_2$O, mp 56-58°C. $^1$H NMR (acetone-d$_6$): $\delta$ 8.83-8.27 (m, 2H), 8.09 (d, 1H, J = 16.4 Hz), 7.95-7.91 (m, 1H), 7.80 (d, 1H, J = 8.0 Hz), 7.58-7.52 (m, 2H), 7.36-7.15 (m, 4H), 7.21 (t, 1H, J = 10.0 Hz), 6.98 (d, 2H, J = 8.8 Hz), 6.82-6.74 (d, 2H, J = 8.8 Hz), 2.90 (s, 6H). $^{13}$C NMR (acetone-d$_6$): $\delta$ 160.49 (d, J = 246.7 Hz), 151.66, 132.85, 129.41, 129.10 (d, J = 8.4 Hz), 128.92, 128.38 (d, J = 4.6 Hz), 127.67 (d, J = 3.8 Hz), 126.27, 125.78 (d, J = 12.2 Hz), 125.17, 124.92, 124.74 (d, J = 3.0 Hz), 124.25, 124.03, 121.75 (d, J = 8.3 Hz), 115.78 (d, J = 22.0 Hz), 114.49, 46.62. MS: m/z (%) 296 (100), 298 (84), 276 (70), 261 (40), 247 (22), 246 (15). Anal. Caled for C$_{22}$H$_{21}$F$_2$N: C, 82.45; H, 6.23. Found: C, 82.42; H, 6.22.

Synthesis of (E)-2-(4-(2-Fluorostyryl)phenyl)-1-methyl-1H-imidazole (4L)

Procedure B. Yield 47%. Colorless crystals from hexane. mp 60-61°C. $^1$H NMR (acetone-d$_6$): $\delta$ 7.82-7.78 (m, 8H), 7.65 (d, 1H, J = 16.0 Hz), 7.35-7.29 (m, 1H), 7.26 (d, 1H, J = 16.0 Hz), 7.22-7.13 (m, 2H), 7.08 (d, 1H, J = 1.2 Hz), 6.96 (d, 1H, J = 0.8 Hz), 3.81 (s, 3H). $^{13}$C NMR (acetone-d$_6$): $\delta$ 160.65 (d, J = 246.7 Hz), 145.39, 129.53 (d, J = 8.3 Hz), 128.89, 127.66 (d, J = 3.0 Hz), 124.98 (d, J = 11.4 Hz), 124.71 (d, J = 3.8 Hz), 122.73 (d, J = 3.8 Hz), 121.18, 116.99 (d, J = 5.3 Hz), 115.83 (d, J = 22.0 Hz), 132.04. MS: m/z (%) 202 (17), 201 (59), 186 (20), 183 (100), 186 (25), 146 (12), 125 (17). Anal. Caled for C$_{16}$H$_{11}$F$_2$N$_2$: C, 71.27; H, 5.48. Found: C, 71.24; H, 5.61.

Synthesis of (E)-2-(2,3-Difluorostyryl)-N,N-dimethylaniline (4M)

Procedure A. Yield 88%. Yellow crystals. mp 112-113°C. $^1$H NMR (acetone-d$_6$): $\delta$ 7.45 (d, 2H, J = 8.4 Hz).
**Synthesis of (E)-4-(2,6-Difluorostyryl)-N,N-diethylaniline (4s)**

Procedures A and B. Yield 57%. Yellow crystals from hexane. mp 136-137°C. 1H NMR (acetone-d6): δ 7.43 (d, 2H, J = 8.8 Hz), 7.32-7.28 (m, 2H), 7.27-7.20 (m, 1H), 7.11 (d, 1H, J = 16.0 Hz), 6.92 (d, 1H, J = 16.4 Hz), 6.71 (2H, J = 8.8 Hz), 2.95 (s, 6H). 13C NMR (acetone-d6): δ 150.82, 150.56 (d, J = 124.8 Hz, J = 12.9 Hz), 148.99 (d, J = 124.3 Hz), J = 12.9 Hz, 127.91 (two C), 125.16, 122.71 (d, J = 6.1 Hz), 122.68 (d, J = 6.1 Hz), 121.68 (d, J = 2.3 Hz), 117.49 (d, J = 17.4 Hz), 113.96 (d, J = 17.5 Hz), 112.43 (two C), 39.68 (two C). MS: m/z (%) 277 (37), 276 (30), 275 (100), 274 (21), 243 (15). Anal. Calcd for C16H16F2N: C, 74.11; H, 6.79. Found: C, 74.08; H, 5.83.

**Synthesis of (E)-4-(3,4-Difluorostyryl)-N,N-diethylaniline (4t)**

Procedures A and B. Yield 59%. Yellow crystals from hexane. mp 159-160°C. 1H NMR (acetone-d6): δ 7.50-7.44 (m, 1H), 7.41 (d, 2H, J = 8.8 Hz), 7.32-7.28 (m, 2H), 7.27-7.20 (m, 1H), 7.11 (d, 1H, J = 16.0 Hz), 6.92 (d, 1H, J = 16.4 Hz), 6.71 (2H, J = 8.8 Hz), 2.95 (s, 6H). 13C NMR (acetone-d6): δ 150.82, 150.56 (d, J = 124.8 Hz, J = 12.9 Hz), 148.99 (d, J = 124.3 Hz), J = 12.9 Hz, 127.91 (two C), 125.16, 122.71 (d, J = 6.1 Hz), 122.68 (d, J = 6.1 Hz), 121.68 (d, J = 2.3 Hz), 117.49 (d, J = 17.4 Hz), 113.96 (d, J = 17.5 Hz), 112.43 (two C), 39.68 (two C). MS: m/z (%) 259 (100), 258 (82), 243 (36), 215 (22), 195 (16). Anal. Calcd for C16H15F2N: C, 74.11; H, 5.83. Found: C, 74.24; H, 5.79.

**Synthesis of (E)-4-(3,4-Difluorostyryl)-N,N-dimethylaniline (4u)**


**Synthesis of (E)-N,N-Dimethyl-4-(2,3,6-trifluorostyryl)aniline (4v)**

Procedures A and B. Yield 45%. Light yellow crystals from hexane. mp 91-92°C. 1H NMR (acetone-d6): δ 7.48 (d, 2H, J = 9.2 Hz), 7.39 (d, 1H, J = 16.8 Hz), 7.22-7.14 (m, 1H), 7.06-7.00 (m, 1H), 6.89 (d, 1H, J = 16.8 Hz), 6.76 (2H, J = 8.0 Hz), 3.00 (s, 6H). 13C NMR (acetone-d6): δ 156.09 (dd, J = 243.9 Hz, J = 5.3 Hz, J = 2.4 Hz), 151.31, 147.94 (two C), 137.17 (t, J = 8.4 Hz), 128.23 (two C), 124.89, 117.43 (dd, J = 17.1 Hz, J = 12.1 Hz), 114.02 (dd, J = 19.4 Hz, J = 10.2 Hz), 112.33 (two C), 111.21 (dd, J = 25.5 Hz, J = 7.6 Hz, J = 3.8 Hz), 108.89, 39.59 (two C). MS: m/z (%) 261 (40), 134 (100), 118 (27), 91 (22). Anal. Calcd for C16H14F3N: C, 73.54; H, 6.56. Found: C, 73.53; H, 6.49.

**Example 2**

**Synthesis of Metabolites of Halogenated Stilbene Analogs**

General Procedure:

To a stirred solution of 4 (0.7 mmol) in CHCl3 (3 mL) was added 70% mCPBA (0.7 mmol, 1 equiv), portionwise at 0°C. The resulting mixture was stirred at room temperature for 5 h. The mixture was diluted with CH2Cl2 (15 mL), washed with saturated NaHCO3 solution and water, dried over anhyd-
drous MgSO₄ and concentrated. The product was purified by chromatography as noted for individual amine N-oxides listed below.

Synthesis of (E)-4-(2,6-difluorostyryl)-N,N-dimethylaminoline (4a)

Yield 72%. R₂=0.31 (1:5 CH₂OH—CHCl₃). mp 100-103°C. ¹H NMR (DMF-d₇): δ 8.11 (d, 2H, J=8.8 Hz), 7.72 (d, 2H, J=8.8 Hz), 4.73-7.35 (m, 2H), 7.21-7.15 (m, 3H), 3.40 (s, 6H). ¹³C NMR (DMF-d₇): δ 161.85 (dd, J₁=249.0 Hz, J₂=7.6 Hz, two C), 156.35, 137.30, 134.60 (t, J=7.6 Hz), 130.13 (t, J=10.7 Hz), 127.42 (two C), 116.40, 114.44 (t, J=15.2 Hz), 112.76 (dd, J₁=19.0 Hz, J₂=6.1 Hz, two C), 63.92 (two C). HRMS (EI) Calcd for C₁₆H₁₅Cl₂NO: 261.0530. Found: 261.0530.

Synthesis of (E)-4-(2-chloro-6-fluorostyryl)-N,N,N-trimethylaminoline (4bb)

Yield 80%. R₂=0.19 (1:1 CH₂OH—CHCl₃). mp 82-84°C. ¹H NMR (acetone-d₆): δ 8.13 (d, 2H, J=9.2 Hz), 7.71 (d, 2H, J=8.4 Hz), 7.34 (t, 1H, J=8.0 Hz), 7.22 (d, 1H, J=16.8 Hz), 7.11 (t, 1H, J=16.8 Hz), 3.41 (s, 6H). ¹³C NMR (acetone-d₆): δ 161.29 (d, J=249.8 Hz), 156.41, 137.41, 135.20 (d, J=12.1 Hz), 134.30 (d, J=10.5 Hz), 129.41 (d, J=10.6 Hz), 126.98 (two C), 126.06 (dd, J₁=3.0 Hz, J₂=12.2 Hz), 123.93 (d, J=14.4 Hz), 121.41 (two C), 120.31 (d, J=1.5 Hz), 115.19 (d, J=23.6 Hz), 63.27 (two C). HRMS (EI) Calcd for C₁₇H₁₄Cl₂FNO: 307.0826. Found: 307.0828.

Synthesis of (E)-4-(2,6-dichlorostyryl)-N,N-dimethylaminoline (4bb)

A solution of 1 g (3.86 mmol) of 4r and 764 mg (7.26 mmol, 2 equiv) of cyanogen bromide in 15 mL of acetone was refluxed for 16 h. The mixture was cooled and concentrated under a stream of argon. The residue was triturated with ether, NaOH (100), 2M HCl for 3 h. The mixture was neutralized with 2M NaOH solution, extracted with ether, dried over anhydrous MgSO₄, and concentrated. The product was purified by chromatography using 1:5 EtOAc-hexane to afford 307 mg (72%) of 4ff as a white solid: mp 198-199°C. ¹H NMR (DMSO-d₆): δ 7.70 (d, 2H, J=8.4 Hz), 7.29-7.21 (m, 2H), 7.14-7.06 (m, 2H), 6.79 (d, 1H, J=16.8 Hz), 6.55 (d, 2H, J=8.8 Hz), 6.02 (q, 1H, J=5.2 Hz), 2.70 (d, 3H, J=5.2 Hz). ¹³C NMR (DMSO-d₆): δ 160.36 (dd, J₁=249.1 Hz, J₂=8.0 Hz, two C), 150.88, 136.35 (t, J=7.5 Hz), 128.42 (two C), 127.96 (d, J=10.7 Hz), 124.53, 115.32 (t, J=15.5 Hz), 112.33 (dd, J₁=19.1 Hz, J₂=6.8 Hz, two C), 112.09 (two C), 108.86, 29.93. MS: m/z (%): 246 (30), 245 (100), 244 (15). Anal. Calcd for C₁₆H₁₄Cl₂NO: C, 73.45; H, 5.34. Found: C, 73.31; H, 5.26.

Synthesis of (E)-4-(2-chloro-6-fluorostyryl)-N,N,N-trimethylaminoline (4ee)

Yield 72%. R₂=0.31 (1:5 CH₂OH—CHCl₃). mp 100-103°C. ¹H NMR (DMF-d₇): δ 8.17 (d, 2H, J=8.8 Hz), 7.70 (d, 2H, J=8.8 Hz), 7.49 (d, 2H, J=8.4 Hz), 7.36 (t, 1H, J=8.0 Hz), 6.99 (d, 1H, J=16.4 Hz), 6.82 (d, 1H, J=16.4 Hz), 6.55 (d, 2H, J=8.8 Hz), 6.01 (q, 1H, J=5.2 Hz), 2.70 (d, 3H, J=5.0 Hz). ¹³C NMR (DMSO-d₆): δ 160.45, 150.80, 134.64, 133.36, 128.86 (two C), 128.28, 127.97 (two C), 123.47, 116.09 (two C), 111.57 (two C), 29.50. HRMS (EI) Calcd for C₁₇H₁₄Cl₂N: 277.0425. Found: 277.0425.

Synthesis of (E)-4-(2,6-difluorostyryl)-N,N,N-trimethylbenzenaminium iodide (4ff)

To a solution of 200 mg (0.77 mmol) of 4r in acetone (2 mL) was added CH₃I 328 mg (2.31 mmol, 3 equiv). The resulting mixture was refluxed for 8 h. The precipitate formed was collected by filtration, washed with ether, and the residual solid was removed in vacuo to afford 200 mg (64%) of 4ff as a white solid: mp 198-199°C. ¹H NMR (DMSO-d₆): δ 7.98 (d, 2H, J=8.4 Hz), 7.47-7.38 (m, 2H), 7.29 (d, 1H, J=16.8 Hz), 7.23-7.17 (m, 2H), 3.62 (s, 9H). ¹³C NMR (DMSO-d₆): δ 160.30 (dd, J₁=249.1 Hz, J₂=7.4 Hz, two C), 146.72, 138.44, 133.04 (t, J=7.8 Hz), 130.00 (t, J=10.8 Hz), 128.05 (two C), 121.03 (two C), 117.44, 113.58 (t, J=15.5 Hz), 112.23 (dd, J₁=19.2 Hz, J₂=5.7 Hz, two C), 56.45 (three C). Anal. Calcd for C₁₇H₁₄F₂I₂N: C, 50.89; H, 4.52. Found: C, 51.10; H, 4.49.

**Example 3**

Synthesis of Biotinylated Analogs of Halogenated Stilbenes

In this example, several biologically active biotin-labeled halogenated stilbene analogs, in particular fluorinated N,N-diarylaminostilbenes (FIDAS or FIDAS agents), were prepared. As shown in FIG. 4, several biotin-FIDAS compounds with variable spacers between the FIDAS agent and the biotin were prepared. It was established, through the synthesis of other amides lacking the biotin heterocycle or possessing other amides lacking the biotin heterocycle or possessing...
To a solution of 1.63 g (6.18 mmol, 1.2 equiv) of diethyl 2,6-difluorobenzoylphosphonate in 15 mL of anhydrous DMF at 0 °C, was added 310 mg (7.72 mmol, 1.5 equiv) of NaH. The mixture was stirred for 30 min, and a solution of 1.0 g (5.15 mmol) of 4-(dimethylamino)-3-nitrobenzaldehyde in 8 mL of anhydrous DMF was added over a 10 min period. The mixture was stirred for 2 h at 0 °C and poured into cold water. The precipitate was collected by filtration and recrystallized from acetonitrile to afford 1.1 g (70%) of 6 as red crystals: mp 152-153°C. 1H NMR (acetone-d6): δ 8.8 (d, J=10.7 Hz, 2H, two C), 7.10-7.05 (m, 2H), 6.61 (d, J=16.4 Hz, 1H), 7.24-7.18 (m, 1H), 7.12-7.03 (m, 3H), 7.01 (d, J=16.8 Hz, 3.1 (s, 6H). 13C NMR (acetone-d6): δ 119.70, 119.63, 119.51, 119.45, 119.42, 119.39 (t, J=11.1 Hz, 3.1). MS: m/z (%) 275 (21), 274 (100), 273 (33), 257 (15), 211 (16). Anal. Caled for C14H11F2N2O2: C, 64.37; H, 5.48. Found: C, 64.56; H, 3.42.

Synthesis of (E)-4-(2,6-Difluorostyryl)-N,N-dimethyl-3-nitroline (6)

A solution of 5 g (26.4 mmol, 8.5 equiv) of SnCl2 in 7 mL of conc HCl was added dropwise to a solution of 0.95 g (3.1 mmol) of 6 in 100 mL of glacial acetic acid. The mixture was stirred for ca. 12 h at 25 °C. A precipitate was collected by filtration, washed with 5 mL of glacial acetic acid, and suspended in 200 mL of water. The aqueous suspension was adjusted to pH 9-10 with NaOH and was extracted with EtO2. The combined ethereal extracts were washed with water, dried over anhydrous MgSO4, and concentrated. The residue was recrystallized from ethanol to afford 560 mg (7.72 mmol, 1.5 equiv) of 6 as colorless crystals: mp 136-137°C. 1H NMR (acetone-d6): δ 7.37 (d, J=16.8 Hz), 7.23-7.17 (m, 2H). 13C NMR (DMSO-d6): δ 147.0 (s, J=147.0 Hz), 137.2 (s, J=137.2 Hz, two C), 133.3 (s, J=133.3 Hz), 131.4 (s, J=131.4 Hz), 125.1 (s, J=125.1 Hz), 124.6 (s, two C), 117.1 (s, J=117.1 Hz, two C), 112.6 (s, J=112.6 Hz, two C), 108.5 (s, J=108.5 Hz, two C), 30.0 (s, two C). MS: m/z (%) 261 (61), 231 (67), 214 (45), 194 (34), 183 (100). Anal. Caled for C14H11F2NO2: C, 36.37; H, 3.47. Found: C, 36.46; H, 3.42.

Synthesis of (E)-4-(2,6-Difluorostyryl)aniline (9)

The procedure described for the preparation of 7 was repeated using 300 mg (1.15 mmol) of 8 in 20 mL of glacial HOAc and 1.85 g (9.76 mmol, 8.5 equiv) of SnCl2 in 3 mL of conc HCl to afford, after stirring ca. 12 h at 25 °C and quenching with water, a precipitate. The precipitate was collected by filtration, washed with 5 mL of glacial acetic acid and suspended in 80 mL of water. The aqueous suspension was adjusted to pH 9-10 with NaOH and was extracted with EtO2. The combined ethereal extracts were washed with water, dried over anhydrous MgSO4, and concentrated. The product was recrystallized from hexane to afford 220 mg (83%) of 9 as colorless crystals: mp 74-75°C. 1H NMR (DMSO-d6): δ 7.08 (d, J=10.3 Hz), 7.27-7.22 (m, 2H), 7.20 (d, J=10.3 Hz), 7.16-7.12 (m, 2H), 6.77 (d, J=10.3 Hz, two C), 6.82 (d, J=10.3 Hz, two C), 5.34 (s, 2H). 13C NMR (DMSO-d6): δ 160.35 (dd, J=246.8 Hz, J=8.0 Hz, two C), 150.06, 136.44 (t, J=7.9 Hz, 2H), 128.42 (t, two C), 127.99 (t, J=10.3 Hz), 124.68, 115.31 (t, J=15.1 Hz), 114.29 (t, two C), 112.33 (dd, J=19.1 Hz, J=6.3 Hz, two C), 108.84. MS: m/z (%) 232 (18), 231 (100), 183 (13). Anal. Caled for C14H11F2N2: C, 72.72; H, 4.79. Found: C, 72.77; H, 4.83.

Synthesis of (E)-N-(2,6-Difluorostyryl)-5-(dimethylamino)phenyl)-5-(2-oxohexahydro-1 H-thieno[3,4-d]imidazol-4-yl)pentanamide (10)

To 200 mg (0.82 mmol) of biotin was added 8 mL (0.11 mol) of SOCl2. The mixture was stirred for 1 h at 25 °C. The mixture was concentrated and co-evaporated with benzene (two 15 mL portions) to give the acid chloride. To a solution of 186 mg (0.68 mmol) of 7 and 83 mg (0.82 mmol, 1.2 equiv) of Et,N in 5 mL of anhydrous THF was added the acid chloride in 8 mL of anhydrous THF dropwise. The mixture was stirred for 2 h at 25 °C, poured into water and extracted with CH2Cl2. The combined organic phases were dried over anhydrous MgSO4 and evaporated to give a product that was purified by chromatography using 1:10 CH3OH—CH2Cl2 to afford 200 mg (50%) of 10 as a yellow solid: mp 183-184°C.

To a solution of 956 mg (2 mmol) of (4-nitrobenzyl)triphenylphosphonium bromide and 284 mg (2 mmol) of 2,6-difluorobenzaldehyde in 20 mL of CH2Cl2 was added 5 mL of 0.48 M NaOH solution (2.4 mmol, 1.2 equiv) dropwise over a 10 min period. The red solution was heated at 50°C for 1 h. The organic layer was separated, washed with a saturated aqueous Na2SO4 solution and water, and dried over anhydrous MgSO4. The residue was recrystallized from ethanol to afford 360 mg (69%) of 8 as light yellow crystals: mp 136-137°C. 1H NMR (DMSO-d6): δ 8.25 (d, J=10.7 Hz, 2H, two C), 8.16 (s, J=10.7 Hz, 2H, two C), 7.93 (d, J=10.7 Hz, 2H, two C), 7.50 (d, J=10.7 Hz, 2H, two C), 7.45-7.40 (m, 2H).

To a suspension of 100 mg (0.41 mmol 1 equiv) of biotin in 3 mL of anhydrous DMF was added 66 mg (0.49 mmol, 1.2 equiv)
equiv) of 1-hydroxybenzotriazole hydrate, 94 mg (0.49 mmol, 1.2 equiv) of N-(3-dimethylaminopropyl)-N'-ethylcarbodiimide hydrochloride, and 79 mg (0.78 mmol, 1.9 equiv) of Et$_3$N. The mixture was stirred for 10 min, and 95 mg (0.41 mmol) of 9 was added. The mixture was stirred for 24 h at 25°C and poured into water. The precipitate was collected by filtration and chromatographed using 1:1 EtOAc-MeOH to give 120 mg (66%) of 11 as white crystals: mp 278-280°C. 1H NMR (DMSO-d$_6$): δ 8.99 (s, 1H), 7.64 (d, 2H, J=8.8 Hz), 7.56 (d, 2H, J=8.8 Hz), 7.37-7.29 (m, 2H), 7.19-7.12 (m, 2H), 7.02 (d, 1H, J=16.4 Hz), 6.44 (s, 1H), 6.36 (s, 1H), 4.33-4.29 (m, 1H), 4.16-4.13 (m, 1H), 3.15-3.10 (m, 1H), 2.83 (dd, 1H, J=12.8 Hz, J=4.8 Hz), 2.58 (d, 1H, J=12.0 Hz), 2.33 (t, 2H, J=7.2 Hz), 1.70-1.33 (m, 6H). 13C NMR (DMSO-d$_6$): δ 171.70, 163.13, 160.52 (dd, J=248.0 Hz, J=11.1 Hz), 128.27 (two C), 119.54 (two C), 114.61 (t, J=15.5 Hz), 113.25, 112.45 (dd, J=19.1 Hz, J=6.3 Hz, two C), 61.48, 59.35, 58.52, 40.28, 36.70, 28.75, 25.87, 25.60. HRMS (EI) Calcd for C$_{24}$H$_{25}$F$_2$N$_3$O$_2$S: 457.1636. Found: 457.1650.

**Example 4**

Natural Stilbene Analogues Resveratrol and Pterostilbene Inhibit Wnt Signaling

Materials and Methods:

The following materials and methods have been used to generate the results in this and other examples in the application.

Cell Culture and Transfection

HEK293T, HCT116 and SW480 cells were grown in DMEM medium (Meditech) supplemented with 10% fetal bovine serum and 1% penicillin/streptomycin. LS 174T cells were grown in RPMI medium (Meditech) supplemented with 5% fetal bovine serum and 1% penicillin/streptomycin. HEK293T cells were transiently transfected using the calcium phosphate method as described in Zhang, W. et al., *Mol Cell Biol* 2006, 26, 2055-2064 (incorporated herein by reference).

Western Blot

Western blots were performed using the following antibodies: β-catenin (Sigma, C20206), e-Myc (Epitomics, 1472-1), Axin2 (Cell Signaling, 2151), β-Aactin (Sigma, A17978), TCF4 (Epitomics, 2114-1) and pygopus2 (Santa Cruz, sc-74878), Cyclin D1 (Cell signaling, 2926).

RT-PCR

LS174 cells were treated with DMSO or Wnt inhibitors.

After 36 h, RNA was isolated using the RNeasy kit (Qiagen). RT-PCR was performed as described in Zhang et al., *Mol Cell Biol* 2006, 26, 2055-2064. The following primers were used: β-catenin (Sigma, C20206), e-Myc (Epitomics, 1472-1), Axin2 (Cell Signaling, 2151), TCF4 (Epitomics, 2114-1) and pygopus2 (Santa Cruz, sc-74878), Cyclin D1 (Cell signaling, 2926).

**Synthesis of (E)-N-(4-(2,6-Difluorostyryl)phenyl)-N-methyl-5-(2-octahydro-1H-thieno[3,4-d]imidazo[4-yl]pentanamide (12)**

The procedure used to prepare 10 was repeated using 167 mg (0.68 mmol) of 4c and 200 mg (0.82 mmol, 1.2 equiv) of biotin to afford a product that was purified by chromatography using 1:10 CH$_3$OH—CH$_2$Cl$_2$ to afford 130 mg (41%) of 12 in a colorless solid: mp 91-93°C. 1H NMR (DMSO-d$_6$): δ 7.71 (d, 2H, J=8.0 Hz), 7.41-7.36 (m, 2H), 7.33 (d, 2H, J=8.4 Hz), 7.21-7.14 (m, 3H), 6.38 (s, 1H), 6.33 (s, 1H), 4.30-4.26 (m, 1H), 4.09-4.06 (m, 1H), 3.17 (s, 3H), 3.05-3.00 (m, 1H), 2.80 (dd, 1H, J=12.2 Hz, J=5.2 Hz), 2.56 (d, 1H, J=12.4 Hz), 2.09 (br.s, 2H), 1.58-1.18 (m, 6H). 13C NMR (DMSO-d$_6$): δ 171.96, 163.13, 160.61 (dd, J=248.0 Hz, J=11.1 Hz), 144.40, 134.71 (t, J=7.9 Hz), 129.80 (t, J=11.1 Hz), 128.27 (two C), 128.07, 120.07, 115.70 (two C), 114.35 (t, J=15.1 Hz), 112.54 (dd, J=19.1 Hz, J=6.4 Hz, two C), 61.42, 59.62, 55.75, 40.27, 37.20, 33.64, 28.54, 28.43, 25.32. MALDI-TOFMS Calcd for C$_{24}$H$_{25}$F$_2$N$_3$O$_2$S: [M+H]$^+$: 637.1805. Found 640.3520.

**Synthesis of N-(2-(4,2-Difluorostyryl)phenyl)-4-o xo-8,11-dioxo-1,5-diazadienecan-13-yl)-5(2-octahydro-1H-thieno[3,4-d]imidazo[4-yl]pentanamide (13)**

To a solution of 34 mg (0.14 mmol, 1.5 equiv) of 4c in 1 mL of absolute ethanol was added 50 mg (0.092 mmol) of (+)-biotinyl-iodoacetamidyl-3,6-dioxoactenediamine and 20 mg (0.14 mmol, 1.5 equiv) of anhydrous K$_2$CO$_3$. The mixture was refluxed for 12 h, filtered, and concentrated. The product was chromatographed using 1:10 CH$_3$OH—CH$_2$Cl$_2$ to afford 16 mg (26%) of 13 as a clear glass that resisted crystallization.

The initial product isolated was the pure (E)-isomer but during concentration, even at low temperature, rapidly equilibrated to a mixture of (E/Z)-isomers. The ratio of isomers varied with solvent rangeing from ca. 10:90 in acetonitrile to 60:40 in DMSO-d$_6$. This isomerization necessarily complicated the NMR spectra, and the data reported below is for the principal (E)-isomer. 1H NMR (acetonitrile-d$_3$): δ 7.48 (d, 2H, J=8.8 Hz), 7.42-7.35 (m, 2H), 7.30-7.22 (m, 1H), 7.13 (br.s, 1H), 7.05-7.00 (m, 2H), 6.95 (d, 1H, J=16.8 Hz), 6.75 (d, 2H, J=9.2 Hz), 5.87 (s, 1H), 5.64 (s, 1H), 4.51-4.46 (m, 1H), 4.34-4.29 (m, 1H), 3.97 (s, 2H), 3.59-3.45 (m, 8H), 4.42-3.29 (m, 4H), 3.23-3.17 (m, 1H), 3.13 (s, 3H), 2.92 (dd, 1H, J=12.4 Hz, J=4.8 Hz), 2.69 (d, 1H, J=12.4 Hz), 2.18 (t, 2H, J=7.2 Hz) 1.81-1.39 (m, 6H). It was noted that the MALDI-TOFMS Calcd for C$_{33}$H$_{44}$F$_2$N$_5$O$_5$S [M+H]+: 660.3038. Found 660.3040.

Luciferase and Cell Proliferation Assay

HEK293T cells were transiently transfected in a 12-well plate with 0.2 µg of the Super8X TOPFlash reporter and 0.05 µg of Renilla luciferase reporter. Culture medium was changed after 12 h. After 6 h, cells were treated with DMSO or Wnt inhibitors for 12 h, and then treated with 25 mM LiCl or Wnt conditioned medium. After 12 h, cells were harvested and luciferase activity measured by Dual-Luciferase Reporter Assay System (Promega, Madison Wis.). All conditions were done in triplicate and each experiment was carried out at least
two times. For cell proliferation assay, CRC cells were treated with DMSO or inhibitors for 2 and 4 d. The cell numbers and viability were analyzed by Vi-Cell Cell Viability Analyzer.

Tumor Xenograft in Nude Mice. LS174 or HT29 colon cancer cells (2×10⁶) were injected subcutaneously into both flanks of 6- to 8-week-old C57BL/6j athymic nude mice as described in Zhang et al., Mol Cell Biol 2006, 26, 2055-2064. Compound 4r or 4dd was dissolved in corn oil or PEG400. The mice were treated with 20 mg/kg/day of 4r by ip injection or gavage (50 μl/mouse). Control mice were treated with same volume of corn oil or PEG400. The body weight and tumor growth were analyzed twice weekly for one month. Tumor size was measured using digital calliper. The tumor volume was calculated by the formula: V=1/2LW² (mm³).

Immunofluorescence. Cells grown on cover glass were fixed by 4% paraformaldehyde for 20 min at room temperature. The cells were permeabilized with PBS containing 0.3% (v/v) Triton X-100 and blocked by 5% normal goat serum in PBS for 30 min. Anti-β-catenin antibody (1:300, Sigma, St. Louis, Mo.) was diluted in blocking solution and incubated with cells over night. The cells were washed 3 times with PBS and further incubated with Alexa-488-labeled anti-rabbit IgG (1:500) diluted in PBS for 40 min. The cover glasses were washed, mounted on glass slides, viewed and photographed with an Olympus FW1000 confocal microscope. Cells grown on cover glass were treated with fluorescent compounds for 2 h, 6 h, 12 h and 24 h respectively. Treated cells were fixed by 4% paraformaldehyde for 20 min at room temperature. Then cells were washed 3 times with PBS and mounted on glass slides, viewed under the fluorescence of 405 nm-wavelength and photographed with an Olympus FW1000 confocal microscope.

To identify Wnt pathway inhibitors for CRC prevention and treatment, a number of anti-cancer agents from plants were screened using the TopFlash reporter assay. The Top-Flash reporter was transfected into HEK293T cells, and the cells were treated with Wnt3A-conditioned medium in order to activate the luciferase reporter. Resveratrol (100 μM) significantly inhibited Wnt-induced luciferase activity. To determine if resveratrol regulates β-catenin degradation, the cells were treated with 25 mM LiCl, which inhibits GSK-3 and stabilizes β-catenin. In this assay, LiCl activated the reporter more strongly than Wnt3A conditioned medium. Resveratrol strongly inhibited LiCl-induced Wnt signaling, suggesting that resveratrol inhibits Wnt signaling by regulating β-catenin activity, but not its degradation. Emodin is an anti-cancer agent from plants; it exists in many unpurified resveratrol products. Emodin had no effect on Wnt signaling. See Zhang et al., J. of Med. Chem. 54, 1288-1297 (2011).

To confirm these results, β-catenin target genes were analyzed in LS174 CRC cells by Western blot and RT-PCR. The protein levels of c-Myc and Cyclin D1, which are β-catenin targets, are reduced by resveratrol but not its isomer, cis- or (Z)-resveratrol. Cyclin B1 levels were decreased, whereas p21WAF1/CIP1 levels increased, consistent with the fact that p21WAF1/CIP1 expression is repressed by c-Myc. β-catenin levels were not affected by resveratrol. Next, the mRNA levels of β-catenin target genes were analyzed using RT-PCR. Expression of survivin, lgr5, CD44, and c-Myc were decreased in resveratrol-treated cells. The cell proliferation marker, Ki67, also decreased. These results confirmed that resveratrol inhibits endogenous Wnt target genes in CRC cells.

Many stilbene derivatives also exhibit anti-cancer activity. To determine the structure/activity relationship of these compounds, several resveratrol analogs were tested. It was found that pterostilbene inhibits Wnt signaling. To determine the effects of resveratrol and pterostilbene on cell growth, LS174 CRC cells were treated with resveratrol and pterostilbene for 2 d and 4 d. Both compounds inhibited cell proliferation. Similar results were observed with other CRC lines. Pterostilbene was more active than resveratrol in these assays, suggesting that an assay involving Western blots to measure Wnt target protein level was effective to identify other resveratrol analogs for Wnt inhibition and CRC repression.

Example 5

Halogenated Stilbene Analogs are Potent Wnt Inhibitors

A panel of stilbene analogs was designed and synthesized (FIGS. 2, 3, 5A and 6A). Various monosubstituted hydroxyl, alkyl, amino and N,N-dialkylaminostilbenes were analyzed using the Western blot assay (FIG. 5B, 5C), and of these substituents, (E)-4-styryl-N,N-dimethylaniline (4d) at 30 μM with an N,N-dimethylaniline substituent strongly repressed Wnt target genes, Axin2 and c-Myc, in CRC cells (FIG. 5C). However, the solubility of 4d was poor and it was not effective below 10 μM concentrations (data not shown). To improve its solubility and activity, compound 4d was modified with 2'-fluoro 4e, 3'-fluoro 4f and 4'-fluoro 4g substituents (FIG. 5D). Both compounds 4e and 4f had good activity at 10 μM, (E)-4-(2-fluorostyryl)-N,N-dimethylaniline. Compound (4e) was best among all of the monofluoro-substituted compounds. Modifications of the N,N-dimethylaniline group within compound 4e were also analyzed, and it was found that the N,N-dimethylaniline group in (E)-4-(2-fluorostyryl)-N,N-dimethylaniline (4h) is also active at 10 μM, but not as potent as compound 4e and the N,N-diphenylamino group in compound 4i was inactive (FIG. 5E). These analogs had no effect on β-catenin levels, further indicating that they affect β-catenin activity, but not its stability. The effects of compound 4e, resveratrol, and pterostilbene on CRC cell growth were compared and it was found that 4e is a significantly better inhibitor in the cell proliferation assay (FIG. 5F).

Based on the improved activity seen in compound 4e relative to compound 4d, dialkylated N,N-dimethylaminostilbenes in which at least one of the fluorne substitutants is in the 2'- or 3'-position were synthesized (FIG. 6A). The compounds with a 2'-fluoro and another fluoro ortho or meta to the double bond (compounds 4m, 4o and 4r) are more active than compound 4e (FIG. 6D). The (E)-4-(2,6-difluorostyryl)-N,N-dimethylaniline (compound 4r) had the best activity. The ortho- and meta-N,N-dimethylaniline analogs of compound 4r (i.e., compounds 4p and 4q) are not as active as compound 4r, indicating that the para-dimethylanioanalog in compound 4r is important for its activity (FIG. 6C). Based on the structure of compound 4r, two trihalogenated dimethylaminostilbenes were synthesized (compounds 4v and 4w) in which two of the fluorne substitutants are in the 2'- and 6'-positions (FIG. 6D). Although compounds 4v and 4w were active at 10 μM, they showed no significant improvements over compound 4r. When the stilbene carbon-carbon double bond in compound 4r was reduced to a saturated, single bond in the 1,2-diarylethane compound 5r, the activity was lost, suggesting that the double bond is essential for biological activity (FIG. 6D).
0.5 μM (FIG. 6E). For example, based on the Western blot and cell proliferation assays, it was determined that stilbene 4r was 10- to 100-fold more potent than resveratrol and pterostilbene.

Example 6

Halogenated Stilbene Analogs Inhibit CRC In Vitro and In Vivo

In this example, the effects of the stilbene analogs of the present disclosure on CRC cell growth was analyzed. Consistent with the Western blot results, stilbene compound 4r was more potent than compound 4e in the cell proliferation assay; it inhibited LS 174 cell proliferation at nanomolar concentrations (FIG. 7A). To test the effects of compound 4r on tumor growth in vivo, LS174 cells were injected subcutaneously into the flanks of athymic nude mice, which had been randomized into two groups. One group of mice was treated with compound 4r (20 mg/kg/day) dissolved in corn oil by intraperitoneal (ip) injection. The control mice were treated with the same volume of corn oil (50 μL) by ip injection. The mice were weighted and tumors measured twice weekly. The compound 4r treated mice and control mice had no significant difference in body weight within one month (FIGS. 7B and 7C), suggesting that compound 4r has no significant toxic effect at this dosage. However, the growth of tumor xenografts were significantly inhibited by 4r treatment (FIG. 7D).

Therefore, as shown in this example, the halogenated stilbene analogs of the present disclosure are capable of inhibiting CRC both in vitro and in vivo. In another study, it was shown that mice could tolerate at least 200 mg/kg of a halogenated stilbene analog, FIDAS 4d. The body weights in these mice were reduced after one week but were recovered to normal weight after stopping 4d treatment (data not shown).

Example 7

Halogenated Stilbene Analogs Inhibit Wnt Signaling in the Nucleus

The stilbene analogs of the present disclosure and in particular, (E)-4-(2,6-difluorostyryl)-N,N-diethylaniline (compound 4s) (FIG. 8) exhibit strong fluorescence at 365 nm (FIG. 8A), albeit compound 4s is slightly less active than compound 4r (FIG. 8B). Nevertheless, compound 4s lends itself well to a mechanistic study of the site of action of these compounds. LS174 cells were treated with 10 μM of compound 4s for 2 h, 6 h, 12 h, and 24 h. The cells were fixed and analyzed by confocal fluorescence microscopy. It was found that compound 4s was localized throughout the nucleus and cytoplasm at 2 h. After 12 h, the nuclear levels of compound 4s were decreased (data not shown, see Zhang et al., J. of Med. Chem. 54, 1288-1297 (2011)). To study the effects of these compounds on β-catenin localization, LS174 cells were treated with 10 μM of compound 4r for 24 h. The cells were fixed and β-catenin localization analyzed by immunofluorescence. The nuclear β-catenin levels were decreased in compound 4r treated cells compared with the DMSO-treated cells. However, significant levels of nuclear β-catenin were still detected in the nucleus of compound 4r treated cells, suggesting that compound 4r may also inhibit Wnt signaling through mechanisms other than regulating β-catenin level and localization. The downstream factors of β-catenin were analyzed and it was found that the protein levels of TCF4 and pygopus2 were reduced by compound 4r and resveratrol in CRC cells (FIG. 8C). RT-PCR assay suggested that compound 4r strongly inhibited the transcription of Wnt target genes. It also inhibited TCF4 genes, but had no significant effects on pygopus2 genes, which suggests that these halogenated stilbene analogs inhibit Wnt/mediated transcription at multiple levels (FIG. 8D).

Example 8

Target Identification for Halogenated Stilbene Analogs

Materials and Methods:
The following materials and methods have been used to generate the results in this and other examples in the application.

Western Blot and Cell Proliferation Assay.
The activity of fluorinated N,N-dialkylaminostilbenes (Fdias or FIDAS agents) on Wnt signaling activity in cancer cells were analyzed by Western blot with antibodies against Wnt target genes, such as e-Myc, Axin2. The effects of FIDAS agents on cancer cell growth were analyzed using Cell Viability Analyzer (Beckman Coulter, Vi-Cell XR). These assays have been described previously (see Zhang et al., J. of Med. Chem. 54, 1288-1297 (2011)).

Lentivirus-Mediated shRNA Assay.
ShRNA constructs for MAT2A and MAT2B were ordered from Sigma. 293T cells were transfected with lentivirus packaging plasmids psPAX2 and pMD2.G, as well as control or shRNA constructs for MAT2A or MAT2B shRNA plasmids. Lentivirus stock was collected 48 h after transfection. HT29, LS174T and Hep3B cell lines were infected by the lentivirus stock for 12 h, followed by sustained growth in fresh medium for 36-48 h. Infected cell lines were seeded in 12-well plate for proliferation assay.

ShRNA efficiency was tested by western blot using lysate from 293T cells co-transfected with pcDNA3.1-MAT2A/2B and plKO.1-shRNA plasmids.

Protein Purification.

To purify the FIDAS target, LS174T cell lysates were incubated with streptavidin beads and biotinylated FIDAS reagent 13 (see FIGS. 4 and 10 A) at 4°C overnight. The beads were washed 3 times with cell lysis buffer. Binding proteins were eluted with 2.5 mM D-Biotin. The purified samples were separated by 4-12% gradient SDS-PAGE and analyzed by silver staining or Sypro Ruby fluorescent staining. The protein bands specifically presented in the samples of the biotinylated analog were excised and analyzed by LC-MS/MS as described previously (See Zhang et al., Novel cross talk of Kruppel-like factor 4 and beta-catenin regulates normal intestinal homeostasis and tumor repression. Mol Cell Biol 2006, 26, 2055-64).

MAT2A and MAT2B were cloned into pGEX6p3 Vector. The constructs were transfected into E. coli BL21. The GST-fusion proteins were induced by IPTG and purified using glutathione beads as described previously (See Liu, beta-Trcp couples beta-catenin phosphorylation-degradation and regulates Xenopus axis formation. Proc Natl Acad Sci USA 1999, 96, 6273-8). For the binding assay, purified proteins were incubated with streptavidin beads and biotinylated FIDAS 13 described above. Eluted proteins were analyzed by western blot with antibodies against GST, MAT2A or MAT2B.

SAM and SAH Analysis by LC-MS/MS.
The LC-MS/MS system consisted of two Varian ProStar 210 LC Pumps coupled with a Varian 1200L triple quadrupole mass spectrometer. The separation was performed on a Hypercarb column (50 mm×2.1 mm, 3 mm, Thermo Scientific #35003-052130). Gradient elution started with 98%
solution A (0.1% formic acid in water), followed by an increase to 38% solution B (0.1% formic acid in acetonitrile) in 8 min. The column was then flushed with 90% B for 5 min and regenerated with 98% A for another 8 min. The flow rate was 0.25 mL/min. Between the 3rd and 11th min, the eluent was switched to the ion source of the mass spectrometer. The precursor product transitions for SAM (m/z 359→250), SAH (m/z 385→250) and [d-4]-SAH (m/z 389→436) were monitored. The optimized ion source parameters were: Capillary temperature 320 °C. The heater was set to 50 °C. The drying gas and nebulizing gas were set to 20 and 50 psi, respectively.

Cell Based SAM Analysis.

LS174T cells were cultured in RPMI1640 medium containing 5% FBS. Cells were treated with FIDAS reagents for 24 h or 48 hours. Cells were harvested and weighted. Perchloric acid (0.4M) was added to cell pellet (100 μl/10 mg) for deproteinization. The sample was mixed vigorously and centrifuged at 10,000 g. 60 μl of supernatant was mixed with 20 μl internal standard (5 μg/ml of SAH-d₆). Sample was adjusted to pH 5-7 with 2.5 M K₂HP₂O₄ and kept on ice for 15 min to precipitate potassium perchlorate. Samples were centrifuged 25,000 V for 15 min. 5 μl of supernatants were analyzed by LC-MS/MS using a modified method based on a previous publication (see Krijt et al., J Chromatogr B Analyt Technol Biomed Life Sci 877, 2061-6, (2009)). SAM and SAH standard were prepared by serial dilutions with 0.4 M perchloric acid (PCA), the individual calibration points were 0.05, 0.5, 5, 50 μg/ml.

SAM Synthesis.

5 mg purified MAT2A was incubated with 1 mM L-methionine and 1 mM ATP in 500 μl reaction solution (50 mM Tris.Cl, 50 mM KCl, 10 mM MgCl₂) for 5 min at 25 °C. The reaction was stopped with 250 μl 0.4 M perchloric acid and neutralized with 2.5 M K₂HP₂O₄. The samples were kept on ice for 15 min to precipitate potassium perchlorate as described above. SAM was analyzed by LC-MS/MS.

In this example, by using the biotinylated compounds of the present disclosure, it was possible to purify and identify twice at the target for the halogenated stilbene analogs described herein. Since MAT2A and MAT2B bind each other and form a complex, to determine which subunit directly interacts with FIDAS reagents, recombinant MAT2A and MAT2B were purified and tested for interaction with FIDAS. Briefly, GST-MAT2A and GST-MAT2B fusion proteins were expressed and purified from E. coli. These proteins were incubated with streptavidin beads with or without biotinylated derivative 13 (Fig. 9A). The binding proteins were eluted by 2.5 mM D-biotin and analyzed by Western blot with an anti-GST-Ab. It was found MAT2A directly binds to biotinylated FIDAS reagents, MAT2B binds FIDAS reagents indirectly through MAT2A (Fig. 10).

The Effects of Halogenated Stilbene Analogs on MAT2A Enzyme Activity

Methionine adenosyltransferases catalyze the reaction of S-adenosylmethionine (SAM or AdoMet) synthesis from ATP and L-methionine. In mammals, there are three types of methionine adenosyltransferases, MATI/III and MATII. MATI and III are tetramer or dimer of α subunit (encoded by MAT1A) and are expressed in adult liver. MAT2A encodes the catalytic subunit (ε2) of type II methionine adenosyltransferases. MAT2B encodes the regulating subunit of ε2. MAT2A and MAT2B are widely expressed in proliferating cells and cancers. MAT2A controls the cellular levels of SAM, which is the major methyl donor for many cellular methylation reactions, including DNA methylation and protein methylation.

To test if FIDAS reagents inhibit the enzymatic activity of MAT2A, an LC-MS/MS method was developed to detect and analyze AdoMet (SAM) and SAH (S-adenosylhomocysteine) (data not shown). Furthermore, an in-vitro method was developed to synthesize SAM from L-methionine and ATP. The results show that both resveratrol and compound 4r inhibit MAT2A activity in SAM synthesis, and that 10 μM of compound 4r reduces MAT2A activity in LS174 cells more significantly than 30 μM of resveratrol. These data suggest that 4r is significantly more potent than resveratrol in MAT2A inhibition (Fig. 11A). A test of another halogenated stilbene analog in an assay for inhibition of SAM and SAH showed that compound 4dd was even more potent than 4r in inhibition of MAT2A and reduction of SAM and SAH (Figs. 11B and 11C). In Figs. 11B and 11C, the effects of 3 μM of 4dd was compared with the 10 nM of 4r and 30 μM of resveratrol in causing reduction in SAM and SAH concentrations, respectively. These results show that compound 4dd is even more potent than compound 4r which is significantly more potent than resveratrol.

The Effects of MAT2A and MAT2B Genes Inhibition on Cell Proliferation

In this example, the effects of inhibition of MAT2A and MAT2B genes on cell proliferation were studied. To study the biological function of MAT2A and MAT2B in cell proliferation, the expression of MAT2A or MAT2B genes were knocked down by shRNAs (Figs. 12A and 12B). Both MAT2A and MAT2B shRNAs inhibited proliferation of liver cancer cells Hep3B (Fig. 12C). To test if MAT2A and MAT2B are required for colon cancer cell proliferation, MAT2A and MAT2B genes were knocked down in colon cancer cells, LS174T and HT29. In a time-course study for the effects of MAT2A and MAT2B inhibition on cell proliferation in LS174T and HT29, it was determined that both MAT2A and MAT2B shRNAs inhibit proliferation of colon cancer cells, and that inhibition of MAT2A is more effective in inhibition of cancer cell proliferation than inhibition of MAT2B (Figs. 13A and 13B).

The Effects the Metabolites of the Halogenated Stilbene Analogs on Cell Proliferation In-Vitro

As previously shown, several metabolites of the halogenated stilbenes of the present disclosure were synthesized...
Example 12

The Effects the Metabolites of the Halogenated Stilbene Analogs on Cell Proliferation In-Vivo in Mice

In this study, the oral efficacy of the metabolites of halogenated stilbene analogs were tested in mice. Xenografted nude mice were developed according to the protocol described above and in Zhang et al., J. of Med. Chem. 54, 1288-1297 (2011). Briefly, HT29 cells were injected subcutaneously into the flanks of nude mice. The mice were then treated with 20 mg/kg compound 4dd dissolved in PEG400 by gavage. As described in Example 7, an IP injection of compound 4r dissolved in corn oil inhibited xenograft tumor growth. Here, it was also shown that the halogenated stilbene analogs of the present disclosure can also be dissolved in other solvents such as PEG400 and cyclicextran.

The results show that 4dd significantly inhibits the growth of xenografted tumors without any adverse effect on body weight (FIG. 16).

Example 13

Halogenated Stilbene Analogs Inhibit Other Cancer Types

As discussed above, the halogenated stilbene analogs of the present disclosure bind to MAT2A and inhibit the enzyme function which leads to inhibition of cancer cell proliferation. Since, for example, in liver cancer, it has been shown that the expression of MAT1A is decreased while the expression of MAT2A is increased (see Cai et al., Hepatology 24, 1090-7 (1996)), Applicants hypothesized that the compounds of the present disclosure should inhibit proliferation of other types of cancers, particularly those in which the MAT2A activity or expression is increased.

To test this hypothesis, a number cancer cell lines were treated with the halogenated stilbene analogs of the present disclosure. The results show that the halogenated stilbene analogs are capable of inhibiting other cancer types as well. As shown in FIG. 17, the compounds of the present disclosure inhibited cell proliferation of breast cancer (FIG. 17A), lung cancer (FIGS. 17B and C), carcinoid tumor (FIG. 17D) and prostate cancer (FIG. 17E) cell lines.

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<223> OTHER INFORMATION: Lgr5 primer

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Thr Gly Ala Cys
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<210> SEQ ID NO 15
<211> LENGTH: 20
<212> TYPE: PRT
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
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<400> SEQUENCE: 15
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Cys Thr Thr Gly
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<210> SEQ ID NO 16
<211> LENGTH: 20
<212> TYPE: PRT
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
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<400> SEQUENCE: 16
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Thr Gly Ala Gly
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What is claimed is:

1. A method of treating liver cancer or colon cancer, the method comprising administering to a patient in need of such treatment an effective amount of a compound according to formula (I):

\[ X - \text{Ar}_1 - CR^a - CR^b - \text{Ar}_2 \]  

or a pharmaceutically acceptable salt thereof, wherein R^a and R^b are independently H, alkyl, halo, alkoxy, cyano; X represents at least one halogen on Ar_1; Ar_1 is phenyl and Ar_2 is pyridyl; provided that Ar_2 contains at least one NR^c R^d Z substituent on Ar_2 where R^c is H, alkyl, alkoxy, aryl, heteroaryl, R^d is an unsubstituted alkyl group, Z is an unshared pair of electrons, H, alkyl, oxygen.

2. The method according to claim 1, wherein Ar_2 is pyridyl substituted with alkylamino, or dialkylamino.

3. The method according to claim 1, wherein X is one, two or three fluorine and/or chlorine on Ar_1.

4. The method according to claim 1, wherein X represents at least one fluorine and at least one chlorine on Ar_1.

5. The method according to claim 1, wherein, X is one or more fluorine and/or chlorine.

6. The method according to claim 1, wherein R^c is H or a lower alkyl and R^d is a lower unsubstituted alkyl.

7. The method according to claim 1, wherein X is one or more fluorine and/or chlorine and R^d is H or a lower alkyl and R^d is a lower unsubstituted alkyl.

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