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(54) Title: METHODS OF DIAGNOSING AND TREATING MOTOR NEURON DISEASES

(57) Abstract: A method of treating a motor neuron disease (MND) in a subject in need thereof is provided. The method comprising administering to the subject a therapeutically effective amount of an agent capable of enhancing processing of a pre-mi RNA, thereby treating the MND in the subject.



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METHODS OF DIAGNOSING AND TREATING MOTOR NEURON DISEASES

FIELD AND BACKGROUND OF THE INVENTION

The present invention, in some embodiments thereof, relates to methods of
5 diagnosing and treating motor neuron diseases.

Motor neuron diseases (MND) and frontotemporal dementia belong to a group of
neurological disorders attributed to the destruction of motor neurons of the central
nervous system and degenerative changes in the motor neuron pathway. Such diseases
are different from other neurodegenerative diseases including Parkinson's disease,
10 Alzheimer's disease, olivopontocerebellar atrophy, etc., which are caused by the
destruction of neurons other than motor neurons. Typically, MNDs are progressive,
degenerative disorders that affect upper and lower motor neurons, leading to successive
global muscular denervation. Generally, MNDs strike in middle age, although a wide
age range of symptomatic disease onset can be observed, spanning from age 18 to 85
15 for several already studied mutants. Symptoms may include difficulty swallowing, limb
weakness, slurred speech, impaired gait, facial weakness and muscle cramps. At the end
stage of the disease, the respiratory musculature loses its innervation due to the death of
motor neurons, which is usually the final cause of death of ALS patients. The cause(s) of
most MNDs are not known, but environmental, toxic, viral or genetic factors are all
20 suspects.

Motor neurons, including upper motor neurons and lower motor neurons, affect
voluntary muscles, stimulating them to contract. Upper motor neurons originate in the
cerebral cortex and send fibers through the brainstem and the spinal cord, and are
involved in controlling lower motor neurons. Lower motor neurons are located in the
25 brainstem and the spinal cord and send fibers out to muscles. Lower motor neuron
diseases are diseases involving lower motor neuron degeneration. When a lower motor
neuron degenerates, the muscle fibers it normally activates become disconnected and do
not contract, causing muscle weakness and diminished reflexes. Loss of either type of
neurons results in weakness, muscle atrophy (wasting) and painless weakness are the
30 clinical hallmarks of MND (for further clinical definition see Online Mendelian
Inheritance in Man[®]).

Amyotrophic Lateral Sclerosis (ALS) is a fatal motor neuron disease characterized by a loss of pyramidal cells in the cerebral motor cortex (i.e., giant Betz cells), anterior spinal motor neurons and brain stem motor neurons, and degeneration thereof into pyramidal cells. ALS shows, from a clinical aspect, both upper motor
5 neurons and lower motor neurons signs, and shows rapid clinical deterioration after onset of the disease, thus leading to death within a few years.

Like many other motor neuron diseases, only a small percentage (about 10 % -20 %) of ALS is inherited. Genetic epidemiology of ALS has revealed at least 12 chromosome locations accountable for the inheritance of disease (ALS1 to ALS12).
10 Among these, several genes have been identified. The first was identified in 1993 as the cytosolic Cu/Zn superoxide dismutase (SOD-1) gene that accounts for 20 % of the autosomal dominant form of ALS (Rosen et al., 1993, Nature, 1993 Mar 4;362(6415):59-62).

Frontotemporal Dementia is a neurodegenerative disease of humans which share
15 in common with ALS etiopathological genetic causes, including mutations in genes such as TDP-43 and FUS. In addition a fraction of the patients populations suffers from both Frontotemporal Dementia and ALS. Thus these diseases are on one molecular and clinical spectrum.

Riluzole is the sole drug approved for ALS in U.S. and Japan. Riluzole was
20 originally developed as an anticonvulsant inhibiting glutamate release and has been reported in several clinical trials to exhibit only slight efficacy for the survival of ALS patients (Rowland L P and Shneider N A, 2001, N Engl J Med, 344, 1688-1700; and Turner M R and Parton M J, 2001, Semin Neurol 21: 167-175).

microRNAs (also known as miRNAs) are 20- to 24-nucleotide (nt) RNA
25 molecule members of the family of non-coding small RNAs. microRNAs were identified in mammals, worms, fruit flies and plants and are believed to regulate the stability of their target messenger RNA (mRNA) transcripts in a tissue- and cell type-specific manner. Principally, micro-RNAs regulate RNA stability by either binding to the 3'-untranslated region (3'-UTR) of target mRNAs and thereby suppressing
30 translation, or in similar manner to siRNAs, binding to and destroying target transcripts in a sequence-dependent manner.

microRNAs have been implicated in various neurological diseases such as ALS, Fragile X syndrome, spinal muscular atrophy (SMA), early onset parkinsonism (Waisman syndrome) and X-linked mental retardation (MRX3).

WO2010/06424 teaches the use of an agent which upregulates an activity or
5 amount of miRNA-9 or miRNA-9* in the preparation of a medicament for the treatment of a motor neuron diseases (MNDs) including ALS.

U.S. Patent Application 20060247193 teaches administration of over 100 miRNAs for the treatment of MNDs including ALS.

U.S. Patent Application 20090246136 teaches administration of miR-206 and/or
10 miR-1 for the treatment of MNDs including ALS.

Additional relevant background art includes U.S. Patent Application 20080176766.

Interestingly, specific mutations in genes encoding for RNA binding proteins, such as TDP-43 and FUS^{1,2} have been associated with the etiology of ALS³⁻⁶.

15 Buratti et al. 2010 (RNA Biology 7:4(420-429) describe a role of TDP-43 and FUS/TLS in RNA metabolism. Mislocalization of these proteins can alter the functioning of the Drosha processing enzyme both with regard to the general miRNA cellular population and for selected members.

Buratti et al. 2010 FEBS J. 2268-2281 shows that TDP-43 affect selected
20 miRNA levels.

Kawahara et al. 2012 PNAS 109(9):3347-3352 shows that cytoplasmic TDP-43 interacts with the Dicer complex and promotes processing of a selected population of miRNAs via binding to the terminal loops.

Neuronal cytoplasmic protein aggregation and defective RNA metabolism were
25 suggested to be common pathogenic mechanisms involved in ALS and possibly in other neurodegenerative disorders. Furthermore, polymorphic miRNA-mediated gene regulation has been specifically suggested as a mechanism for neurodegeneration, including motor neuron diseases⁷⁻¹⁰. In addition, it was recently demonstrated that loss of miRNAs bioprocessing by inactivation of Dicer1 is sufficient to cause spinal
30 motoneuron degeneration¹¹.

Related background art:

U.S. 20120071539 discloses methods and compositions comprising chemical compounds that modulate the silencing of a polynucleotide of interest in a cell are provided. Such chemical compounds when used in combination with an appropriate silencing element can be used to modulate (increase or decrease) the level of the polynucleotide targeted by the silencing element. Methods of using such compositions both in therapies involving RNAi-mediated suppression of gene expression, as well as, in vitro methods that allow for the targeted modulation of expression of a polynucleotide of interest are provided. Pharmaceutical or cosmetic compositions comprising such compounds and silencing elements also are disclosed. Methods for screening a compound of interest for the ability to modulate the activity of a heterologous silencing element also are provided.

Additional background related art: U.S. 6,756,369.

15 SUMMARY OF THE INVENTION

According to an aspect of some embodiments of the present invention there is provided a method of treating a motor neuron disease (MND) in a subject in need thereof, the method comprising administering to the subject a therapeutically effective amount of an agent capable of enhancing processing of a pre-miRNA, thereby treating the motor neuron disease (MND) in the subject.

According to an aspect of some embodiments of the present invention there is provided an agent capable of enhancing processing of a pre-miRNA for use in treating a motor neuron disease (MND) in a subject in need thereof.

According to some embodiments of the invention, the agent capable of enhancing processing of pre-miRNA is selected from the group consisting of a nuclear processing enhancer, a nuclear export enhancer and a cytoplasmic processing enhancer.

According to some embodiments of the invention, the cytoplasmic processing enhancer comprises a Dicer enhancer.

According to some embodiments of the invention, the Dicer enhancer comprises a quinolone.

According to some embodiments of the invention, the Dicer enhancer is selected from the group consisting of enoxacin, ciproflaxin and ofloxacin.

According to some embodiments of the invention, the quinolone comprises enoxacin.

According to some embodiments of the invention, the MND comprises amyotrophic lateral sclerosis (ALS).

5 According to an aspect of some embodiments of the present invention there is provided a method of treating an Amyotrophic Lateral Sclerosis (ALS) in a subject in need thereof, the method comprising administering to the subject a therapeutically effective amount of an agent capable of enhancing processing of a pre-miRNA and an anti-ALS agent, thereby treating the ALS in the subject.

10 According to an aspect of some embodiments of the present invention there is provided an agent capable of enhancing processing of a pre-miRNA and an anti-ALS agent for use in treating an Amyotrophic Lateral Sclerosis (ALS) in a subject in need thereof.

15 According to some embodiments of the invention, the anti-ALS agent comprises a Riluzole.

According to an aspect of some embodiments of the present invention there is provided a pharmaceutical composition comprising as an active ingredient an agent capable of enhancing processing of a pre-miRNA, an anti-ALS agent and a pharmaceutically acceptable carrier or diluent.

20 According to an aspect of some embodiments of the present invention there is provided an article of manufacture comprising an agent capable of enhancing processing of a pre-miRNA and an anti-ALS agent being packaged in a packaging material and identified in print, in or on the packaging material for use in the treatment of ALS.

25 According to some embodiments of the invention, the agent capable of enhancing processing of a pre-miRNA comprises a quinolone.

According to some embodiments of the invention, the quinolone comprises enoxacin.

30 According to an aspect of some embodiments of the present invention there is provided a method diagnosing a MND, the method comprising analyzing in a sample of a subject in need thereof:

- (i) total miR expression; and optionally

(ii) total pre-miR expression, wherein a down-regulation in the (i) or (i)/(ii) beyond a predetermined threshold is indicative of the MND.

According to an aspect of some embodiments of the present invention there is provided a method diagnosing a MND, the method comprising analyzing in a sample of
5 a subject in need thereof:

(i) a miR expression; and
(ii) an expression of a precursor of the miR, wherein a down-regulation in (i)/(ii) beyond a predetermined threshold is indicative of the MND.

According to some embodiments of the invention, the miR is miR-9.

10 According to some embodiments of the invention, the MND is selected from the group consisting of ALS, primary lateral sclerosis, progressive muscular atrophy, pseudobulbar palsy, progressive bulbar palsy, lower motor neuron disease and spinal muscular atrophy.

According to some embodiments of the invention, the motor neuron disease
15 comprises amyotrophic lateral sclerosis (ALS).

According to some embodiments of the invention, the ALS is associated with a gene having a mutation associated with an impaired RNA metabolism.

According to some embodiments of the invention, the gene is selected from the group consisting of TDP-43 and FUS.

20 According to some embodiments of the invention, the ALS is an inherited ALS.

According to some embodiments of the invention, the ALS is a sporadic ALS.

According to some embodiments of the invention, the sample comprises a cerebrospinal fluid (CSF) sample or a blood sample.

According to an aspect of some embodiments of the present invention there is
25 provided a method of identifying an agent for the treatment of a MND, the method comprising:

(a) contacting a motor neuron of an ALS patient or an ALS model with a candidate agent;

(b) analyzing prior to (a) and following (a):

30 (i) total miR expression in the motor neuron; and optionally

(ii) total pre-miR expression in the motor neuron,

wherein an up-regulation in the (i) or (i)/(ii) beyond a predetermined threshold following (a) as compared to prior to (a), is indicative of that the candidate compound is a therapeutic agent for the treatment of MND.

Unless otherwise defined, all technical and/or scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which the invention pertains. Although methods and materials similar or equivalent to those described herein can be used in the practice or testing of embodiments of the invention, exemplary methods and/or materials are described below. In case of conflict, the patent specification, including definitions, will control. In addition, the materials, methods, and examples are illustrative only and are not intended to be necessarily limiting.

BRIEF DESCRIPTION OF THE DRAWINGS

The patent or application file contains at least one drawing executed in color. Copies of this patent or patent application publication with color drawing(s) will be provided by the Office upon request and payment of the necessary fee.

Some embodiments of the invention are herein described, by way of example only, with reference to the accompanying drawings. With specific reference now to the drawings in detail, it is stressed that the particulars shown are by way of example and for purposes of illustrative discussion of embodiments of the invention. In this regard, the description taken with the drawings makes apparent to those skilled in the art how embodiments of the invention may be practiced.

In the drawings:

FIGs. 1A-C show that miRNAs are globally reduced in motoneurons of sporadic ALS patients. (FIG. 1A) Representative fluorescent *in-situ* hybridization micrographs for miR-9 in non-neurodegeneration (control) and ALS motoneurons (patients). Scale bar indicates 10 μ M. Bar-graph revealing miR-9 (FIG. 1B) or miR-124 (FIG. 1C) signal-intensity, quantified in 300 different motoneurons, after *in-situ* performed on samples from two ALS-patients and two non-ALS controls. Arbitrary units, normalized to the expression-signal of small-RNA U6.

FIGs. 2A-H show impaired miRNA processing upon expression of ALS-causing TDP-43 or FUS mutants can be rescued by Enoxacin. Transfection of Doxycyclin-inducible forms of ALS-causing (FIG. 2A) TDP-43^{A315T}, (FIG. 2B) TDP-

43^{M337V}, (FIG. 2C) FUS^{495X}, or of (FIG. 2D) FUS^{R521G} mutants, into NSC-34 cells results in downregulation of mature miRNAs, whilst pre-miRNA levels are correspondently upregulated. Depicted are bar-graph representations of relative miRNA expression levels in cells, transfected with GFP and treated with Doxycyclin, compared to the expression of the small RNAs U6 or 5S, on a log₂ scale. Introduction of 100 μM Enoxacin recovers the downregulation of mature miRNA expression in HEK293 cells transfected with ALS-causing mutants: (FIG. 2E) TDP-43^{A315T} or (FIG. 2F) FUS^{495X} and reverses pre-miRNA upregulation by (FIG. 2G) TDP-43^{A315T} or (FIG. 2H) FUS^{495X}. Data normalized to miRNA levels in cultures that were transfected with GFP and treated with Doxycyclin and to the expression of the small RNAs U6 or 5S. Pre-miRNA expression normalized to beta-actin. Statistics were performed using two-tailed Student's t-test with post-hoc Benjamini-Hochberg corrections. * *p-value* < 0.05; ** *p-value* < 0.005.

FIG. 3 shows impaired miRNA processing upon expression of ALS-causing TDP-43 or FUS mutants can be rescued by Enoxacin. The impact of FUS495X was globally studied by deep sequencing of pre-miRNAs and mature miRNAs, revealing widespread repression of Dicer activity and miRNA maturation.

FIGs. 4A-D show Enoxacin impact on disease progression. (FIG. 4A) Continuous administration of Enoxacin into the drinking water of SOD1 G93A mice had marginal effect on overall lifespan but exhibited beneficial impact on (FIG. 4B) neurological score, (FIG. 4C) gross strength in a hang-wire test and (FIG. 4D) on overall locomotive function in a computerized cat-walk assay.

FIGs. 5A-B show that miR-expression is altered in familial forms of SOD1 mutant ALS and can be normalized in vitro by Enoxacin. Introduction of 100 μM Enoxacin recovers the downregulation of mature miRNA expression in HEK293 cells transfected with ALS-causing mutants: (FIG. 5A) SOD1^{G93A} and reverses pre-miRNA upregulation by (FIG. 5B) Sod1^{G93A}. Data normalized to miRNA levels in cultures that were transfected with GFP and treated with Doxycyclin and to the expression of the small RNAs 5S. Pre-miRNA expression normalized to beta-actin. Statistics were performed using two-tailed Student's t-test with post-hoc Benjamini-Hochberg corrections. * *p-value* < 0.05; ** *p-value* < 0.005.

DESCRIPTION OF SPECIFIC EMBODIMENTS OF THE INVENTION

The present invention, in some embodiments thereof, relates to methods of diagnosing and treating motor neuron diseases.

Before explaining at least one embodiment of the invention in detail, it is to be understood that the invention is not necessarily limited in its application to the details set forth in the following description or exemplified by the Examples. The invention is capable of other embodiments or of being practiced or carried out in various ways.

Amyotrophic Lateral Sclerosis (ALS) is a neurodegenerative disease of the human motor system. ALS-causing mutations were recently discovered in genes encoding for RNA-binding proteins and were associated with dysregulated RNA metabolism (mostly downregulated miRNA levels in ALS subjects).

While conceiving the present invention, the present inventors have hypothesized that since the general (non-specific) micro RNA (miRNA) metabolism is altered in motor neuron diseases (MNDs), the reversal of this altered metabolism can be used as a novel therapeutic modality for the treatment of such diseases.

The present inventors have affirmed this by showing that microRNAs are broadly downregulated in ALS motoneurons (Figures 1A-C and Figures 2A-D), whilst their precursors are present at high levels (Figures 2A-D and Figure 3). The present inventors have further shown that ALS-causing mutations in RNA binding proteins hamper the dicing of microRNA precursors, and that this activity is restored by the fluoroquinolon, enoxacin, on the genetic background of ALS-causing mutations (TDP-43, FUS and SOD1, see Figures 2E-H and Figure 5C-D), suggesting the global nature of the observed miRNA dysregulation in the presence of various disease causing mutants. The present inventors have further illustrated in an ALS mouse model that the deterioration in mouse neuromuscular function was slower under Enoxacin treatment as assayed by neurological score (Figure 4b), hang-wire test (Figure 4c) and automated cat-walk study (Figure 4d). Thus, dysregulated microRNAs provide new mechanistic insight into ALS pathogenesis and a potential therapeutic lead. Furthermore, the miRNA expression profile can be used in the diagnosis of MNDs in general and ALS in particular.

Thus, according to an aspect of the invention there is provided a method of treating a motor neuron disease (MND) in a subject in need thereof, the method

comprising administering to the subject a therapeutically effective amount of an agent capable of enhancing processing of a pre-miRNA, thereby treating the motor neuron disease (MND) in the subject.

As used herein, the term "treating" includes abrogating, substantially inhibiting, 5 slowing or reversing the progression of a condition, substantially ameliorating clinical or aesthetical symptoms of a condition or substantially preventing the appearance of clinical or aesthetical symptoms of a condition.

The phrase "motor neuron disease (MND)" as used herein, refers to a neurological disorder that selectively destroys motor neurons. As such, diseases such as 10 Huntington's chorea are not classified as MNDs.

According to a further aspect of the invention, the subject suffers from Frontotemporal Dementia.

Examples of motor neuron diseases include, but are not limited to Amyotrophic Lateral Sclerosis (ALS), also known as Lou Gehrig's Disease, primary lateral sclerosis, 15 progressive muscular atrophy, pseudobulbar palsy, progressive bulbar palsy, lower motor neuron disease and spinal muscular atrophy 1 (SMA1, Werdnig-Hoffmann Disease), Spinal Muscular Atrophy Type 2 (SMA2) and Spinal Muscular Atrophy Type 3 (SMA3, Kugelberg-Welander Disease) and Charcot-Marie-Tooth Disorders.

According to a specific embodiment the MND is amyotrophic lateral sclerosis 20 (ALS).

According to further specific embodiments, the subject is affected with MND or ALS in which changes in RNA metabolism are reported or can be determined according to the present teachings. Examples of mutations associated with changes in RNA 25 metabolism include, but are not limited to, mutations in TDP-43, FUS, ANG and SETX, (Chen et al., 2004; Greenway et al., 2006; Kabashi et al., 2008; Sreedharan et al., 2008; Kwiatkowski et al., 2009; Lagier-Tourenne and Cleveland, 2009; Vance et al., 2009).

As used herein, the term "subject" or "subject in need thereof" refers to a mammal e.g., a human being of any gender or age that has been diagnosed with MND. The disease (e.g., ALS) may be familial (inherited) or sporadic.

According to a further embodiment, the subject does not suffer from Chlamydia 30 infection.

As used herein "an agent capable of enhancing processing of a pre-miRNA" refers to a molecule or a composition which upregulates or activates any part of the miRNA processing pathway. Typically, the agent upregulates or activates the pathway downstream to the pre-miRNA production. This is because the present inventors have shown that pre-miRs are normally formed and even upregulated in ALS derived cells. The agent may be referred to as an "RNAi enhancer".

Following are some key components of the miRNA processing pathway, each of which can be upregulated or activated according to the teachings of the present invention.

Nuclear processing

A single pri-miRNA may contain from one to six miRNA precursors. These hairpin loop structures are composed of about 70 nucleotides each. Each hairpin is flanked by sequences necessary for efficient processing. The double-stranded RNA structure of the hairpins in a pri-miRNA is recognized by a nuclear protein known as DiGeorge Syndrome Critical Region 8 (DGCR8 or "Pasha" in invertebrates), named for its association with DiGeorge Syndrome. DGCR8 associates with the enzyme Drosha, a protein that cuts RNA, to form the "Microprocessor" complex. In this complex, DGCR8 orients the catalytic RNase III domain of Drosha to liberate hairpins from pri-miRNAs by cleaving RNA about eleven nucleotides from the hairpin base (two helical RNA turns into the stem). The product resulting has a two-nucleotide overhang at its 3' end; it has 3' hydroxyl and 5' phosphate groups. It is often termed as a pre-miRNA (precursor-miRNA).

Nuclear export

pre-miRNA hairpins are exported from the nucleus in a process involving the nucleocytoplasmic shuttle Exportin-5. This protein, a member of the *karyopherin* family, recognizes a two-nucleotide overhang left by the RNase III enzyme Drosha at the 3' end of the pre-miRNA hairpin. Exportin-5-mediated transport to the cytoplasm is energy-dependent, using GTP bound to the Ran protein.

Cytoplasmic processing

In cytoplasm, the pre-miRNA hairpin is cleaved by the RNase III enzyme Dicer. This endoribonuclease interacts with the 3' end of the hairpin and cuts away the loop joining the 3' and 5' arms, yielding an imperfect miRNA:miRNA* duplex about 22

nucleotides in length. Overall hairpin length and loop size influence the efficiency of Dicer processing, and the imperfect nature of the miRNA:miRNA* pairing also affects cleavage. Although either strand of the duplex may potentially act as a functional miRNA, only one strand is usually incorporated into the RNA-induced silencing complex (RISC) where the miRNA and its mRNA target interact.

Thus, according to embodiments of the invention, the agent capable of enhancing processing of pre-miRNA is selected from the group consisting of a nuclear processing enhancer, a nuclear export enhancer and a cytoplasmic processing enhancer.

According to specific embodiments of the invention, the agent upregulates by at least 5 %, 10 %, 20 %, 30 %, 40 %, 50 %, 60 %, 70 %, 80 % (e.g., 50 % or more) or even more, processing of the pre-miRNA as compared to pre-miRNA processing in an untreated sample of a MND affected subject (e.g., of cells carrying MND causing mutations).

Methods of assessing miRNA processing are well known in the art. For example, analyzing the levels of total miRNA as compared to pre-miRNA can be used as a strong indicator of miRNA processing and is exemplified in the Examples section which follows.

According to a specific embodiment, the agent is selected from the group consisting of a nuclear processing enhancer, a nuclear export enhancer and a cytoplasmic processing enhancer.

According to a further embodiment the cytoplasmic processing enhancer comprises a Dicer enhancer (i.e., upregulates or activates Dicer activity).

Ge Shan et al. 2008 Nature Biotechnology 26(8):933 teach a method of identifying modulators of the RNAi pathway. Such methods can be implemented in order to identify further agents which can be used along with the present teachings.

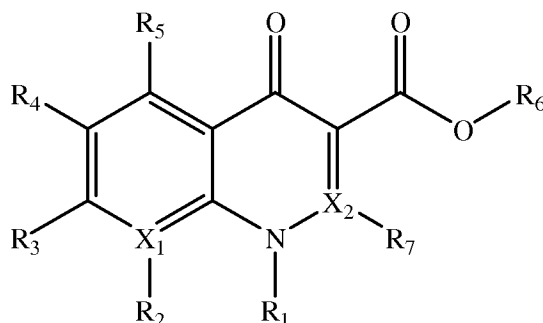
U.S. 20090306035 teaches quinolones as RNAi enhancers and is hereby incorporated by reference in its entirety.

Quinolone (or quinolone) compounds form a class of broad-spectrum antibiotics. Quinolones are believed to act by inhibiting the bacterial DNA gyrase and/or the topoisomerase IV enzyme. In this way, quinolones inhibit DNA replication and act bacterioidically. As such, quinolones are considered chemotherapeutic agents as opposed to a true antibiotic, because they prevent replication of the bacterial cell by

interfering with the genetic replication of the bacterium. Representative, non-limiting quinolone antibiotics are provided in Table 1 of U.S. 20090306035 and some are provided infra.

The pharmacophore common to quinolone antibiotics is provided in Formula (a):

5



wherein:

X_1 and X_2 are each independently carbon or nitrogen;

10 R_1 is selected from the group consisting of H, alkyl, substituted alkyl, alkylamino, cycloalkyl, substituted cycloalkyl, aryl, and substituted aryl;

R_2 can be present or absent and when present is selected from the group consisting of H, halo, alkyl, substituted alkyl, and alkoxy; or

15 R_1 and R_2 together form a portion of a 4- to 6-member heterocyclic ring structure, wherein the 4- to 6-member heterocyclic ring structure comprises atoms selected from the group consisting of carbon, nitrogen, oxygen, sulfur, and combinations thereof;

20 R_3 is selected from the group consisting of H, halo, alkyl, substituted alkyl, aryl, substituted aryl, cycloalkyl, substituted cycloalkyl, cycloheteroalkyl, substituted cycloheteroalkyl, heteroaryl, and substituted heteroaryl;

R_4 is halo;

R_5 is selected from the group consisting of H, alkyl, substituted alkyl, amino, alkoxy, hydroxyl, and halo;

R_6 is selected from the group consisting of H, alkyl, and substituted alkyl;

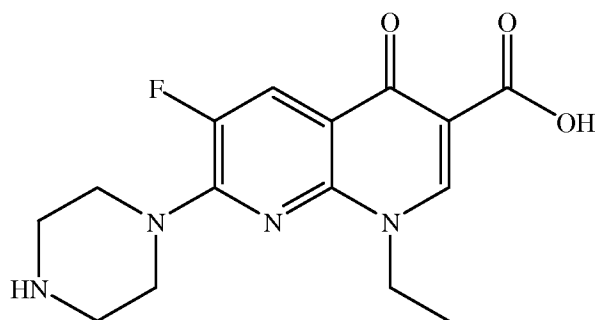
25 R_7 can be present or absent and when present is selected from the group consisting of H, alkyl, substituted alkyl, amino, alkoxy, hydroxyl, and halo; or

R₁ and R₇ together form a portion of a 4- to 6-member heterocyclic ring structure, wherein the 4- to 6-member heterocyclic ring structure comprises atoms selected from the group consisting of carbon, nitrogen, oxygen, sulfur, and combinations thereof; or

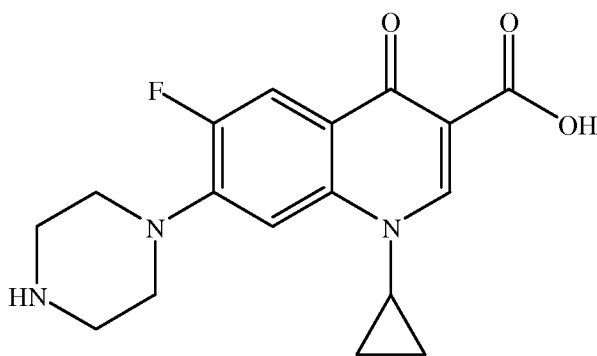
5 a pharmaceutically or cosmetically acceptable salt thereof.

In some embodiments, the quinolone compound of Formula (a) is selected from the group consisting of enoxacin, ciprofloxacin, and ofloxacin, the structures of which are provided in Scheme I.

10 Scheme I. Chemical Structures of Enoxacin, ciprofloxacin, and ofloxacin

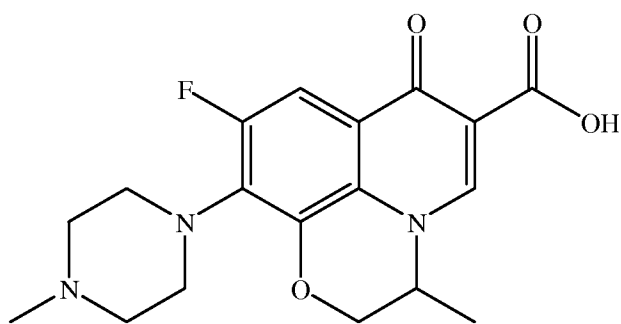


Enoxacin



Ciprofloxacin

15

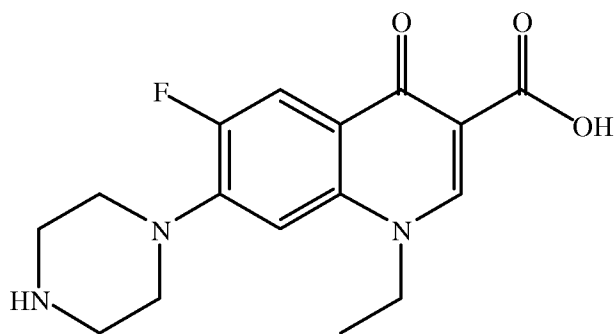


Ofloxacin

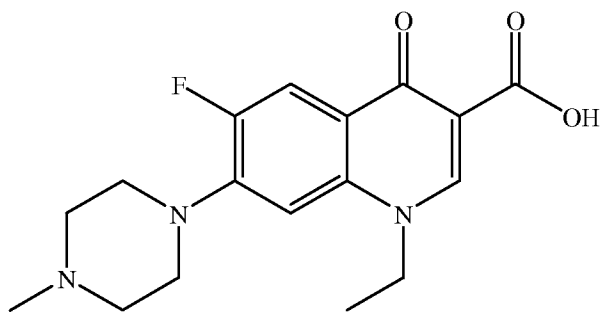
Enoxacin, ciprofloxacin, and ofloxacin generally are classified as "second generation" quinolones. Second generation quinolones also include, but are not limited to, fleroxacin, levofloxacin, lomefloxacin, nadifloxacin, norfloxacin, pefloxacin, rufloxacin, and tosufloxacin, the chemical structures of which are provided in Scheme II.

Scheme II. Chemical Structures of Second Generation Quinolones

10



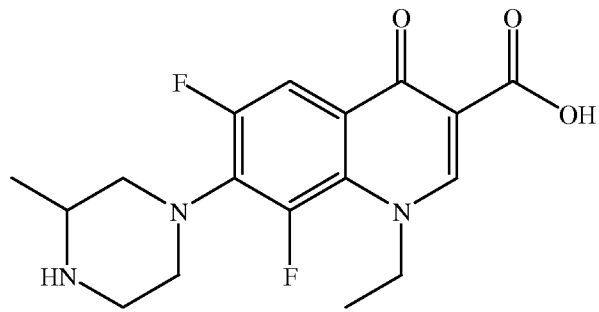
Norfloxacin



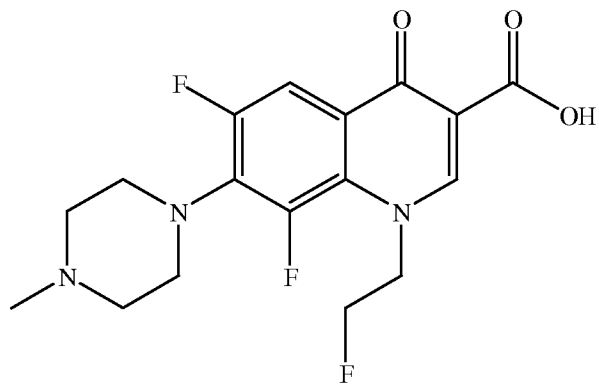
Pefloxacin

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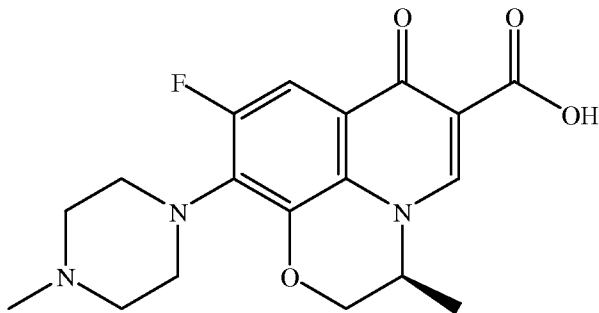
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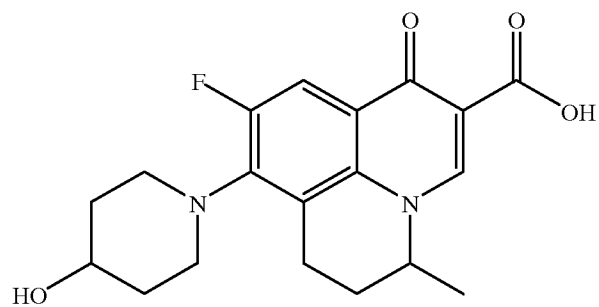
Lomefloxacin



Fleroxacin



Levofloxacin

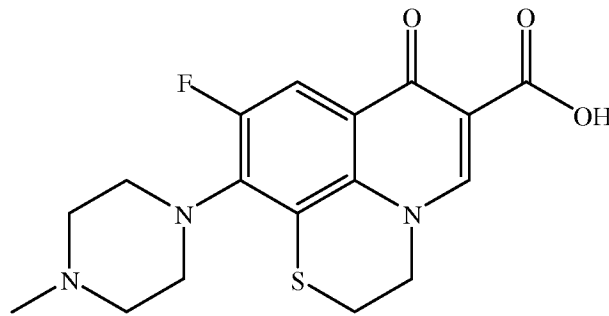


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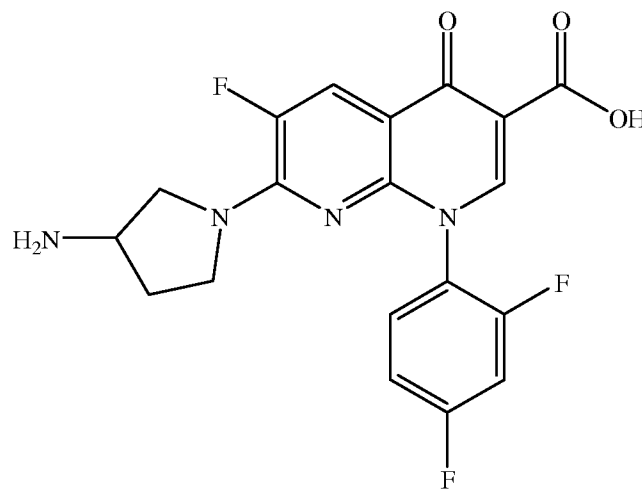
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Nadifloxacin



Rufloxacin

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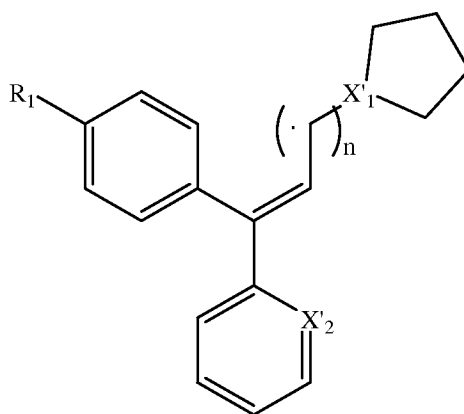


Tosufloxacin

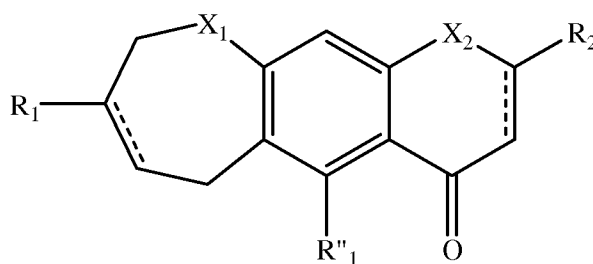
U.S. Patent Application Number 20120071539 teaches further enhancers of
10 RNAi.

(a) triprolidine, derivatives, and analogs thereof (formula b):

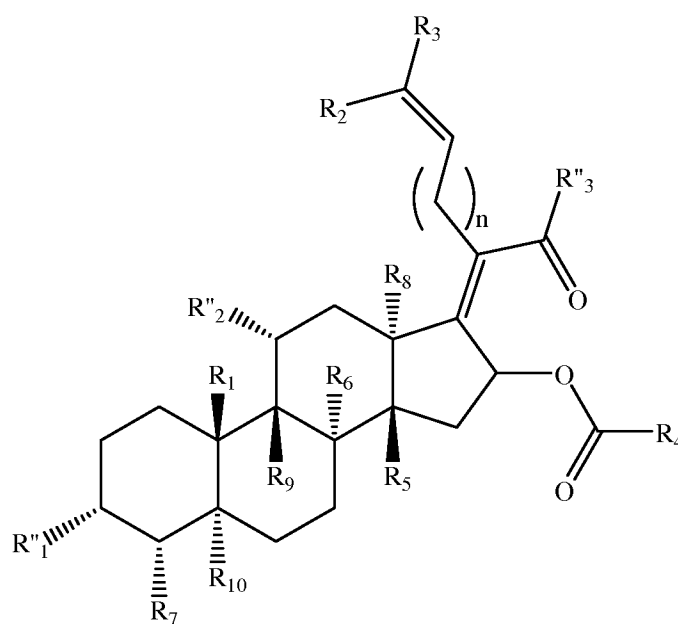
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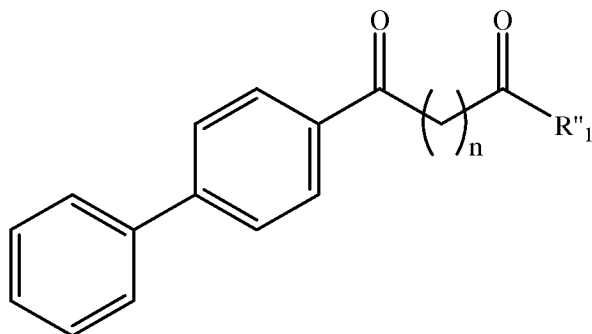
(b) dihydroptaeroxylin, derivatives, and analogs thereof (formula c):



5 (c) fusidic acid, derivatives, and analogs thereof (formula d):

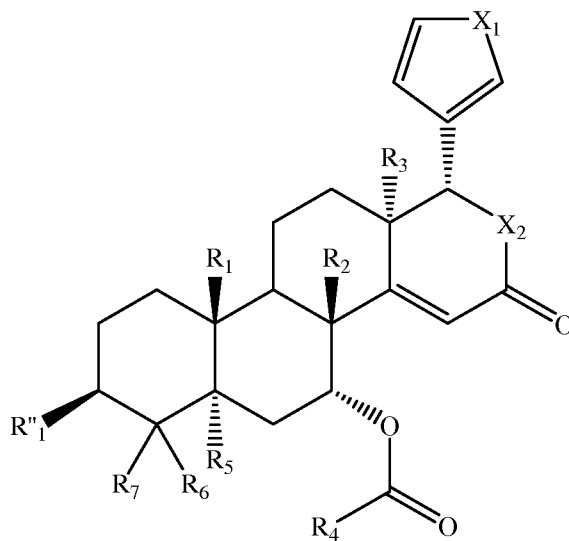


(d) fenbufen, derivatives, and analogs thereof (formula e):



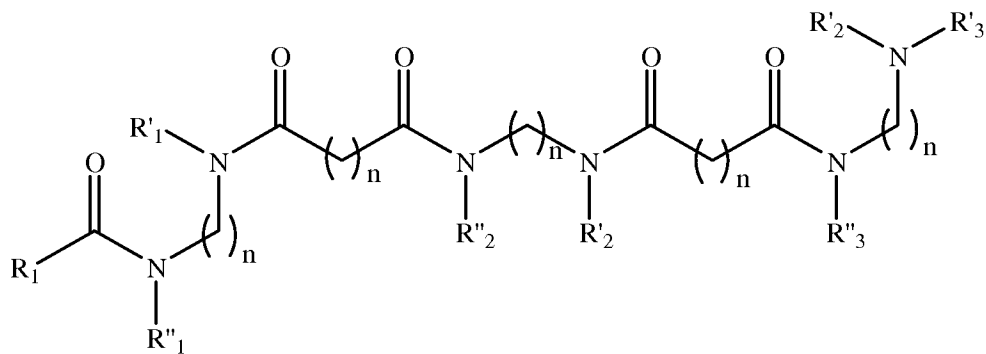
(e) 3-beta-hydroxydeoxydihydrodeoxygedunin, derivatives, and analogs thereof

5 (formula f):

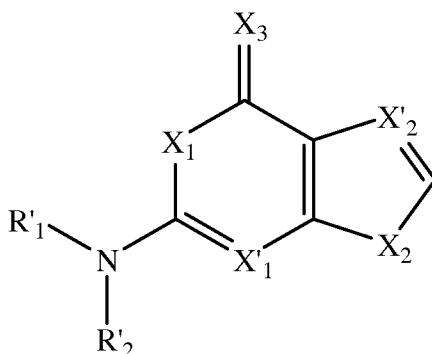


(f) deferoxamine, derivatives, and analogs thereof (formula g):

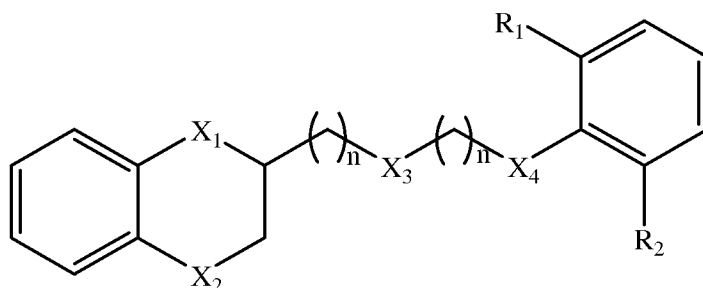
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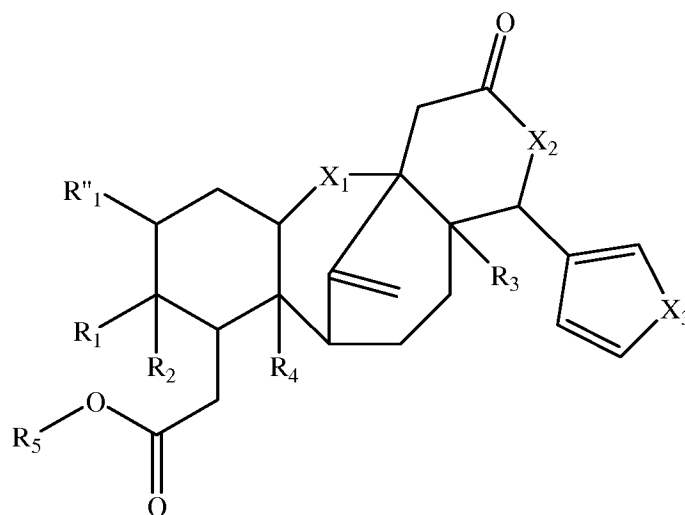
(g) thioguanine, derivatives, and analogs thereof (formula h):



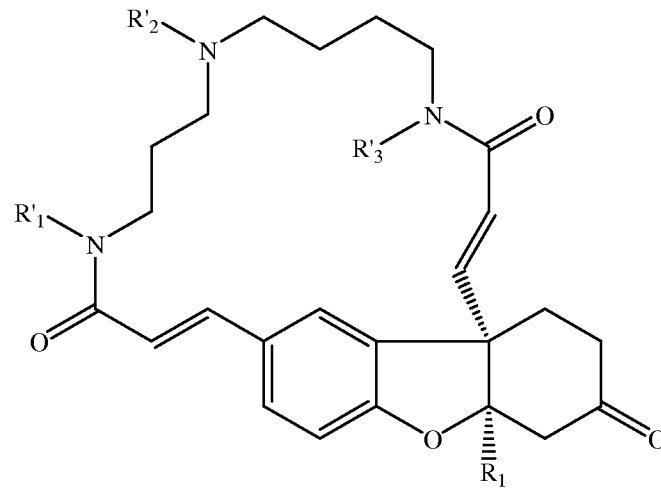
5 (h) 2-aminomethyl-1,4-benzodioxane, derivatives, and analogs thereof (formula i):



10 (i) 3- α -hydroxy-3-deoxyangolensic acid methyl ester, derivatives, and analogs thereof (formula j):

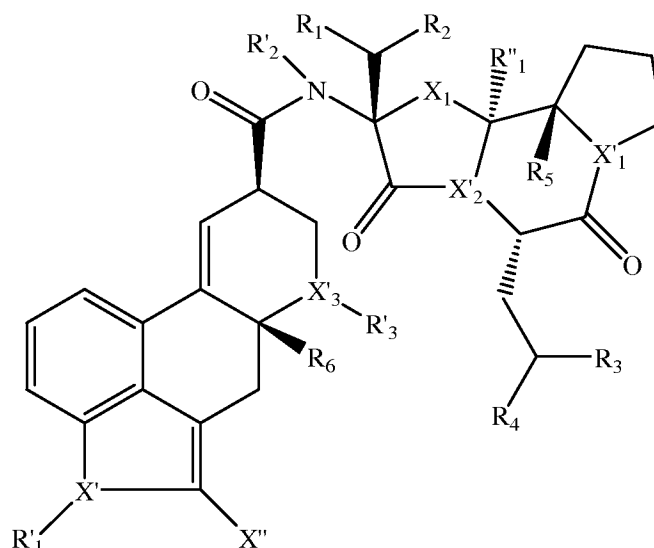


(j) lunarine, derivatives, and analogs thereof (formula k): and



5 (k) bromocriptine, derivatives, and analogs thereof (formula l):

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each n is independently an integer from 1 to 20;

5 a dashed line in a cyclic ring structure represents a bond that can be either present or absent in the ring;

each R_1 , R_2 , R_3 , R_4 , R_5 , R_6 , R_7 , R_8 , R_9 , and R_{10} is independently selected from the group consisting of H, alkyl, substituted alkyl, cycloalkyl, substituted cycloalkyl, aryl, and substituted aryl;

10 each R'_1 , R'_2 , and R'_3 is independently selected from the group consisting of H, alkyl, substituted alkyl, cycloalkyl, substituted cycloalkyl, aryl, substituted aryl, hydroxyl, and alkoxyl;

15 each R''_1 , R''_2 , and R''_3 is independently selected from the group consisting of -- OR_{11} and -- $O(C.dbd.O)-R_{12}$, wherein R_{11} and R_{12} are selected from the group consisting of H, alkyl, substituted alkyl, cycloalkyl, substituted cycloalkyl, aryl, and substituted aryl;

each X_1 , X_2 , X_3 , and X_4 is independently selected from the group consisting of CH_2 , O, S, and NR'_4 , wherein R'_4 is selected from the group consisting of H, alkyl, substituted alkyl, cycloalkyl, substituted cycloalkyl, aryl, substituted aryl, hydroxyl, and alkoxyl;

20 each X'_1 , X'_2 , and X'_3 is independently N or CH; and

each X'' is independently halogen; and

pharmaceutically and cosmetically acceptable salts thereof.

In some embodiments, the RNAi enhancer is selected from the group consisting of triprolidine, dihydropaeroxylin, fusidic acid, fenbufen, 3-beta-hydroxydeoxodihydrodeoxygedunin, deferoxamine, thioguanin, 2-aminomethyl-1,4-benzodioxane, 3-alpha-hydroxy-3-deoxyangloensic acid methyl ester, lunarine, bromocriptine, and pharmaceutically and cosmetically acceptable salts thereof.

According to a specific embodiment, the RNAi enhancer is enoxacin.

Enoxacin is sold under the following trade names Almitil, Bactidan, Bactidron, Comprecin, Enoksetin, Enoxen, Enroxil, Enoxin, Enoxor, Flumark, Penetrex, Gyramid, Vinone. The compound is an oral broad-spectrum fluoroquinolone antibacterial agent used in the treatment of urinary tract infections and gonorrhea.

While the following terms are believed to be well understood by one of ordinary skill in the art, the following definitions are set forth to facilitate explanation of the presently disclosed subject matter.

When the term "independently selected" is used, the substituents being referred to (e.g., R groups, such as groups R₁, R₂, and the like, or groups X₁ and X₂), can be identical or different. For example, both R₁ and R₂ can be substituted alkyls, or R₁ can be hydrogen and R₂ can be a substituted alkyl, and the like.

A named "R" or "X" group will generally have the structure that is recognized in the art as corresponding to a group having that name, unless specified otherwise herein. For the purposes of illustration, certain representative "R" and "X" groups as set forth above are defined below. These definitions are intended to supplement and illustrate, not preclude, the definitions that would be apparent to one of ordinary skill in the art upon review of the present disclosure.

As used herein the term "alkyl" refers to C1-20 inclusive, linear (i.e., "straight-chain"), branched, or cyclic, saturated or at least partially and in some cases fully unsaturated (i.e., alkenyl and alkynyl) hydrocarbon chains, including for example, methyl, ethyl, propyl, isopropyl, butyl, isobutyl, tert-butyl, pentyl, hexyl, octyl, ethenyl, propenyl, butenyl, pentenyl, hexenyl, octenyl, butadienyl, propynyl, butynyl, pentynyl, hexynyl, heptynyl, and alkenyl groups. "Branched" refers to an alkyl group in which a lower alkyl group, such as methyl, ethyl or propyl, is attached to a linear alkyl chain. "Lower alkyl" refers to an alkyl group having 1 to about 8 carbon atoms (i.e., a C1-8 alkyl), e.g., 1, 2, 3, 4, 5, 6, 7, or 8 carbon atoms. "Higher alkyl" refers to an alkyl group

having about 10 to about 20 carbon atoms, e.g., 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, or carbon atoms. In certain embodiments, "alkyl" refers, in particular, to C₁₋₈ straight-chain alkyls. In other embodiments, "alkyl" refers, in particular, to C₁₋₈ branched-chain alkyls.

Alkyl groups can optionally be substituted (a "substituted alkyl") with one or
5 more alkyl group substituents, which can be the same or different. The term "alkyl group
substituent" includes but is not limited to alkyl, substituted alkyl, halo, arylamino, acyl,
hydroxyl, aryloxy, alkoxy, alkylthio, arylthio, aralkyloxy, aralkylthio, carboxyl,
alkoxycarbonyl, oxo, and cycloalkyl. There can be optionally inserted along the alkyl
chain one or more oxygen, sulfur or substituted or unsubstituted nitrogen atoms, wherein
10 the nitrogen substituent is hydrogen, lower alkyl (also referred to herein as
"alkylaminoalkyl"), or aryl.

Thus, as used herein, the term "substituted alkyl" includes alkyl groups, as
defined herein, in which one or more atoms or functional groups of the alkyl group are
replaced with another atom or functional group, including for example, alkyl, substituted
15 alkyl, halogen, aryl, substituted aryl, alkoxy, hydroxyl, nitro, amino, alkylamino,
dialkylamino, sulfate, and mercapto.

"Cyclic" and "cycloalkyl" refer to a non-aromatic mono- or multicyclic ring
system of about 3 to about 10 carbon atoms, e.g., 3, 4, 5, 6, 7, 8, 9, or 10 carbon atoms.
The cycloalkyl group can be optionally partially unsaturated. The cycloalkyl group also
20 can be optionally substituted with an allyl group substituent as defined herein, oxo,
and/or alkylene. There can be optionally inserted along the cyclic alkyl chain one or
more oxygen, sulfur or substituted or unsubstituted nitrogen atoms, wherein the nitrogen
substituent is hydrogen, alkyl, substituted alkyl, aryl, or substituted aryl, thus providing a
heterocyclic group. Representative monocyclic cycloalkyl rings include cyclopentyl,
25 cyclohexyl, and cycloheptyl. Multicyclic cycloalkyl rings include adamantyl,
octahydronaphthyl, decalin, camphor, camphane, and noradamantyl.

The term "cycloalkylalkyl," as used herein, refers to a cycloalkyl group as
defined hereinabove, which is attached to the parent molecular moiety through an alkyl
group, also as defined above. Examples of cycloalkylalkyl groups include
30 cyclopropylmethyl and cyclopentylethyl.

The terms "cycloheteroalkyl" or "heterocycloalkyl" refer to a non-aromatic ring
system, such as a 3- to 7-member substituted or unsubstituted cycloalkyl ring system,

including one or more heteroatoms, which can be the same or different, and are selected from the group consisting of N, O, and S, and optionally can include one or more double bonds. The cycloheteroalkyl ring can be optionally fused to or otherwise attached to other cycloheteroalkyl rings and/or non-aromatic hydrocarbon rings. Representative cycloheteroalkyl ring systems include, but are not limited to pyrrolidinyl, pyrrolinyl, imidazolidinyl, imidazoliny, pyrazolidinyl, pyrazolinyl, piperidyl, piperazinyl, indolinyl, quinuclidinyl, morpholinyl, thiomorpholinyl, thiadiazinanyl, tetrahydrofuranyl, and the like.

The term "alkenyl" as used herein refers to a straight or branched hydrocarbon of a designed number of carbon atoms containing at least one carbon-carbon double bond. Examples of "alkenyl" include vinyl, allyl, 2-methyl-3-heptene, and the like.

The term "cycloalkenyl" as used herein refers to a cyclic hydrocarbon containing at least one carbon-carbon double bond. Examples of cycloalkenyl groups include cyclopropenyl, cyclobutenyl, cyclopentenyl, cyclopentadiene, cyclohexenyl, 1,3-cyclohexadiene, cycloheptenyl, cycloheptatrienyl, and cyclooctenyl.

The term "alkynyl" as used herein refers to a straight or branched hydrocarbon of a designed number of carbon atoms containing at least one carbon-carbon triple bond. Examples of "alkynyl" include propargyl, propyne, and 3-hexyne.

"Alkylene" refers to a straight or branched bivalent aliphatic hydrocarbon group having from 1 to about 20 carbon atoms, e.g., 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, or 20 carbon atoms. The alkylene group can be straight, branched or cyclic. The alkylene group also can be optionally unsaturated and/or substituted with one or more "alkyl group substituents." There can be optionally inserted along the alkylene group one or more oxygen, sulfur or substituted or unsubstituted nitrogen atoms (also referred to herein as "alkylaminoalkyl"), wherein the nitrogen substituent is alkyl as previously described.

An alkylene group can have about 2 to about 3 carbon atoms and can further have 6-20 carbons.

The term "aryl" is used herein to refer to an aromatic substituent that can be a single aromatic ring, or multiple aromatic rings that are fused together, linked covalently, or linked to a common group, such as, but not limited to, a methylene or ethylene moiety. The common linking group also can be a carbonyl, as in benzophenone,

or oxygen, as in diphenylether, or nitrogen, as in diphenylamine. The term "aryl" specifically encompasses heterocyclic aromatic compounds. The aromatic ring(s) can comprise phenyl, naphthyl, biphenyl, diphenylether, diphenylamine and benzophenone, among others. In particular embodiments, the term "aryl" means a cyclic aromatic comprising about 5 to about 10 carbon atoms, e.g., 5, 6, 7, 8, 9, or 10 carbon atoms, and including 5- and 6-membered hydrocarbon and heterocyclic aromatic rings.

The aryl group can be optionally substituted (a "substituted aryl") with one or more aryl group substituents, which can be the same or different, wherein "aryl group substituent" includes alkyl, substituted alkyl, aryl, substituted aryl, aralkyl, hydroxyl, alkoxy, aryloxy, aralkyloxy, carboxyl, acyl, halo, nitro, alkoxycarbonyl, aryloxy carbonyl, aralkoxy carbonyl, acyloxy, acylamino, aroylamino, carbamoyl, alkylcarbamoyl, dialkylcarbamoyl, arylthio, alkylthio, alkylene, and --NR'R", wherein R' and R" can each be independently hydrogen, alkyl, substituted alkyl, aryl, substituted aryl, and aralkyl.

Thus, as used herein, the term "substituted aryl" includes aryl groups, as defined herein, in which one or more atoms or functional groups of the aryl group are replaced with another atom or functional group, including for example, alkyl, substituted alkyl, halogen, aryl, substituted aryl, alkoxy, hydroxyl, nitro, amino, alkylamino, dialkylamino, sulfate, and mercapto.

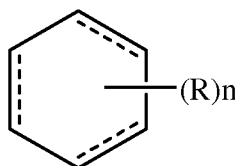
Specific examples of aryl groups include, but are not limited to, cyclopentadienyl, phenyl, furan, thiophene, pyrrole, pyran, pyridine, imidazole, benzimidazole, isothiazole, isoxazole, pyrazole, pyrazine, triazine, pyrimidine, quinoline, isoquinoline, indole, carbazole, and the like.

The term "heteroaryl" refers to an aromatic ring system, such as, but not limited to a 5- or 6-member ring system, including one or more heteroatoms, which can be the same or different, and are selected from the group consisting of N, O and S. The heteroaryl ring can be fused or otherwise attached to one or more heteroaryl rings, aromatic or non-aromatic hydrocarbon rings, or heterocycloalkyl rings. Representative heteroaryl ring systems include, but are not limited to, pyridyl, pyrimidyl, pyrrolyl, pyrazolyl, azolyl, oxazolyl, isoxazolyl, oxadiazolyl, thiazolyl, isothiazolyl, imidazolyl, furanyl, thienyl, quinolinyl, isoquinolinyl, indolyl, benzothienyl,

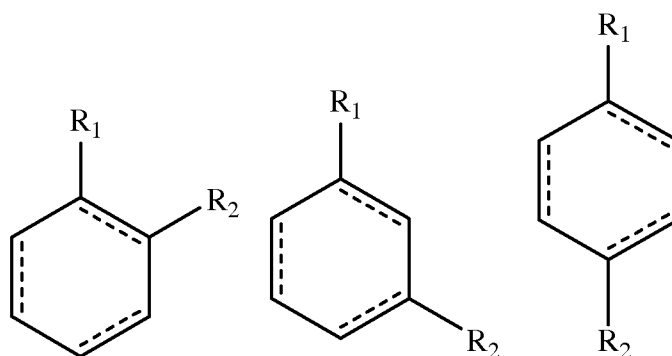
benzothiazolyl, enzofuranyl, benzimidazolyl, benzisoxazolyl, benzopyrazolyl, triazolyl, tetrazolyl, and the like.

A structure represented generally by the formula, wherein the ring structure can be aromatic or non-aromatic:

5



as used herein refers to a ring structure, for example, but not limited to a 3-carbon, a 4-carbon, a 5-carbon, a 6-carbon, and the like, aliphatic and/or aromatic cyclic
 10 compound, including a saturated ring structure, a partially saturated ring structure, and an unsaturated ring structure as defined herein, comprising a substituent R group, wherein the R group can be present or absent, and when present, one or more R groups can each be substituted on one or more available carbon atoms of the ring structure. The presence or absence of the R group and number of R groups is determined by the value
 15 of the integer n. Each R group, if more than one, is substituted on an available carbon of the ring structure rather than on another R group. For example, the structure above where n is 0 to 2 would comprise compound groups including, but not limited to:



20

and the like.

A dashed line representing a bond in a cyclic ring structure indicates that the bond can be either present or absent in the ring. That is a dashed line representing a bond in a cyclic ring structure indicates that the ring structure is selected from the group

consisting of a saturated ring structure, a partially saturated ring structure, and an unsaturated ring structure.

When a named atom of an aromatic ring or a heterocyclic aromatic ring is defined as being "absent," the named atom is replaced by a direct bond.

5 As used herein, the term "acyl" refers to an organic acid group wherein the --OH of the carboxyl group has been replaced with another substituent (i.e., as represented by RCO--, wherein R is an alkyl or an aryl group as defined herein). As such, the term "acyl" specifically includes arylacyl groups, such as an acetylfuran and a phenacyl group. Specific examples of acyl groups include acetyl and benzoyl.

10 "Alkoxy" refers to an alkyl-O-- group wherein alkyl is as previously described. The term "alkoxy" as used herein can refer to C₁₋₂₀ inclusive, linear, branched, or cyclic, saturated or unsaturated oxo-hydrocarbon chains, including, for example, methoxyl, ethoxyl, propoxyl, isopropoxyl, butoxyl, t-butoxyl, and pentoxyl.

The term "alkoxyalkyl" as used herein refers to an alkyl-O-alkyl ether, for
15 example, a methoxyethyl or an ethoxymethyl group.

"Aryloxyl" refers to an aryl-O-- group wherein the aryl group is as previously described, including a substituted aryl. The term "aryloxyl" as used herein can refer to phenyloxyl or hexyloxyl, and alkyl, substituted alkyl, halo, or alkoxy substituted phenyloxyl or hexyloxyl.

20 The term "alkyl-thio-alkyl" as used herein refers to an alkyl-S-alkyl thioether, for example, a methylthiomethyl or a methylthioethyl group.

"Aralkyl" refers to an aryl-alkyl-group wherein aryl and alkyl are as previously described, and included substituted aryl and substituted alkyl. Exemplary aralkyl groups include benzyl, phenylethyl, and naphthylmethyl.

25 "Aralkyloxyl" refers to an aralkyl-O-- group wherein the aralkyl group is as previously described. An exemplary aralkyloxyl group is benzyloxyl.

"Alkoxy carbonyl" refers to an alkyl-O--CO-- group. Exemplary alkoxy carbonyl groups include methoxycarbonyl, ethoxycarbonyl, butyloxycarbonyl, and t-butylloxycarbonyl. "Aryloxycarbonyl" refers to an aryl-O--CO-- group. Exemplary
30 aryloxycarbonyl groups include phenoxy- and naphthoxy-carbonyl. "Aralkoxy carbonyl" refers to an aralkyl-O--CO-- group. An exemplary aralkoxy carbonyl group is benzyloxycarbonyl.

"Carbamoyl" refers to an $\text{H}_2\text{N}-\text{CO}-$ group. "Alkylcarbamoyl" refers to a $\text{R}'\text{RN}-\text{CO}-$ group wherein one of R and R' is hydrogen and the other of R and R' is alkyl and/or substituted alkyl as previously described. "Dialkylcarbamoyl" refers to a $\text{R}'\text{RN}-\text{CO}-$ group wherein each of R and R' is independently alkyl and/or substituted allyl as previously described.

"Acyloxyl" refers to an acyl-O- group wherein acyl is as previously described.

The term "amino" refers to the $-\text{NH}_2$ group and also refers to a nitrogen containing group as is known in the art derived from ammonia by the replacement of one or more hydrogen radicals by organic radicals. For example, the terms "acylamino" and "alkylamino" refer to specific N-substituted organic radicals with acyl and alkyl substituent groups respectively.

The term "alkylamino" refers to an $-\text{NHR}$ group wherein R is an alkyl group and/or a substituted alkyl group as previously described. Exemplary alkylamino groups include methylamino, ethylamino, and the like.

"Dialkylamino" refers to an $-\text{NRR}'$ group wherein each of R and R' is independently an alkyl group and/or a substituted alkyl group as previously described. Exemplary dialkylamino groups include ethylmethylamino, dimethylamino, and diethylamino.

"Acylamino" refers to an acyl-NH- group wherein acyl is as previously described. "Aroylamino" refers to an aroyl-NH- group wherein aroyl is as previously described.

The term "carbonyl" refers to the $-\text{(C=O)}-$ group.

The term "carboxyl" refers to the $-\text{COOH}$ group.

The terms "halo", "halide", or "halogen" as used herein refer to fluoro, chloro, bromo, and iodo groups.

The term "hydroxyl" refers to the $-\text{OH}$ group.

The term "hydroxyalkyl" refers to an alkyl group substituted with an $-\text{OH}$ group.

The term "mercapto" refers to the $-\text{SH}$ group.

The term "oxo" refers to a compound described previously herein wherein a carbon atom is replaced by an oxygen atom.

The term "nitro" refers to the $-\text{NO}_2$ group.

The term "thio" refers to a compound described previously herein wherein a carbon or oxygen atom is replaced by a sulfur atom.

The term "sulfate" refers to the --SO₄ group.

In some embodiments, the RNAi enhancer comprises a protein which is involved
5 in processing of a pre-miRNA.

In some embodiments, the RNAi enhancer comprises the protein Dicer (e.g. Dicer1).

In some embodiments, the RNAi enhancer comprises a double-stranded RNA (dsRNA)-binding protein, e.g. the protein activator of PKR (PACT) and/or the trans-
10 activation response RNA-binding protein (TRBP), or a member of the Argonaute (Ago) protein family, or hyperactive mutant versions thereof.

In some embodiments, the RNAi enhancer comprises a poly(C)-binding protein [e.g. poly(C)-binding protein 2, as taught for example by Li Y. et al., Cell Metab. 2012 Jun 6;15(6):895-904].

15 According to a specific embodiment, the RNAi enhancer comprises overexpression of any of the above mentioned proteins.

As mentioned above, the methods of the present invention may be used for the treatment of ALS.

According to one embodiment, the method comprises administering to the
20 subject a therapeutically effective amount of an agent capable of enhancing processing of a pre-miRNA and an anti-ALS agent, thereby treating the ALS in the subject.

Any anti-ALS agent capable of alleviating, treating or slowing ALS disease progression may be used in accordance with the present teachings.

25 An exemplary anti-ALS agent which may be used in accordance with the present teachings is Riluzole (e.g. Rilutek[®]).

According to a specific embodiment, the method comprises administering to the subject a quinolone (e.g. enoxacin) and an anti-ALS agent (e.g. Riluzole).

It will be appreciated that when administering more than one agent to the
30 subject, the agents may be administered concomitantly or at separate times (e.g. within minutes, hours, days, weeks or months of each other).

The agents of some embodiments of the invention can be administered to the subject *per se*, or in a pharmaceutical composition where it is mixed with suitable carriers or excipients.

As used herein a "pharmaceutical composition" refers to a preparation of one or more of the active ingredients described herein with other chemical components such as physiologically suitable carriers and excipients. The purpose of a pharmaceutical composition is to facilitate administration of a compound to an organism.

Herein the term "active ingredient" refers to the agent accountable for the biological effect.

Hereinafter, the phrases "physiologically acceptable carrier" and "pharmaceutically acceptable carrier" which may be interchangeably used refer to a carrier or a diluent that does not cause significant irritation to an organism and does not abrogate the biological activity and properties of the administered compound. An adjuvant is included under these phrases.

Herein the term "excipient" refers to an inert substance added to a pharmaceutical composition to further facilitate administration of an active ingredient. Examples, without limitation, of excipients include calcium carbonate, calcium phosphate, various sugars and types of starch, cellulose derivatives, gelatin, vegetable oils and polyethylene glycols.

Techniques for formulation and administration of drugs may be found in "Remington's Pharmaceutical Sciences," Mack Publishing Co., Easton, PA, latest edition, which is incorporated herein by reference.

Suitable routes of administration may, for example, include oral, rectal, transmucosal, especially transnasal, intestinal or parenteral delivery, including intramuscular, subcutaneous and intramedullary injections as well as intrathecal, direct intraventricular, intracardiac, e.g., into the right or left ventricular cavity, into the common coronary artery, intravenous, intraperitoneal, intranasal, or intraocular injections.

Conventional approaches for drug delivery to the central nervous system (CNS) include: neurosurgical strategies (e.g., intracerebral injection or intracerebroventricular infusion); molecular manipulation of the agent (e.g., production of a chimeric fusion protein that comprises a transport peptide that has an affinity for an endothelial cell

surface molecule in combination with an agent that is itself incapable of crossing the BBB) in an attempt to exploit one of the endogenous transport pathways of the BBB; pharmacological strategies designed to increase the lipid solubility of an agent (e.g., conjugation of water-soluble agents to lipid or cholesterol carriers); and the transitory
5 disruption of the integrity of the BBB by hyperosmotic disruption (resulting from the infusion of a mannitol solution into the carotid artery or the use of a biologically active agent such as an angiotensin peptide). However, each of these strategies has limitations, such as the inherent risks associated with an invasive surgical procedure, a size limitation imposed by a limitation inherent in the endogenous transport systems,
10 potentially undesirable biological side effects associated with the systemic administration of a chimeric molecule comprised of a carrier motif that could be active outside of the CNS, and the possible risk of brain damage within regions of the brain where the BBB is disrupted, which renders it a suboptimal delivery method.

Notably, small molecules such as Enoxacin are known to be able to cross the
15 blood brain barrier without further chemical modifications.

Alternately, one may administer the pharmaceutical composition in a local rather than systemic manner, for example, via injection of the pharmaceutical composition directly into a tissue region of a patient (e.g., brain or spinal cord).

Pharmaceutical compositions of some embodiments of the invention may be
20 manufactured by processes well known in the art, e.g., by means of conventional mixing, dissolving, granulating, dragee-making, levigating, emulsifying, encapsulating, entrapping or lyophilizing processes.

The pharmaceutical composition can be for chronic use (e.g., oral chronic).

Alternatively, the pharmaceutical composition can be for acute use.

25 Pharmaceutical compositions for use in accordance with some embodiments of the invention thus may be formulated in conventional manner using one or more physiologically acceptable carriers comprising excipients and auxiliaries, which facilitate processing of the active ingredients into preparations which, can be used pharmaceutically. Proper formulation is dependent upon the route of administration
30 chosen.

For injection, the active ingredients of the pharmaceutical composition may be formulated in aqueous solutions, preferably in physiologically compatible buffers such

as Hank's solution, Ringer's solution, or physiological salt buffer. For transmucosal administration, penetrants appropriate to the barrier to be permeated are used in the formulation. Such penetrants are generally known in the art.

For oral administration, the pharmaceutical composition can be formulated
5 readily by combining the active compounds with pharmaceutically acceptable carriers well known in the art. Such carriers enable the pharmaceutical composition to be formulated as tablets, pills, dragees, capsules, liquids, gels, syrups, slurries, suspensions, and the like, for oral ingestion by a patient. Pharmacological preparations for oral use can be made using a solid excipient, optionally grinding the resulting mixture, and
10 processing the mixture of granules, after adding suitable auxiliaries if desired, to obtain tablets or dragee cores. Suitable excipients are, in particular, fillers such as sugars, including lactose, sucrose, mannitol, or sorbitol; cellulose preparations such as, for example, maize starch, wheat starch, rice starch, potato starch, gelatin, gum tragacanth, methyl cellulose, hydroxypropylmethyl-cellulose, sodium carbomethylcellulose; and/or
15 physiologically acceptable polymers such as polyvinylpyrrolidone (PVP). If desired, disintegrating agents may be added, such as cross-linked polyvinyl pyrrolidone, agar, or alginic acid or a salt thereof such as sodium alginate.

Dragee cores are provided with suitable coatings. For this purpose, concentrated sugar solutions may be used which may optionally contain gum arabic, talc, polyvinyl
20 pyrrolidone, carbopol gel, polyethylene glycol, titanium dioxide, lacquer solutions and suitable organic solvents or solvent mixtures. Dyestuffs or pigments may be added to the tablets or dragee coatings for identification or to characterize different combinations of active compound doses.

Pharmaceutical compositions which can be used orally, include push-fit capsules
25 made of gelatin as well as soft, sealed capsules made of gelatin and a plasticizer, such as glycerol or sorbitol. The push-fit capsules may contain the active ingredients in admixture with filler such as lactose, binders such as starches, lubricants such as talc or magnesium stearate and, optionally, stabilizers. In soft capsules, the active ingredients may be dissolved or suspended in suitable liquids, such as fatty oils, liquid paraffin, or
30 liquid polyethylene glycols. In addition, stabilizers may be added. All formulations for oral administration should be in dosages suitable for the chosen route of administration.

For buccal administration, the compositions may take the form of tablets or lozenges formulated in conventional manner.

For administration by nasal inhalation, the active ingredients for use according to some embodiments of the invention are conveniently delivered in the form of an aerosol spray presentation from a pressurized pack or a nebulizer with the use of a suitable propellant, e.g., dichlorodifluoromethane, trichlorofluoromethane, dichloro-
5 tetrafluoroethane or carbon dioxide. In the case of a pressurized aerosol, the dosage unit may be determined by providing a valve to deliver a metered amount. Capsules and cartridges of, e.g., gelatin for use in a dispenser may be formulated containing a
10 powder mix of the compound and a suitable powder base such as lactose or starch.

The pharmaceutical composition described herein may be formulated for parenteral administration, e.g., by bolus injection or continuous infusion. Formulations for injection may be presented in unit dosage form, e.g., in ampoules or in multidose containers with optionally, an added preservative. The compositions may be
15 suspensions, solutions or emulsions in oily or aqueous vehicles, and may contain formulatory agents such as suspending, stabilizing and/or dispersing agents.

Pharmaceutical compositions for parenteral administration include aqueous solutions of the active preparation in water-soluble form. Additionally, suspensions of the active ingredients may be prepared as appropriate oily or water based injection
20 suspensions. Suitable lipophilic solvents or vehicles include fatty oils such as sesame oil, or synthetic fatty acids esters such as ethyl oleate, triglycerides or liposomes. Aqueous injection suspensions may contain substances, which increase the viscosity of the suspension, such as sodium carboxymethyl cellulose, sorbitol or dextran. Optionally, the suspension may also contain suitable stabilizers or agents which
25 increase the solubility of the active ingredients to allow for the preparation of highly concentrated solutions.

Alternatively, the active ingredient may be in powder form for constitution with a suitable vehicle, e.g., sterile, pyrogen-free water based solution, before use.

The pharmaceutical composition of some embodiments of the invention may
30 also be formulated in rectal compositions such as suppositories or retention enemas, using, e.g., conventional suppository bases such as cocoa butter or other glycerides.

Pharmaceutical compositions suitable for use in context of some embodiments of the invention include compositions wherein the active ingredients are contained in an amount effective to achieve the intended purpose. More specifically, a therapeutically effective amount means an amount of active ingredients (the agent) effective to prevent, alleviate or ameliorate symptoms of a disorder (e.g., MND e.g., ALS) or prolong the survival of the subject being treated.

Determination of a therapeutically effective amount is well within the capability of those skilled in the art, especially in light of the detailed disclosure provided herein.

For any preparation used in the methods of the invention, the therapeutically effective amount or dose can be estimated initially from in vitro and cell culture assays. For example, a dose can be formulated in animal models to achieve a desired concentration or titer. Such information can be used to more accurately determine useful doses in humans.

Animal models of amyotrophic lateral sclerosis (ALS) provide a unique opportunity to study this incurable and fatal human disease both clinically and pathologically. Nonetheless, postmortem ALS tissue remains the "gold standard" against which pathologic findings in animal models must be compared. Four natural disease models have been most extensively studied, including three mouse models: motor neuron degeneration (Mnd), progressive motor neuronopathy (pmn), wobbler, and one canine model: hereditary canine spinal muscular atrophy (HCSMA). The wobbler mouse has been the most extensively studied of these models with analyses of clinical, pathological (perikaryon, axon, muscle), and biochemical features. Experimentally induced ALS animal models have allowed controlled testing of various neurotoxic, viral and immune-mediated mechanisms. Molecular techniques have recently generated mouse models in which genes relevant to the human disease or motor neuron biology have been manipulated. Transgenic mouse overexpressing the mutated SOD1 gene of FALS patients, provide significant insights into mechanisms of motor neuron degeneration in this disease (reviewed by Pioro Clin Neurosci. 1995-1996;3(6):375-85).

Of specific relevance is a new transgenic mouse model with mutant *TDP-43* appears to be similar to human sporadic amyotrophic lateral sclerosis, opening up new opportunities for research on targeted therapies, described in Talan Neurology Today:

19 November 2009 - Volume 9 - Issue 22 - p 10-11.

According to a specific embodiment, the mouse model is the A315T stop mouse model (Wegorzewska, 2009 PNAS 106, p. 18809-14) from Jackson Laboratories Inc.).

Another exemplary mouse model are the transgenic SOD1 (superoxide
5 dismutase 1) mice (described in the Examples section which follows) which express a G93A mutant form of human SOD1. SOD1 mice (TgN-SOD1-G93A-1Gur) exhibit a phenotype similar to amyotrophic lateral sclerosis (ALS) in humans (Gurney, 1994, Science 264 p. 1772-5).

10 Mouse doses vary from 10-1000 mg/kg/day, 10-500 mg/kg/day, 50-200 mg/kg/day, 50-100 mg/kg/day. The doses can be effectively transformed to human uses by employing FDA conversion tables.

The intermediate dose of 100 mg/kg orally in drinking water per day was previously described to be active and non-toxic in mice, leading to mean serum peak concentrations of 4 mg/l [Enoxacin pharmacokinetics and efficacy in CF-1 mice,
15 Chartand S.A. et al, Journal of Antimicrobial Chemotherapy (1987) 19, 221-224]. This corresponds to a dose of 12.5 μ M Enoxacin. Given the fact that the dose is applied continuously and well absorbed, a certain tissue specific accumulation can be assumed. Enoxacin was previously described to cross the blood brain barrier.

Comparable serum peak concentrations were observed in humans, where a
20 single Enoxacin of 600 mg led to a plasma peak concentration of 3.7 mg/ml. Depending on the necessary tissue penetrance, common doses of Enoxacin vary between 2x200 mg/day and 2x400 mg/day, the later has been regarded as a standard dose for many years. Given this, our employed dose fits perfectly in the necessary serum peak concentration range of antimicrobial efficacy of the drug, whether this is sufficient for
25 miRNA enhancing activity *in vivo* motorneurons needs to be yet evaluated. Wise R, Lockley R, Webberly M, Adhami ZN. The pharmacokinetics and tissue penetration of enoxacin and norfloxacin. J Antimicrob Chemother. 1984 Sep;14 Suppl C:75-81. PubMed PMID: 6238932. Wolf R, Eberl R, Dunky A, Mertz N, Chang T, Goulet JR, Latts J. The clinical pharmacokinetics and tolerance of enoxacin in healthy volunteers. J
30 Antimicrob Chemother. 1984 Sep;14 Suppl C:63-9. PubMed PMID: 6389476.

Thus according to a specific embodiment, human doses are 100-2000 mg/day, 100-1000 mg/day, 400-800 mg/day or 200-600 mg/day. The dose can be divided to multiple unit doses forms given once, twice or more per day.

Toxicity and therapeutic efficacy of the active ingredients described herein can be determined by standard pharmaceutical procedures in vitro, in cell cultures or experimental animals. The data obtained from these in vitro and cell culture assays and animal studies can be used in formulating a range of dosage for use in human. The dosage may vary depending upon the dosage form employed and the route of administration utilized. The exact formulation, route of administration and dosage can be chosen by the individual physician in view of the patient's condition. (See e.g., Fingl, et al., 1975, in "The Pharmacological Basis of Therapeutics", Ch. 1 p.1).

Dosage amount and interval may be adjusted individually to provide optimal levels of the active ingredient are sufficient to induce or suppress the biological effect (minimal effective concentration, MEC). The MEC will vary for each preparation, but can be estimated from in vitro data. Dosages necessary to achieve the MEC will depend on individual characteristics and route of administration. Detection assays can be used to determine plasma concentrations.

Depending on the severity and responsiveness of the condition to be treated, dosing can be of a single or a plurality of administrations, with course of treatment lasting from several days to several weeks or until cure is effected or diminution of the disease state is achieved.

The amount of a composition to be administered will, of course, be dependent on the subject being treated, the severity of the affliction, the manner of administration, the judgment of the prescribing physician, etc.

The pharmaceutical compositions of the present invention may further comprise as an active ingredient an anti-ALS agent.

An exemplary anti-ALS agent comprises Riluzole (e.g. Rilutek[®]).

According to a specific embodiment, the pharmaceutical composition comprises a quinolone (e.g. enoxacin) and an anti-ALS agent (e.g. Riluzole).

According to an embodiment, the pharmaceutical compositions of the present invention may further comprise additional factors which enhance processing of a pre-

miRNA, including for example, Dicer (e.g. Dicer1), PACT, TRBP and/or poly(C)-binding protein 2.

Compositions of some embodiments of the invention may, if desired, be presented in a pack or dispenser device, such as an FDA approved kit, which may contain one or more unit dosage forms containing the active ingredient. The pack may, for example, comprise metal or plastic foil, such as a blister pack. The pack or dispenser device may be accompanied by instructions for administration. The pack or dispenser may also be accommodated by a notice associated with the container in a form prescribed by a governmental agency regulating the manufacture, use or sale of pharmaceuticals, which notice is reflective of approval by the agency of the form of the compositions or human or veterinary administration. Such notice, for example, may be of labeling approved by the U.S. Food and Drug Administration for prescription drugs or of an approved product insert. Compositions comprising a preparation of the invention formulated in a compatible pharmaceutical carrier may also be prepared, placed in an appropriate container, and labeled for treatment of an indicated condition, as is further detailed above.

According to one embodiment, there is provided an article of manufacture comprising an agent capable of enhancing processing of a pre-miRNA and an anti-ALS agent being packaged in a packaging material and identified in print, in or on the packaging material for use in the treatment of ALS.

According to a specific embodiment, the article of manufacture comprises a quinolone (e.g. enoxacin) and an anti-ALS agent (e.g. Riluzole).

The present findings that the general miRNA metabolism is impaired in MND, suggests further diagnostic implications of these diseases.

Thus, according to an additional aspect of the invention there is provided a method of diagnosing a MND, the method comprising analyzing in a sample of a subject in need thereof:

- (i) total miR expression; and optionally
- (ii) total pre-miR expression, wherein a down-regulation in said (i) or (i)/(ii) beyond a predetermined threshold is indicative of the MND.

Alternatively or additionally, there is provided a method of diagnosing a MND, the method comprising analyzing in a sample of a subject in need thereof:

- (i) a miR expression; and
- (ii) an expression of a precursor of said miR, wherein a down-regulation in (i)/(ii) beyond a predetermined threshold is indicative of the MND.

As used herein the phrase "total miRNA" refers to non-specific miRNA
5 quantification per cell/cells/tissue. According to a specific embodiment only the levels of the mature miRNA and not its precursor are measured, so as to quantify only the portion of the miRNA in the cell/cells/tissue.

As used herein the phrase "total pre-miRNA" refers to non-specific miRNA
10 quantification per cell/cells/tissue. According to a specific embodiment only the levels of the pre-miRNA and not its mature product (miRNA) are measured, so as to quantify only the portion of the pre-miRNA in the cell/cells/tissue.

Thus, the ratio between miRNA (mature) and pre-miRNA is crucial to the etiology of the disease.

Therefore, the present invention further contemplates analyzing the levels of a
15 specific miRNA which lack thereof (or insufficient level thereof) has been associated with MND or ALS, provided that this is effected also by quantifying the precursor level of the specific miRNA tested.

Such miRNAs are provided in U.S. Patent Applications 20060247193 and 20090246136, each of which is hereby incorporated by reference in its entirety.

20 According to a specific embodiment, the specific miRNA selected from the group consisting of miR-9, miR-206, miR-1, miR-2-1, miR-5, miR-7, miR-8, miR-11, miR-12, miR-13, miR-14, miR-15, miR-16, miR-17, miR-18, miR-19, miR-20, miR-21, miR-22, miR-23, miR-24, miR-25, miR-26, miR-27, miR-28, miR-29, miR-30, miR-31, miR-32, miR-33, miR-34, miR-92, miR-93, miR-94, miR-95, miR-96, miR-97, miR-98,
25 miR-99, miR-100, miR101, miR-103, miR-104, miR-105, miR-106, miR-107, miR-109, miR-110, miR-111, miR-112, miR-113, miR-114, miR-116, miR-119, miR-122, miR-125, miR-126, miR-127, miR-129, miR-130, miR-132, miR-133, miR-134, miR-136, miR-138, miR-140, miR-141, miR-144, miR-145, miR-146, miR-147, miR-148, miR-149, miR-150, miR-151, miR-153, miR-154, miR-157, miR-158, miR-160, miR-
30 162, miR-164, miR-172, miR-173, miR-174, miR-175, miR-176, miR-177, miR-178, miR-179, miR-180, miR-182, miR-183, miR-184, miR-185, miR-186, miR-187, miR-

188, miR-189, miR-191, miR-192, miR-193, miR-195, miR-196, miR-197, miR-199, miR-201, miR-203, miR-205, and miR-224 or a precursor thereof.

As used herein, the term "diagnosing" refers to classifying a pathology (e.g., a disease, disorder, syndrome, medical condition and/or a symptom thereof), determining a severity of the pathology, monitoring the progression of a pathology, forecasting an outcome of the pathology and/or prospects of recovery (e.g., prognosis).

As used herein "a biological sample" refers to a sample of fluid or tissue sample derived from a subject. Examples of fluid samples include, but are not limited to, blood, plasma, serum, spinal fluid, lymph fluid, tears, saliva, sputum and milk. An example of a tissue sample includes a brain tissue sample or a nerve tissue sample (e.g. for post-mortem diagnosis).

Methods of obtaining such biological samples are known in the art including but not limited to standard blood retrieval procedures and lumbar puncture.

As used herein, the term "subject" refers to a mammal, such as a human being as described above. The subject may be healthy or showing preliminary signs of a MND, such as muscle fatigue. Alternatively, the subject may have a genetic predisposition to the disease.

Determining the total miRNA level with and without determining the precursor level is performed using methods which are well known in the art. A brief exemplary description is provided herein. RNA is extracted such as by using an RNA isolation kit e.g., Triagent (Molecular Research Center Inc.). Reverse transcription for consecutive parallel analysis of pre-miRNA and miRNA expression is done using miScript I & II Kits (Quiagen). Quantitative analysis of miRNA and pre-miRNA expression performed with StepOnePlus Real-Time PCR System (Life technologies Inc.). All experiments are preferably performed independent biological repeats. qPCR is preferably performed in technical duplicates.

Following analysis of the total miRs and optionally pre-miR, the results are typically recorded and the subject is informed. The diagnosis may be substantiated with other means including those that make up the El Escorial criteria. Other diagnostic methods that can be used in conjunction with the method of the present invention are those that involve transcranial magnetic stimulation (TMS). This noninvasive procedure creates a magnetic pulse inside the brain that stimulates motor activity in a certain area

of the body. Electrodes taped to different areas of the body pick up and record the electrical activity in the muscles.

It will be appreciated that the diagnostic method of the present invention may also be substantiated with other tests to rule out the involvement of other diseases or to measure the extent of muscle involvement. Below is a list of such tests:

1. Electromyography (EMG) is used to diagnose muscle and nerve dysfunction and spinal cord disease. It is also used to measure the speed at which impulses travel along a particular nerve. EMG records the electrical activity from the brain and/or spinal cord to a peripheral nerve root (found in the arms and legs) that controls muscles during contraction and at rest. Very fine wire electrodes are inserted one at a time into a muscle to assess changes in electrical voltage that occur during movement and when the muscle is at rest. The electrodes are attached to a recording instrument. Testing usually lasts about an hour or more, depending on the number of muscles and nerves to be tested.

2. EMG is usually done in conjunction with a nerve conduction velocity study. This procedure also measures electrical energy to test the nerve's ability to send a signal. A technician tapes two sets of flat electrodes on the skin over the muscles. The first set of electrodes is used to send small pulses of electricity (similar to a jolt from static electricity) to stimulate the nerve that directs a particular muscle. The second set of electrodes transmits the responding electrical signal to a recording machine. The physician then reviews the response to verify any nerve damage or muscle disease.

3. Laboratory screening tests of blood, urine, or other substances can rule out muscle diseases and other disorders that may have symptoms similar to those of MND. For example, analysis of the fluid that surrounds the brain and spinal cord can detect a number of disorders, including PPS. Blood tests may be ordered to measure levels of the protein creatine kinase (which is needed for the chemical reactions that produce energy for muscle contractions); high levels may help diagnose muscle diseases such as muscular dystrophy.

4. Magnetic resonance imaging (MRI) uses computer-generated radio waves and a powerful magnetic field to produce detailed images of body structures including tissues, organs, bones, and nerves. These images can help diagnose brain and spinal cord tumors, eye disease, inflammation, infection, and vascular irregularities that may

lead to stroke. MRI can also detect and monitor degenerative disorders such as multiple sclerosis and can document brain injury from trauma. MRI is often used to rule out diseases other than the MNDs that affect the head, neck, and spinal cord.

5 5. Muscle or nerve biopsy can help confirm nerve disease and nerve regeneration. A small sample of the muscle or nerve is removed under local anesthetic and studied under a microscope. The sample may be removed either surgically, through a slit made in the skin, or by needle biopsy, in which a thin hollow needle is inserted through the skin and into the muscle. A small piece of muscle remains in the hollow
10 needle when it is removed from the body. Although this test can provide valuable information about the degree of damage, it is an invasive procedure that may itself cause neuropathic side effects. Many experts do not believe that a biopsy is always needed for diagnosis.

The present invention further contemplates a method of identifying an agent for the treatment of a MND, the method comprising:

15 (a) contacting a motor neuron of an ALS patient or an ALS model with a candidate agent;

 (b) analyzing prior to (a) and following (a):

 (i) total miR expression in said motor neuron; and optionally

 (ii) total pre-miR expression in said motor neuron,

20 wherein an up-regulation in said (i) or (i)/(ii) beyond a predetermined threshold following (a) as compared to prior to (a), is indicative of that the candidate compound is a therapeutic agent for the treatment of MND.

The motor neuron may be isolated from any animal, including a mouse, a rat or a human. Alternatively, the motor neuron may be part of a motor neuron cell line –
25 such as for example the murine motor neuron cell line, NSC19 [Smirnova IV Spine (Phila Pa 1976). 1998 Jan 15;23(2):151-8].

Yet alternatively, the motor neuron may be differentiated from a stem cell. According to one embodiment the stem cell is an embryonic stem cell (ESC). Such embryonic stem cells may be isolated from transgenic animals (e.g. mice) that serve as
30 models for MNDs. For example embryonic stem cells may be isolated from a Tg(Hlxb9-GFP)1Tmj Tg(SMN2)89Ahmb *Smn1*^{tm1Msd}/J mouse (Jackson lab stock number 006570). Alternatively, embryonic stem cells may be isolated from transgenic

animals, comprising a cholinergic-specific knock-out of DICER. This model for MND is further described herein below.

Various methods are known for differentiation of embryonic stem cells into motor neurons, such as for example those described by Wichterle, H., et al., [Cell 110, 5 385-97 (2002)].

Exemplary candidate agents include small molecule agents, polynucleotide agents, chemicals, antibiotic compounds known to modify gene expression, modified or unmodified polynucleotides (including oligonucleotides), polypeptides, peptides, small RNA molecules and miRNAs.

10 It will be appreciated that the methods of contacting according to this aspect of the present invention typically depend on the type of candidate agent being tested. Thus, for example a polynucleotide agent is typically contacted with the motor neuron together with a transfection agent. A small chemical is typically placed in the motor neuron culture medium without additional agents.

15 To be considered a therapeutic agent, the candidate agents of the present invention typically upregulates (i) or (i)/(ii) beyond a predetermined threshold following (a) as compared to prior to (a).

Following selection of a candidate agent as a therapeutic agent for the treatment of an MND, the agent may be tested – for example on an animal model for the disease 20 and ultimately the agent may be tested in humans. Validation of therapeutic efficacy may then lead to the preparation of the candidate agent as a pharmaceutical composition.

Such a method, beyond its significance to research and pharmaceutical industry, is also valuable in the field of personalized medicine. Cells of the subject are contacted 25 with a candidate treating agent (e.g., enoxacin) and compliance to treatment is dependent on upregulation in (i) or (i)/(ii) following contacting.

As used herein the term “about” refers to $\pm 10\%$.

The terms "comprises", "comprising", "includes", "including", "having" and their conjugates mean "including but not limited to".

30 The term “consisting of” means “including and limited to”.

The term "consisting essentially of" means that the composition, method or structure may include additional ingredients, steps and/or parts, but only if the

additional ingredients, steps and/or parts do not materially alter the basic and novel characteristics of the claimed composition, method or structure.

As used herein, the singular form "a", "an" and "the" include plural references unless the context clearly dictates otherwise. For example, the term "a compound" or
5 "at least one compound" may include a plurality of compounds, including mixtures thereof.

Throughout this application, various embodiments of this invention may be presented in a range format. It should be understood that the description in range format is merely for convenience and brevity and should not be construed as an inflexible
10 limitation on the scope of the invention. Accordingly, the description of a range should be considered to have specifically disclosed all the possible subranges as well as individual numerical values within that range. For example, description of a range such as from 1 to 6 should be considered to have specifically disclosed subranges such as from 1 to 3, from 1 to 4, from 1 to 5, from 2 to 4, from 2 to 6, from 3 to 6 etc., as well
15 as individual numbers within that range, for example, 1, 2, 3, 4, 5, and 6. This applies regardless of the breadth of the range.

Whenever a numerical range is indicated herein, it is meant to include any cited numeral (fractional or integral) within the indicated range. The phrases "ranging/ranges between" a first indicate number and a second indicate number and "ranging/ranges
20 from" a first indicate number "to" a second indicate number are used herein interchangeably and are meant to include the first and second indicated numbers and all the fractional and integral numerals therebetween.

As used herein the term "method" refers to manners, means, techniques and procedures for accomplishing a given task including, but not limited to, those manners,
25 means, techniques and procedures either known to, or readily developed from known manners, means, techniques and procedures by practitioners of the chemical, pharmacological, biological, biochemical and medical arts.

It is appreciated that certain features of the invention, which are, for clarity, described in the context of separate embodiments, may also be provided in combination
30 in a single embodiment. Conversely, various features of the invention, which are, for brevity, described in the context of a single embodiment, may also be provided separately or in any suitable subcombination or as suitable in any other described

embodiment of the invention. Certain features described in the context of various embodiments are not to be considered essential features of those embodiments, unless the embodiment is inoperative without those elements.

Various embodiments and aspects of the present invention as delineated hereinabove and as claimed in the claims section below find experimental support in the following examples.

EXAMPLES

Reference is now made to the following examples, which together with the above descriptions illustrate some embodiments of the invention in a non limiting fashion.

Generally, the nomenclature used herein and the laboratory procedures utilized in the present invention include molecular, biochemical, microbiological and recombinant DNA techniques. Such techniques are thoroughly explained in the literature. See, for example, "Molecular Cloning: A laboratory Manual" Sambrook et al., (1989); "Current Protocols in Molecular Biology" Volumes I-III Ausubel, R. M., ed. (1994); Ausubel et al., "Current Protocols in Molecular Biology", John Wiley and Sons, Baltimore, Maryland (1989); Perbal, "A Practical Guide to Molecular Cloning", John Wiley & Sons, New York (1988); Watson et al., "Recombinant DNA", Scientific American Books, New York; Birren et al. (eds) "Genome Analysis: A Laboratory Manual Series", Vols. 1-4, Cold Spring Harbor Laboratory Press, New York (1998); methodologies as set forth in U.S. Pat. Nos. 4,666,828; 4,683,202; 4,801,531; 5,192,659 and 5,272,057; "Cell Biology: A Laboratory Handbook", Volumes I-III Cellis, J. E., ed. (1994); "Culture of Animal Cells - A Manual of Basic Technique" by Freshney, Wiley-Liss, N. Y. (1994), Third Edition; "Current Protocols in Immunology" Volumes I-III Coligan J. E., ed. (1994); Stites et al. (eds), "Basic and Clinical Immunology" (8th Edition), Appleton & Lange, Norwalk, CT (1994); Mishell and Shiigi (eds), "Selected Methods in Cellular Immunology", W. H. Freeman and Co., New York (1980); available immunoassays are extensively described in the patent and scientific literature, see, for example, U.S. Pat. Nos. 3,791,932; 3,839,153; 3,850,752; 3,850,578; 3,853,987; 3,867,517; 3,879,262; 3,901,654; 3,935,074; 3,984,533; 3,996,345; 4,034,074; 4,098,876; 4,879,219; 5,011,771 and 5,281,521; "Oligonucleotide Synthesis" Gait, M. J., ed. (1984); "Nucleic Acid Hybridization" Hames, B. D., and

Higgins S. J., eds. (1985); "Transcription and Translation" Hames, B. D., and Higgins S. J., eds. (1984); "Animal Cell Culture" Freshney, R. I., ed. (1986); "Immobilized Cells and Enzymes" IRL Press, (1986); "A Practical Guide to Molecular Cloning" Perbal, B., (1984) and "Methods in Enzymology" Vol. 1-317, Academic Press; "PCR Protocols: A Guide To Methods And Applications", Academic Press, San Diego, CA (1990); Marshak et al., "Strategies for Protein Purification and Characterization - A Laboratory Course Manual" CSHL Press (1996); all of which are incorporated by reference as if fully set forth herein. Other general references are provided throughout this document. The procedures therein are believed to be well known in the art and are provided for the convenience of the reader. All the information contained therein is incorporated herein by reference.

EXAMPLE 1

Experimental Procedures

Human Tissue miRNA analysis

In situ-hybridization was performed on 7 μm sections of frozen spinal tissue from lumbar regions, following¹⁰, Hybridization of sections with 4 pmol of 5' and 3' DIG-labeled anti-miR-9 and anti-miR-124 LNA probe followed manufacturer instructions (Exiqon).

For miRNA studies in cultured cells, reverse transcription for consecutive parallel analysis of pre-miRNA and miRNA expression was performed using miScript I & II Kits (Quiagen). Quantitative analysis of miRNA and pre-miRNA expression performed with StepOnePlus Real-Time PCR System (Life technologies Inc.). All experiments were performed in at least 3 independent biological repeats and qPCR performed in technical duplicates.

For *in vivo* experiments, transgenic SOD1 (superoxide dismutase 1) mice were used which express a G93A mutant form of human SOD1. SOD1 mice (TgN-SOD1-G93A-1Gur) exhibit a phenotype similar to amyotrophic lateral sclerosis (ALS) in humans. 20 mice were fed with Enoxacin (at a dose of 200 mg/kg) from the age of 50 days in drinking water. Mouse life span and neuromuscular function were monitored. Neuromuscular function was assessed by neurological score that tests the mouse muscle

tonus reflexes and overall in-cage locomotive activity as previously described in Alves CJ et al. [Alves CJ et al., Brain Res. (2011) Jun 7; 1394:90-104]. Hang-wire test was utilized which measures gross physical strength of forelimbs, hindlimbs, capacity to adduct when hand on a pole and to walk. Automated Catwalk gait analysis system was
5 utilized which is based on camera monitored computerized locomotion testing automated system by Noldus Information Technology, The Netherlands.

Statistical analysis was performed using the two-tailed Student's t-test with post-hoc Benjamini-Hochberg corrections. Values were considered statistically significant when $p < 0.05$. Results are representative of at least 3 independent experiments and
10 presented with standard deviations. qPCR data statistics for the human miRNA study was obtained using the DataAssist Software (Life Technologies).

EXAMPLE 2

miRNA Expression is Altered in ALS

15 Previous reports have indicated that a general (non-specific) microRNA (miRNA) metabolism is altered in ventral lumbar spinal cord (SC) tissue in sporadic ALS (sALS) subjects as compared to controls [Campos-Melo D. et al. Mol Brain. (2013) 6:26]. In the present study, the present inventors have tested the hypothesis that the altered miRNA expression in ALS subjects is related to a mutation in miRNA
20 bioprocessing and may be reversed by proper treatment.

First, the observation that miRNAs are globally downregulated in ALS subjects was substantiated by miRNA in-situ hybridization¹⁰, which revealed comparable downregulation of miR-9 and miR-124 in patient tissue, relative to control (Figures 1a-c). These data suggest that miRNAs are broadly downregulated in ALS motoneurons.
25 To gain mechanistic insight into miRNA dysregulation in ALS, the present inventors transfected HEK293 or NSC-34 cells with vectors for expression of ALS-causing mutant forms of FUS and TDP-43 and examined miRNA expression. Transfection of the mixed motor-neuron cell line, NSC-34, with vectors for expression of ALS-causing mutant forms of TDP-43 and FUS revealed that mature miRNA expression was
30 downregulated in all cases (Figures 2a-d and Figure 3). These data reveal that the presence of toxic ALS-causing mutants is sufficient to disrupt miRNA processing. Canonical miRNA bioprocessing involves the digestion of pre-miRNA precursors by

the Drosha/Dgcr8 complex in the nucleus and subsequently by Dicer1 in the cytoplasm. Therefore specific impairment of the bioprocessing system may be revealed by the accumulation of intermediate miRNA forms. Quantitative analysis of pre-miRNAs in NSC-34 cells extracts, revealed that while mature miRNAs were downregulated, the levels of their cognate pre-miRNA precursors were in fact upregulated by the expression of ALS-causing mutant-forms of TDP-43 or FUS (Figures 2a–d and Figure 3). Noteworthy, the impairment of pre-miRNA processing into mature miRNAs seems to correlate with the reported clinical severity, reported for different FUS and TDP-43 mutants. Attempts to measure pre-miRNAs in human LCM samples were unsuccessful, probably due to the very low expression levels of these intermediate precursors. This reciprocity, whereby mature miRNAs levels are low and per-miRNA precursors are higher than in the control, suggested inhibition of pre-miRNA processing by Dicer1 ¹¹.

The present inventors reasoned that Dicing of pre-miRNAs is inhibited by the expression of ALS-causing versions of TDP-43 or FUS and thus searched for changes in mRNA encoding for miRNA–processing factors in gene expression and splicing data from the same patients⁹. However, these interrogations did not reveal any change in the expression of these factors in ALS patients relative to controls. To provide functional experimental support to the role of Dicing in disturbed miRNA processing by ALS-causing mutant forms of TDP-43 and FUS, the present inventors sought employ Enoxacin, a Fluoroquinolone antibiotic, which is known to increase miRNA levels via enhancement of Dicer1 activity ¹². Indeed, introduction of Enoxacin onto HEK293 cells reversed the negative impact of ALS-causing TDP-43 or FUS mutants on miRNA maturation (Figures 2e–h). Thus, impaired miRNA bioprocessing in ALS may be reversible by a non-toxic Fluoroquinolone.

This observation encouraged a hypothesis that Enoxacin may be beneficial also *in vivo*, in the classic SOD1 G93A model of ALS (high copy number, missed genetic background). Therefore the present inventors set to perform a preclinical study by feeding a cohort of mice with Enoxacin from the age of 50 days in drinking water. This preliminary study failed to clearly show - mechanism involved in several forms of ALS that may be of therapeutic usage in the future, employing existing or yet to be developed more potent molecules modulating miRNA maturation or activity.

Since miRNAs are detectable in bodily fluids including in cerebrospinal fluid, this may allow future development of miRNA-based markers for ALS. Additionally, these observations advance understanding of molecular mechanisms acting in other forms of neurodegeneration, as dysregulation of miRNAs was suggested in several other brain diseases.

Acknowledging that loss of miRNA and Dicer1 activity in motoneurons is sufficient for causing motoneuron disease in mice ⁷, strongly suggests that the global miRNA downregulation reported here may affect motoneuron survival also in human ALS patients. Thus, the present findings suggest a common mechanism involved in several forms of ALS that may be of therapeutic usage in the future, if potent molecules modulating miRNA maturation or activity could be developed.

Although the invention has been described in conjunction with specific embodiments thereof, it is evident that many alternatives, modifications and variations will be apparent to those skilled in the art. Accordingly, it is intended to embrace all such alternatives, modifications and variations that fall within the spirit and broad scope of the appended claims.

All publications, patents and patent applications mentioned in this specification are herein incorporated in their entirety by reference into the specification, to the same extent as if each individual publication, patent or patent application was specifically and individually indicated to be incorporated herein by reference. In addition, citation or identification of any reference in this application shall not be construed as an admission that such reference is available as prior art to the present invention. To the extent that section headings are used, they should not be construed as necessarily limiting.

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Kwiatkowski, T. J., Jr., Bosco, D. A., Leclerc, A. L., Tamrazian, E., Vanderburg, C. R., Russ, C., Davis, A., Gilchrist, J., Kasarskis, E. J., Munsat, T. et al. (2009) 'Mutations in the FUS/TLS gene on chromosome 16 cause familial amyotrophic lateral sclerosis', *Science* **323**(5918): 1205-8.

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WHAT IS CLAIMED IS:

1. A method of treating a motor neuron disease (MND) in a subject in need thereof, the method comprising administering to the subject a therapeutically effective amount of an agent capable of enhancing processing of a pre-miRNA, thereby treating the MND in the subject.
2. An agent capable of enhancing processing of a pre-miRNA for use in treating a motor neuron disease (MND) in a subject in need thereof.
3. The method of claim 1, or agent of claim 2, wherein said agent capable of enhancing processing of pre-miRNA is selected from the group consisting of a nuclear processing enhancer, a nuclear export enhancer and a cytoplasmic processing enhancer.
4. The method of claim 1, or agent of claim 2, wherein said cytoplasmic processing enhancer comprises a Dicer enhancer.
5. The method or agent of claim 4, wherein said Dicer enhancer comprises a quinolone.
6. The method or agent of claim 5, wherein said Dicer enhancer is selected from the group consisting of enoxacin, ciproflaxin and ofloxacin.
7. The method or agent of claim 5, wherein said quinolone comprises enoxacin.
8. A method of treating an Amyotrophic Lateral Sclerosis (ALS) in a subject in need thereof, the method comprising administering to the subject a therapeutically effective amount of an agent capable of enhancing processing of a pre-miRNA and an anti-ALS agent, thereby treating the ALS in the subject.

9. An agent capable of enhancing processing of a pre-miRNA and an anti-ALS agent for use in treating an Amyotrophic Lateral Sclerosis (ALS) in a subject in need thereof.

10. The method of claim 8, or agent of claim 9, wherein said anti-ALS agent comprises a Riluzole.

11. A pharmaceutical composition comprising as an active ingredient an agent capable of enhancing processing of a pre-miRNA, an anti-ALS agent and a pharmaceutically acceptable carrier or diluent.

12. An article of manufacture comprising an agent capable of enhancing processing of a pre-miRNA and an anti-ALS agent being packaged in a packaging material and identified in print, in or on said packaging material for use in the treatment of ALS.

13. The pharmaceutical composition of claim 11, or article of manufacture of claim 12, wherein said agent capable of enhancing processing of a pre-miRNA comprises a quinolone.

14. The pharmaceutical composition of claim 11, or article of manufacture of claim 12, wherein said quinolone comprises enoxacin.

15. A method diagnosing a MND, the method comprising analyzing in a sample of a subject in need thereof:

- (i) total miR expression; and optionally
- (ii) total pre-miR expression, wherein a down-regulation in said (i) or (i)/(ii) beyond a predetermined threshold is indicative of the MND.

16. A method diagnosing a MND, the method comprising analyzing in a sample of a subject in need thereof:

- (i) a miR expression; and

(ii) an expression of a precursor of said miR, wherein a down-regulation in (i)/(ii) beyond a predetermined threshold is indicative of the MND.

17. The method of claim 16, wherein said miR is miR-9.

18. The method of claim 1, 15 or 16, or agent of claim 2, wherein the MND is selected from the group consisting of ALS, primary lateral sclerosis, progressive muscular atrophy, pseudobulbar palsy, progressive bulbar palsy, lower motor neuron disease and spinal muscular atrophy.

19. The method of claim 1, 15 or 16, or agent of claim 2, wherein said MND comprises Amyotrophic Lateral Sclerosis (ALS).

20. The method of claim 8 or 19, or agent of claim 9, wherein said ALS is associated with a gene having a mutation associated with an impaired RNA metabolism.

21. The method of claim 8 or 19, or agent of claim 9, wherein said ALS is an inherited ALS.

22. The method of claim 8 or 19, or agent of claim 9, wherein said ALS is a sporadic ALS.

23. The method of claim 15 or 16, wherein said sample comprises a cerebrospinal fluid (CSF) sample or a blood sample.

24. A method of identifying an agent for the treatment of a MND, the method comprising:

(a) contacting a motor neuron of an ALS patient or an ALS model with a candidate agent;

(b) analyzing prior to (a) and following (a):

(i) total miR expression in said motor neuron; and optionally

(ii) total pre-miR expression in said motor neuron,

wherein an up-regulation in said (i) or (i)/(ii) beyond a predetermined threshold following (a) as compared to prior to (a), is indicative of that the candidate compound is a therapeutic agent for the treatment of MND.

FIG. 1C

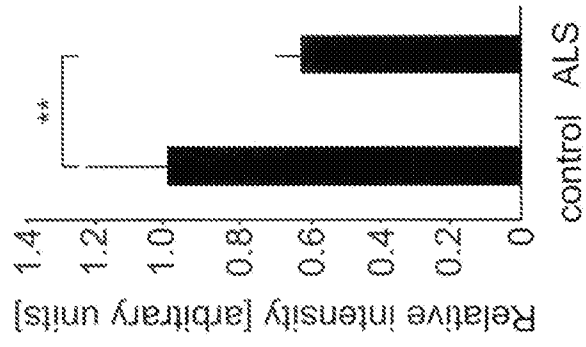


FIG. 1B

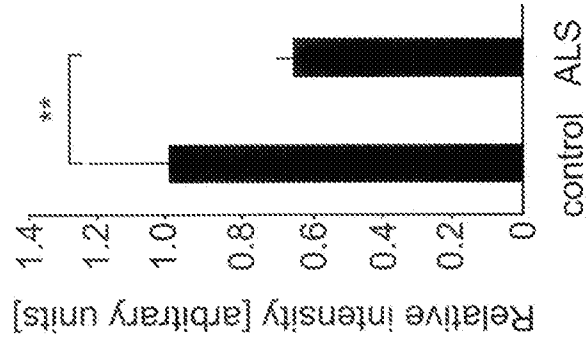
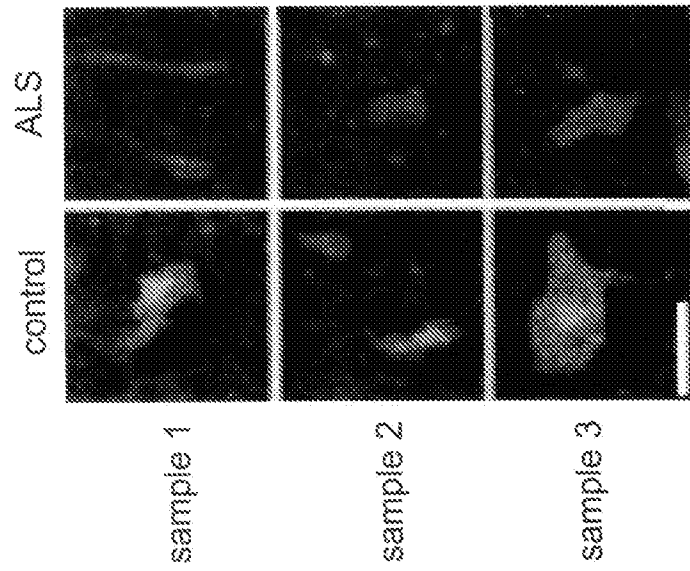


FIG. 1A



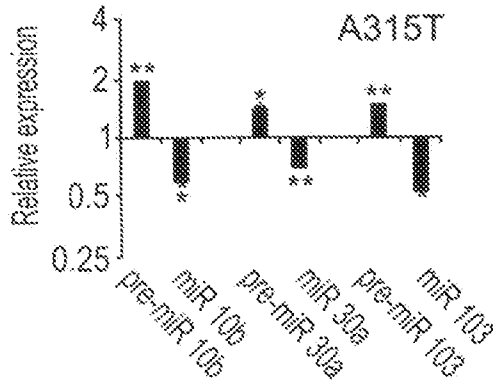


FIG. 2A

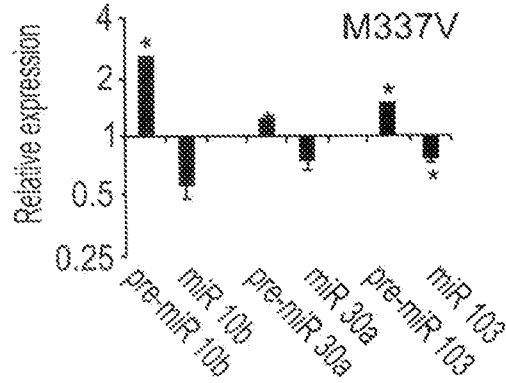


FIG. 2B

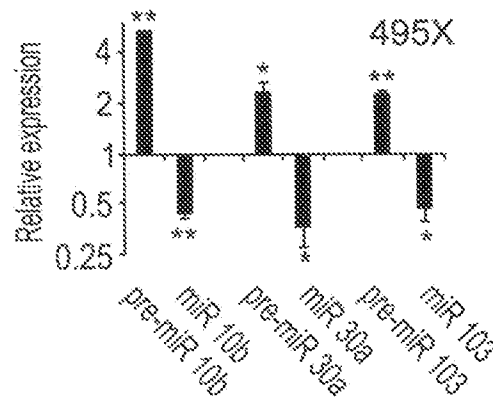


FIG. 2C

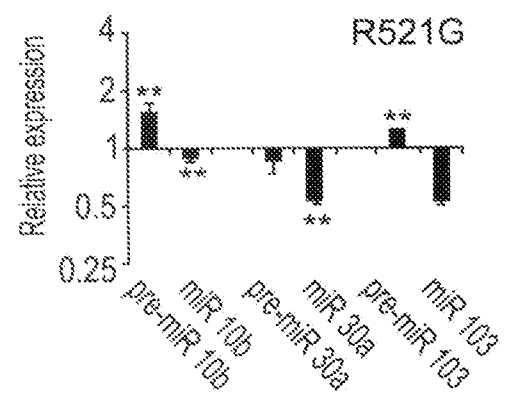


FIG. 2D

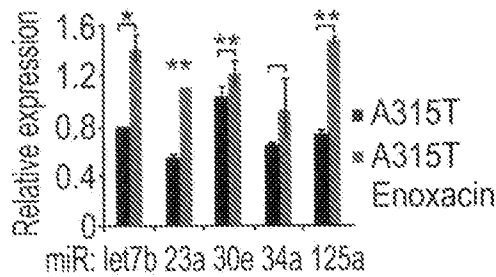


FIG. 2E

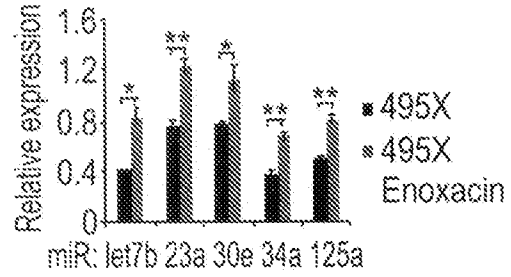


FIG. 2F

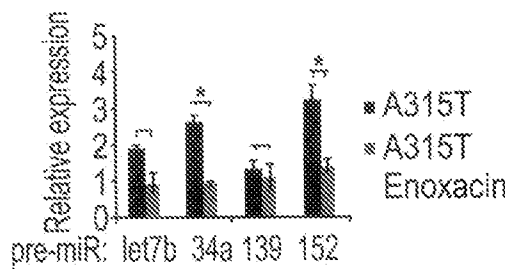


FIG. 2G

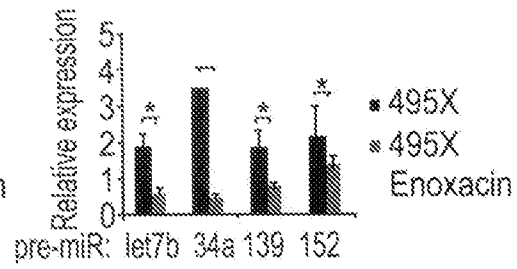


FIG. 2H

FIG. 3

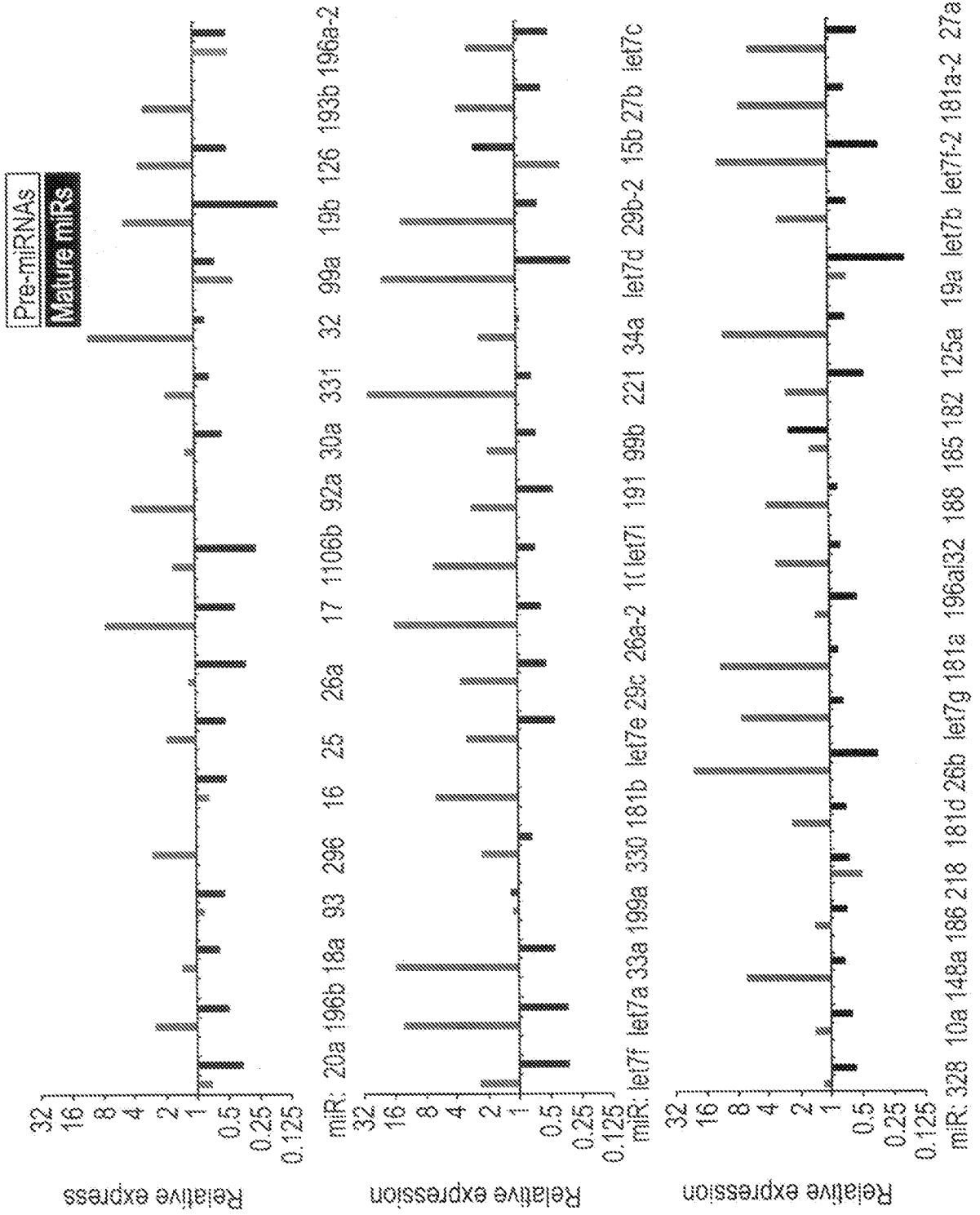


FIG. 4B

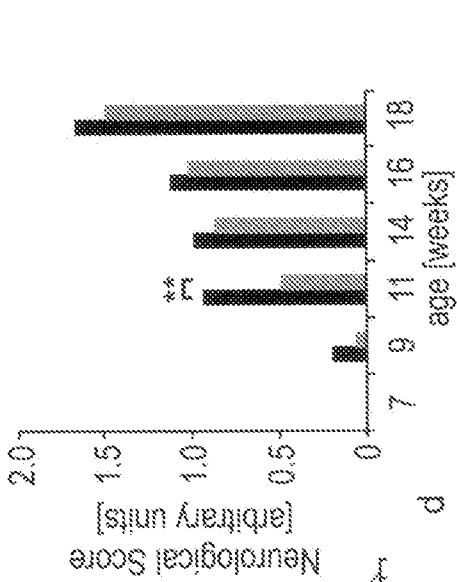


FIG. 4A

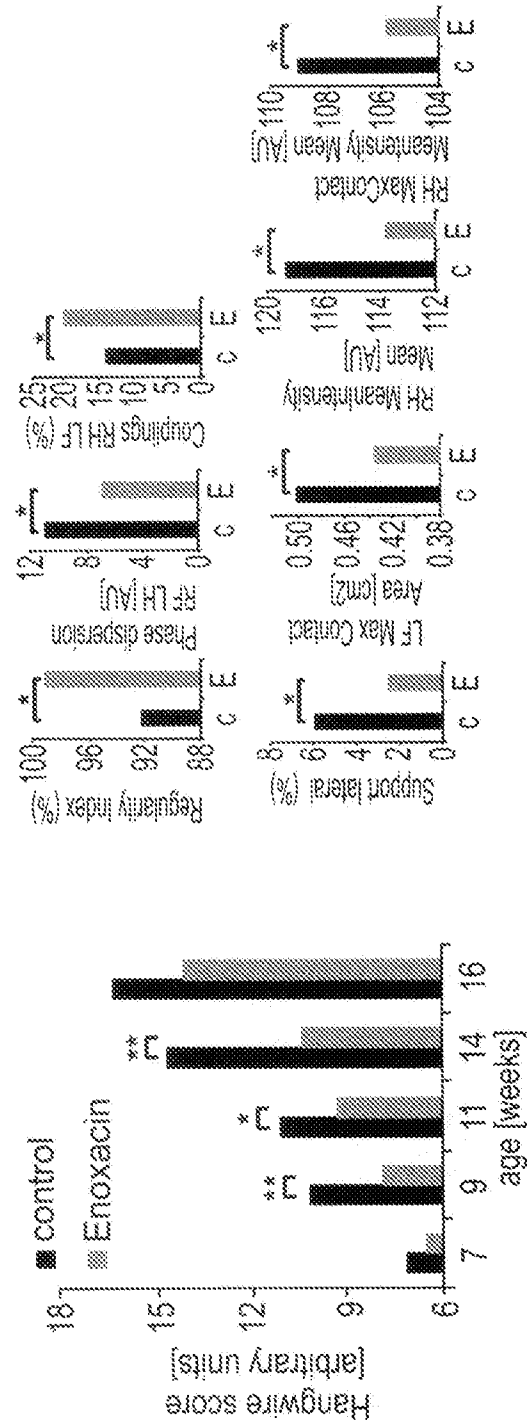
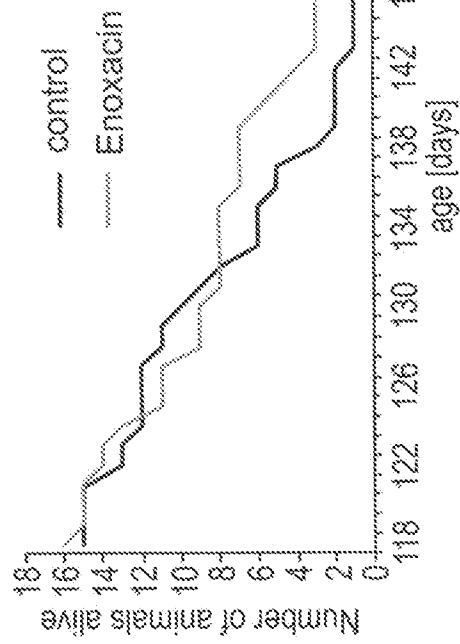


FIG. 4D

FIG. 4C

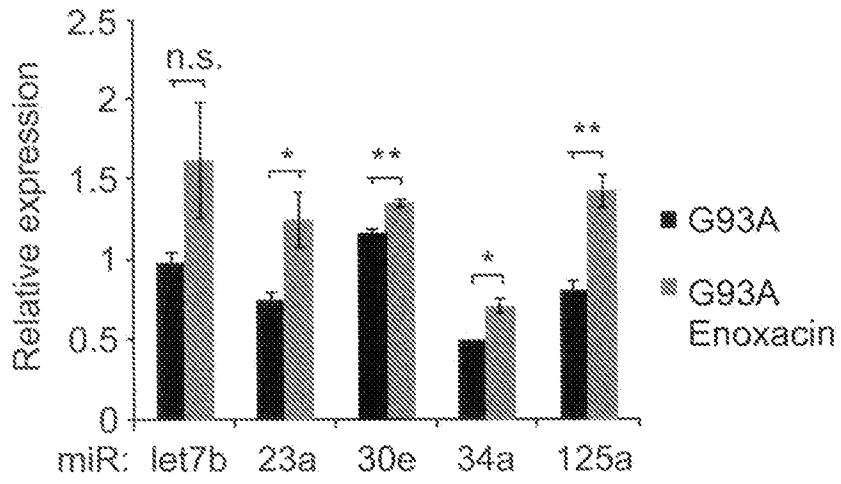


FIG. 5A

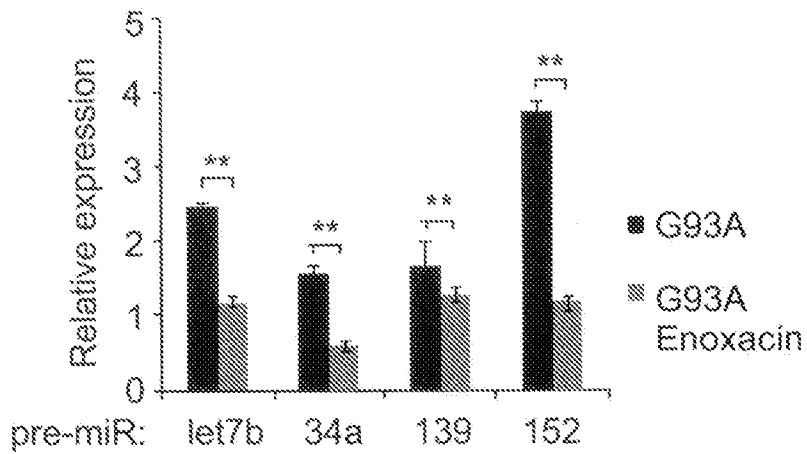


FIG. 5B

INTERNATIONAL SEARCH REPORT

International application No
PCT/IL2013/050655

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61K31/496 A61K31/538 A61P25/00 A61P25/28
ADD.
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
A61K A61P
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, BIOSIS, CHEM ABS Data, EMBASE, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	<p>EDUARDO GASCON ET AL: "Cause or Effect: Misregulation of microRNA Pathways in Neurodegeneration", FRONTIERS IN NEUROSCIENCE, vol. 6, 9 April 2012 (2012-04-09), pages 1-10, XP055081041, DOI: 10.3389/fnins.2012.00048 abstract "ALS AND FTD"; page 5, left-hand column - right-hand column page 5, right-hand column, line 3 - line 23</p> <p style="text-align: center;">----- -/--</p>	1-24

Further documents are listed in the continuation of Box C.

See patent family annex.

* Special categories of cited documents :

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier application or patent but published on or after the international filing date
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- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed

- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
- "&" document member of the same patent family

Date of the actual completion of the international search 1 October 2013	Date of mailing of the international search report 08/10/2013
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Economou, Dimitrios

INTERNATIONAL SEARCH REPORT

International application No
PCT/IL2013/050655

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	<p>Y. KAWAHARA ET AL: "TDP-43 promotes microRNA biogenesis as a component of the Drosha and Dicer complexes", PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES, vol. 109, no. 9, 9 February 2012 (2012-02-09), pages 3347-3352, XP055081044, ISSN: 0027-8424, DOI: 10.1073/pnas.1112427109 cited in the application the whole document</p>	1-24
Y	<p>S. MELO ET AL: "Small molecule enoxacin is a cancer-specific growth inhibitor that acts by enhancing TAR RNA-binding protein 2-mediated microRNA processing", PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES, vol. 108, no. 11, 15 March 2011 (2011-03-15), pages 4394-4399, XP055081058, ISSN: 0027-8424, DOI: 10.1073/pnas.1014720108 the whole document abstract page 4394, right-hand column, paragraph 2</p>	1-24
Y	<p>GE SHAN ET AL: "A small molecule enhances RNA interference and promotes microRNA processing", NATURE BIOTECHNOLOGY, vol. 26, no. 8, 20 July 2008 (2008-07-20), pages 933-940, XP055081064, ISSN: 1087-0156, DOI: 10.1038/nbt.1481 cited in the application the whole document abstract page 933 - page 939, line 4</p>	1-24