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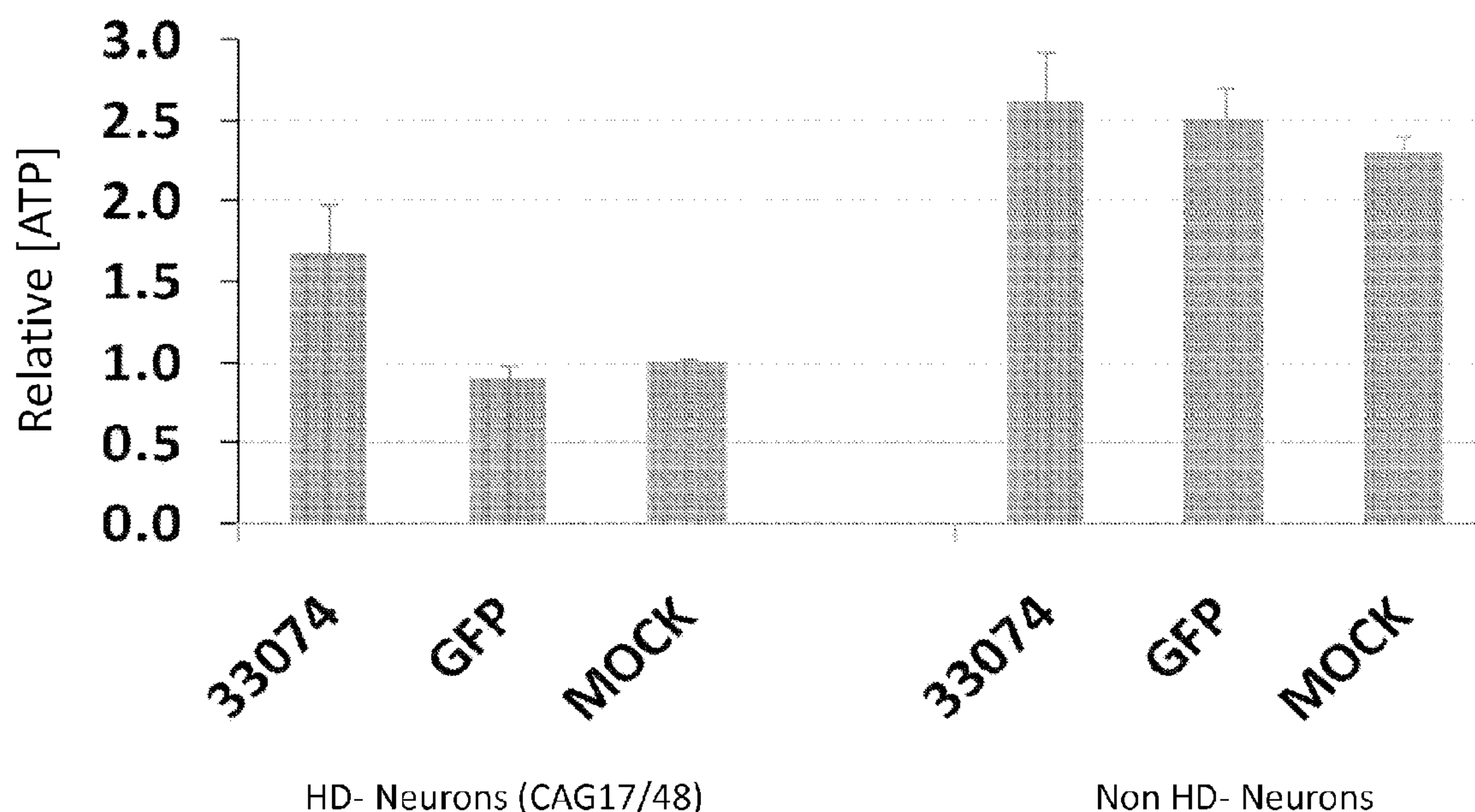


FIGURE 1

(57) **Abrégé/Abstract:**

Disclosed are methods and compositions for treating or preventing Huntington's Disease (HD). Specifically, provided are methods and compositions for reducing and/or eliminating Huntingtin (Htt) aggregates, ameliorating motor deficits, increasing cellular activity (e.g., ATP activity), and/or reducing apoptosis in subject with HD, the methods comprising administering a repressor of a mutant Htt (mHtt) allele to the subject. Further disclosed are methods of diagnosis of HD and/or monitoring the disease progression comprising detecting mHtt in a subject.



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(54) Title: METHODS AND COMPOSITIONS FOR TREATING HUNTINGTON'S DISEASE

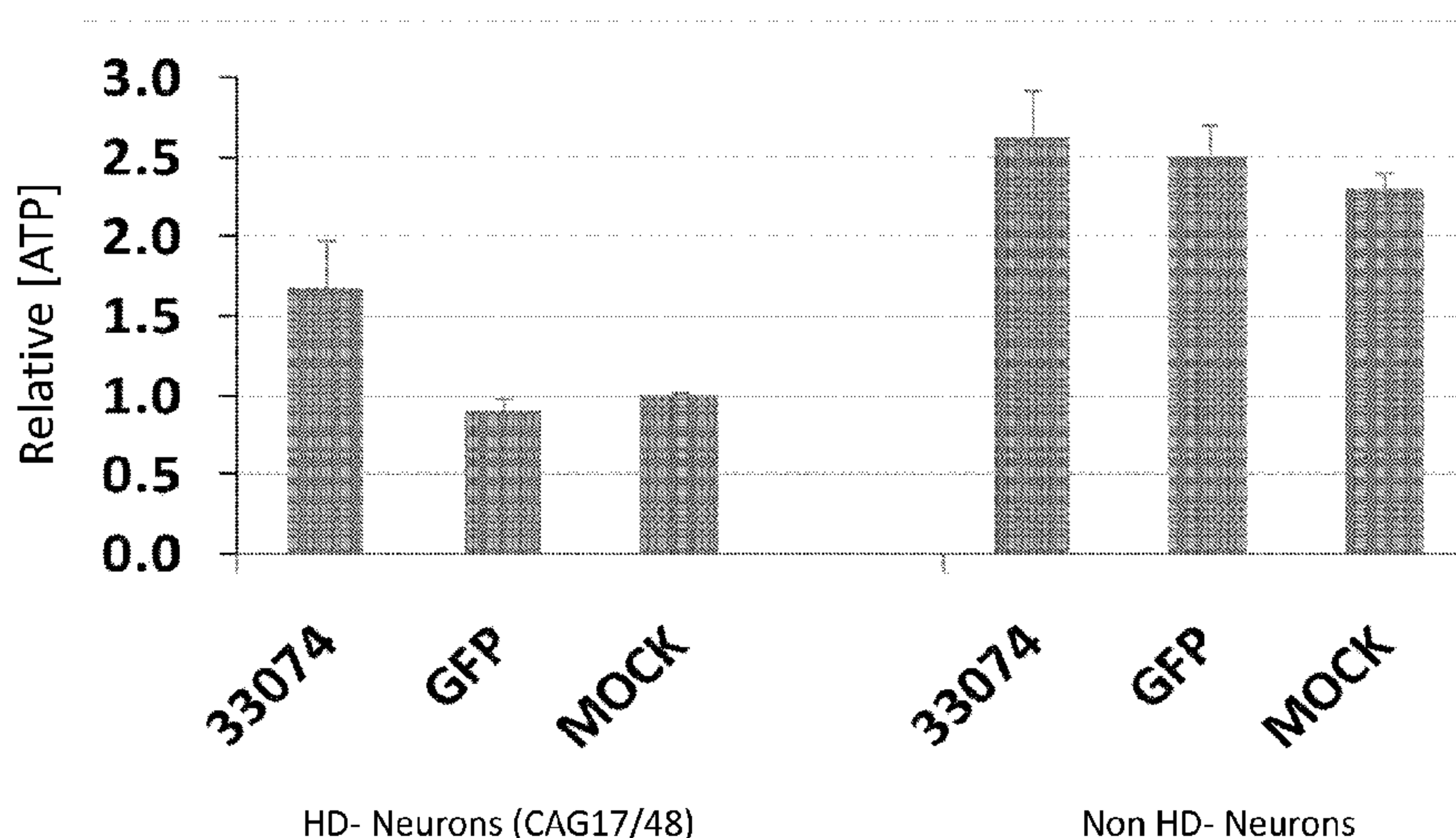


FIGURE 1

(57) Abstract: Disclosed are methods and compositions for treating or preventing Huntington's Disease (HD). Specifically, provided are methods and compositions for reducing and/or eliminating Huntingtin (Htt) aggregates, ameliorating motor deficits, increasing cellular activity (e.g., ATP activity), and/or reducing apoptosis in subject with HD, the methods comprising administering a repressor of a mutant Htt (mHtt) allele to the subject. Further disclosed are methods of diagnosis of HD and/or monitoring the disease progression comprising detecting mHtt in a subject.

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METHODS AND COMPOSITIONS FOR TREATING HUNTINGTON'S DISEASE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims the benefit of U.S. Provisional Application No. 61/990,521 filed May 8, 2014 and U.S. Provisional Application No. 62/051,724, filed September 17, 2014, the disclosures of which are hereby incorporated by reference in their entirety.

TECHNICAL FIELD

[0002] The present disclosure is in the field of diagnostics and therapeutics for Huntington's Disease.

BACKGROUND

[0003] Huntington's Disease (HD), also known as Huntington's Chorea, is a progressive disorder of motor, cognitive and psychiatric disturbances. The mean age of onset for this disease is age 35-44 years, although in about 10% of cases, onset occurs prior to age 21, and the average lifespan post-diagnosis of the disease is 15-18 years. Prevalence is about 3 to 7 among 100,000 people of western European descent.

[0004] Huntington's Disease is an example of a trinucleotide repeat expansion disorders were first characterized in the early 1990s (*see* Di Prospero and Fischbeck (2005) *Nature Reviews Genetics* 6:756-765). These disorders involve the localized expansion of unstable repeats of sets of three nucleotides and can result in loss of function of the gene in which the expanded repeat resides, a gain of toxic function, or both. Trinucleotide repeats can be located in any part of the gene, including non-coding and coding gene regions. Repeats located within the coding regions typically involve either a repeated glutamine encoding triplet (CAG) or an alanine encoding triplet (CGA). Expanded repeat regions within non-coding sequences can lead to aberrant expression of the gene while expanded repeats within coding regions (also known as codon reiteration disorders) may cause mis-folding and protein aggregation. The exact cause of the pathophysiology associated with the aberrant proteins is often not known. Typically, in the wild-type genes that are subject to trinucleotide

expansion, these regions contain a variable number of repeat sequences in the normal population, but in the afflicted populations, the number of repeats can increase from a doubling to a log order increase in the number of repeats. In HD, repeats are inserted within the N terminal coding region of the large cytosolic protein Huntingtin (Htt).

5 Normal Htt alleles contain 15-20 CAG repeats, while alleles containing 35 or more repeats can be considered potentially HD causing alleles and confer risk for developing the disease. Alleles containing 36-39 repeats are considered incompletely penetrant, and those individuals harboring those alleles may or may not develop the disease (or may develop symptoms later in life) while alleles containing 40 repeats or
10 more are considered completely penetrant. In fact, no asymptomatic persons containing HD alleles with this many repeats have been reported. Those individuals with juvenile onset HD (<21 years of age) are often found to have 60 or more CAG repeats. In addition to an increase in CAG repeats, it has also been shown that HD can involve +1 and +2 frameshifts within the repeat sequences such that the region
15 will encode a poly-serine polypeptide (encoded by AGC repeats in the case of a +1 frameshift) track rather than poly-glutamine (Davies and Rubinsztein (2006) *Journal of Medical Genetics* 43: 893-896).

[0005] In HD, the mutant Htt allele is usually inherited from one parent as a dominant trait. Any child born of a HD patient has a 50% chance of developing the
20 disease if the other parent was not afflicted with the disorder. In some cases, a parent may have an intermediate HD allele and be asymptomatic while, due to repeat expansion, the child manifests the disease. In addition, the HD allele can also display a phenomenon known as anticipation wherein increasing severity or decreasing age of onset is observed over several generations due to the unstable nature of the repeat
25 region during spermatogenesis.

[0006] Furthermore, trinucleotide expansion in Htt leads to neuronal loss in the medium spiny gamma-aminobutyric acid (GABA) projection neurons in the striatum, with neuronal loss also occurring in the neocortex. Medium spiny neurons that contain enkephalin and that project to the external globus pallidum are more
30 involved than neurons that contain substance P and project to the internal globus pallidum. Other brain areas greatly affected in people with Huntington's disease include the substantia nigra, cortical layers 3, 5, and 6, the CA1 region of the hippocampus, the angular gyrus in the parietal lobe, Purkinje cells of the cerebellum,

lateral tuberal nuclei of the hypothalamus, and the centromedialparafascicular complex of the thalamus (Walker (2007) *Lancet* 369:218-228).

[0007] The role of the normal Htt protein is poorly understood, but it may be involved in neurogenesis, apoptotic cell death, and vesicle trafficking. In addition, there is evidence that wild-type Htt stimulates the production of brain-derived neurotrophic factor (BDNF), a pro-survival factor for the striatal neurons. It has been shown that progression of HD correlates with a decrease in BDNF expression in mouse models of HD (Zuccato *et al* (2005) *Pharmacological Research* 52(2): 133-139), and that delivery of either BDNF or glial cell line-derived neurotrophic factor (GDNF) via adeno-associated viral (AAV) vector-mediated gene delivery may protect straital neurons in mouse models of HD (Kells *et al*, (2004) *Molecular Therapy* 9(5): 682-688).

[0008] Diagnostic and treatment options for HD are currently very limited. In terms of diagnostics, altered (mutant) Htt (mHTT) levels are significantly associated with disease burden score, and soluble mHTT species increase in concentration with disease progression. However, low-abundance mHTT is difficult to quantify in the patient CNS, which limits both study of the role in the neuropathobiology of HD *in vivo*, and precludes the demonstration of target engagement by HTT-lowering drugs. See, e.g., Wild *et al*. (2014) *J Neurol Neurosurg Psychiatry* 85:e4.

[0009] With regard to treatment, some potential methodologies designed to prevent the toxicities associated with protein aggregation that occurs through the extended poly-glutamine tract such as overexpression of chaperonins or induction of the heat shock response with the compound geldanamycin have shown a reduction in these toxicities in *in vitro* models. Other treatments target the role of apoptosis in the clinical manifestations of the disease. For example, slowing of disease symptoms has been shown via blockage of caspase activity in animal models in the offspring of a pairing of mice where one parent contained a HD allele and the other parent had a dominant negative allele for caspase 1. Additionally, cleavage of mutant HD Htt by caspase may play a role in the pathogenicity of the disease. Transgenic mice carrying caspase-6 resistant mutant Htt were found to maintain normal neuronal function and did not develop striatal neurodegeneration as compared to mice carrying a non-caspase resistant mutant Htt allele (see Graham *et al* (2006) *Cell* 125: 1179-1191). Molecules which target members of the apoptotic pathway have also been shown to

have a slowing effect on symptomology. For example, the compounds zVAD-fmk and minocycline, both of which inhibit caspase activity, have been shown to slow disease manifestation in mice. The drug remacemide has also been used in small HD human trials because the compound was thought to prevent the binding of the mutant Htt to the NDMA receptor to prevent the exertion of toxic effects on the nerve cell. However, no statistically significant improvements were observed in neuron function in these trials. In addition, the Huntington Study Group conducted a randomized, double-blind study using Co-enzyme Q. Although a trend towards slower disease progression among patients that were treated with coenzyme Q10 was observed, there was no significant change in the rate of decline of total functional capacity. (Di Prospero and Fischbeck, *ibid*).

[0010] Recombinant transcription factors comprising the DNA binding domains from zinc finger proteins ("ZFPs"), TAL-effector domains ("TALEs") and CRISPR/Cas transcription factor systems have the ability to regulate gene expression of endogenous genes (*see, e.g.*, U.S. Patent Nos. 8,586,526; 6,534,261; 6,599,692; 6,503,717; 6,689,558; 7,067,317; 7,262,054; Perez-Pinera et al. (2013) *Nature Methods* 10:973–976; Platek et al. (2014) *Plant Biotechnology J.* doi: 10.1111/pbi.12284). Clinical trials using these engineered transcription factors containing zinc finger proteins have shown that these novel transcription factors are capable of treating various conditions. (*see, e.g.*, Yu et al. (2006) *FASEB J.* 20:479–481). In addition, artificial nucleases comprising the DNA binding domains from zinc finger proteins ("ZFPs"), TAL-effector domains ("TALEs"), Ttgo and CRISPR/Cas or Ttgo nuclease systems have the ability to modify gene expression of endogenous genes via nuclease-mediated modification of the gene, including either homology directed repair (HDR), following non-homologous end joining (NHEJ) and/or by end capture during non-homologous end joining (NHEJ) driven processes. *See, for example*, 8,623,618; 8,034,598; 8,586,526; 6,534,261; 6,599,692; 6,503,717; 6,689,558; 7,067,317; 7,262,054; 7,888,121; 7,972,854; 7,914,796; 7,951,925; 8,110,379; 8,409,861; U.S. Patent Publications 20030232410; 20050208489; 20050026157; 20060063231; 20080159996; 201000218264; 20120017290; 20110265198; 20130137104; 20130122591; 20130177983; 20130177960 and 20150056705, the disclosures of which are incorporated by reference in their entireties for all purposes. Thus, these methods often involve the use of engineered

cleavage systems to induce a double strand break (DSB) or a nick in a target DNA sequence such that repair of the break by an error born process such as non-homologous end joining (NHEJ) or repair using a repair template (homology directed repair or HDR) can result in the knock out of a gene or the insertion of a sequence of interest (targeted integration). Introduction of a double strand break in the absence of an externally supplied repair template (*e.g.* “donor” or “transgene”) is commonly used for the inactivation of the targeted gene via mutations (insertions and/or deletions known as “indels”) introduced by the cellular NHEJ pathway. For instance, U.S. Patent Publication 20110082093 discloses specific zinc finger proteins targeted to Htt and U.S. Patent Publication No. 20130253040 relates to DNA-binding proteins that modulate expression of an HD allele such as Htt.

[0011] However, there remains a need for methods for the diagnosis, study, treatment and/or prevention of Huntington’s Disease, including detection of mHTT for monitoring disease progression, for increased understanding of the neuropathobiology of HD and to evaluate disease-modifying HD therapeutics.

SUMMARY

[0012] Disclosed herein are methods and compositions for diagnosing and/or treating Huntington’s Disease. In particular, provided herein are methods and compositions for detecting, reducing and/or eliminating Htt aggregates, ameliorating motor deficits, increasing cellular activity (*e.g.*, ATP activity) and/or reducing apoptosis in subject with HD.

[0013] Thus, in one aspect, described here is a method of modifying a neuron in a subject with HD, the method comprising administering a repressor of a mutant Htt allele to the subject such that the neuron is modified. In certain embodiments, the neuron is a neuron that comprises a mutant Htt allele and/or that comprises an increased amount of intracellular aggregated Htt (an “HD neuron”). In certain embodiments, the modification comprises reducing the aggregation of Htt in the neuron (*e.g.*, an HD neuron); increasing neuron (*e.g.*, an HD neuron) energy metabolism, *e.g.*, by increasing intracellular ATP levels; and/or reducing susceptibility to apoptosis in the neuron (*e.g.*, an HD neuron) . In certain embodiments, the subject is a mammal.

[0014] Thus, in other aspects, described herein is a method of preventing and/or reducing the formation of Htt aggregates in HD neurons of a subject with HD, the method comprising administering a repressor of a mutant Htt allele to the subject.

[0015] In other aspects, described herein is a method of increasing cellular activity (*e.g.*, ATP activity) in a neuron (*e.g.*, an HD neuron), the method comprising administering a repressor of a mutant Htt allele to the neuron.

[0016] In other aspects, described herein is a method of reducing apoptosis in a neuron (*e.g.*, an HD neuron), the method comprising administering a repressor of a mutant Htt allele to the neuron.

10 [0017] In another aspect, described herein is a method for reducing motor deficits (*e.g.*, claspings) in HD subjects in need thereof by administering a repressor of a mutant Htt allele to the subject in need thereof.

[0018] In yet another aspect, described herein is a method for detecting mHtt in a subject (*e.g.*, in the CSF), including detecting mHtt in response to therapy (*e.g.*, in response to administration of an Htt repressor as described herein). In certain
15 embodiments, the detecting involves quantifying the amount of mHtt in the subject. Any of the detection methods described herein can be used for diagnosis of HD and/or for monitoring of disease progression, as mHTT levels are significantly associated with disease burden score and mHTT levels increase in concentration as the disease
20 progresses. Furthermore, any of the methods of detecting (*e.g.*, quantifying) mHtt in a subject can be used in methods of evaluating the neuropathobiology of HD and/or to evaluate the efficacy of disease-modifying HD therapeutics.

[0019] In any of the methods described herein, the repressor of the mutant Htt allele may be a ZFP-TF, for example a fusion protein comprising a ZFP that binds
25 specifically to a mutant Htt allele and a transcriptional repression domain (*e.g.*, KOX, KRAB, etc.). In other embodiments, the repressor of the mutant Htt allele may be a TALE-TF, for example a fusion protein comprising a TALE polypeptide that binds specifically to a mutant Htt allele and a transcriptional repression domain (*e.g.*, KOX, KRAB, etc.). In some embodiments, the mutant Htt allele repressor is a
30 CRISPR/Cas-TF where the nuclease domains in the Cas protein have been inactivated such that the protein no longer cleaves DNA. The resultant Cas RNA-guided DNA binding domain is fused to a transcription repressor (*e.g.* KOX, KRAB etc.) to repress the mutant Htt allele. In still further embodiments, the repressor may comprise a

nuclease (*e.g.*, ZFN, TALEN and/or CRISPR/Cas system) that represses the mutant Htt allele by cleaving and thereby inactivating the mutant Htt allele. In certain embodiments, the nuclease introduces an insertion and/or deletion (“indel”) via non-homologous end joining (NHEJ) following cleavage by the nuclease. In other
 5 embodiments, the nuclease introduces a donor sequence (by homology or non-homology directed methods), in which the donor integration inactivates the mutant Htt allele.

[0020] In any of the methods described herein, the repressor may be delivered to the neuron (*e.g.*, HD neuron) as a protein, polynucleotide or any combination of
 10 protein and polynucleotide. In certain embodiments, the repressor(s) is(are) delivered using an expression construct, for example a plasmid, or a viral vector (*e.g.*, a lentiviral vector, an adenoviral (Ad) vector, an adeno-associated viral (AAV) vector or the like). In other embodiments, the repressor is delivered as an mRNA. In other embodiments, the repressor(s) is(are) delivered using a combination of any of the
 15 expression constructs described herein, for example one repressor (or portion thereof) on one expression construct and one repressor (or portion thereof) on a separate expression construct.

[0021] Furthermore, in any of the methods described herein, the repressors can be delivered at any concentration (dose) that provides the desired effect. In
 20 certain embodiments, the repressor is delivered using a lentiviral vector at MOI between 250 and 1,000 (or any value therebetween). In other embodiments, the repressor is delivered using a plasmid vector at 150-1,500 ng/100,000 cells (or any value therebetween). In still further embodiments, the repressor is delivered using an adeno-associated virus vector at 10,000 - 500,000 vector genome/cell (or any value
 25 therebetween). In other embodiments, the repressor is delivered as mRNA at 150-1,500 ng/100,000 cells (or any value therebetween).

[0022] In any of the methods described herein, the method can yield about 85% or greater, about 90% or greater, about 92% or greater, or about 95% or greater repression of the mutant Htt alleles in one or more HD neurons of the subject.

30 [0023] In further aspects, the invention described herein comprises one or more Htt-modulating transcription factors, such as a Htt-modulating transcription factors comprising one or more of a zinc finger protein (ZFP TFs), a TALEs (TALE-TF), and a CRISPR/Cas-TFs for example, ZFP-TFs, TALE-TFs or CRISPR/Cas-TFs.

In certain embodiments, the Htt-modulating transcription factor can repress expression of a mutant Htt allele in one or more HD neurons of a subject. The repression can be about 85% or greater, about 90% or greater, about 92% or greater, or about 95% or greater repression of the mutant Htt alleles in the one or more HD neurons of the subject as compared to untreated (wild-type) neurons of the subject. In certain embodiments, the Htt-modulating transcription factor can be used to achieve one or more of the methods described herein.

[0024] Also provided is a kit comprising one or more of the Htt-modulators (*e.g.*, repressors) and/or polynucleotides comprising components of and/or encoding the Htt-modulators (or components thereof) as described herein. The kits may further comprise cells (*e.g.*, neurons), reagents (*e.g.*, for detecting and/or quantifying mHtt protein, for example in CSF) and/or instructions for use, including the methods as described herein.

[0025] These and other aspects will be readily apparent to the skilled artisan in light of disclosure as a whole.

BRIEF DESCRIPTION OF THE DRAWINGS

[0026] **Figure 1** is a graph depicting relative intracellular ATP levels in HD-neurons (3 left bars as indicated) and non-HD neurons (3 right bars as indicated) after administration of the indicated constructs to the neurons. “33074” refers to ZFP-TF repressor including ZFP 33074 (Table 1A, that is specific for mutant Htt) fused to a transcriptional repression domain (KOX) as well as a GFP encoding sequences; “GFP” refers to a construct that encodes only GFP (no ZFP-TF); and “mock” refers to constructs without encoding sequences.

[0027] **Figure 2** is a graph depicting percentage of apoptotic cells in HD-neurons (3 left bars as indicated) and non-HD neurons (3 right bars as indicated), as determined by TUNEL assay, after administration of the indicated constructs (see Figure 1) to the neurons.

[0028] **Figures 3A through 3K** depict the prevention of mutant Htt aggregation in Q175 mice following treatment with ZFP-TF repressors of Htt mutant alleles. Figures 3A-3H show representative images of immunohistochemical analysis of brain slices obtained from the mice treated with ZFP-TF expression constructs. Figures 3A to 3D show images stained with 4',6-diamidino-2-phenylindole (DAPI),

which labels nuclear DNA and an antibody for the FLAG epitope tag (which indicates the presence of the ZFP-TF). The ZFP-TF is present only to the side to which it was administered (ipsilateral). Figures 3E to 3H show representative images following staining with an antibody (mEM48) directed to mutant Htt aggregates. In the

5 contralateral striatum that received no injection, mutant Htt aggregation was readily detected by the mEM48 antibody as compared the ipsilateral striatum that received the ZFP-TF expression construct via injection, in which very low levels of mutant Htt aggregation were observed. Figure 3I is a graph showing the number of nuclear Htt aggregates per cell (as quantified for FLAG(+) and GFP(+) cells) in the ipsilateral

10 striatum normalized to the number of aggregates per cell in the uninjected contralateral striatum with the indicated constructs. Figure 3J is a graph showing the intensity of nuclear mEM48 staining for Htt aggregates in cells receiving the indicated constructs normalized to that in neurons from the contralateral striatum. Figure 3K is a graph showing the density of perinuclear mutant Htt aggregates in ZFP-TF repressor

15 or GFP-expressing cells normalized to that in contralateral striatal neurons. In Figures 3I to 3K, “GFP” refers to a construct that encodes GFP but does encode a ZFP-TF Htt repressor; “30640” and “30645” refer to the specific ZFP designs used in the injected constructs (Table 1). Statistical analysis was performed by Kruskal Wallis test and Dunn’s multiple comparison; * $p < 0.05$; ** $p < 0.01$, *** $p < 0.001$; data

20 are displayed as bar graphs with mean + SEM.

[0029] Figures 4A through 4D depict the reversal of mutant Htt aggregation in Q175 mice following treatment with ZFP-TF repressors of Htt mutant alleles. Figure 4A shows representative images of ZFP-TF and control animal brain sections stained with DARPP-32 (a striatum-specific protein) and an anti-Htt aggregate

25 antibody mEM48 in the contralateral and ipsilateral striatum. Figure 4B is a graph showing the number of nuclear Htt aggregates per cell (as quantified for FLAG(+) and GFP(+) cells) in the ipsilateral striatum normalized to the number of aggregates per cell in the uninjected contralateral striatum with the indicated constructs. Figure 4C is a graph showing the intensity of nuclear mEM48 staining for Htt aggregates in

30 cells receiving the indicated constructs normalized to that in neurons from the contralateral striatum. Figure 4D is a graph showing the density of perinuclear mutant Htt aggregates in ZFP-TF repressor or GFP-expressing cells normalized to that in contralateral striatal neurons. In Figures 4B to 4D, “GFP” refers to a construct that

encodes GFP but does encode a ZFP-TF Htt repressor; “GFP-2A-30640” and “GFP-2A-30645” refer to constructs encoding GFP and the specific ZFP designs used in the injected constructs (Table 1). Statistical analysis was performed by Kruskal Wallis test and Dunn’s multiple comparison; * $p < 0.05$; ** $p < 0.01$, *** $p < 0.001$; data are
 5 displayed as bar graphs with mean + SEM.

[0030] Figures 5A through 5C depict the prevention of mutant Htt aggregation in the striatum of Q175 mice following injection AAV-ZFP-33074. The AAV vector was delivered into the striatum at 2 months of age, the analysis was performed at 4 months of age. Figure 5A is a graph showing the number of nuclear
 10 Htt aggregates in AAV-transduced (labeled by GFP) medium spiny neuron (MSN, labeled by a DARPP32 antibody). Figure 5B is a graph showing the density of extranuclear mutant Htt aggregates in AAV-transduced MSNs. Figure 5C is a graph showing the intensity of nuclear mEM48 antibody staining for Htt aggregates in AAV-transduced MSNs. “Control AAV” refers to an AAV vector that expresses
 15 GFP, “ZFP 33074” refers to an AAV vector that expresses both ZFP 33074 and GFP, linked by the self-cleaving 2A peptide. Data are displayed as dot plots with mean +/- SEM. Statistical analysis was performed using Kruskal-Wallis test with Dunn post test versus the control; ***= $p < 0.001$. For every group an n of 4 animals with 6 sections per animal were used for quantitation.

[0031] Figures 6A through 6C depict the reduction of mutant Htt aggregation in the striatum of Q175 mice following injection AAV-ZFP-33074. The AAV vector was delivered into the striatum at 6 months of age, the analysis was performed at 10 months of age. Figure 6A is a graph showing the number of nuclear
 20 Htt aggregates in AAV-transduced (labeled by GFP) medium spiny neuron (MSN, labeled by a DARPP32 antibody). Figure 6B is a graph showing the density of extranuclear mutant Htt aggregates in AAV-transduced MSNs. Figure 6C is a graph showing the intensity of nuclear mEM48 antibody staining for Htt aggregates in AAV-transduced MSNs. “Control AAV” refers to an AAV vector that expresses
 25 GFP, “ZFP 33074” refers to an AAV vector that expresses both ZFP 33074 and GFP, linked by the self-cleaving 2A peptide. “ZFP Δ DBD” refers to a control AAV vector that is similar to “ZFP 33074” except it lacks the zinc finger DNA binding domain (DBD). Data are displayed as dot plots with mean +/- SEM. Statistical analysis was
 30 performed using Kruskal-Wallis test with Dunn post test versus the control; ***=

$p < 0.001$; n.s.=not significant. For every group an n of 4 animals with 6 sections per animal were used for quantitation.

[0032] **Figures 7A and 7B** depict the increased DARPP32 expression by immunostaining in the striatum of Q175 mice following injection AAV-ZFP-33074.

5 The AAV vector was delivered into the striatum at 6 months of age, the analysis was performed at 10 months of age. Figure 7A shows that DARPP32 expression is reduced in 10-month-old Q175 mice compared to wild type mice of the same age. Figure 7B shows DARPP32 levels in Q175 striata treated with AAV vector for ZFP 33074 or control AAV vectors. “Control AAV” refers to an AAV vector that
 10 expresses GFP, “ZFP 33074” refers to an AAV vector that expresses both ZFP 33074 and GFP, linked by the self-cleaving 2A peptide. “ZFP Δ DBD” refers to a control AAV vector that is similar to “ZFP 33074” except it lacks the zinc finger DNA binding domain (DBD). Data are displayed as dot plots with mean $\pm$ SEM. Statistical analysis was performed using Kruskal-Wallis test with Dunn post test
 15 versus the control; $*=p < 0.05$, $***=p < 0.001$; n.s.=not significant. For every group an n of 4 animals with 6 sections per animal were used for quantitation.

DETAILED DESCRIPTION

[0033] Disclosed herein are compositions and methods for detecting,
 20 monitoring disease progression, treating and/or preventing Huntington’s disease (HD). In particular, the methods described herein allow for altering of the brain (*e.g.*, HD neurons) in a subject with HD, thereby providing a therapy for HD. Using Htt-modulating transcription factors, such as Htt-modulating transcription factors comprising zinc finger proteins (ZFP TFs), TALEs (TALE-TF), or CRISPR/Cas-TFs
 25 for example, ZFP-TFs, TALE-TFs or CRISPR/Cas-TFs which repress expression of a mutant Htt allele, HD neurons in an HD subject can be modified such that the effects and/or symptoms of HD are reduced or eliminated, for example by reducing the aggregation of Htt in HD neurons, by increasing HD neuron energetics (*e.g.*, increasing ATP levels), by reducing apoptosis in HD neurons and/or by reducing
 30 motor deficits in HD subjects. In addition, the compositions and methods described herein allow for the detection of HD in a patient sample (*e.g.*, CSF). Detecting mHtt levels in patient samples can allow for diagnosis of HD; monitoring of disease progression based on mHtt levels; as well as for evaluation of HD therapies.

General

[0034] Practice of the methods, as well as preparation and use of the compositions disclosed herein employ, unless otherwise indicated, conventional techniques in molecular biology, biochemistry, chromatin structure and analysis, computational chemistry, cell culture, recombinant DNA and related fields as are within the skill of the art. These techniques are fully explained in the literature. *See*, for example, Sambrook *et al.* MOLECULAR CLONING: A LABORATORY MANUAL, Second edition, Cold Spring Harbor Laboratory Press, 1989 and Third edition, 2001; Ausubel *et al.*, CURRENT PROTOCOLS IN MOLECULAR BIOLOGY, John Wiley & Sons, New York, 1987 and periodic updates; the series METHODS IN ENZYMOLOGY, Academic Press, San Diego; Wolffe, CHROMATIN STRUCTURE AND FUNCTION, Third edition, Academic Press, San Diego, 1998; METHODS IN ENZYMOLOGY, Vol. 304, "Chromatin" (P.M. Wassarman and A. P. Wolffe, eds.), Academic Press, San Diego, 1999; and METHODS IN MOLECULAR BIOLOGY, Vol. 119, "Chromatin Protocols" (P.B. Becker, ed.) Humana Press, Totowa, 1999.

Definitions

[0035] The terms "nucleic acid," "polynucleotide," and "oligonucleotide" are used interchangeably and refer to a deoxyribonucleotide or ribonucleotide polymer, in linear or circular conformation, and in either single- or double-stranded form. For the purposes of the present disclosure, these terms are not to be construed as limiting with respect to the length of a polymer. The terms can encompass known analogues of natural nucleotides, as well as nucleotides that are modified in the base, sugar and/or phosphate moieties (*e.g.*, phosphorothioate backbones). In general, an analogue of a particular nucleotide has the same base-pairing specificity; *i.e.*, an analogue of A will base-pair with T.

[0036] The terms "polypeptide," "peptide" and "protein" are used interchangeably to refer to a polymer of amino acid residues. The term also applies to amino acid polymers in which one or more amino acids are chemical analogues or modified derivatives of a corresponding naturally-occurring amino acid.

[0037] "Binding" refers to a sequence-specific, non-covalent interaction between macromolecules (*e.g.*, between a protein and a nucleic acid). Not all components of a binding interaction need be sequence-specific (*e.g.*, contacts with

phosphate residues in a DNA backbone), as long as the interaction as a whole is sequence-specific. Such interactions are generally characterized by a dissociation constant (K_d) of 10^{-6} M⁻¹ or lower. "Affinity" refers to the strength of binding: increased binding affinity being correlated with a lower K_d .

5 [0038] A "binding protein" is a protein that is able to bind non-covalently to another molecule. A binding protein can bind to, for example, a DNA molecule (a DNA-binding protein), an RNA molecule (an RNA-binding protein) and/or a protein molecule (a protein-binding protein). In the case of a protein-binding protein, it can bind to itself (to form homodimers, homotrimers, *etc.*) and/or it can bind to one or more molecules of a
10 different protein or proteins. A binding protein can have more than one type of binding activity. For example, zinc finger proteins have DNA-binding, RNA-binding and protein-binding activity.

[0039] A "zinc finger DNA binding protein" (or binding domain) is a protein, or a domain within a larger protein, that binds DNA in a sequence-specific manner through one
15 or more zinc fingers, which are regions of amino acid sequence within the binding domain whose structure is stabilized through coordination of a zinc ion. The term zinc finger DNA binding protein is often abbreviated as zinc finger protein or ZFP.

[0040] A "TALE DNA binding domain" or "TALE" is a polypeptide comprising one or more TALE repeat domains/units. The repeat domains are involved in binding of
20 the TALE to its cognate target DNA sequence. A single "repeat unit" (also referred to as a "repeat") is typically 33-35 amino acids in length and exhibits at least some sequence homology with other TALE repeat sequences within a naturally occurring TALE protein. *See, e.g.,* U.S. Patent No. 8,586,526.

[0041] "TtAgo" is a prokaryotic Argonaute protein thought to be involved in
25 gene silencing. TtAgo is derived from the bacteria *Thermus thermophilus*. *See, e.g.,* Swarts *et al* (2014) *Nature* 507(7491):258-261, G. Sheng *et al.*, (2013) *Proc. Natl. Acad. Sci. U.S.A.* 111, 652). A "TtAgo system" is all the components required including, for example, guide DNAs for cleavage by a TtAgo enzyme.

"Recombination" refers to a process of exchange of genetic information between two
30 polynucleotides, including but not limited to, donor capture by non-homologous end joining (NHEJ) and homologous recombination. For the purposes of this disclosure, "homologous recombination (HR)" refers to the specialized form of such exchange that takes place, for example, during repair of double-strand breaks in cells via

homology-directed repair mechanisms. This process requires nucleotide sequence homology, uses a "donor" molecule to template repair of a "target" molecule (*i.e.*, the one that experienced the double-strand break), and is variously known as "non-crossover gene conversion" or "short tract gene conversion," because it leads to the transfer of genetic information from the donor to the target. Without wishing to be bound by any particular theory, such transfer can involve mismatch correction of heteroduplex DNA that forms between the broken target and the donor, and/or "synthesis-dependent strand annealing," in which the donor is used to resynthesize genetic information that will become part of the target, and/or related processes. Such specialized HR often results in an alteration of the sequence of the target molecule such that part or all of the sequence of the donor polynucleotide is incorporated into the target polynucleotide.

[0042] Zinc finger binding domains or TALE DNA binding domains can be "engineered" to bind to a predetermined nucleotide sequence, for example via engineering (altering one or more amino acids) of the recognition helix region of a naturally occurring zinc finger protein or by engineering the RVDs of a TALE protein. Therefore, engineered zinc finger proteins or TALEs are proteins that are non-naturally occurring. Non-limiting examples of methods for engineering zinc finger proteins or TALEs are design and selection. A "designed" zinc finger protein or TALE is a protein not occurring in nature whose design/composition results principally from rational criteria. Rational criteria for design include application of substitution rules and computerized algorithms for processing information in a database storing information of existing ZFP designs and binding data. A "selected" zinc finger protein or TALE is a protein not found in nature whose production results primarily from an empirical process such as phage display, interaction trap or hybrid selection. See, for example, U.S. Patents 8,586,526; 6,140,081; 6,453,242; 6,746,838; 7,241,573; 6,866,997; 7,241,574 and 6,534,261; see also WO 03/016496.

[0043] The term "sequence" refers to a nucleotide sequence of any length, which can be DNA or RNA; can be linear, circular or branched and can be either single-stranded or double stranded. The term "donor sequence" refers to a nucleotide sequence that is inserted into a genome. A donor sequence can be of any length, for example between 2 and 10,000 nucleotides in length (or any integer value therebetween or thereabove), preferably between about 100 and 1,000 nucleotides in

length (or any integer therebetween), more preferably between about 200 and 500 nucleotides in length.

[0044] A "target site" or "target sequence" is a nucleic acid sequence that defines a portion of a nucleic acid to which a binding molecule will bind, provided
5 sufficient conditions for binding exist.

[0045] An "exogenous" molecule is a molecule that is not normally present in a cell, but can be introduced into a cell by one or more genetic, biochemical or other methods. "Normal presence in the cell" is determined with respect to the particular developmental stage and environmental conditions of the cell. Thus, for example, a
10 molecule that is present only during embryonic development of muscle is an exogenous molecule with respect to an adult muscle cell. Similarly, a molecule induced by heat shock is an exogenous molecule with respect to a non-heat-shocked cell. An exogenous molecule can comprise, for example, a functioning version of a malfunctioning endogenous molecule or a malfunctioning version of a normally-
15 functioning endogenous molecule.

[0046] An exogenous molecule can be, among other things, a small molecule, such as is generated by a combinatorial chemistry process, or a macromolecule such as a protein, nucleic acid, carbohydrate, lipid, glycoprotein, lipoprotein, polysaccharide, any modified derivative of the above molecules, or any complex
20 comprising one or more of the above molecules. Nucleic acids include DNA and RNA, can be single- or double-stranded; can be linear, branched or circular; and can be of any length. Nucleic acids include those capable of forming duplexes, as well as triplex-forming nucleic acids. See, for example, U.S. Patent Nos. 5,176,996 and 5,422,251. Proteins include, but are not limited to, DNA-binding proteins,
25 transcription factors, chromatin remodeling factors, methylated DNA binding proteins, polymerases, methylases, demethylases, acetylases, deacetylases, kinases, phosphatases, integrases, recombinases, ligases, topoisomerases, gyrases and helicases.

[0047] An exogenous molecule can be the same type of molecule as an
30 endogenous molecule, *e.g.*, an exogenous protein or nucleic acid. For example, an exogenous nucleic acid can comprise an infecting viral genome, a plasmid or episome introduced into a cell, or a chromosome that is not normally present in the cell. Methods for the introduction of exogenous molecules into cells are known to those of

skill in the art and include, but are not limited to, lipid-mediated transfer (*i.e.*, liposomes, including neutral and cationic lipids), electroporation, direct injection, cell fusion, particle bombardment, calcium phosphate co-precipitation, DEAE-dextran-mediated transfer and viral vector-mediated transfer. An exogenous molecule can also
5 be the same type of molecule as an endogenous molecule but derived from a different species than the cell is derived from. For example, a human nucleic acid sequence may be introduced into a cell line originally derived from a mouse or hamster.

[0048] By contrast, an "endogenous" molecule is one that is normally present in a particular cell at a particular developmental stage under particular environmental
10 conditions. For example, an endogenous nucleic acid can comprise a chromosome, the genome of a mitochondrion, chloroplast or other organelle, or a naturally-occurring episomal nucleic acid. Additional endogenous molecules can include proteins, for example, transcription factors and enzymes.

[0049] A "fusion" molecule is a molecule in which two or more subunit
15 molecules are linked, preferably covalently. The subunit molecules can be the same chemical type of molecule, or can be different chemical types of molecules. Examples of the first type of fusion molecule include, but are not limited to, fusion proteins (for example, a fusion between a ZFP or TALE DNA-binding domain and one or more activation domains) and fusion nucleic acids (for example, a nucleic acid
20 encoding the fusion protein described *supra*). Examples of the second type of fusion molecule include, but are not limited to, a fusion between a triplex-forming nucleic acid and a polypeptide, and a fusion between a minor groove binder and a nucleic acid.

[0050] Expression of a fusion protein in a cell can result from delivery of the
25 fusion protein to the cell or by delivery of a polynucleotide encoding the fusion protein to a cell, wherein the polynucleotide is transcribed, and the transcript is translated, to generate the fusion protein. Trans-splicing, polypeptide cleavage and polypeptide ligation can also be involved in expression of a protein in a cell. Methods for polynucleotide and polypeptide delivery to cells are presented elsewhere in this
30 disclosure.

[0051] A "multimerization domain", (also referred to as a "dimerization domain" or "protein interaction domain") is a domain incorporated at the amino, carboxy or amino and carboxy terminal regions of a ZFP TF or TALE TF. These

domains allow for multimerization of multiple ZFP TF or TALE TF units such that larger tracts of trinucleotide repeat domains become preferentially bound by multimerized ZFP TFs or TALE TFs relative to shorter tracts with wild-type numbers of lengths. Examples of multimerization domains include leucine zippers.

5 Multimerization domains may also be regulated by small molecules wherein the multimerization domain assumes a proper conformation to allow for interaction with another multimerization domain only in the presence of a small molecule or external ligand. In this way, exogenous ligands can be used to regulate the activity of these domains.

10 **[0052]** A "gene," for the purposes of the present disclosure, includes a DNA region encoding a gene product (see *infra*), as well as all DNA regions which regulate the production of the gene product, whether or not such regulatory sequences are adjacent to coding and/or transcribed sequences. Accordingly, a gene includes, but is not necessarily limited to, promoter sequences, terminators, translational regulatory
15 sequences such as ribosome binding sites and internal ribosome entry sites, enhancers, silencers, insulators, boundary elements, replication origins, matrix attachment sites and locus control regions.

[0053] "Gene expression" refers to the conversion of the information, contained in a gene, into a gene product. A gene product can be the direct
20 transcriptional product of a gene (*e.g.*, mRNA, tRNA, rRNA, antisense RNA, ribozyme, structural RNA or any other type of RNA) or a protein produced by translation of an mRNA. Gene products also include RNAs which are modified, by processes such as capping, polyadenylation, methylation, and editing, and proteins modified by, for example, methylation, acetylation, phosphorylation, ubiquitination,
25 ADP-ribosylation, myristilation, and glycosylation.

[0054] "Modulation" of gene expression refers to a change in the activity of a gene. Modulation of expression can include, but is not limited to, gene activation and gene repression. Genome editing (*e.g.*, cleavage, alteration, inactivation, random mutation) can be used to modulate expression. Gene inactivation refers to any
30 reduction in gene expression as compared to a cell that does not include a ZFP or TALE protein as described herein. Thus, gene inactivation may be partial or complete.

[0055] A "region of interest" is any region of cellular chromatin, such as, for example, a gene or a non-coding sequence within or adjacent to a gene, in which it is desirable to bind an exogenous molecule. Binding can be for the purposes of targeted DNA cleavage and/or targeted recombination. A region of interest can be present in a chromosome, an episome, an organellar genome (*e.g.*, mitochondrial, chloroplast), or an infecting viral genome, for example. A region of interest can be within the coding region of a gene, within transcribed non-coding regions such as, for example, leader sequences, trailer sequences or introns, or within non-transcribed regions, either upstream or downstream of the coding region. A region of interest can be as small as a single nucleotide pair or up to 2,000 nucleotide pairs in length, or any integral value of nucleotide pairs.

[0056] "Eukaryotic" cells include, but are not limited to, fungal cells (such as yeast), plant cells, animal cells, mammalian cells and human cells (*e.g.*, T-cells).

[0057] The terms "operative linkage" and "operatively linked" (or "operably linked") are used interchangeably with reference to a juxtaposition of two or more components (such as sequence elements), in which the components are arranged such that both components function normally and allow the possibility that at least one of the components can mediate a function that is exerted upon at least one of the other components. By way of illustration, a transcriptional regulatory sequence, such as a promoter, is operatively linked to a coding sequence if the transcriptional regulatory sequence controls the level of transcription of the coding sequence in response to the presence or absence of one or more transcriptional regulatory factors. A transcriptional regulatory sequence is generally operatively linked in *cis* with a coding sequence, but need not be directly adjacent to it. For example, an enhancer is a transcriptional regulatory sequence that is operatively linked to a coding sequence, even though they are not contiguous.

[0058] With respect to fusion polypeptides, the term "operatively linked" can refer to the fact that each of the components performs the same function in linkage to the other component as it would if it were not so linked. For example, with respect to a fusion polypeptide in which a ZFP or TALE DNA-binding domain is fused to an activation domain, the ZFP or TALE DNA-binding domain and the activation domain are in operative linkage if, in the fusion polypeptide, the ZFP or TALE DNA-binding domain portion is able to bind its target site and/or its binding site, while the

activation domain is able to upregulate gene expression. ZFPs fused to domains capable of regulating gene expression are collectively referred to as “ZFP-TFs” or “zinc finger transcription factors”, while TALEs fused to domains capable of regulating gene expression are collectively referred to as “TALE-TFs” or “TALE transcription factors.” When a fusion polypeptide in which a ZFP DNA-binding domain is fused to a cleavage domain (a “ZFN” or “zinc finger nuclease”), the ZFP DNA-binding domain and the cleavage domain are in operative linkage if, in the fusion polypeptide, the ZFP DNA-binding domain portion is able to bind its target site and/or its binding site, while the cleavage domain is able to cleave DNA in the vicinity of the target site. When a fusion polypeptide in which a TALE DNA-binding domain is fused to a cleavage domain (a “TALEN” or “TALE nuclease”), the TALE DNA-binding domain and the cleavage domain are in operative linkage if, in the fusion polypeptide, the TALE DNA-binding domain portion is able to bind its target site and/or its binding site, while the cleavage domain is able to cleave DNA in the vicinity of the target site. With respect to a fusion polypeptide in which a Cas DNA-binding domain is fused to an activation domain, the Cas DNA-binding domain and the activation domain are in operative linkage if, in the fusion polypeptide, the Cas DNA-binding domain portion is able to bind its target site and/or its binding site, while the activation domain is able to up-regulate gene expression. When a fusion polypeptide in which a Cas DNA-binding domain is fused to a cleavage domain, the Cas DNA-binding domain and the cleavage domain are in operative linkage if, in the fusion polypeptide, the Cas DNA-binding domain portion is able to bind its target site and/or its binding site, while the cleavage domain is able to cleave DNA in the vicinity of the target site.

[0059] A "functional fragment" of a protein, polypeptide or nucleic acid is a protein, polypeptide or nucleic acid whose sequence is not identical to the full-length protein, polypeptide or nucleic acid, yet retains the same function as the full-length protein, polypeptide or nucleic acid. A functional fragment can possess more, fewer, or the same number of residues as the corresponding native molecule, and/or can contain one or more amino acid or nucleotide substitutions. Methods for determining the function of a nucleic acid (*e.g.*, coding function, ability to hybridize to another nucleic acid) are well-known in the art. Similarly, methods for determining protein function are well-known. For example, the DNA-binding function of a polypeptide

can be determined, for example, by filter-binding, electrophoretic mobility-shift, or immunoprecipitation assays. DNA cleavage can be assayed by gel electrophoresis. See Ausubel *et al.*, *supra*. The ability of a protein to interact with another protein can be determined, for example, by co-immunoprecipitation, two-hybrid assays or
5 complementation, both genetic and biochemical. See, for example, Fields *et al.* (1989) *Nature* **340**:245-246; U.S. Patent No. 5,585,245 and PCT WO 98/44350.

[0060] A "vector" is capable of transferring gene sequences to target cells. Typically, "vector construct," "expression vector," and "gene transfer vector," mean any nucleic acid construct capable of directing the expression of a gene of interest and
10 which can transfer gene sequences to target cells. Thus, the term includes cloning, and expression vehicles, as well as integrating vectors.

[0061] A "reporter gene" or "reporter sequence" refers to any sequence that produces a protein product that is easily measured, preferably although not necessarily in a routine assay. Suitable reporter genes include, but are not limited to, sequences
15 encoding proteins that mediate antibiotic resistance (e.g., ampicillin resistance, neomycin resistance, G418 resistance, puromycin resistance), sequences encoding colored or fluorescent or luminescent proteins (e.g., green fluorescent protein, enhanced green fluorescent protein, red fluorescent protein, luciferase), and proteins which mediate enhanced cell growth and/or gene amplification (e.g., dihydrofolate
20 reductase). Epitope tags include, for example, one or more copies of FLAG, His, myc, Tap, HA or any detectable amino acid sequence. "Expression tags" include sequences that encode reporters that may be operably linked to a desired gene sequence in order to monitor expression of the gene of interest.

25 **DNA-binding domains**

[0062] The methods described herein make use of compositions, for example Htt-modulating transcription factors, comprising a DNA-binding domain that specifically binds to a target sequence in an Htt gene, particularly that bind to a mutant Htt allele comprising a plurality of trinucleotide repeats. Any DNA-binding
30 domain can be used in the compositions and methods disclosed herein.

[0063] In certain embodiments, the Htt-modulating transcription factor, or DNA binding domain therein, comprises a zinc finger protein. Selection of target sites; ZFPs and methods for design and construction of fusion proteins (and

polynucleotides encoding same) are known to those of skill in the art and described in detail in U.S. Patent Nos. 6,140,081; 5,789,538; 6,453,242; 6,534,261; 5,925,523; 6,007,988; 6,013,453; 6,200,759; WO 95/19431; WO 96/06166; WO 98/53057; WO 98/54311; WO 00/27878; WO 01/60970 WO 01/88197; WO 02/099084; 5 WO 98/53058; WO 98/53059; WO 98/53060; WO 02/016536 and WO 03/016496.

[0064] In certain embodiments, the ZFPs can bind selectively to either a mutant Htt allele or a wild-type Htt sequence. Htt target sites typically include at least one zinc finger but can include a plurality of zinc fingers (*e.g.*, 2, 3, 4, 5, 6 or more fingers). Usually, the ZFPs include at least three fingers. Certain of the ZFPs include 10 four, five or six fingers, while some ZFPs include 8, 9, 10, 11 or 12 fingers. The ZFPs that include three fingers typically recognize a target site that includes 9 or 10 nucleotides; ZFPs that include four fingers typically recognize a target site that includes 12 to 14 nucleotides; while ZFPs having six fingers can recognize target sites that include 18 to 21 nucleotides. The ZFPs can also be fusion proteins that include 15 one or more regulatory domains, which domains can be transcriptional activation or repression domains. In some embodiments, the fusion protein comprises two ZFP DNA binding domains linked together. These zinc finger proteins can thus comprise 8, 9, 10, 11, 12 or more fingers. In some embodiments, the two DNA binding domains are linked via an extendable flexible linker such that one DNA binding 20 domain comprises 4, 5, or 6 zinc fingers and the second DNA binding domain comprises an additional 4, 5, or 5 zinc fingers. In some embodiments, the linker is a standard inter-finger linker such that the finger array comprises one DNA binding domain comprising 8, 9, 10, 11 or 12 or more fingers. In other embodiments, the linker is an atypical linker such as a flexible linker. The DNA binding domains are 25 fused to at least one regulatory domain and can be thought of as a ‘ZFP-ZFP-TF’ architecture. Specific examples of these embodiments can be referred to as “ZFP-ZFP-KOX” which comprises two DNA binding domains linked with a flexible linker and fused to a KOX repressor and “ZFP-KOX-ZFP-KOX” where two ZFP-KOX fusion proteins are fused together via a linker.

30 [0065] Alternatively, the DNA-binding domain may be derived from a nuclease. For example, the recognition sequences of homing endonucleases and meganucleases such as I-*SceI*, I-*CeuI*, PI-*PspI*, PI-*Sce*, I-*SceIV*, I-*CsmI*, I-*PanI*, I-*SceII*, I-*PpoI*, I-*SceIII*, I-*CreI*, I-*TevI*, I-*TevII* and I-*TevIII* are known. See also U.S.

Patent No. 5,420,032; U.S. Patent No. 6,833,252; Belfort *et al.* (1997) *Nucleic Acids Res.* **25**:3379–3388; Dujon *et al.* (1989) *Gene* **82**:115–118; Perler *et al.* (1994) *Nucleic Acids Res.* **22**, 1125–1127; Jasin (1996) *Trends Genet.* **12**:224–228; Gimble *et al.* (1996) *J. Mol. Biol.* **263**:163–180; Argast *et al.* (1998) *J. Mol. Biol.* **280**:345–353 and the New England Biolabs catalogue. In addition, the DNA-binding specificity of homing endonucleases and meganucleases can be engineered to bind non-natural target sites. *See*, for example, Chevalier *et al.* (2002) *Molec. Cell* **10**:895–905; Epinat *et al.* (2003) *Nucleic Acids Res.* **31**:2952–2962; Ashworth *et al.* (2006) *Nature* **441**:656–659; Paques *et al.* (2007) *Current Gene Therapy* **7**:49–66; U.S. Patent Publication No. 20070117128.

[0066] “Two handed” zinc finger proteins are those proteins in which two clusters of zinc finger DNA binding domains are separated by intervening amino acids so that the two zinc finger domains bind to two discontinuous target sites. An example of a two handed type of zinc finger binding protein is SIP1, where a cluster of four zinc fingers is located at the amino terminus of the protein and a cluster of three fingers is located at the carboxyl terminus (*see* Remacle *et al.*, (1999) *EMBO Journal* **18** (18): 5073–5084). Each cluster of zinc fingers in these proteins is able to bind to a unique target sequence and the spacing between the two target sequences can comprise many nucleotides. Two-handed ZFPs may include a functional domain, for example fused to one or both of the ZFPs. Thus, it will be apparent that the functional domain may be attached to the exterior of one or both ZFPs (*see*, Figure 1C) or may be positioned between the ZFPs (attached to both ZFPs) (*see*, Figure 4).

[0067] Specific examples of Htt-targeted ZFPs are disclosed in U.S. Patent Publication No. 20130253040, which is incorporated by reference for all purposes in its entirety herein, as well as in Table 1 below. The first column in this table is an internal reference name (number) for a ZFP and corresponds to the same name in column 1 of Table 2. “F” refers to the finger and the number following “F” refers which zinc finger (*e.g.*, “F1” refers to finger 1).

Table 1: Htt-targeted zinc finger proteins

SBS #	Design					
	F1	F2	F3	F4	F5	F6
18856	RSDDLRS (SEQ ID NO: 1)	RNDNRTK (SEQ ID NO: 2)	RSDDLTR (SEQ ID NO: 3)	RSDDRKT (SEQ ID NO: 4)	RSADLTR (SEQ ID NO: 5)	QSSDLRR (SEQ ID NO: 6)
25920	RSAALSR (SEQ ID NO: 7)	RSDALAR (SEQ ID NO: 8)	RSDNLSE (SEQ ID NO: 9)	KRCNLRC (SEQ ID NO: 10)	QSSDLRR (SEQ ID NO: 6)	NA
25921	WRSCRSA (SEQ ID NO: 11)	DRSNLSR (SEQ ID NO: 12)	QRTHLTQ (SEQ ID NO: 13)	RSAHLRS (SEQ ID NO: 14)	TSGHLRS (SEQ ID NO: 15)	NA
25923	RSDDLRS (SEQ ID NO: 1)	RNDNRTK (SEQ ID NO: 2)	WRSCRSA (SEQ ID NO: 11)	RSDNLAR (SEQ ID NO: 16)	QSGHLRS (SEQ ID NO: 17)	NA
25922	RSAALSR (SEQ ID NO: 7)	RSDALAR (SEQ ID NO: 8)	RSDNLSE (SEQ ID NO: 9)	KRCNLRC (SEQ ID NO: 10)	QSSDLRS (SEQ ID NO: 18)	DRSHLAR (SEQ ID NO: 19)
32468	RSDNLAR (SEQ ID NO: 16)	WRGDRVK (SEQ ID NO: 20)	DRSNLSR (SEQ ID NO: 12)	TSGSLTR (SEQ ID NO: 21)	ERGTLAR (SEQ ID NO: 22)	RSDDRKT (SEQ ID NO: 4)
32501	RSDALSR (SEQ ID NO: 23)	DRSHLAR (SEQ ID NO: 19)	RSDHLRS (SEQ ID NO: 24)	QSSDLTR (SEQ ID NO: 25)	TSGNLTR (SEQ ID NO: 26)	DRSHLAR (SEQ ID NO: 19)
31809	RSDDLRS (SEQ ID NO: 1)	RNDNRTK (SEQ ID NO: 2)	RSDDLTR (SEQ ID NO: 3)	RSDDRKT (SEQ ID NO: 4)	RSDDLTR (SEQ ID NO: 3)	QSSDLRR (SEQ ID NO: 6)
32528	QSGHLQR (SEQ ID NO: 27)	TSGNLTR (SEQ ID NO: 26)	QSGDLTR (SEQ ID NO: 28)	DRSHLAR (SEQ ID NO: 19)	RSDVLST (SEQ ID NO: 29)	VRSLRRL (SEQ ID NO: 30)
30580	RSDNLAR (SEQ ID NO: 16)	WRGDRVK (SEQ ID NO: 20)	DRSDLSR (SEQ ID NO: 31)	RSDALAR (SEQ ID NO: 8)	ERGTLAR (SEQ ID NO: 22)	RSDDRKT (SEQ ID NO: 4)
30929	DRSTLRQ (SEQ ID NO: 32)	DRSDLSR (SEQ ID NO: 31)	QSSTRAR (SEQ ID NO: 33)	RSDTLSE (SEQ ID NO: 34)	HRRSRWG (SEQ ID NO: 35)	NA
32538	DRSDLSR (SEQ ID NO: 31)	RRDTLRS (SEQ ID NO: 36)	RSDHLST (SEQ ID NO: 37)	QSAHRIT (SEQ ID NO: 38)	QSGDLTR (SEQ ID NO: 28)	DRSHLAR (SEQ ID NO: 19)
32567	RSDHLSE (SEQ ID NO: 39)	QNAHRKT (SEQ ID NO: 40)	QSSDLRS (SEQ ID NO: 18)	HRSTRNR (SEQ ID NO: 41)	QSSDLRS (SEQ ID NO: 18)	HRSTRNR (SEQ ID NO: 41)
29627	DRSNLSR (SEQ ID NO:)	LRQDLKR (SEQ ID NO:)	DRSHLTR (SEQ ID NO:)	DRSNLTR (SEQ ID NO:)	RSDHLST (SEQ ID NO:)	QSAHRIT (SEQ ID NO:)

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	12)	42)	43)	44)	37)	38)
29628	TSGNLTR (SEQ ID NO: 26)	LKQMLAV (SEQ ID NO: 45)	RSDSLSA (SEQ ID NO: 46)	DRSDLSR (SEQ ID NO: 31)	RSDALST (SEQ ID NO: 47)	DRSTRTK (SEQ ID NO: 48)
29631	QSSDLSR (SEQ ID NO: 18)	DRSALAR (SEQ ID NO: 49)	QSSDLSR (SEQ ID NO: 18)	QSGHLSR (SEQ ID NO: 17)	RSDVLSE (SEQ ID NO: 50)	TSGHLSR (SEQ ID NO: 15)
29632	RSDTLSE (SEQ ID NO: 34)	KLCNRKC (SEQ ID NO: 51)	TSGNLTR (SEQ ID NO: 26)	HRTSLTD (SEQ ID NO: 52)	RSAHLSR (SEQ ID NO: 14)	QSGNLAR (SEQ ID NO: 53)
29637	DRSNLSR (SEQ ID NO: 12)	QSGNLAR (SEQ ID NO: 53)	DRSNLSR (SEQ ID NO: 12)	LKHHLTD (SEQ ID NO: 54)	QSGDLTR (SEQ ID NO: 28)	YRWLRNN (SEQ ID NO: 55)
29638	RSDHLSQ (SEQ ID NO: 56)	RS AVRKN (SEQ ID NO: 57)	QSSDLSR (SEQ ID NO: 18)	QSGDLTR (SEQ ID NO: 28)	WSTSLRA (SEQ ID NO: 58)	NA
25917	DRSNLSR (SEQ ID NO: 12)	QRTHLTQ (SEQ ID NO: 13)	RSSHLSR (SEQ ID NO: 59)	TSGSLSR (SEQ ID NO: 60)	TRQNRDT (SEQ ID NO: 61)	NA
25916	DQSTLRN (SEQ ID NO: 62)	RSAALSR (SEQ ID NO: 7)	RSDALAR (SEQ ID NO: 8)	RSDNLSE (SEQ ID NO: 9)	KRCNLRC (SEQ ID NO: 10)	NA
33074	RSDNLSE (SEQ ID NO: 9)	KRCNLRC (SEQ ID NO: 10)	QSGDLTR (SEQ ID NO: 28)	QSGDLTR (SEQ ID NO: 28)	RSDNLSE (SEQ ID NO: 9)	KRCNLRC (SEQ ID NO: 10)
33080	QSGDLTR (SEQ ID NO: 28)	QSGDLTR (SEQ ID NO: 28)	RSDNLSE (SEQ ID NO: 9)	KRCNLRC (SEQ ID NO: 10)	QSGDLTR (SEQ ID NO: 28)	QSGDLTR (SEQ ID NO: 28)
33084	QSSDLSR (SEQ ID NO: 18)	HRSTRNR (SEQ ID NO: 41)	RSDTLSE (SEQ ID NO: 34)	RRWTLVG (SEQ ID NO: 63)	NA	NA
33088	QSSDLSR (SEQ ID NO: 18)	HRSTRNR (SEQ ID NO: 41)	RS AVLSE (SEQ ID NO: 64)	QSSDLSR (SEQ ID NO: 18)	HRSTRNR (SEQ ID NO: 41)	NA
30643	RSDNLSE (SEQ ID NO: 9)	KRCNLRC (SEQ ID NO: 10)	QSSDLSR (SEQ ID NO: 18)	QWSTRKR (SEQ ID NO: 65)	QSSDLSR (SEQ ID NO: 18)	QWSTRKR (SEQ ID NO: 65)
30648	RSDNLSE (SEQ ID NO: 9)	KRCNLRC (SEQ ID NO: 10)	RSDNLSE (SEQ ID NO: 9)	KRCNLRC (SEQ ID NO: 10)	RSDNLSE (SEQ ID NO: 9)	KRCNLRC (SEQ ID NO: 10)
30645	RSDNLSE (SEQ ID NO: 9)	KRCNLRC (SEQ ID NO: 10)	QSSDLSR (SEQ ID NO: 18)	QWSTRKR (SEQ ID NO: 65)	QSGDLTR (SEQ ID NO: 28)	NA
30640	QSSDLSR (SEQ ID	QWSTRKR (SEQ ID	QSSDLSR (SEQ ID	QWSTRKR (SEQ ID	QSGDLTR (SEQ ID	NA

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	NO: 18)	NO: 65)	NO: 18)	NO: 65)	NO: 28)	
30657	RSDTLSE (SEQ ID NO: 34)	RRWTLVG (SEQ ID NO: 63)	QSSDLR (SEQ ID NO: 18)	HRSTRNR (SEQ ID NO: 41)	QSSDLR (SEQ ID NO: 18)	HRSTRNR (SEQ ID NO: 41)
30642	QSGDLTR (SEQ ID NO: 28)	QSSDLR (SEQ ID NO: 18)	QWSTRKR (SEQ ID NO: 65)	QSSDLR (SEQ ID NO: 18)	QWSTRKR (SEQ ID NO: 65)	NA
30646	RSDNLSE (SEQ ID NO: 9)	KRCNLRC (SEQ ID NO: 10)	QSGDLTR (SEQ ID NO: 28)	QSSDLR (SEQ ID NO: 18)	QWSTRKR (SEQ ID NO: 65)	NA
32220	RSDVLSE (SEQ ID NO: 50)	QSSDLR (SEQ ID NO: 18)	HRSTRNR (SEQ ID NO: 41)	NA	NA	NA
32210	QSGDLTR (SEQ ID NO: 28)	QSSDLR (SEQ ID NO: 18)	QWSTRKR (SEQ ID NO: 65)	NA	NA	NA
32215	RSDNLRE (SEQ ID NO: 66)	RSDNLSE (SEQ ID NO: 9)	KRCNLRC (SEQ ID NO: 10)	NA	NA	NA
30658	QSSDLR (SEQ ID NO:18)	HRSTRNR (SEQ ID NO:41)	QSSDLR (SEQ ID NO:18)	HRSTRNR (SEQ ID NO:41)	QSSDLR (SEQ ID NO:18)	NA
32218	QSSDLR (SEQ ID NO: 18)	QSSDLR (SEQ ID NO: 18)	NA	NA	NA	NA
32427	ERGTAR (SEQ ID NO:22)	TSGSLTR (SEQ ID NO:21)	RSDNLAR (SEQ ID NO:16)	DPSNRVG (SEQ ID NO:67)	RSDDLK (SEQ ID NO:68)	DNSNRK (SEQ ID NO:69)
32653	RSDHLSE (SEQ ID NO: 39)	QSGHLR (SEQ ID NO: 17)	RSDDLTR (SEQ ID NO: 3)	YRWLLRS (SEQ ID NO: 70)	QSSDLR (SEQ ID NO: 18)	RKDALVA (SEQ ID NO: 71)
32677	QSGDLTR (SEQ ID NO: 28)	RRADLR (SEQ ID NO: 72)	DRSHLTR (SEQ ID NO: 43)	DRSHLAR (SEQ ID NO: 19)	DRSNLSR (SEQ ID NO: 12)	LAQPRNK (SEQ ID NO: 73)
33560	ERGTAR (SEQ ID NO:22)	QSGSLTR (SEQ ID NO:74)	RSDNLAR (SEQ ID NO:16)	DDSHRKD (SEQ ID NO:75)	RSDDLK (SEQ ID NO:68)	DNSNRK (SEQ ID NO:69)
33583	DRSNLSR (SEQ ID NO:12)	HKQHRDA (SEQ ID NO:76)	DRSDLR (SEQ ID NO:31)	RRTDLRR (SEQ ID NO:77)	RSANLAR (SEQ ID NO:78)	DRSHLAR (SEQ ID NO:19)
32685	RSDHLA (SEQ ID NO: 79)	RSADRTR (SEQ ID NO: 80)	RSDVLSE (SEQ ID NO: 50)	TSGHLR (SEQ ID NO: 15)	RSDDLTR (SEQ ID NO: 3)	TSSDRKK (SEQ ID NO: 81)
32422	RSANLAR (SEQ ID NO: 78)	RSDDLTR (SEQ ID NO: 3)	RSDTLSE (SEQ ID NO: 34)	HHSARRC (SEQ ID NO: 82)	ERGTAR (SEQ ID NO: 22)	DRSNLTR (SEQ ID NO: 44)
32428	RSDVLST	DNSSRTR	DRSNLSR	HKQHRDA	DRSDLR	RRTDLRR

	(SEQ ID NO: 29)	(SEQ ID NO: 83)	(SEQ ID NO: 12)	(SEQ ID NO: 76)	(SEQ ID NO: 31)	(SEQ ID NO: 77)
32430	RSDVLST (SEQ ID NO: 29)	VRSRLRR (SEQ ID NO: 30)	ERGTLLAR (SEQ ID NO: 22)	TSGSLTR (SEQ ID NO: 21)	RSDNLAR (SEQ ID NO: 16)	DPSNRVG (SEQ ID NO: 67)
32432	RSDVLST (SEQ ID NO: 29)	VRSRLRR (SEQ ID NO: 30)	ERGTLLAR (SEQ ID NO: 22)	TSGSLTR (SEQ ID NO: 21)	RSDHLSA (SEQ ID NO: 79)	RSADLSR (SEQ ID NO: 84)
32714	RSDVLST (SEQ ID NO: 29)	DNSSRTR (SEQ ID NO: 83)	ERGTLLAR (SEQ ID NO: 22)	QSGNLAR (SEQ ID NO: 53)	DRSHLTR (SEQ ID NO: 43)	RNDDRKK (SEQ ID NO: 85)
32733	DRSNLSR (SEQ ID NO: 12)	QKVTLAA (SEQ ID NO: 86)	RSAHLSR (SEQ ID NO: 14)	TSGNLTR (SEQ ID NO: 26)	DRSDLSR (SEQ ID NO: 31)	RRSTLRS (SEQ ID NO: 87)
30901	DRSALSR (SEQ ID NO: 88)	QSGSLTR (SEQ ID NO: 74)	QSSDLSR (SEQ ID NO: 18)	LKWNLRT (SEQ ID NO: 89)	RSDNLAR (SEQ ID NO: 16)	LKWDRQT (SEQ ID NO: 90)
31952	QSGALAR (SEQ ID NO:91)	RSDDLTR (SEQ ID NO:3)	DRSALSR (SEQ ID NO:88)	RSDHLTQ (SEQ ID NO:92)	QSGDLTR (SEQ ID NO:28)	WSTSLRA (SEQ ID NO:58)
31921	RSDSLLR (SEQ ID NO:93)	RSDDLTR (SEQ ID NO:3)	QSGDLTR (SEQ ID NO:28)	RRDWLPQ (SEQ ID NO:94)	DRSNLSR (SEQ ID NO:12)	RSDDRKT (SEQ ID NO:4)
30906	DRSHLSR (SEQ ID NO: 95)	TSGNLTR (SEQ ID NO: 26)	QSGDLTR (SEQ ID NO: 28)	DRSHLAR (SEQ ID NO: 19)	RSDVLST (SEQ ID NO: 29)	VRSRLRR (SEQ ID NO: 30)

[0068] The sequence and location for the target sites of these proteins are disclosed in Table 2. Nucleotides in the target site that are contacted by the ZFP recognition helices are indicated in uppercase letters; non-contacted nucleotides indicated in lowercase.

Table 2: Target sites on human and mouse Htt

SBS #	Target Site
18856	AcGCTGCGCCGGCGGAGGCGgggcccgcg (SEQ ID NO:96)
25920	gcGCTCAGCAGGTGGTGaccttgtggac_(SEQ ID NO:97)
25921	atGGTGGGAGAGACTGTgaggcggcagc_(SEQ ID NO:98)
25923	tgGGAGAGacTGTGAGGCGgcagctggg (SEQ ID NO:99)
25922	atGGCGCTCAGCAGGTGGTGaccttgtg_(SEQ ID NO:100)
32468	agCCGGCCGTGGACTCTGAGccgaggtg_(SEQ ID NO:101)
32427	cgCACTCGcCGCGAGgGTTGCCgggacg_(SEQ ID NO:102)
32501	gtGGCGATGCGGGGGGCGTGgtgaggtg_(SEQ ID NO:103)
31809	acGCTGCGCCGGCGGAGGCGgggcccgcg_(SEQ ID NO:96)
32528	ccGGGACGGGTCCAaGATGGAcggccgc_(SEQ ID NO:104)
30580	agCCGGCCGTGGACTCTGAGccgaggtg_(SEQ ID NO:101)

30929	ccGTCCCGGCAGCCCCacggcgccttg_(SEQ ID NO:105)
30658	ctGCTGCTGCTGCTGCTgctggaaggac_(SEQ ID NO:106)
32538	cgGGTCCAAGATGGACGGCCgctcaggt_(SEQ ID NO:107)
32567	ctGCTGCTGCTGCTGGAAGGacttgagg_(SEQ ID NO:108)
29627	tcAGATGGGACGGCGCTGACctggctgg_(SEQ ID NO:109)
29628	ctGCCATGGACCTGAATGATgggaccca_(SEQ ID NO:110)
29631	gtGGTCTGGGAGCTGTCGCTgatgggcg_(SEQ ID NO:111)
29632	ccGAAGGGCCTGATtCAGCTGttacccc_(SEQ ID NO:112)
29637	aaCTTGCAAGTAACaGAAGACTcatcct_(SEQ ID NO:113)
29638	ctTGTACAGCTGTGAGGgtgagcataat_(SEQ ID NO:114)
25917	gcCATGGTGGGAGAGACTgtgaggcggc_(SEQ ID NO:115)
25916	ctCAGCAGGTGGTGACCTtgtggacatt_(SEQ ID NO:116)
33074	agCAGCAGcaGCAGCAgCAGCAGcagca_(SEQ ID NO:117)
33080	caGCAGCAgCAGCAGcaGCAGCAgcagc_(SEQ ID NO:118)
33084	tgCTGCTGctGCTGCTgctgctggaagg_(SEQ ID NO:119)
33088	ctGCTGCTgCTGctGCTGCTgctggaag_(SEQ ID NO:120)
30643	caGCAGCAGCAGCAgCAGCAGcagcagc_(SEQ ID NO:118)
30648	agCAGCAGCAGCAGCAGCAGcagcagca_(SEQ ID NO:117)
30645	caGCAGCAGCAgCAGCAGcagcagcagc_(SEQ ID NO:118)
30640	caGCAGCAGCAGCAGCAgcagcagcagc_(SEQ ID NO:118)
30657	ctGCTGCTGCTGCTgCTGCTGgaaggac_(SEQ ID NO:106)
30642	caGCAGCAGCAGCAGCAgcagcagcagc_(SEQ ID NO:118)
30646	caGCAGCAGCAgCAGCAGcagcagcagc_(SEQ ID NO:118)
32220	ctGCTGCTgCTGctgctgctgctggaagg_(SEQ ID NO:121)
32210	caGCAGCAGCAgcagcagcagcagcagc_(SEQ ID NO:118)
32215	agCAGCAGCAGcagcagcagcagcagca_(SEQ ID NO:117)
32218	tGCTGCTgctgctgctgctgctggaagg_(SEQ ID NO:122)
32653	ggCTGGCTTTTGC GGGAAGGggcggggc_(SEQ ID NO:123)
32677	gaATTGACaGGCGGAtGCGTCGtcctct_(SEQ ID NO:124)
33560	cgCACTCGcCGCGAGgGTTGCCgggacg_(SEQ ID NO:102)
33583	gcGGCGAGtGCGTCCCGTGACgtcatgc_(SEQ ID NO:103)
32685	atTCTGCGGGTCTGGCGTGgcctcgtct_(SEQ ID NO:104)
32422	gtGACGTCATGCCGGCGGAGacgaggcc_(SEQ ID NO:105)
32428	gtGCGTCCCGTGACGTCATGccggcgga_(SEQ ID NO:106)
32430	gcCGCGAGgGTTGCCGGGACGggcccaa_(SEQ ID NO:107)
32432	ccGCGAGGGTTGCCGGGACGggcccaag_(SEQ ID NO:108)
32714	caTCGGGCagGAAGCCGTCATGgcaacc_(SEQ ID NO:109)
32733	tcCTGCCCCGATGGGACAGACcctgaaga_(SEQ ID NO:110)
30901	gtACTGAGcAATGCTGTAGTCagcaatc_(SEQ ID NO:111)
31952	ccTGTCCAgAGGGTCGCGGTAcctccct_(SEQ ID NO:112)
31921	tgCCGGACCTGGCAGCGGCGgtggtggc_(SEQ ID NO:113)
30906	ccGGGACGGGTCCAaGATGGAcggccgc_(SEQ ID NO:104)

[0069] In certain embodiments, the DNA-binding domain comprises a naturally occurring or engineered (non-naturally occurring) TAL effector (TALE)

DNA binding domain. *See, e.g.*, U.S. Patent No. 8,586,526, incorporated by reference in its entirety herein.

[0070] The plant pathogenic bacteria of the genus *Xanthomonas* are known to cause many diseases in important crop plants. Pathogenicity of *Xanthomonas* depends on a conserved type III secretion (T3S) system which injects more than 25 different effector proteins into the plant cell. Among these injected proteins are transcription activator-like effectors (TALE) which mimic plant transcriptional activators and manipulate the plant transcriptome (see Kay *et al* (2007) *Science* 318:648-651).

These proteins contain a DNA binding domain and a transcriptional activation domain. One of the most well characterized TALEs is AvrBs3 from *Xanthomonas campestris* pv. *Vesicatoria* (see Bonas *et al* (1989) *Mol Gen Genet* 218: 127-136 and WO2010079430). TALEs contain a centralized domain of tandem repeats, each repeat containing approximately 34 amino acids, which are key to the DNA binding specificity of these proteins. In addition, they contain a nuclear localization sequence and an acidic transcriptional activation domain (for a review see Schornack S, *et al* (2006) *J Plant Physiol* 163(3): 256-272). In addition, in the phytopathogenic bacteria *Ralstonia solanacearum* two genes, designated brg11 and hpx17 have been found that are homologous to the AvrBs3 family of *Xanthomonas* in the *R. solanacearum* biovar 1 strain GMI1000 and in the biovar 4 strain RS1000 (See Heuer *et al* (2007) *Appl and Envir Micro* 73(13): 4379-4384). These genes are 98.9% identical in nucleotide sequence to each other but differ by a deletion of 1,575 bp in the repeat domain of hpx17. However, both gene products have less than 40% sequence identity with AvrBs3 family proteins of *Xanthomonas*.

[0071] Specificity of these TALEs depends on the sequences found in the tandem repeats. The repeated sequence comprises approximately 102 bp and the repeats are typically 91-100% homologous with each other (Bonas *et al, ibid*). Polymorphism of the repeats is usually located at positions 12 and 13 and there appears to be a one-to-one correspondence between the identity of the hypervariable diresidues at positions 12 and 13 with the identity of the contiguous nucleotides in the TALE's target sequence (see Moscou and Bogdanove (2009) *Science* 326:1501 and Boch *et al* (2009) *Science* 326:1509-1512). Experimentally, the code for DNA recognition of these TALEs has been determined such that an HD sequence at positions 12 and 13 leads to a binding to cytosine (C), NG binds to T, NI to A, C, G or

T, NN binds to A or G, and NG binds to T. These DNA binding repeats have been assembled into proteins with new combinations and numbers of repeats, to make artificial transcription factors that are able to interact with new sequences. In addition, U.S. Patent No. 8,586,526 and U.S. Publication No. 20130196373, incorporated by reference in their entireties herein, describe TALEs with N-cap polypeptides, C-cap polypeptides (*e.g.*, +63, +231 or +278) and/or novel (atypical) RVDs.

[0072] Exemplary TALE are described in U.S. Patent Publication No. 20130253040, incorporated by reference in its entirety, and below in Table 3.

10 [0073] The targets and numeric identifiers for the TALE TFs tested are shown below in Table 3. Numeric identifiers are labeled “SBS#”, specificity for the Sense or Antisense strand is indicated (“S/A”), as well as the target, the number of repeat units or RVDs and the type of C-terminus.

Table 3: Htt specific TALE-TFs

SBS#	S/A	Target (5' - 3')	SEQ ID NO	RVDs	C term
102449	S	gcAGCAGCAGCAGCAGCAGca	114	17	+63
102450	S	gcAGCAGCAGCAGCAGCAGca	115	14	+63
102451	S	gcAGCAGCAGCAGCAGca	116	11	+63
102452	S	gcAGCAGCAGCAGca	117	8	+63
102453	A	ctGCTGCTGCTGCTGCTGctg	118	17	+63
102454	A	ctGCTGCTGCTGCTGCTGctg	119	14	+63
102455	A	ctGCTGCTGCTGCTGctg	120	11	+63
102456	A	ctGCTGCTGCTGctg	121	8	+63
102457	S	gcAGCAGCAGCAGCAGCAGca	114	17	+231
102458	S	gcAGCAGCAGCAGCAGCAGca	115	14	+231
102459	S	gcAGCAGCAGCAGCAGca	116	11	+231
102460	S	gcAGCAGCAGCAGca	117	8	+231
102462	A	ctGCTGCTGCTGCTGCTGctg	119	14	+231
102463	A	ctGCTGCTGCTGCTGctg	120	11	+231
102464	A	ctGCTGCTGCTGctg	121	8	+231
102466	S	gcAGCAGCAGCAGCAGCAGca	115	14	+278
102467	S	gcAGCAGCAGCAGCAGca	116	11	+278
102468	S	gcAGCAGCAGCAGca	117	8	+278
102469	A	ctGCTGCTGCTGCTGCTGctg	118	17	+278
102470	A	ctGCTGCTGCTGCTGCTGctg	119	14	+278
102471	A	ctGCTGCTGCTGCTGctg	120	11	+278
102472	A	ctGCTGCTGCTGctg	121	8	+278

[0074] In certain embodiments, the DNA binding domains include a dimerization and/or multimerization domain, for example a coiled-coil (CC) and dimerizing zinc finger (DZ). *See*, U.S. Patent Publication No. 20130253040.

[0075] Compelling evidence has recently emerged for the existence of an RNA-mediated genome defense pathway in archaea and many bacteria that has been hypothesized to parallel the eukaryotic RNAi pathway (for reviews, see Godde and Bickerton, 2006. *J. Mol. Evol.* 62: 718-729; Lillestol *et al.*, 2006. *Archaea* 2: 59-72; Makarova *et al.*, 2006. *Biol. Direct* 1: 7.; Sorek *et al.*, 2008. *Nat. Rev. Microbiol.* 6: 181-186). Known as the CRISPR-Cas system or prokaryotic RNAi (pRNAi), the pathway is proposed to arise from two evolutionarily and often physically linked gene loci: the CRISPR (clustered regularly interspaced short palindromic repeats) locus, which encodes RNA components of the system, and the cas (CRISPR-associated) locus, which encodes proteins (Jansen *et al.*, 2002. *Mol. Microbiol.* 43: 1565-1575; Makarova *et al.*, 2002. *Nucleic Acids Res.* 30: 482-496; Makarova *et al.*, 2006. *Biol. Direct* 1: 7; Haft *et al.*, 2005. *PLoS Comput. Biol.* 1: e60). CRISPR loci in microbial hosts contain a combination of CRISPR-associated (Cas) genes as well as non-coding RNA elements capable of programming the specificity of the CRISPR-mediated nucleic acid cleavage. The individual Cas proteins do not share significant sequence similarity with protein components of the eukaryotic RNAi machinery, but have analogous predicted functions (*e.g.*, RNA binding, nuclease, helicase, etc.) (Makarova *et al.*, 2006. *Biol. Direct* 1: 7). The CRISPR-associated (*cas*) genes are often associated with CRISPR repeat-spacer arrays. More than forty different Cas protein families have been described. Of these protein families, Cas1 appears to be ubiquitous among different CRISPR/Cas systems. Particular combinations of *cas* genes and repeat structures have been used to define 8 CRISPR subtypes (Ecoli, Ypest, Nmeni, Dvulg, Tneap, Hmari, Apern, and Mtube), some of which are associated with an additional gene module encoding repeat-associated mysterious proteins (RAMPs). More than one CRISPR subtype may occur in a single genome. The sporadic distribution of the CRISPR/Cas subtypes suggests that the system is subject to horizontal gene transfer during microbial evolution.

[0076] The Type II CRISPR, initially described in *S. pyogenes*, is one of the most well characterized systems and carries out targeted DNA double-strand break in four sequential steps. First, two non-coding RNA, the pre-crRNA array and

tracrRNA, are transcribed from the CRISPR locus. Second, tracrRNA hybridizes to the repeat regions of the pre-crRNA and mediates the processing of pre-crRNA into mature crRNAs containing individual spacer sequences where processing occurs by a double strand-specific RNase III in the presence of the Cas9 protein. Third, the mature crRNA:tracrRNA complex directs Cas9 to the target DNA via Watson-Crick base-pairing between the spacer on the crRNA and the protospacer on the target DNA next to the protospacer adjacent motif (PAM), an additional requirement for target recognition. In addition, the tracrRNA must also be present as it base pairs with the crRNA at its 3' end, and this association triggers Cas9 activity. Finally, Cas9 mediates cleavage of target DNA to create a double-stranded break within the protospacer. Activity of the CRISPR/Cas system comprises of three steps: (i) insertion of alien DNA sequences into the CRISPR array to prevent future attacks, in a process called 'adaptation,' (ii) expression of the relevant proteins, as well as expression and processing of the array, followed by (iii) RNA-mediated interference with the alien nucleic acid. Thus, in the bacterial cell, several of the so-called 'Cas' proteins are involved with the natural function of the CRISPR/Cas system.

[0077] Type II CRISPR systems have been found in many different bacteria. BLAST searches on publically available genomes by Fonfara *et al* ((2013) *Nuc Acid Res* 42(4):2377-2590) found Cas9 orthologs in 347 species of bacteria. Additionally, this group demonstrated *in vitro* CRISPR/Cas cleavage of a DNA target using Cas9 orthologs from *S. pyogenes*, *S. mutans*, *S. therophilus*, *C. jejuni*, *N. meningitides*, *P. multocida* and *F. novicida*. Thus, the term "Cas9" refers to an RNA guided DNA nuclease comprising a DNA binding domain and two nuclease domains, where the gene encoding the Cas9 may be derived from any suitable bacteria.

[0078] The Cas9 protein has at least two nuclease domains: one nuclease domain is similar to a HNH endonuclease, while the other resembles a Ruv endonuclease domain. The HNH-type domain appears to be responsible for cleaving the DNA strand that is complementary to the crRNA while the Ruv domain cleaves the non-complementary strand. The Cas 9 nuclease can be engineered such that only one of the nuclease domains is functional, creating a Cas nickase (see Jinek *et al*, *ibid*). Nickases can be generated by specific mutation of amino acids in the catalytic domain of the enzyme, or by truncation of part or all of the domain such that it is no longer functional. Since Cas 9 comprises two nuclease domains, this approach may

be taken on either domain. A double strand break can be achieved in the target DNA by the use of two such Cas 9 nickases. The nickases will each cleave one strand of the DNA and the use of two will create a double strand break.

[0079] The requirement of the crRNA-tracrRNA complex can be avoided by use of an engineered “single-guide RNA” (sgRNA) that comprises the hairpin normally formed by the annealing of the crRNA and the tracrRNA (see Jinek *et al* (2012) *Science* 337:816 and Cong *et al* (2013)

Sciencexpress/10.1126/science.1231143). In *S. pyrogenes*, the engineered tracrRNA:crRNA fusion, or the sgRNA, guides Cas9 to cleave the target DNA when a double strand RNA:DNA heterodimer forms between the Cas associated RNAs and the target DNA. This system comprising the Cas9 protein and an engineered sgRNA containing a PAM sequence has been used for RNA guided genome editing (see Ramalingam, *ibid*) and has been useful for zebrafish embryo genomic editing *in vivo* (see Hwang *et al* (2013) *Nature Biotechnology* 31 (3):227) with editing efficiencies similar to ZFNs and TALENs.

[0080] The primary products of the CRISPR loci appear to be short RNAs that contain the invader targeting sequences, and are termed guide RNAs or prokaryotic silencing RNAs (psiRNAs) based on their hypothesized role in the pathway (Makarova *et al.*, 2006. *Biol. Direct* 1: 7; Hale *et al.*, 2008. *RNA*, 14: 2572-2579).

RNA analysis indicates that CRISPR locus transcripts are cleaved within the repeat sequences to release ~60- to 70-nt RNA intermediates that contain individual invader targeting sequences and flanking repeat fragments (Tang *et al.* 2002. *Proc. Natl. Acad. Sci.* 99: 7536-7541; Tang *et al.*, 2005. *Mol. Microbiol.* 55: 469-481; Lillestol *et al.* 2006. *Archaea* 2: 59-72; Brouns *et al.* 2008. *Science* 321: 960-964; Hale *et al.*, 2008. *RNA*, 14: 2572-2579). In the archaeon *Pyrococcus furiosus*, these intermediate RNAs are further processed to abundant, stable ~35- to 45-nt mature psiRNAs (Hale *et al.* 2008. *RNA*, 14: 2572-2579).

[0081] The requirement of the crRNA-tracrRNA complex can be avoided by use of an engineered “single-guide RNA” (sgRNA) that comprises the hairpin normally formed by the annealing of the crRNA and the tracrRNA (see Jinek *et al* (2012) *Science* 337:816 and Cong *et al* (2013)

Sciencexpress/10.1126/science.1231143). In *S. pyrogenes*, the engineered tracrRNA:crRNA fusion, or the sgRNA, guides Cas9 to cleave the target DNA when

a double strand RNA:DNA heterodimer forms between the Cas associated RNAs and the target DNA. This system comprising the Cas9 protein and an engineered sgRNA containing a PAM sequence has been used for RNA guided genome editing (see Ramalingam *ibid*) and has been useful for zebrafish embryo genomic editing *in vivo* (see Hwang *et al* (2013) *Nature Biotechnology* 31 (3):227) with editing efficiencies similar to ZFNs and TALENs.

[0082] Chimeric or sgRNAs can be engineered to comprise a sequence complementary to any desired target. In some embodiments, a guide sequence is about or more than about 5, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 35, 40, 45, 50, 75, or more nucleotides in length. In some embodiments, a guide sequence is less than about 75, 50, 45, 40, 35, 30, 25, 20, 15, 12, or fewer nucleotides in length. In some embodiments, the RNAs comprise 22 bases of complementarity to a target and of the form G[n19], followed by a protospacer-adjacent motif (PAM) of the form NGG or NAG for use with a *S. pyogenes* CRISPR/Cas system. Thus, in one method, sgRNAs can be designed by utilization of a known ZFN target in a gene of interest by (i) aligning the recognition sequence of the ZFN heterodimer with the reference sequence of the relevant genome (human, mouse, or of a particular plant species); (ii) identifying the spacer region between the ZFN half-sites; (iii) identifying the location of the motif G[N20]GG that is closest to the spacer region (when more than one such motif overlaps the spacer, the motif that is centered relative to the spacer is chosen); (iv) using that motif as the core of the sgRNA. This method advantageously relies on proven nuclease targets. Alternatively, sgRNAs can be designed to target any region of interest simply by identifying a suitable target sequence that conforms to the G[n20]GG formula. Along with the complementarity region, an sgRNA may comprise additional nucleotides to extend to tail region of the tracrRNA portion of the sgRNA (see Hsu *et al* (2013) *Nature Biotech* doi:10.1038/nbt.2647). Tails may be of +67 to +85 nucleotides, or any number therebetween with a preferred length of +85 nucleotides. Truncated sgRNAs may also be used, “tru-gRNAs” (see Fu *et al*, (2014) *Nature Biotech* 32(3): 279). In tru-gRNAs, the complementarity region is diminished to 17 or 18 nucleotides in length.

[0083] Further, alternative PAM sequences may also be utilized, where a PAM sequence can be NAG as an alternative to NGG (Hsu 2014, *ibid*) using a *S.*

pyogenes Cas9. Additional PAM sequences may also include those lacking the initial G (Sander and Joung (2014) *Nature Biotech* 32(4):347). In addition to the *S. pyogenes* encoded Cas9 PAM sequences, other PAM sequences can be used that are specific for Cas9 proteins from other bacterial sources. For example, the PAM sequences shown below (adapted from Sander and Joung, *ibid*, and Esvelt *et al*, (2013) *Nat Meth* 10(11):1116) are specific for these Cas9 proteins:

	Species	PAM
	<i>S. pyogenes</i>	NGG
	<i>S. pyogenes</i>	NAG
10	<i>S. mutans</i>	NGG
	<i>S. thermophilus</i>	NGGNG
	<i>S. thermophilus</i>	NNAAAW
	<i>S. thermophilus</i>	NNAGAA
	<i>S. thermophilus</i>	NNNGATT
15	<i>C. jejuni</i>	NNNNACA
	<i>N. meningitides</i>	NNNNGATT
	<i>P. multocida</i>	GNNNCNNA
	<i>F. novicida</i>	NG

[0084] Thus, a suitable target sequence for use with a *S. pyogenes* CRISPR/Cas system can be chosen according to the following guideline: [n17, n18, n19, or n20](G/A)G. Alternatively the PAM sequence can follow the guideline G[n17, n18, n19, n20](G/A)G. For Cas9 proteins derived from non-*S. pyogenes* bacteria, the same guidelines may be used where the alternate PAMs are substituted in for the *S. pyogenes* PAM sequences.

25 [0085] Most preferred is to choose a target sequence with the highest likelihood of specificity that avoids potential off target sequences. These undesired off target sequences can be identified by considering the following attributes: i) similarity in the target sequence that is followed by a PAM sequence known to function with the Cas9 protein being utilized; ii) a similar target sequence with fewer
30 than three mismatches from the desired target sequence; iii) a similar target sequence

as in ii), where the mismatches are all located in the PAM distal region rather than the PAM proximal region (there is some evidence that nucleotides 1-5 immediately adjacent or proximal to the PAM, sometimes referred to as the 'seed' region (Wu *et al* (2014) *Nature Biotech* doi:10.1038/nbt2889) are the most critical for recognition, so putative off target sites with mismatches located in the seed region may be the least likely be recognized by the sg RNA); and iv) a similar target sequence where the mismatches are not consecutively spaced or are spaced greater than four nucleotides apart (Hsu 2014, *ibid*). Thus, by performing an analysis of the number of potential off target sites in a genome for whichever CRISPR/Cas system is being employed, using these criteria above, a suitable target sequence for the sgRNA may be identified.

[0086] In certain embodiments, Cas protein may be a "functional derivative" of a naturally occurring Cas protein. A "functional derivative" of a native sequence polypeptide is a compound having a qualitative biological property in common with a native sequence polypeptide. "Functional derivatives" include, but are not limited to, fragments of a native sequence and derivatives of a native sequence polypeptide and its fragments, provided that they have a biological activity in common with a corresponding native sequence polypeptide. A biological activity contemplated herein is the ability of the functional derivative to hydrolyze a DNA substrate into fragments. The term "derivative" encompasses both amino acid sequence variants of polypeptide, covalent modifications, and fusions thereof. In some aspects, a functional derivative may comprise a single biological property of a naturally occurring Cas protein. In other aspects, a function derivative may comprise a subset of biological properties of a naturally occurring Cas protein. Suitable derivatives of a Cas polypeptide or a fragment thereof include but are not limited to mutants, fusions, covalent modifications of Cas protein or a fragment thereof. Cas protein, which includes Cas protein or a fragment thereof, as well as derivatives of Cas protein or a fragment thereof, may be obtainable from a cell or synthesized chemically or by a combination of these two procedures. The cell may be a cell that naturally produces Cas protein, or a cell that naturally produces Cas protein and is genetically engineered to produce the endogenous Cas protein at a higher expression level or to produce a Cas protein from an exogenously introduced nucleic acid, which nucleic acid encodes a Cas that is same or different from the endogenous Cas. In some case, the cell does not naturally produce Cas protein and is genetically engineered to produce a Cas protein.

[0087] Exemplary CRISPR/Cas nuclease systems targeted to specific genes are disclosed for example, in U.S. Provisional Application No. 61/823,689.

[0088] Thus, the nuclease comprises a DNA-binding domain in that specifically binds to a target site in any gene into which it is desired to insert a donor
5 (transgene) in combination with a nuclease domain that cleaves DNA.

Fusion Molecules

[0089] The DNA-binding domains may be fused to any additional molecules (e.g., polypeptides) for use in the methods described herein. In certain embodiments,
10 the methods employ fusion molecules comprising at least one DNA-binding molecule (e.g., ZFP, TALE or single guide RNA) and a heterologous regulatory (functional) domain (or functional fragment thereof).

[0090] In certain embodiments, the functional domain comprises a transcriptional regulatory domain. Common domains include, e.g., transcription
15 factor domains (activators, repressors, co-activators, co-repressors), silencers, oncogenes (e.g., myc, jun, fos, myb, max, mad, rel, ets, bcl, myb, mos family members etc.); DNA repair enzymes and their associated factors and modifiers; DNA rearrangement enzymes and their associated factors and modifiers; chromatin associated proteins and their modifiers (e.g. kinases, acetylases and deacetylases); and
20 DNA modifying enzymes (e.g., methyltransferases, topoisomerases, helicases, ligases, kinases, phosphatases, polymerases, endonucleases) and their associated factors and modifiers. See, e.g., U.S. Publication No. 20130253040, incorporated by reference in its entirety herein.

[0091] Suitable domains for achieving activation include the HSV VP16
25 activation domain (see, e.g., Hagmann *et al.*, *J. Virol.* 71, 5952-5962 (1997)) nuclear hormone receptors (see, e.g., Torchia *et al.*, *Curr. Opin. Cell. Biol.* 10:373-383 (1998)); the p65 subunit of nuclear factor kappa B (Bitko & Barik, *J. Virol.* 72:5610-5618 (1998) and Doyle & Hunt, *Neuroreport* 8:2937-2942 (1997)); Liu *et al.*, *Cancer Gene Ther.* 5:3-28 (1998)), or artificial chimeric functional domains such as VP64
30 (Beerli *et al.*, (1998) *Proc. Natl. Acad. Sci. USA* 95:14623-33), and degron (Molinari *et al.*, (1999) *EMBO J.* 18, 6439-6447). Additional exemplary activation domains include, Oct 1, Oct-2A, Sp1, AP-2, and CTF1 (Seipel *et al.*, *EMBO J.* 11, 4961-4968 (1992) as well as p300, CBP, PCAF, SRC1 P_vALF, AtHD2A and ERF-2. See, for

example, Robyr *et al.* (2000) *Mol. Endocrinol.* 14:329-347; Collingwood *et al.* (1999) *J. Mol. Endocrinol.* 23:255-275; Leo *et al.* (2000) *Gene* 245:1-11; Manteuffel-Cymborowska (1999) *Acta Biochim. Pol.* 46:77-89; McKenna *et al.* (1999) *J. Steroid Biochem. Mol. Biol.* 69:3-12; Malik *et al.* (2000) *Trends Biochem. Sci.* 25:277-283; and Lemon *et al.* (1999) *Curr. Opin. Genet. Dev.* 9:499-504. Additional exemplary activation domains include, but are not limited to, OsGAI, HALF-1, C1, AP1, ARF-5, -6, -7, and -8, CPRF1, CPRF4, MYC-RP/GP, and TRAB1. *See, for example, Ogawa et al.* (2000) *Gene* 245:21-29; Okanami *et al.* (1996) *Genes Cells* 1:87-99; Goff *et al.* (1991) *Genes Dev.* 5:298-309; Cho *et al.* (1999) *Plant Mol. Biol.* 40:419-429; Ulmason *et al.* (1999) *Proc. Natl. Acad. Sci. USA* 96:5844-5849; Sprenger-Haussels *et al.* (2000) *Plant J.* 22:1-8; Gong *et al.* (1999) *Plant Mol. Biol.* 41:33-44; and Hobo *et al.* (1999) *Proc. Natl. Acad. Sci. USA* 96:15,348-15,353.

[0092] Exemplary repression domains include, but are not limited to, KRAB A/B, KOX, TGF-beta-inducible early gene (TIEG), v-erbA, SID, MBD2, MBD3, members of the DNMT family (*e.g.*, DNMT1, DNMT3A, DNMT3B), Rb, and MeCP2. *See, for example, Bird et al.* (1999) *Cell* 99:451-454; Tyler *et al.* (1999) *Cell* 99:443-446; Knoepfler *et al.* (1999) *Cell* 99:447-450; and Robertson *et al.* (2000) *Nature Genet.* 25:338-342. Additional exemplary repression domains include, but are not limited to, ROM2 and AtHD2A. *See, for example, Chem et al.* (1996) *Plant Cell* 8:305-321; and Wu *et al.* (2000) *Plant J.* 22:19-27.

[0093] Fusion molecules are constructed by methods of cloning and biochemical conjugation that are well known to those of skill in the art. Fusion molecules comprise a DNA-binding domain and a functional domain (*e.g.*, a transcriptional activation or repression domain). Fusion molecules also optionally comprise nuclear localization signals (such as, for example, that from the SV40 medium T-antigen) and epitope tags (such as, for example, FLAG and hemagglutinin). Fusion proteins (and nucleic acids encoding them) are designed such that the translational reading frame is preserved among the components of the fusion.

[0094] Fusions between a polypeptide component of a functional domain (or a functional fragment thereof) on the one hand, and a non-protein DNA-binding domain (*e.g.*, antibiotic, intercalator, minor groove binder, nucleic acid) on the other, are constructed by methods of biochemical conjugation known to those of skill in the art. *See, for example, the Pierce Chemical Company (Rockford, IL) Catalogue. Methods*

and compositions for making fusions between a minor groove binder and a polypeptide have been described. Mapp *et al.* (2000) *Proc. Natl. Acad. Sci. USA* 97:3930-3935.

[0095] The fusion molecule may be formulated with a pharmaceutically acceptable carrier, as is known to those of skill in the art. *See*, for example, Remington's Pharmaceutical Sciences, 17th ed., 1985; and co-owned WO 00/42219.

[0096] The functional component/domain of a fusion molecule can be selected from any of a variety of different components capable of influencing transcription of a gene once the fusion molecule binds to a target sequence via its DNA binding domain. Hence, the functional component can include, but is not limited to, various transcription factor domains, such as activators, repressors, co-activators, co-repressors, and silencers.

[0097] In certain embodiments, the fusion protein comprises a DNA-binding domain and a nuclease domain to create functional entities that are able to recognize their intended nucleic acid target through their engineered (ZFP or TALE) DNA binding domains and create nucleases (*e.g.*, zinc finger nuclease or TALE nucleases) cause the DNA to be cut near the DNA binding site via the nuclease activity.

[0098] Thus, the methods and compositions described herein are broadly applicable and may involve any nuclease of interest. Non-limiting examples of nucleases include meganucleases, TALENs and zinc finger nucleases. The nuclease may comprise heterologous DNA-binding and cleavage domains (*e.g.*, zinc finger nucleases; TALENs; meganuclease DNA-binding domains with heterologous cleavage domains) or, alternatively, the DNA-binding domain of a naturally-occurring nuclease may be altered to bind to a selected target site (*e.g.*, a meganuclease that has been engineered to bind to site different than the cognate binding site).

[0099] The nuclease domain may be derived from any nuclease, for example any endonuclease or exonuclease. Non-limiting examples of suitable nuclease (cleavage) domains that may be fused to Htt DNA-binding domains as described herein include domains from any restriction enzyme, for example a Type IIS Restriction Enzyme (*e.g.*, FokI). In certain embodiments, the cleavage domains are cleavage half-domains that require dimerization for cleavage activity. *See, e.g.*, U.S. Patent Nos. 8,586,526; 8,409,861 and 7,888,121, incorporated by reference in their entireties herein. In general, two fusion proteins are required for cleavage if the

fusion proteins comprise cleavage half-domains. Alternatively, a single protein comprising two cleavage half-domains can be used. The two cleavage half-domains can be derived from the same endonuclease (or functional fragments thereof), or each cleavage half-domain can be derived from a different endonuclease (or functional fragments thereof). In addition, the target sites for the two fusion proteins are preferably disposed, with respect to each other, such that binding of the two fusion proteins to their respective target sites places the cleavage half-domains in a spatial orientation to each other that allows the cleavage half-domains to form a functional cleavage domain, *e.g.*, by dimerizing.

10 [0100] The nuclease domain may also be derived any meganuclease (homing endonuclease) domain with cleavage activity may also be used with the nucleases described herein, including but not limited to I-SceI, I-CeuI, PI-PspI, PI-Sce, I-SceIV, I-CsmI, I-PanI, I-SceII, I-PpoI, I-SceIII, I-CreI, I-TevI, I-TevII and I-TevIII.

[0101] In certain embodiments, the nuclease comprises a compact TALEN (cTALEN). These are single chain fusion proteins linking a TALE DNA binding domain to a TevI nuclease domain. The fusion protein can act as either a nickase localized by the TALE region, or can create a double strand break, depending upon where the TALE DNA binding domain is located with respect to the meganuclease (*e.g.*, *TevI*) nuclease domain (see Beurdeley *et al* (2013) *Nat Comm*: 1-8 DOI: 10.1038/ncomms2782).

[0102] In other embodiments, the TALE-nuclease is a mega TAL. These mega TAL nucleases are fusion proteins comprising a TALE DNA binding domain and a meganuclease cleavage domain. The meganuclease cleavage domain is active as a monomer and does not require dimerization for activity. (See Boissel *et al.*, (2013) *Nucl Acid Res*: 1-13, doi: 10.1093/nar/gkt1224).

[0103] In addition, the nuclease domain of the meganuclease may also exhibit DNA-binding functionality. Any TALENs may be used in combination with additional TALENs (*e.g.*, one or more TALENs (cTALENs or FokI-TALENs) with one or more mega-TALs) and/or ZFNs.

30 [0104] In addition, cleavage domains may include one or more alterations as compared to wild-type, for example for the formation of obligate heterodimers that reduce or eliminate off-target cleavage effects. *See, e.g.*, U.S. Patent Nos. 7,914,796; 8,034,598; and 8,623,618, incorporated by reference in their entireties herein.

[0105] Nucleases as described herein may generate double- or single-stranded breaks in a double-stranded target (*e.g.*, gene). The generation of single-stranded breaks (“nicks”) is described, for example in U.S. Patent No. 8,703,489, incorporated herein by reference which describes how mutation of the catalytic domain of one of
5 the nucleases domains results in a nickase.

[0106] Thus, a nuclease (cleavage) domain or cleavage half-domain can be any portion of a protein that retains cleavage activity, or that retains the ability to multimerize (*e.g.*, dimerize) to form a functional cleavage domain.

[0107] Alternatively, nucleases may be assembled *in vivo* at the nucleic acid
10 target site using so-called “split-enzyme” technology (*see e.g.* U.S. Patent Publication No. 20090068164). Components of such split enzymes may be expressed either on separate expression constructs, or can be linked in one open reading frame where the individual components are separated, for example, by a self-cleaving 2A peptide or IRES sequence. Components may be individual zinc finger binding domains or
15 domains of a meganuclease nucleic acid binding domain.

[0108] Nucleases can be screened for activity prior to use, for example in a yeast-based chromosomal system as described in U.S. Publication No. 20090111119. Nuclease expression constructs can be readily designed using methods known in the art.

[0109] Expression of the fusion proteins may be under the control of a
20 constitutive promoter or an inducible promoter, for example the galactokinase promoter which is activated (de-repressed) in the presence of raffinose and/or galactose and repressed in presence of glucose. In certain embodiments, the promoter self-regulates expression of the fusion protein, for example via inclusion of high
25 affinity binding sites. *See, e.g.*, U.S. Application No. 61,955,002, filed March 18, 2014.

Delivery

[0110] The proteins and/or polynucleotides (*e.g.*, ZFPs, TALEs,
30 CRISPR/Cas), and compositions comprising the proteins and/or polynucleotides described herein may be delivered to a target cell by any suitable means including, for example, by injection of proteins, via mRNA and/or using an expression construct (*e.g.*, plasmid, lentiviral vector, AAV vector, Ad vector, etc.).

[0111] Methods of delivering proteins comprising zinc finger proteins as described herein are described, for example, in U.S. Patent Nos. 6,453,242; 6,503,717; 6,534,261; 6,599,692; 6,607,882; 6,689,558; 6,824,978; 6,933,113; 6,979,539; 7,013,219; and 7,163,824, the disclosures of all of which are incorporated
5 by reference herein in their entireties.

[0112] Any vector systems may be used including, but not limited to, plasmid vectors, retroviral vectors, lentiviral vectors, adenovirus vectors, poxvirus vectors; herpesvirus vectors and adeno-associated virus vectors, etc. *See, also*, U.S. Patent Nos. 8,586,526; 6,534,261; 6,607,882; 6,824,978; 6,933,113; 6,979,539; 7,013,219;
10 and 7,163,824, incorporated by reference herein in their entireties. Furthermore, it will be apparent that any of these vectors may comprise one or more DNA-binding protein-encoding sequences. Thus, when one or more ZFPs, TALEs or CRISPR/Cas proteins are introduced into the cell, the sequences encoding the ZFPs, TALEs or CRISPR/Cas proteins may be carried on the same vector or on different vectors.

15 When multiple vectors are used, each vector may comprise a sequence encoding one or multiple ZFPs, TALEs or CRISPR/Cas systems.

[0113] Conventional viral and non-viral based gene transfer methods can be used to introduce nucleic acids encoding engineered ZFPs, TALEs or CRISPR/Cas systems in cells (*e.g.*, mammalian cells) and target tissues. Such methods can also be
20 used to administer nucleic acids encoding ZFPs, TALEs or a CRISPR/Cas system to cells *in vitro*. In certain embodiments, nucleic acids encoding the ZFPs, TALEs or CRISPR/Cas system are administered for *in vivo* or *ex vivo* gene therapy uses. Non-viral vector delivery systems include DNA plasmids, naked nucleic acid, and nucleic acid complexed with a delivery vehicle such as a liposome or poloxamer. Viral
25 vector delivery systems include DNA and RNA viruses, which have either episomal or integrated genomes after delivery to the cell. For a review of gene therapy procedures, see Anderson, *Science* 256:808-813 (1992); Nabel & Felgner, *TIBTECH* 11:211-217 (1993); Mitani & Caskey, *TIBTECH* 11:162-166 (1993); Dillon, *TIBTECH* 11:167-175 (1993); Miller, *Nature* 357:455-460 (1992); Van Brunt, *Biotechnology* 6(10):1149-1154 (1988); Vigne, *Restorative Neurology and Neuroscience* 8:35-36 (1995); Kremer & Perricaudet, *British Medical Bulletin* 51(1):31-44 (1995); Haddada *et al.*, in *Current Topics in Microbiology and*
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Immunology Doerfler and Böhm (eds.) (1995); and Yu *et al.*, *Gene Therapy* 1:13-26 (1994).

[0114] Methods of non-viral delivery of nucleic acids include electroporation, lipofection, microinjection, biolistics, virosomes, liposomes, immunoliposomes, polycation or lipid:nucleic acid conjugates, naked DNA, naked RNA, artificial virions, and agent-enhanced uptake of DNA. Sonoporation using, *e.g.*, the Sonitron 2000 system (Rich-Mar) can also be used for delivery of nucleic acids. In a preferred embodiment, one or more nucleic acids are delivered as mRNA. Also preferred is the use of capped mRNAs to increase translational efficiency and/or mRNA stability.

10 Especially preferred are ARCA (anti-reverse cap analog) caps or variants thereof. See US patents US7074596 and US8153773, incorporated by reference herein.

[0115] Additional exemplary nucleic acid delivery systems include those provided by Amaxa Biosystems (Cologne, Germany), Maxcyte, Inc. (Rockville, Maryland), BTX Molecular Delivery Systems (Holliston, MA) and Copernicus Therapeutics Inc, (*see* for example US6008336). Lipofection is described in *e.g.*, U.S. Patent Nos. 5,049,386; 4,946,787; and 4,897,355) and lipofection reagents are sold commercially (*e.g.*, Transfectam™ and Lipofectin™ and Lipofectamine™ RNAiMAX). Cationic and neutral lipids that are suitable for efficient receptor-recognition lipofection of polynucleotides include those of Felgner, WO 91/17424, 20 WO 91/16024. Delivery can be to cells (*ex vivo* administration) or target tissues (*in vivo* administration).

[0116] The preparation of lipid:nucleic acid complexes, including targeted liposomes such as immunolipid complexes, is well known to one of skill in the art (*see, e.g.*, Crystal, *Science* 270:404-410 (1995); Blaese *et al.*, *Cancer Gene Ther.* 2:291-297 (1995); Behr *et al.*, *Bioconjugate Chem.* 5:382-389 (1994); Remy *et al.*, *Bioconjugate Chem.* 5:647-654 (1994); Gao *et al.*, *Gene Therapy* 2:710-722 (1995); Ahmad *et al.*, *Cancer Res.* 52:4817-4820 (1992); U.S. Pat. Nos. 4,186,183, 4,217,344, 4,235,871, 4,261,975, 4,485,054, 4,501,728, 4,774,085, 4,837,028, and 4,946,787).

[0117] Additional methods of delivery include the use of packaging the nucleic acids to be delivered into EnGeneIC delivery vehicles (EDVs). These EDVs are specifically delivered to target tissues using bispecific antibodies where one arm of the antibody has specificity for the target tissue and the other has specificity for the EDV. The antibody brings the EDVs to the target cell surface and then the EDV is

brought into the cell by endocytosis. Once in the cell, the contents are released (*see* MacDiarmid *et al* (2009) *Nature Biotechnology* 27(7):643).

[0118] The use of RNA or DNA viral based systems for the delivery of nucleic acids encoding engineered ZFPs, TALEs or CRISPR/Cas systems take advantage of highly evolved processes for targeting a virus to specific cells in the body and trafficking the viral payload to the nucleus. Viral vectors can be administered directly to patients (*in vivo*) or they can be used to treat cells *in vitro* and the modified cells are administered to patients (*ex vivo*). Conventional viral based systems for the delivery of ZFPs, TALEs or CRISPR/Cas systems include, but are not limited to, retroviral, lentivirus, adenoviral, adeno-associated, vaccinia and herpes simplex virus vectors for gene transfer. Integration in the host genome is possible with the retrovirus, lentivirus, and adeno-associated virus gene transfer methods, often resulting in long term expression of the inserted transgene. Additionally, high transduction efficiencies have been observed in many different cell types and target tissues.

[0119] The tropism of a retrovirus can be altered by incorporating foreign envelope proteins, expanding the potential target population of target cells. Lentiviral vectors are retroviral vectors that are able to transduce or infect non-dividing cells and typically produce high viral titers. Selection of a retroviral gene transfer system depends on the target tissue. Retroviral vectors are comprised of *cis*-acting long terminal repeats with packaging capacity for up to 6-10 kb of foreign sequence. The minimum *cis*-acting LTRs are sufficient for replication and packaging of the vectors, which are then used to integrate the therapeutic gene into the target cell to provide permanent transgene expression. Widely used retroviral vectors include those based upon mouse leukemia virus (MuLV), gibbon ape leukemia virus (GaLV), Simian Immunodeficiency virus (SIV), human immunodeficiency virus (HIV), and combinations thereof (*see, e.g.,* Buchscher *et al., J. Virol.* 66:2731-2739 (1992); Johann *et al., J. Virol.* 66:1635-1640 (1992); Sommerfelt *et al., Virol.* 176:58-59 (1990); Wilson *et al., J. Virol.* 63:2374-2378 (1989); Miller *et al., J. Virol.* 65:2220-2224 (1991); PCT/US94/05700).

[0120] In applications in which transient expression is preferred, adenoviral based systems can be used. Adenoviral based vectors are capable of very high transduction efficiency in many cell types and do not require cell division. With such

vectors, high titer and high levels of expression have been obtained. This vector can be produced in large quantities in a relatively simple system. Adeno-associated virus (“AAV”) vectors are also used to transduce cells with target nucleic acids, *e.g.*, in the *in vitro* production of nucleic acids and peptides, and for *in vivo* and *ex vivo* gene therapy procedures (*see, e.g.*, West *et al.*, *Virology* 160:38-47 (1987); U.S. Patent No. 4,797,368; WO 93/24641; Kotin, *Human Gene Therapy* 5:793-801 (1994); Muzyczka, *J. Clin. Invest.* 94:1351 (1994). Construction of recombinant AAV vectors are described in a number of publications, including U.S. Pat. No. 5,173,414; Tratschin *et al.*, *Mol. Cell. Biol.* 5:3251-3260 (1985); Tratschin, *et al.*, *Mol. Cell. Biol.* 4:2072-2081 (1984); Hermonat & Muzyczka, *PNAS* 81:6466-6470 (1984); and Samulski *et al.*, *J. Virol.* 63:03822-3828 (1989).

[0121] At least six viral vector approaches are currently available for gene transfer in clinical trials, which utilize approaches that involve complementation of defective vectors by genes inserted into helper cell lines to generate the transducing agent.

[0122] pLASN and MFG-S are examples of retroviral vectors that have been used in clinical trials (Dunbar *et al.*, *Blood* 85:3048-305 (1995); Kohn *et al.*, *Nat. Med.* 1:1017-102 (1995); Malech *et al.*, *PNAS* 94:22 12133-12138 (1997)). PA317/pLASN was the first therapeutic vector used in a gene therapy trial. (Blaese *et al.*, *Science* 270:475-480 (1995)). Transduction efficiencies of 50% or greater have been observed for MFG-S packaged vectors. (Ellem *et al.*, *Immunol Immunother.* 44(1):10-20 (1997); Dranoff *et al.*, *Hum. Gene Ther.* 1:111-2 (1997)).

[0123] Recombinant adeno-associated virus vectors (rAAV) are a promising alternative gene delivery systems based on the defective and nonpathogenic parvovirus adeno-associated type 2 virus. All vectors are derived from a plasmid that retains only the AAV 145 bp inverted terminal repeats flanking the transgene expression cassette. Efficient gene transfer and stable transgene delivery due to integration into the genomes of the transduced cell are key features for this vector system. (Wagner *et al.*, *Lancet* 351:9117 1702-3 (1998), Kearns *et al.*, *Gene Ther.* 9:748-55 (1996)). Other AAV serotypes, including AAV1, AAV3, AAV4, AAV5, AAV6, AAV8AAV 8.2, AAV9, and AAV rh10 and pseudotyped AAV such as AAV2/8, AAV2/5 and AAV2/6 can also be used in accordance with the present invention.

[0124] Replication-deficient recombinant adenoviral vectors (Ad) can be produced at high titer and readily infect a number of different cell types. Most adenovirus vectors are engineered such that a transgene replaces the Ad E1a, E1b, and/or E3 genes; subsequently the replication defective vector is propagated in human 293 cells that supply deleted gene function in *trans*. Ad vectors can transduce multiple types of tissues *in vivo*, including nondividing, differentiated cells such as those found in liver, kidney and muscle. Conventional Ad vectors have a large carrying capacity. An example of the use of an Ad vector in a clinical trial involved polynucleotide therapy for antitumor immunization with intramuscular injection (Stermann *et al.*, *Hum. Gene Ther.* 7:1083-9 (1998)). Additional examples of the use of adenovirus vectors for gene transfer in clinical trials include Rosenecker *et al.*, *Infection* 24:1 5-10 (1996); Stermann *et al.*, *Hum. Gene Ther.* 9:7 1083-1089 (1998); Welsh *et al.*, *Hum. Gene Ther.* 2:205-18 (1995); Alvarez *et al.*, *Hum. Gene Ther.* 5:597-613 (1997); Topf *et al.*, *Gene Ther.* 5:507-513 (1998); Stermann *et al.*, *Hum. Gene Ther.* 7:1083-1089 (1998).

[0125] Packaging cells are used to form virus particles that are capable of infecting a host cell. Such cells include 293 cells, which package adenovirus, and ψ 2 cells or PA317 cells, which package retrovirus. Viral vectors used in gene therapy are usually generated by a producer cell line that packages a nucleic acid vector into a viral particle. The vectors typically contain the minimal viral sequences required for packaging and subsequent integration into a host (if applicable), other viral sequences being replaced by an expression cassette encoding the protein to be expressed. The missing viral functions are supplied in *trans* by the packaging cell line. For example, AAV vectors used in gene therapy typically only possess inverted terminal repeat (ITR) sequences from the AAV genome which are required for packaging and integration into the host genome. Viral DNA is packaged in a cell line, which contains a helper plasmid encoding the other AAV genes, namely *rep* and *cap*, but lacking ITR sequences. The cell line is also infected with adenovirus as a helper. The helper virus promotes replication of the AAV vector and expression of AAV genes from the helper plasmid. The helper plasmid is not packaged in significant amounts due to a lack of ITR sequences. Contamination with adenovirus can be reduced by, *e.g.*, heat treatment to which adenovirus is more sensitive than AAV.

[0126] In many gene therapy applications, it is desirable that the gene therapy vector be delivered with a high degree of specificity to a particular tissue type.

Accordingly, a viral vector can be modified to have specificity for a given cell type by expressing a ligand as a fusion protein with a viral coat protein on the outer surface of the virus. The ligand is chosen to have affinity for a receptor known to be present on the cell type of interest. For example, Han *et al.*, *Proc. Natl. Acad. Sci. USA* 92:9747-9751 (1995), reported that Moloney mouse leukemia virus can be modified to express human heregulin fused to gp70, and the recombinant virus infects certain human breast cancer cells expressing human epidermal growth factor receptor. This principle can be extended to other virus-target cell pairs, in which the target cell expresses a receptor and the virus expresses a fusion protein comprising a ligand for the cell-surface receptor. For example, filamentous phage can be engineered to display antibody fragments (*e.g.*, FAB or Fv) having specific binding affinity for virtually any chosen cellular receptor. Although the above description applies primarily to viral vectors, the same principles can be applied to nonviral vectors. Such vectors can be engineered to contain specific uptake sequences which favor uptake by specific target cells.

[0127] Gene therapy vectors can be delivered *in vivo* by administration to an individual patient, typically by systemic administration (*e.g.*, intravenous, intraperitoneal, intramuscular, subdermal, or intracranial infusion) or topical application, as described below. Alternatively, vectors can be delivered to cells *ex vivo*, such as cells explanted from an individual patient (*e.g.*, lymphocytes, bone marrow aspirates, tissue biopsy) or universal donor hematopoietic stem cells, followed by reimplantation of the cells into a patient, usually after selection for cells which have incorporated the vector.

[0128] In certain embodiments, the compositions as described herein (*e.g.*, polynucleotides and/or proteins) are delivered directly *in vivo*. The compositions (cells, polynucleotides and/or proteins) may be administered directly into the central nervous system (CNS), including but not limited to direct injection into the brain or spinal cord. One or more areas of the brain may be targeted, including but not limited to, the hippocampus, the substantia nigra, the nucleus basalis of Meynert (NBM), the striatum and/or the cortex. Alternatively or in addition to CNS delivery, the compositions may be administered systemically (*e.g.*, intravenous, intraperitoneal,

intracardial, intramuscular, intrathecal, subdermal, and/or intracranial infusion).

Methods and compositions for delivery of compositions as described herein directly to a subject (including directly into the CNS) include but are not limited to direct injection (*e.g.*, stereotactic injection) via needle assemblies. Such methods are described, for example, in U.S. Patent Nos. 7,837,668; 8,092,429, relating to delivery of compositions (including expression vectors) to the brain and U.S. Patent Publication No. 20060239966, incorporated herein by reference in their entireties.

[0129] *Ex vivo* cell transfection for diagnostics, research, or for gene therapy (*e.g.*, via re-infusion of the transfected cells into the host organism) is well known to those of skill in the art. In a preferred embodiment, cells are isolated from the subject organism, transfected with a ZFP, TALE or CRISPR/Cas system nucleic acid (gene, cDNA or mRNA), and re-infused back into the subject organism (*e.g.*, patient). In a preferred embodiment, one or more nucleic acids are delivered as mRNA. Also preferred is the use of capped mRNAs to increase translational efficiency and/or mRNA stability. Especially preferred are ARCA (anti-reverse cap analog) caps or variants thereof. See U.S. patents 7,074,596 and 8,153,773, incorporated by reference herein in their entireties. Various cell types suitable for *ex vivo* transfection are well known to those of skill in the art (*see, e.g.*, Freshney *et al.*, *Culture of Animal Cells, A Manual of Basic Technique* (3rd ed. 1994)) and the references cited therein for a discussion of how to isolate and culture cells from patients).

[0130] In one embodiment, stem cells are used in *ex vivo* procedures for cell transfection and gene therapy. The advantage to using stem cells is that they can be differentiated into other cell types *in vitro*, or can be introduced into a mammal (such as the donor of the cells) where they will engraft in the bone marrow. Methods for differentiating CD34+ cells *in vitro* into clinically important immune cell types using cytokines such as GM-CSF, IFN- γ and TNF- α are known (*see Inaba et al., J. Exp. Med.* 176:1693-1702 (1992)).

[0131] Stem cells are isolated for transduction and differentiation using known methods. For example, stem cells are isolated from bone marrow cells by panning the bone marrow cells with antibodies which bind unwanted cells, such as CD4+ and CD8+ (T cells), CD45+ (panB cells), GR-1 (granulocytes), and Iad (differentiated antigen presenting cells) (*see Inaba et al., J. Exp. Med.* 176:1693-1702 (1992)).

[0132] Stem cells that have been modified may also be used in some embodiments. For example, neuronal stem cells that have been made resistant to apoptosis may be used as therapeutic compositions where the stem cells also contain the ZFP TFs of the invention. Resistance to apoptosis may come about, for example, by knocking out BAX and/or BAK using BAX- or BAK-specific TALENs or ZFNs (see, U.S. Patent No. 8,597,912) in the stem cells, or those that are disrupted in a caspase, again using caspase-6 specific ZFNs for example. These cells can be transfected with the ZFP TFs or TALE TFs that are known to regulate mutant or wild-type Htt.

[0133] Vectors (*e.g.*, retroviruses, adenoviruses, liposomes, etc.) containing therapeutic ZFP nucleic acids can also be administered directly to an organism for transduction of cells *in vivo*. Alternatively, naked DNA can be administered. Administration is by any of the routes normally used for introducing a molecule into ultimate contact with blood or tissue cells including, but not limited to, injection, infusion, topical application and electroporation. Suitable methods of administering such nucleic acids are available and well known to those of skill in the art, and, although more than one route can be used to administer a particular composition, a particular route can often provide a more immediate and more effective reaction than another route.

[0134] Methods for introduction of DNA into hematopoietic stem cells are disclosed, for example, in U.S. Patent No. 5,928,638. Vectors useful for introduction of transgenes into hematopoietic stem cells, *e.g.*, CD34⁺ cells, include adenovirus Type 35.

[0135] Vectors suitable for introduction of transgenes into immune cells (*e.g.*, T-cells) include non-integrating lentivirus vectors. *See*, for example, Ory *et al.* (1996) *Proc. Natl. Acad. Sci. USA* **93**:11382-11388; Dull *et al.* (1998) *J. Virol.* **72**:8463-8471; Zuffery *et al.* (1998) *J. Virol.* **72**:9873-9880; Follenzi *et al.* (2000) *Nature Genetics* **25**:217-222.

[0136] Pharmaceutically acceptable carriers are determined in part by the particular composition being administered, as well as by the particular method used to administer the composition. Accordingly, there is a wide variety of suitable formulations of pharmaceutical compositions available, as described below (*see, e.g.*, *Remington's Pharmaceutical Sciences*, 17th ed., 1989).

[0137] As noted above, the disclosed methods and compositions can be used in any type of cell including, but not limited to, prokaryotic cells, fungal cells, Archaeal cells, plant cells, insect cells, animal cells, vertebrate cells, mammalian cells and human cells. Suitable cell lines for protein expression are known to those of skill in the art and include, but are not limited to COS, CHO (*e.g.*, CHO-S, CHO-K1, CHO-DG44, CHO-DUXB11), VERO, MDCK, WI38, V79, B14AF28-G3, BHK, HaK, NS0, SP2/0-Ag14, HeLa, HEK293 (*e.g.*, HEK293-F, HEK293-H, HEK293-T), perC6, insect cells such as *Spodoptera fugiperda* (Sf), and fungal cells such as *Saccharomyces*, *Pischia* and *Schizosaccharomyces*. Progeny, variants and derivatives of these cell lines can also be used.

[0138] The effective amount to be administered will vary from patient to patient and according to the mode of administration and site of administration. Accordingly, effective amounts are best determined by the physician administering the compositions and appropriate dosages can be determined readily by one of ordinary skill in the art. After allowing sufficient time for integration and expression (typically 4-15 days, for example), analysis of the serum or other tissue levels of the therapeutic polypeptide and comparison to the initial level prior to administration will determine whether the amount being administered is too low, within the right range or too high. Suitable regimes for initial and subsequent administrations are also variable, but are typified by an initial administration followed by subsequent administrations if necessary. Subsequent administrations may be administered at variable intervals, ranging from daily to annually to every several years. In certain embodiments,

[0139] To deliver ZFPs using adeno-associated viral (AAV) vectors directly to the human brain, a dose range of 1×10^{10} - 5×10^{12} (or any value therebetween) vector genome per striatum can be applied. As noted, dosages may be varied for other brain structures and for different delivery protocols.

Applications

[0140] Htt-binding molecules (*e.g.*, ZFPs, TALEs, CRISPR/Cas systems, Ttago, etc.) as described herein, and the nucleic acids encoding them, can be used for a variety of applications. These applications include therapeutic methods in which a Htt-binding molecule (including a nucleic acid encoding a DNA-binding protein) is administered to a subject and used to modulate the expression of a target gene within

the subject. The modulation can be in the form of repression, for example, repression of mHtt that is contributing to an HD disease state. Alternatively, the modulation can be in the form of activation when activation of expression or increased expression of an endogenous cellular gene can ameliorate a diseased state. In still further

5 embodiments, the modulation can be cleavage (*e.g.*, by one or more nucleases), for example, for inactivation of a mutant Htt gene. As noted above, for such applications, the Htt-binding molecules, or more typically, nucleic acids encoding them are formulated with a pharmaceutically acceptable carrier as a pharmaceutical composition.

10 **[0141]** The Htt-binding molecules, or vectors encoding them, alone or in combination with other suitable components (*e.g.* liposomes, nanoparticles or other components known in the art), can be made into aerosol formulations (*i.e.*, they can be “nebulized”) to be administered via inhalation. Aerosol formulations can be placed into pressurized acceptable propellants, such as dichlorodifluoromethane, propane,
15 nitrogen, and the like. Formulations suitable for parenteral administration, such as, for example, by intravenous, intramuscular, intradermal, and subcutaneous routes, include aqueous and non-aqueous, isotonic sterile injection solutions, which can contain antioxidants, buffers, bacteriostats, and solutes that render the formulation isotonic with the blood of the intended recipient, and aqueous and non-aqueous sterile
20 suspensions that can include suspending agents, solubilizers, thickening agents, stabilizers, and preservatives. Compositions can be administered, for example, by intravenous infusion, orally, topically, intraperitoneally, intravesically or intrathecally. The formulations of compounds can be presented in unit-dose or multi-dose sealed containers, such as ampules and vials. Injection solutions and suspensions can be
25 prepared from sterile powders, granules, and tablets of the kind previously described.

[0142] The dose administered to a patient should be sufficient to effect a beneficial therapeutic response in the patient over time. The dose is determined by the efficacy and K_d of the particular Htt-binding molecule employed, the target cell, and the condition of the patient, as well as the body weight or surface area of the
30 patient to be treated. The size of the dose also is determined by the existence, nature, and extent of any adverse side-effects that accompany the administration of a particular compound or vector in a particular patient

[0143] In other applications, efficacy of the molecules as described herein is analyzed using detection methods designed to measure the amount of mHTT protein in a patient for example in samples such as cerebral spinal fluid (CSF). For example, an ultra-sensitive immunoassay as described in Wild *et al.* (2014) *J. Neurol Neurosurg Psychiatry* 85:10 can be used to detect (and/or quantify) the presence of mutant Htt protein associated with HD in patient samples. In certain embodiments, the detection of changes in mHtt levels in the CSF provides a diagnostic for determining the progression of HD in a subject in response to HD therapy as described herein (*e.g.*, ZFPs, TALEs, etc.).

10 [0144] Any suitable format for performing diagnostic assays can be used, including immunoassays. For example, capture reagents (*e.g.* antibodies, receptors or the like) can be immobilized on an ELISA plate. Alternatively, detection reagents are used with ultrasensitive immunodetection on-chip for quantitation by methods known in the art such as magnetic particle scanning (see *e.g.* Cornaglia *et al* (2014) *Anal Chem* 86(16):8213-23). The detection reagent is contacted with a sample suspected of containing a mutant Htt protein under conditions in which binding can occur, and quantitation is done by methods known in the art.

[0145] Therefore, as mHTT levels are associated with disease burden score and levels increase in concentration with disease progression, detection of mHtt in CSF or other patient samples allows monitoring of efficacy of Htt-binding molecule therapy in HD as well aids in the ability to study the effects of treatment on the neuropathobiology of HD, and can be used to support clinical trials of disease-modifying HD therapeutics as described herein.

25 [0146] The following Examples relate to exemplary embodiments of the present disclosure in which the Htt-modulator comprises a zinc finger protein or a CRISPR/Cas system. It will be appreciated that this is for purposes of exemplification only and that other Htt-modulates can be used, including, but not limited to, TALE-TFs, additional ZFPs, ZFNs, TALENs, additional CRISPR/Cas systems, homing endonucleases (meganucleases) with engineered DNA-binding domains.

EXAMPLES

Example 1: ZFP-TFs rescue phenotypes of cultured HD neurons

[0147] Various studies have shown phenotypic changes associated with expanded CAG repeats in HD patient derived cells, such as reduced intracellular ATP levels and increased vulnerability to growth factor withdrawal. *See, e.g., Jung-II et al. (2012) Biochemical Journal 446(3):359-371; HD IPSC Consortium (2012) Cell Stem Cell 11(2):264-278; An et al. (2012) Cell Stem Cell 11(2):253-263.*

[0148] Accordingly, we evaluated whether expression of an allele-specific ZFP repressor of Htt rescues such phenotypes in patient derived neurons. Briefly, lentiviral vectors for Venus (GFP) and ZFP-TF 33074-KOX-2A-Venus were generated as described herein and in U.S. Patent Publication No. 20130253040. The cleavable 2A peptide allows Venus (GFP) and ZFP to be expressed from the same vector, and ZFP-expressing cells can be identified by GFP expression. The lentiviral expression constructs were the third generation self-inactivating HIV-based LVs. The 33074 expression vectors were constructed by inserting the ZFP-TF with the 2A linker and GFP Venus downstream of the CMV promoter. The GFP expression construct contains only the GFP-Venus downstream of the CMV promoter. Recombinant LVs were prepared by transient transfection of 293T cells using a lipofectamine 2000 (Life Technologies). The viral supernatants were harvested 48 and 72 hours post-transfection and filtered through a 0.45- μ m filter before being concentrated 300-fold by ultracentrifugation at 4°C (Optima L-80K preparative ultracentrifuge, Beckman Coulter) at 50,000 $\times g$ for 90 min. The viral pellets were then resuspended in Hank's Buffered Salt Solution (Lonza) and stored at -80C. The viral titers were determined by infection of 293T cells and measured by flow cytometry analysis of GFP-VENUS expression.

[0149] HD-ESCs were passaged with accutase and cultured on matrigel coated plates in E8 media (Life Technologies). Neural stem cells were derived using StemPro Neural Induction Medium (Life Technologies). Briefly, ESCs were seeded into geltrex coated 6 well dish with 200,000 cells/well and when 10-20% confluent the medium was changed to StemPro Neural Induction Medium. Medium was changed every 2 days and NSC harvested and expanded on day 7. StemPro NSC SFM medium (Life Technologies) was used to culture HD-NSCs and non-HD NSCs

(HIP™ Globalstem). NSCs were passaged with accutase on geltrex coated plates. Neuron differentiation was induced by changing medium to neural differentiation medium containing of Neurobasal medium with B-27 Serum-Free Supplement and GlutaMAX™ (Life Technologies). Medium was changed every 3-4 days.

5 [0150] Differentiated neurons were transduced with lentiviral vectors for Venus (GFP) and ZFP-TF 33074-KOX-2A-Venus at an MOI of 500. Subsequently, the supernatant was replaced with fresh neural differentiation media and cultures maintained for up to 21 days.

[0151] Intracellular ATP levels of cultured neurons, derived from an HD
10 patient (CAG17/48) or a normal subject, were measured using the CellTiter-Glo® Luminescent Assay (Promega), cell numbers in each sample were determined using the ApoLive-Glo® assay (Promega). Briefly, Intracellular ATP levels in neurons were measured using the CellTiter-Glo Luminescent Assay (Promega) according to manufacturer's instructions. Luminescence (RLU) was measured 30min later on a
15 Perkin Elmer Wallac 1420 Victor2 Microplate Reader and the values were normalized to the cell number in the well by using the ApoLive-Glo assay (Promega) and measuring fluorescence (A.U.). ATP level per cell values from different cells/treatment were then normalized to that of mock-infected HD neurons.

[0152] As shown in Figure 1, mock infected or Lenti-GFP-infected HD
20 neurons have significantly reduced intracellular levels of ATP relative to non-HD (normal) neurons. By contrast, Lenti-33074-KOX-2A-GFP infection resulted in ~60% increase of intracellular ATP levels in HD neurons, indicating that ZFP-driven repression of mutant Htt alleles normalizes impaired the energy metabolism of these cells.

25 [0153] Cell death of HD and non-HD neurons induced by growth factor withdrawal was measured using a terminal deoxynucleotidyl transferase dUTP nick end labeling (TUNEL) assay. Briefly, Neurons were infected with LV in triplicate as described above for the ATP assay. The cells were cultured for 12 days then media was changed to fresh neurobasal media without any additive (growth factors). Cells
30 were kept in this growth factor withdrawal media for 48 hours. TUNEL assay was performed using the ApoBrdU Red DNA fragmentation kit (BioVision). Neurons were fixed with 4% paraformaldehyde on ice for 15min. Apoptosis was assessed by quantifying TUNEL -positive cells according to the manufacturer recommendations

(ApoBrdU Red DNA fragmentation kit, BioVision). Flow cytometry was used to measure both apoptosis by anti-BrdU-Red staining and LV transduction by GFP.

[0154] As shown in Figure 2, after 48 hours of growth factor withdrawal, HD neurons (mock infected) showed a higher rate of cell death (~50%) than non-HD neurons (~20%). While Lenti-GFP infection did not affect the level of cell death in HD neurons, Lenti-33074-KOX-2A-GFP infection lead to a significant neuron decrease in the percentage of apoptotic cells (from ~50% to 20%).

[0155] Thus, ZFP-driven repression of mutant Htt reduces the vulnerability of HD neurons to growth factor withdrawal.

Example 2: ZFP-TFs prevent and reverse mutant Htt aggregation in Q175 mice

[0156] The *in vivo* efficacy of allele-specific repressor of mutant Htt ZFP-TFs (ZFP-30640 and 30645), was tested in the Q175 knock-in mouse model (Menalled *et al.* (2012) *PLoS One* 7(12):e49838), in which exon 1 of one of mouse Htt allele was replaced by human Htt exon 1 sequence that contains an expanded CAG repeat (~179 CAGs). Pathological aggregation of mutant Htt can begin to be detected in the striatum of Q175 mice by 2 months of age, and continues to increase with age; aggregation becomes well-established by 6 months of age.

[0157] To test whether ZFPs can prevent accumulation of mutant Htt in the striatum, unilateral intrastriatal injection of AAV-ZFP, or AAV-GFP as a negative control, (2×10^{10} vector genome/striatum) was performed on 2-month-old Q175 mice; ZFP and GFP expression was driven by human Synapsin 1 promoter.

[0158] Two months after the injection (4 months of age), brains were harvested, sectioned and subjected to immunohistochemistry analysis to assess ZFP and Htt expression. ZFP expression was detected by an antibody against the FLAG epitope tag, and mutant Htt aggregation was detected by an anti-Htt antibody (mEM48). Representative images from an AAV-30645-injected mouse are shown in Figure 3A to 3H. In the contralateral striatum that received no injection, mutant Htt (mEM48) aggregation was readily detected; in the ipsilateral striatum that received AAV-30645 injection, only very a low level of mutant Htt aggregation was observed in ZFP-expressing cells (indicated by positive FLAG staining).

[0159] As shown in Figure 3I, when the number of nuclear Htt aggregates per cell was quantified for FLAG(+) and GFP(+) cells in the ipsilateral striatum of AAV-

ZFP and AAV-GFP-injected mice, respectively, and then normalized to the number of aggregates per cell in the uninjected contralateral striatum, both ZFP-30640 and 30645 significantly reduced (>90%) the number of nuclear Htt aggregates ($P<0.001$, Kruskal Wallis test and Dunn's multiple comparison).

5 [0160] As shown in Figure 3J, when the intensity of nuclear mEM48 staining in ZFP- or GFP-expressing cells was normalized to that in neurons from the contralateral striatum, a 50-60% reduction in nuclear mEM48 intensity was observed in ZFP-injected striatum ($P<0.001$). As shown in Figure 3K, the density of perinuclear mutant Htt aggregates in ZFP- or GFP-expressing cells was normalized to
10 that in contralateral striatal neurons, 45-70% reduction in the perinuclear Htt aggregate density was observed in ZFP-injected striatum ($P<0.01$).

[0161] These results show that, when injected at 2 months of age, ZFP-TFs prevented mutant Htt aggregation in the striatum of Q175 mice at 4 months of age.

[0162] To test whether ZFPs can reverse well-established Htt aggregation,
15 unilateral intrastriatal injection of AAV-GFP-2A-ZFP was performed on 6-month-old Q175 mice; the cleavable 2A peptide allows GFP and ZFP to be expressed from the same vector, and ZFP-expressing cells can be identified by GFP expression. At 8 months of age, brains were harvested, sectioned and subjected to immunohistochemistry analysis to assess Htt aggregation. Representative images
20 from an AAV-GFP-2A-30645-injected mouse are shown in Figure 4A. An antibody to DARPP-32, which is a striatum-specific protein, was used to label striatum. In the contralateral striatum that received no injection, a high level of mutant Htt aggregation (detected by the mEM48 antibody) was observed; in the ipsilateral striatum that received AAV-GFP-2A-30645 injection, reduction of mutant Htt
25 aggregation was observed.

[0163] Furthermore, the number of nuclear Htt aggregates per cell was quantified for GFP(+) cells in the ipsilateral striatum of AAV-GFP-2A-ZFP and AAV-GFP-injected mice, and then normalized to the number of aggregates per cell in the uninjected contralateral striatum. As shown in Figure 4B, delivery of GFP-2A-
30 30640 led to ~20% reduction in the number of Htt nuclear aggregates ($P<0.001$, Kruskal Wallis test and Dunn's multiple comparison), delivery of GFP-2A-30645 also caused a small reduction in the number of Htt nuclear aggregates per cell.

[0164] The intensity of nuclear mEM48 staining in GFP(+) cells from the ipsilateral striatum of AAV-GFP-2A-ZFP- and AAV-GFP-injected mice was also normalized to that in neurons from the contralateral striatum. As shown in Figure 4C, an approximately 20% reduction ($P < 0.001$) in nuclear mEM48 intensity was observed in GFP-2A-30645-injected striatum. An approximately 10% reduction in nuclear mEM48 intensity was also observed in GFP-2A-30640-injected striatum.

[0165] The density of perinuclear mutant Htt aggregates in GFP(+) cells in the ipsilateral striatum of AAV-GFP-2A-ZFP- and AAV-GFP-injected mice was measured and normalized to that in contralateral striatal neurons. As shown in Figure 4D, 30-50% reduction ($P < 0.001$) in the perinuclear Htt aggregate density was observed in ZFP-injected striatum.

[0166] These results show that, when injected at 6 months of age, ZFP-TFs reversed pre-existing mutant Htt aggregation in the striatum of Q175 mice after only 2 months. More substantial clearance of mutant Htt aggregation is expected if expression of ZFP is allowed to continue for longer than 2 months before mouse brains are analyzed.

[0167] Taken together, the data demonstrates that mutant Htt-allele repressors delivered to the brain of HD subjects led to increased levels of intracellular ATP concentrations in HD neurons, reduced apoptosis in HD neurons, and prevented and cleared existing Htt aggregates.

Example 3: Efficacy of ZFP-TF treatment

[0168] A diagnostic test is conducted on subjects treated with an Htt-binding molecule (*e.g.*, ZFP-TF, TALE-TF *etc.*) that is specific for the mutant Htt allele. HD subjects are treated with the Htt-binding molecules as described herein. CSF is extracted from the subject by standard methods (*e.g.* lumbar puncture) and is then subject to methods known in the art to detect and quantitate mHtt protein (see Wild *et al, ibid*). mHtt protein levels decrease in the CSF following therapy as described herein.

Example 4: A ZFP-TF prevents and reduces mutant Htt aggregation in Q175 mice, and increases expression of the DARPP32 gene.

[0169] The *in vivo* efficacy of another allele-specific repressor of mutant Htt ZFP-TFs (ZFP-33074) was tested in the Q175 knock-in mouse model (Menalled *et al.* (2012) *PLoS One* 7(12):e49838), in which exon 1 of one of mouse Htt allele was replaced by human Htt exon 1 sequence that contains an expanded CAG repeat (~179 CAGs). Pathological aggregation of mutant Htt can begin to be detected in the striatum of Q175 mice by 2 months of age, and continues to increase with age; aggregation becomes well-established by 6 months of age.

[0170] To test whether ZFPs can prevent accumulation of mutant Htt in the striatum, unilateral intrastriatal injection of AAV-ZFP-2A-GFP, or AAV-GFP as a negative control, (2×10^{10} vector genome/striatum) was performed on 2-month-old Q175 mice; ZFP and GFP expression was driven by human Synapsin 1 promoter. The self-cleavable 2A peptide allows GFP and ZFP to be expressed from the same vector, and ZFP-expressing cells can be identified by GFP expression.

[0171] Two months after the injection (4 months of age), brains were harvested, sectioned and subjected to immunohistochemistry analysis to assess Htt expression. Transduced cells were marked by GFP, medium spiny neurons (MSNs) were labeled by a DARPP32 antibody, and mutant Htt aggregation was detected by an anti-Htt antibody (mEM48).

[0172] As shown in Figure 5A, in AAV-transduced MSNs (labeled by GFP and a DARPP32 antibody), the number of nuclear Htt aggregates or inclusions per cell was significantly reduced by ZFP 33074 ($P < 0.001$). Figure 5B shows that the density of extranuclear mutant Htt aggregates in AAV-transduced cells was significantly reduced in ZFP-treated striata. ($P < 0.0001$). Figure 5C shows that the intensity of nuclear mEM48 staining (mutant Htt) was significantly reduced in ZFP-treated mice ($P < 0.001$).

[0173] These results show that, when injected at 2 months of age, ZFP 33074 prevents mutant Htt aggregation in the striatum of Q175 mice.

[0174] To test whether ZFPs can reduce Htt aggregation after it has been well established in the Q175 striatum, unilateral intrastriatal injection of AAV-GFP-2A-ZFP or AAV-GFP was performed on 6-month-old Q175 mice. At 10 months of age, brains were harvested, sectioned and subjected to immunohistochemistry.

[0175] Figure 6A shows that in AAV-transduced MSNs (labeled by GFP and a DARPP32 antibody), the number of nuclear Htt aggregates/inclusions per cell was significantly reduced by ZFP 33074 ($P<0.001$). Figure 6B shows that the density of extranuclear mutant Htt aggregates in AAV-transduced cells was significantly
 5 reduced in ZFP-treated striata. ($P<0.0001$). Figure 6C shows that the intensity of nuclear mEM48 staining (mutant Htt) was significantly reduced in ZFP-treated mice ($P<0.001$).

[0176] Figure 7A shows that in 10-month old Q175 mice, expression of MSN marker DARPP32 is reduced ($P<0.05$) compared to age-matched wild type mice,
 10 suggesting degeneration of MSNs in these mice. Figure 7B shows that, when Q175 mice was injected with AAV-ZFP-2A-GFP at 6 month of age and analyzed for DARPP32 expression at 10 months of age, a significantly increase in DARPP32 expression was found in ZFP 33074-treated mice compare to control-treated mice.

[0177] Together, these results demonstrate that, when injected at 6 months of
 15 age, ZFP 33074 is able to reduce mutant Htt expression and aggregation in the presence of existing aggregates. Moreover, ZFP 33074 is able to rescue the expression of DARPP32, suggesting protection of MSNs. The DNA binding domain (DBD), which recruits the ZFP to the expanded CAG repeat, is required, as a control vector that lacks the DBD (ZFP Δ DBD) has no effect on mutant Htt aggregation or
 20 DARPP32 expression.

Example 5: A CRISPR/Cas-TF prevents and reduces mutant Htt aggregation in HD neurons

[0178] sgRNAs for use in the CRISPR/Cas system are made synthetically by
 25 methods known in the art (see Hsu *et al* (2013) *Nature Biotech* doi:10.1038/nbt.2647 or Sternberg *et al*, (2014) *Nature* 507: 62). The sgRNAs are engineered as described above and are designed to target a sequence in mHtt. For example, a sgRNA may have one of the following sequences, where the PAM sequences are underlined:

30 5' GCAGCAGCAGCAGCAGCAGCAGCAGCAG 3' SEQ ID NO:122

5'GCAGCAGCAGCAGCAGCAGCAGCAGCAG 3' SEQ ID NO:123

5'GCAGCAGCAGCAGCAGCAGCAGCAG 3' SEQ ID NO:124

5'GCAGCAGCAGCAGCAGCAGCAG 3' SEQ ID NO:125

[0179] CRISPR/Cas transcription factors are made according to methods known in the art (see e.g. Perez-Pinera (2013) *Nature* 10(10):973 and Qi and Arkin (2014) *Nature Reviews Microbiology* 12:341). In brief, a nuclease defective Cas9
5 protein is used and fused to a repression domain (*i.e.* KRAB).

[0180] Cultured HD neurons are transfected with Cas9(nuclease-)-KRAB fusion protein encoding mRNA (20 µg/mL) and a sgRNA as described above, wherein the sgRNAs are introduced via mRNA (*e.g.* 2-4 µg) or a DNA expression vector (*e.g.* 400 ng- 800 ng) by electroporation using a BTX ECM830. Cells are
10 collected 5 days later quantitative Taqman analysis to measure mHtt expression. Additionally, the cells are subject to the experiments described above to measure intercellular ATP levels and to analyze apoptosis. The data shows that the mHtt-specific CRISPR/Cas transcription factors using a sgRNA can repress expression of mHtt and reduce the phenotypic characteristics caused by mHtt protein aggregation.

15

Example 6: Reducing Motor Deficits

[0181] Animals (*e.g.*, mice) are administered Htt-repressors as described herein and tested regularly for clasping behavior, which is a well-established motor defect exhibited by these animals (Mangiarini *et al.* 1996 *Cell* 87, 493–506). In brief,
20 each animal is removed from its home cage and placed onto the lid of the cage. The animal is then gently pulled backward and upward by the observer in a smooth motion until the animal is suspended above the surface by about 12 inches. The animal is then scored for 30 seconds. If only forelimb clasp is observed, the animal is given a score of 1. If only hind limb clasp is observed, the animal is given a score of 2. If both hind
25 limb and forelimb clasp are observed, but not at the same time, the animal is given a score of 3. A full clasp, defined by simultaneous hind limb and forelimb clasp pulled tightly into the core, is given a score of 4. After the 30-second suspension, the animal is returned to its home cage. For each treatment group, as well as age-matched wild type littermates, the proportion of animals that display full clasping (score of 4) at
30 each weekly observation is determined.

[0182] Compared to controls (no Htt-repressors), the Htt-repressors described herein improve clasping behavior, a well-characterized motor defect.

[0183] All patents, patent applications and publications mentioned herein are hereby incorporated by reference for all purposes in their entirety.

[0184] Although disclosure has been provided in some detail by way of
5 illustration and example for the purposes of clarity of understanding, it will be apparent to those skilled in the art that various changes and modifications can be practiced without departing from the spirit or scope of the disclosure. Accordingly, the foregoing descriptions and examples should not be construed as limiting.

CLAIMS

What is claimed is:

1. A method of modifying a neuron in a subject with Huntington's Disease (HD), the method comprising administering a repressor of a mutant Htt (mHtt) allele to the subject such that the neuron is modified.
2. The method of claim 1, wherein the neuron is an HD neuron.
3. The method of claim 1 or claim 2, wherein the modification comprises reducing aggregation of Htt in the neuron; increasing energy metabolism in the neuron; reducing susceptibility to apoptosis in the neuron and combinations thereof.
4. The method of claim 3, wherein intracellular ATP levels are increased.
5. A method of preventing or reducing the formation of Htt aggregates in an HD neuron, the method comprising modifying the HD neuron according to the method of claim 3.
6. A method of increasing cellular activity in an HD neuron, the method comprising modifying the HD neuron according to the method of claim 3.
7. A method of reducing apoptosis in an HD neuron, the method comprising modifying the HD neuron according to the method of claim 3.
8. A method for reducing motor deficits in an HD subject in need thereof, the method comprising modifying an HD neuron in the subject according to the method of claim 2.
9. The method of claim 8, wherein the motor deficit comprises claspings.
10. The method of any of claims 1 to 9, further comprising detecting mHtt levels in the subject.

11. The method of claim 10, wherein the mHtt levels are detected in cerebrospinal fluid (CSF).

5 12. The method of any of claims 1 to 11, wherein the repressor comprises a zinc finger protein transcription factor (ZF)-TF), a TAL-effector domain transcription factor (TALE-TF), a CRISPR/Cas-transcription factor, a zinc finger nuclease (ZFN), TAL-effector domain nuclease (TALEN) or a CRISPR/Cas nuclease system.

10

13. The method of any of claims 1 to 12, wherein the repressor is delivered to the neuron as a protein or as polynucleotide.

14. The method of claim 13, wherein the polynucleotide comprises mRNA
15 or an expression construct selected from the group consisting of a plasmid and a viral vector.

15. The method of any of claims 1 to 14, wherein the repressor reduces mHtt expression by at least 85%.

20

16. A kit comprising an Htt repressor and reagents for detecting and/or quantifying mHtt protein levels.

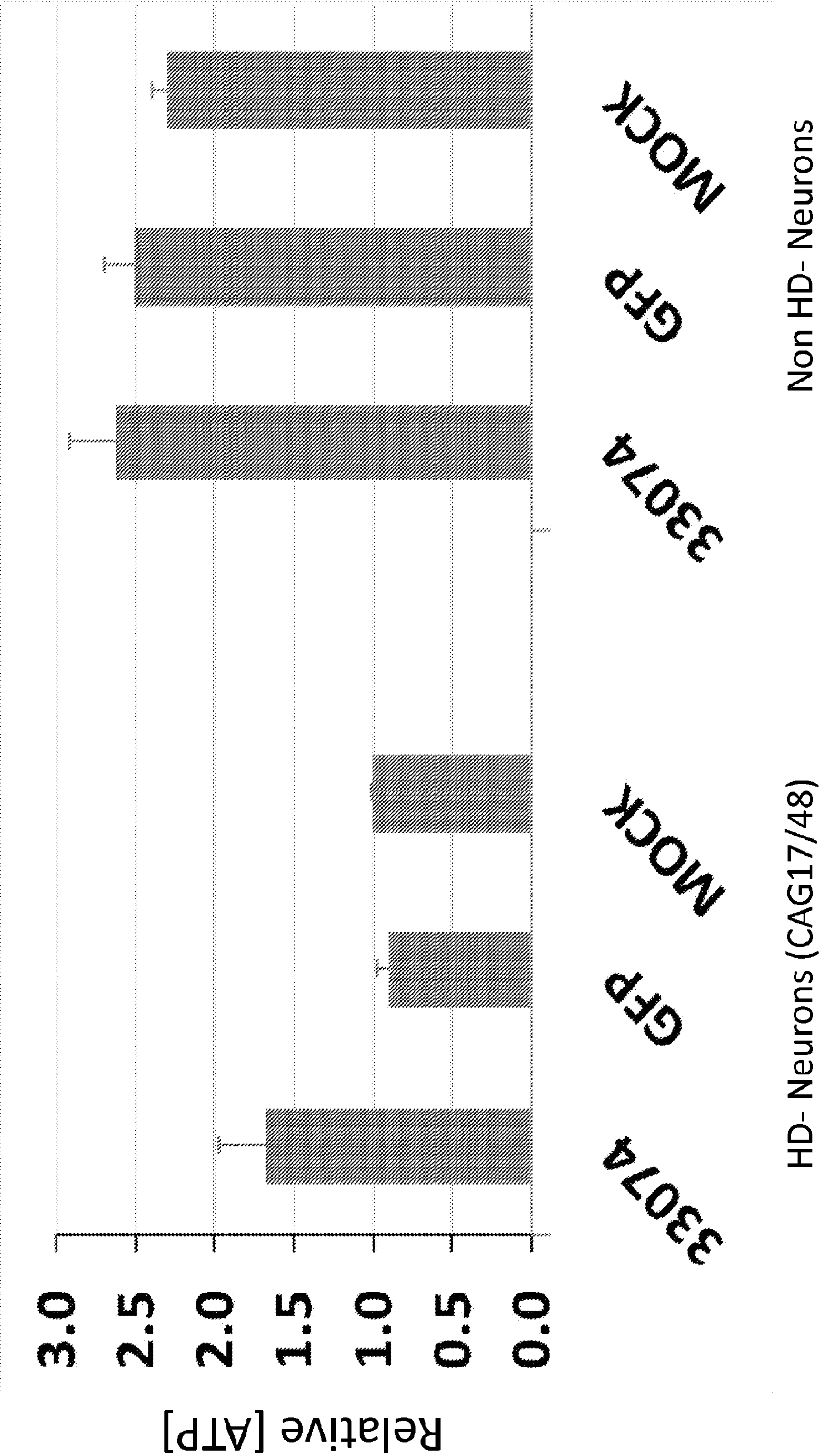


FIGURE 1

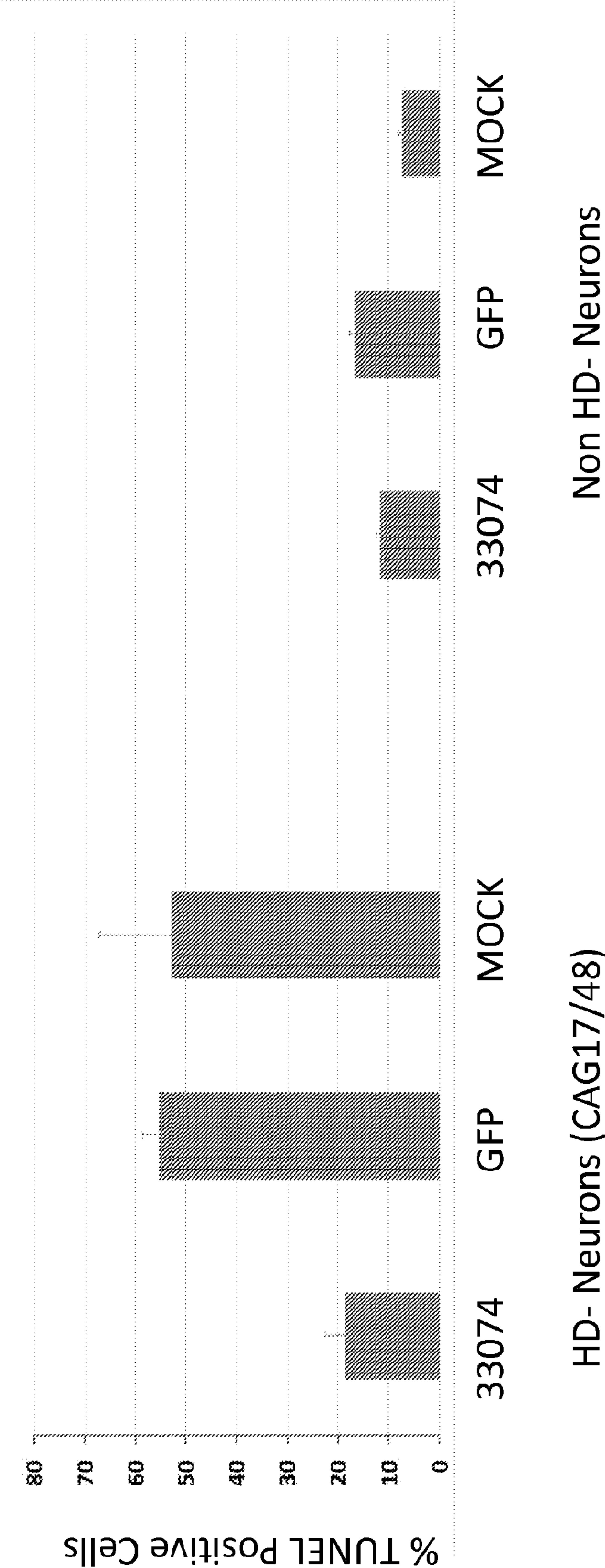


FIGURE 2

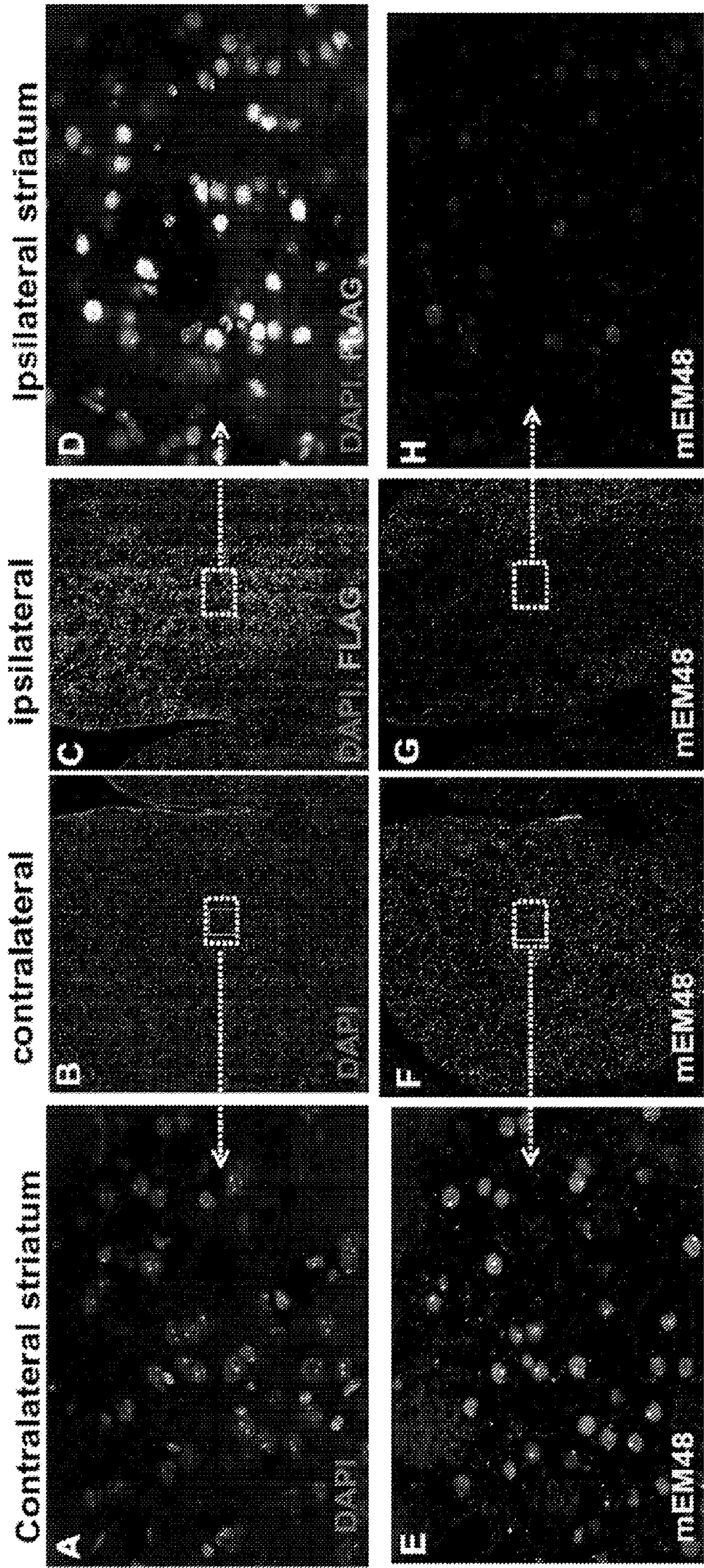


FIGURE 3

Figure 3I

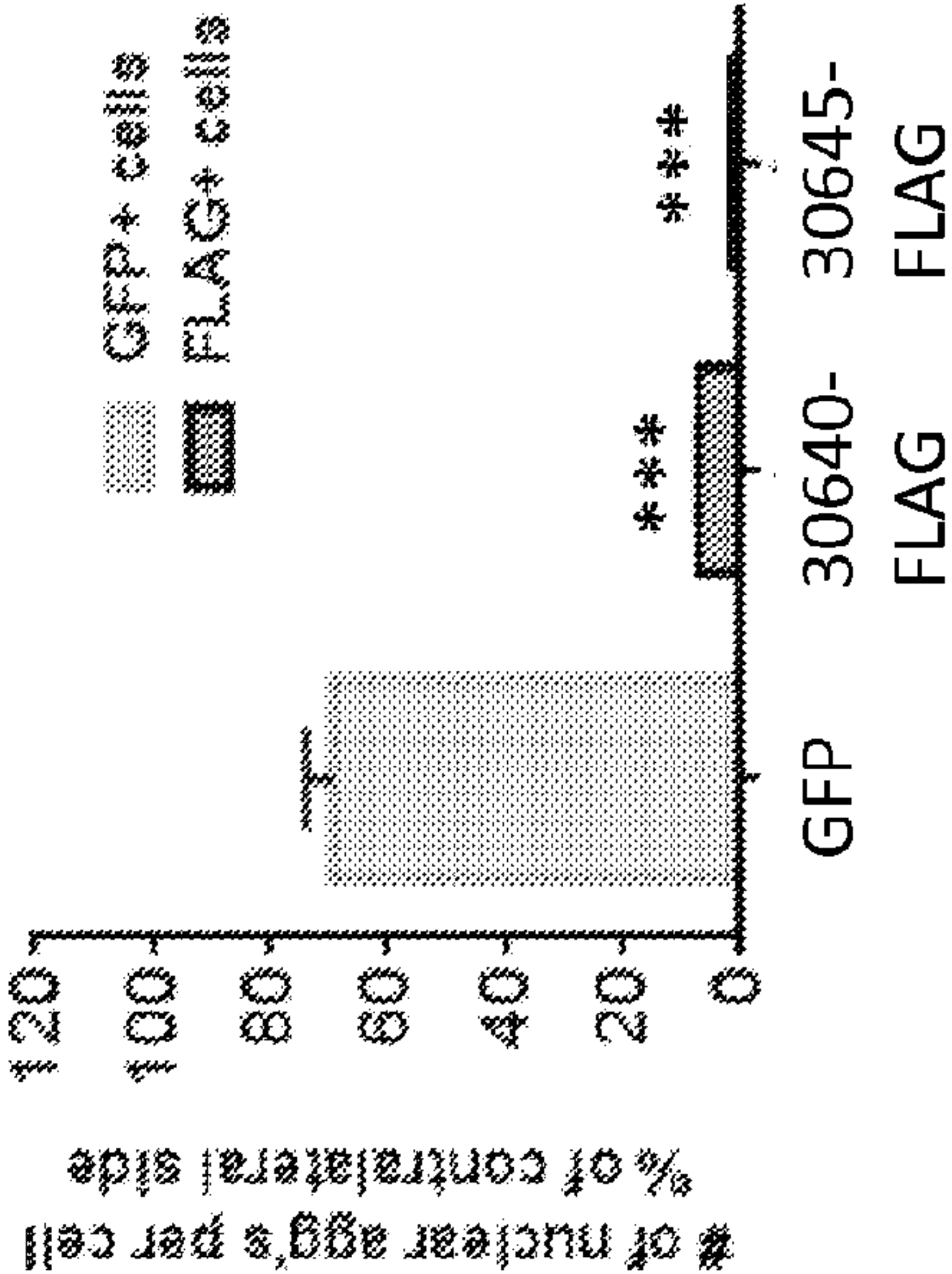


Figure 3J

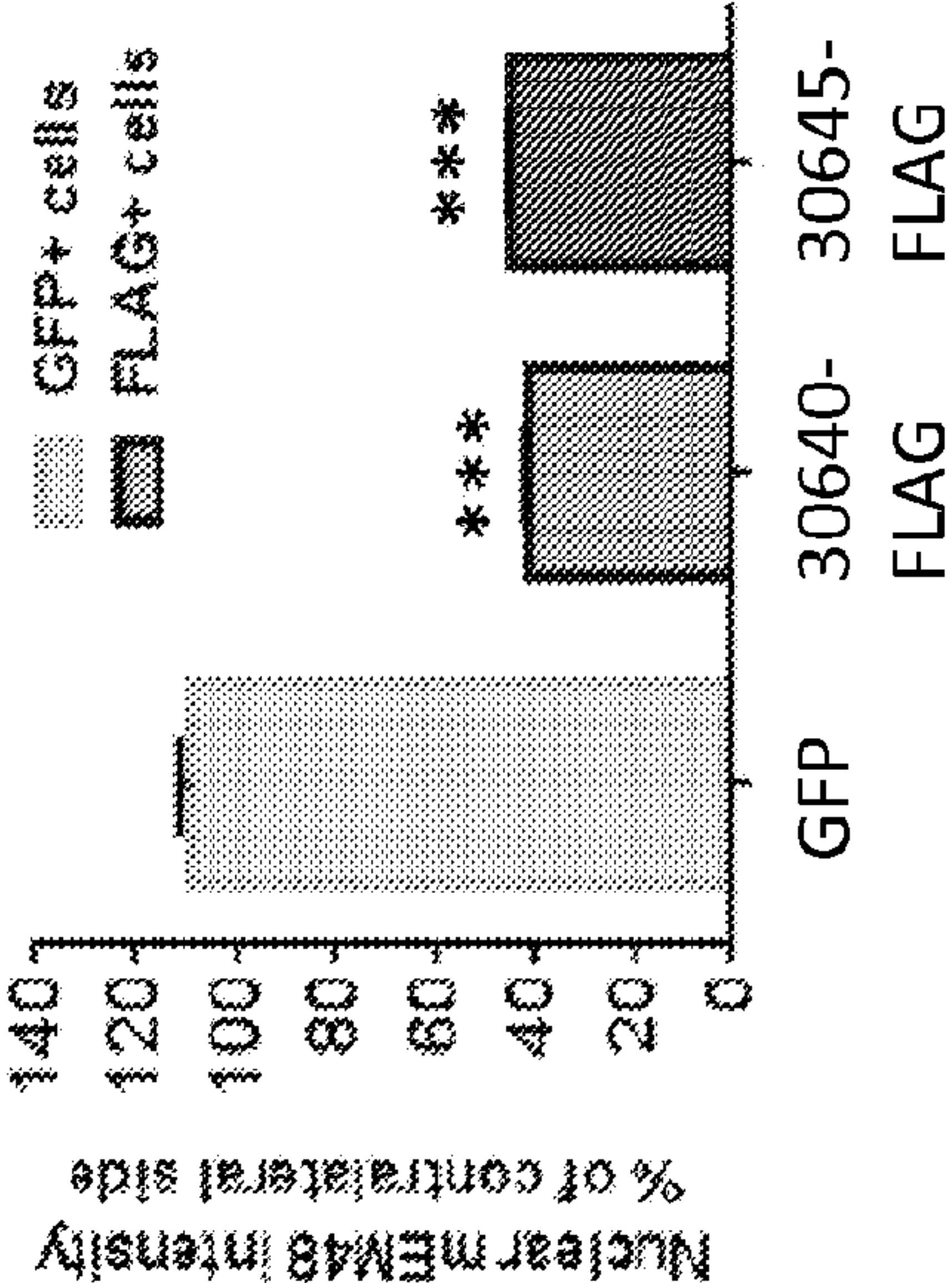
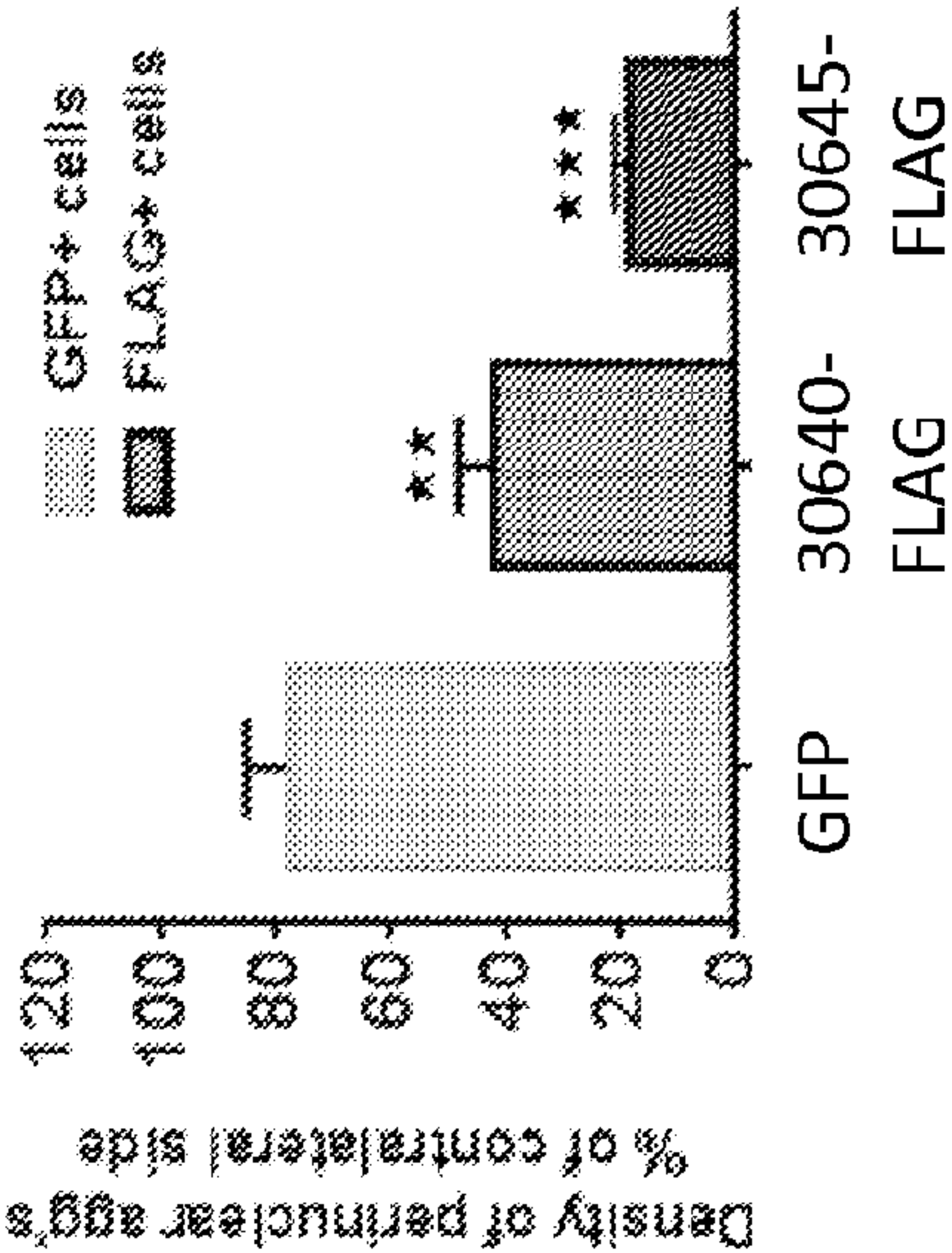


Figure 3K



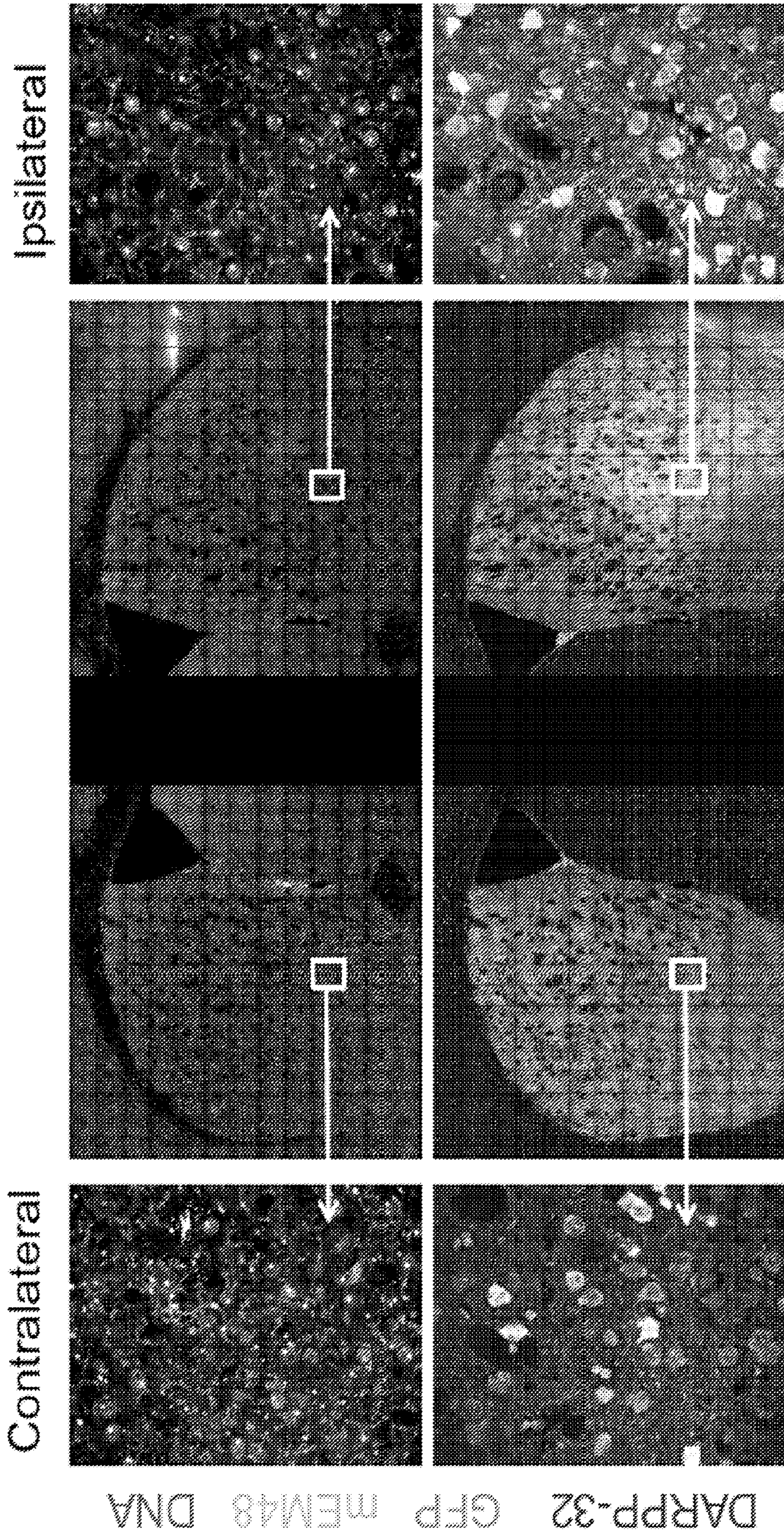


FIGURE 4A

Figure 4B

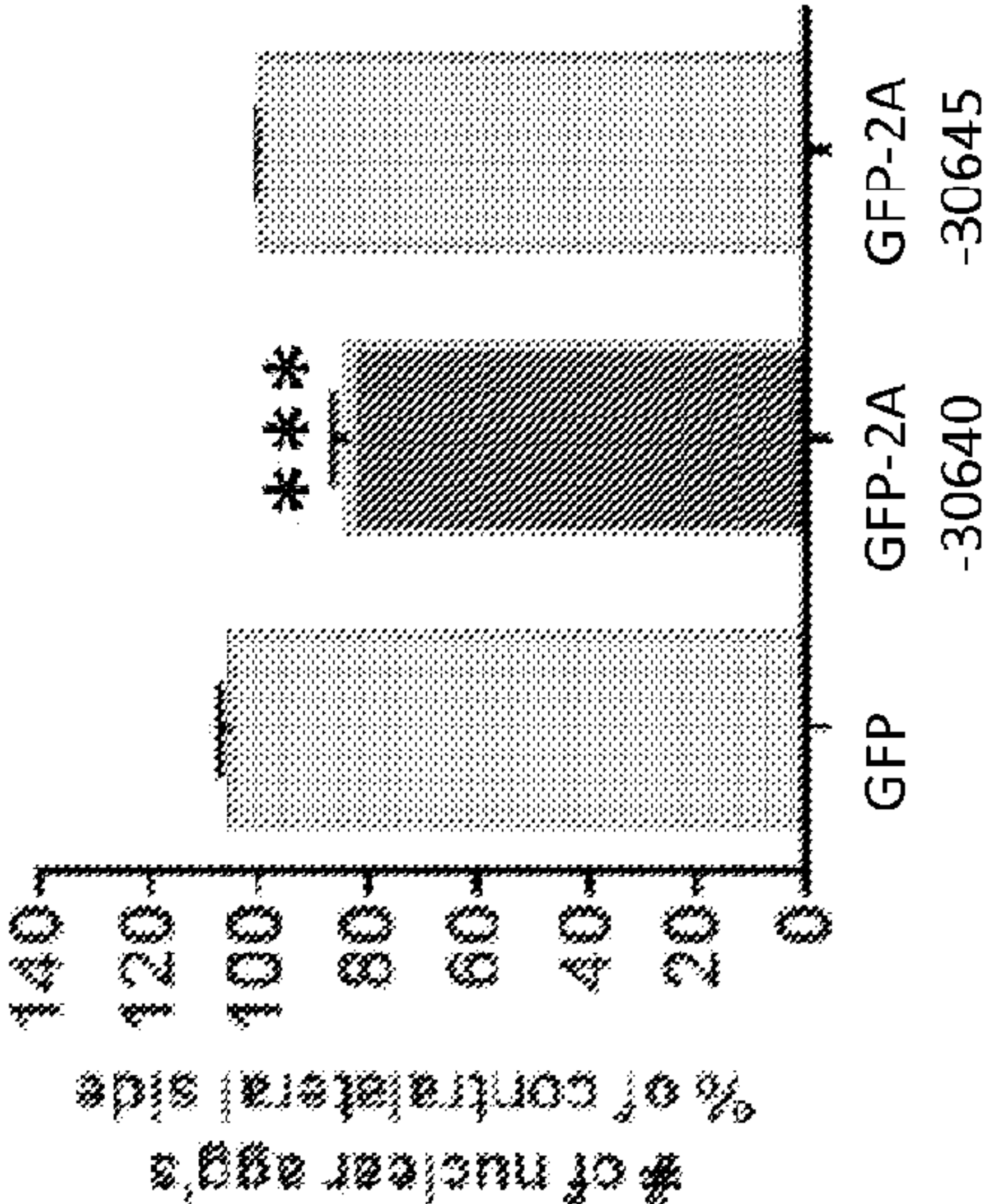


Figure 4C

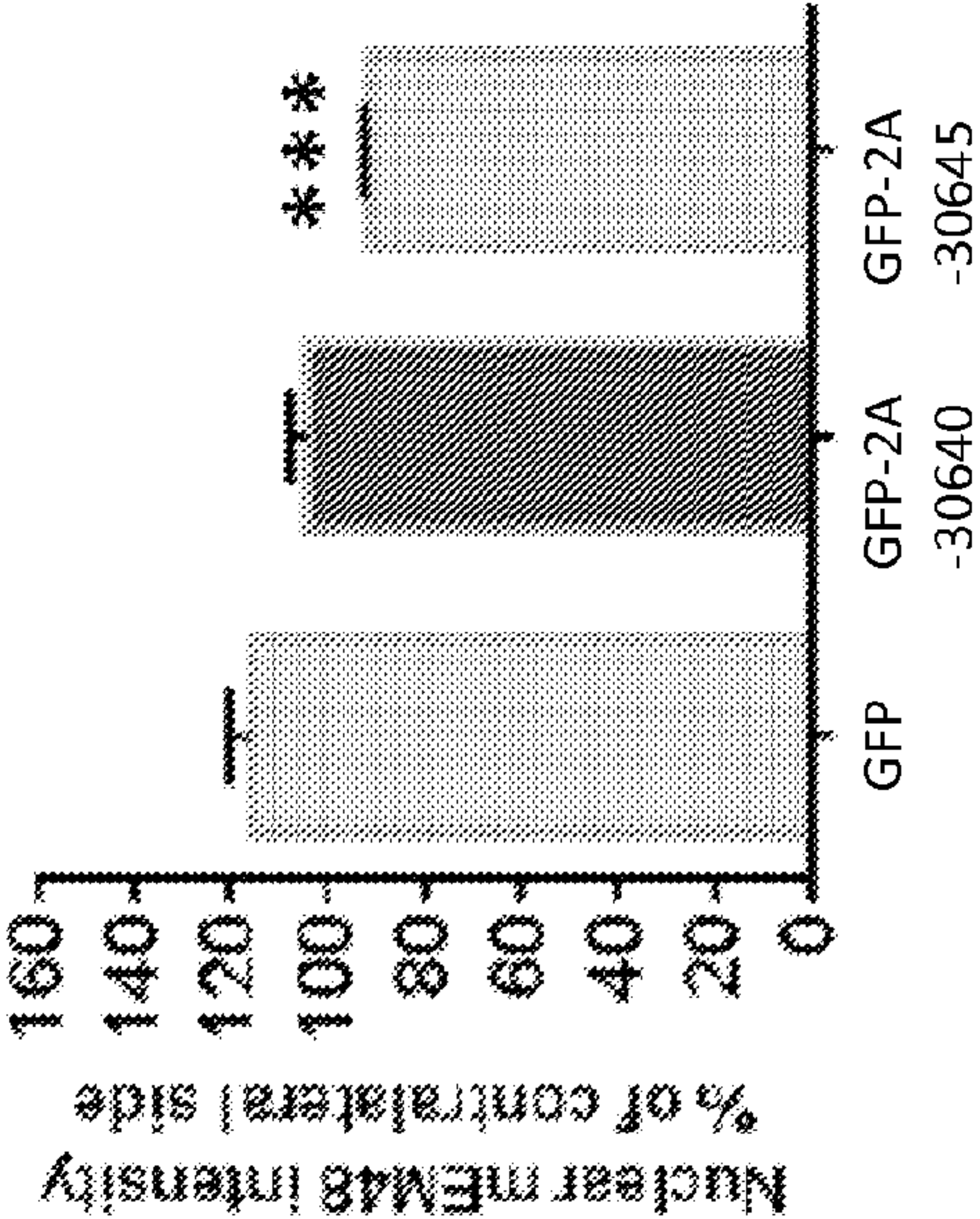


Figure 4D

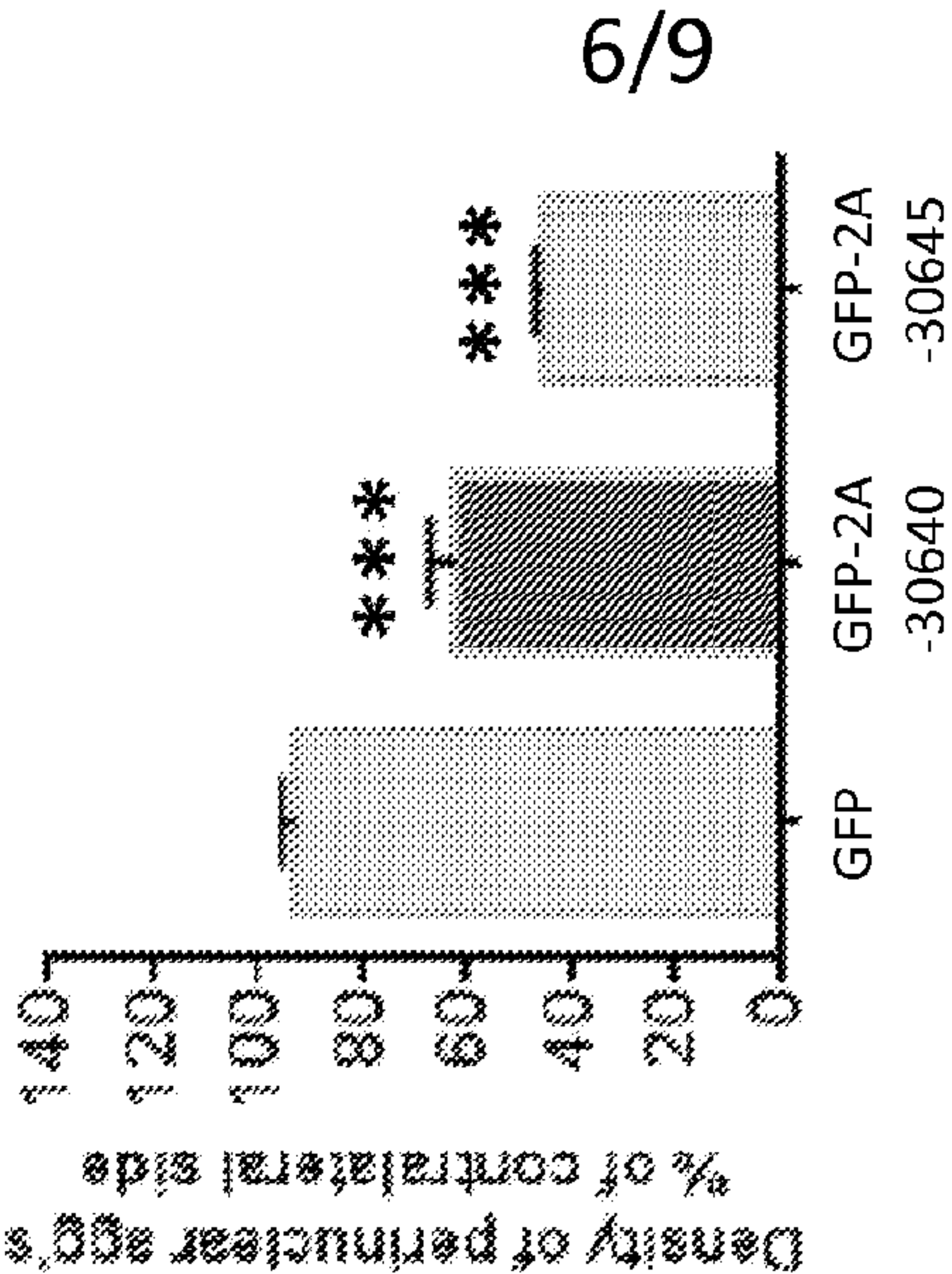


Figure 5B

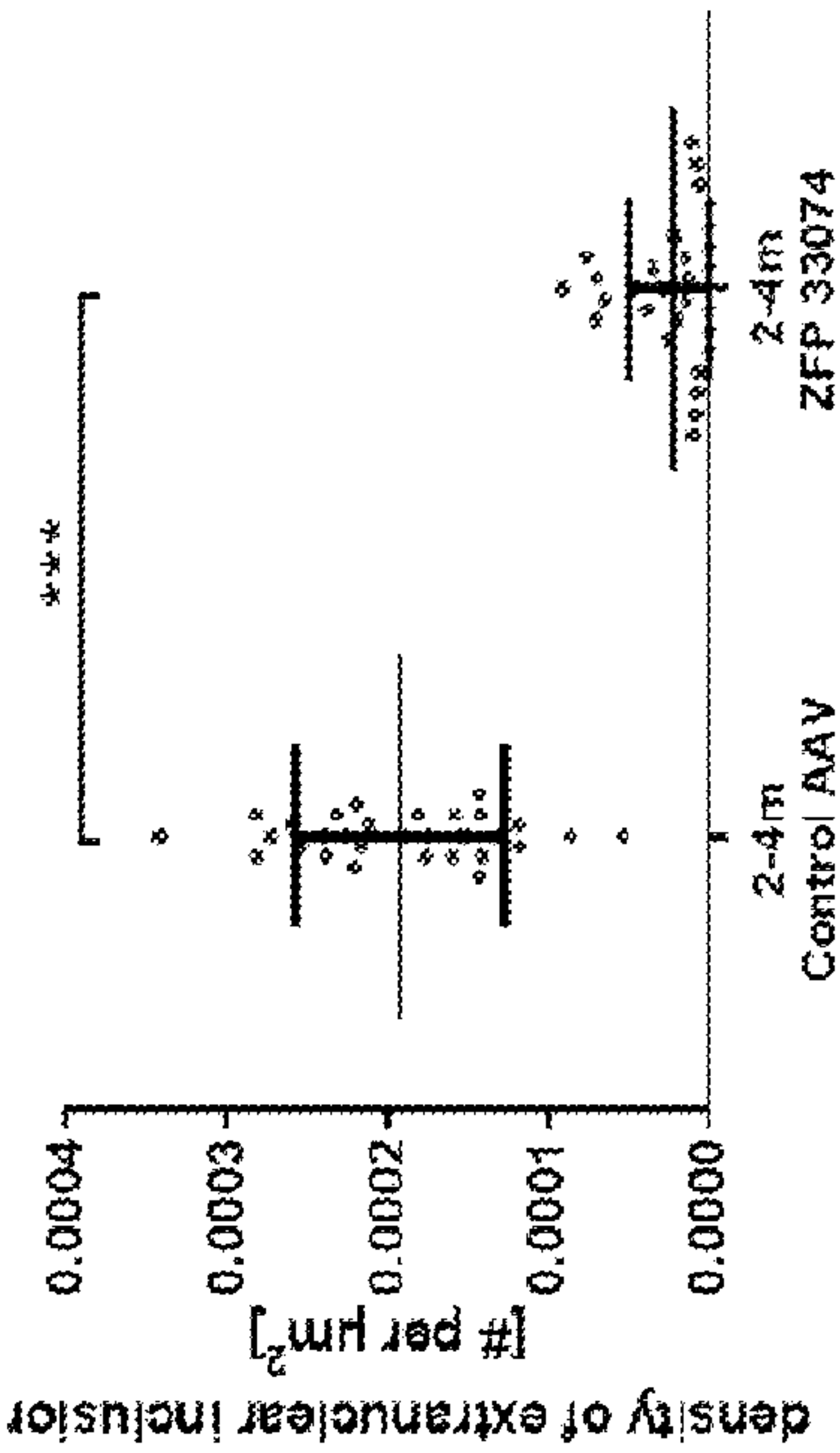


Figure 5A

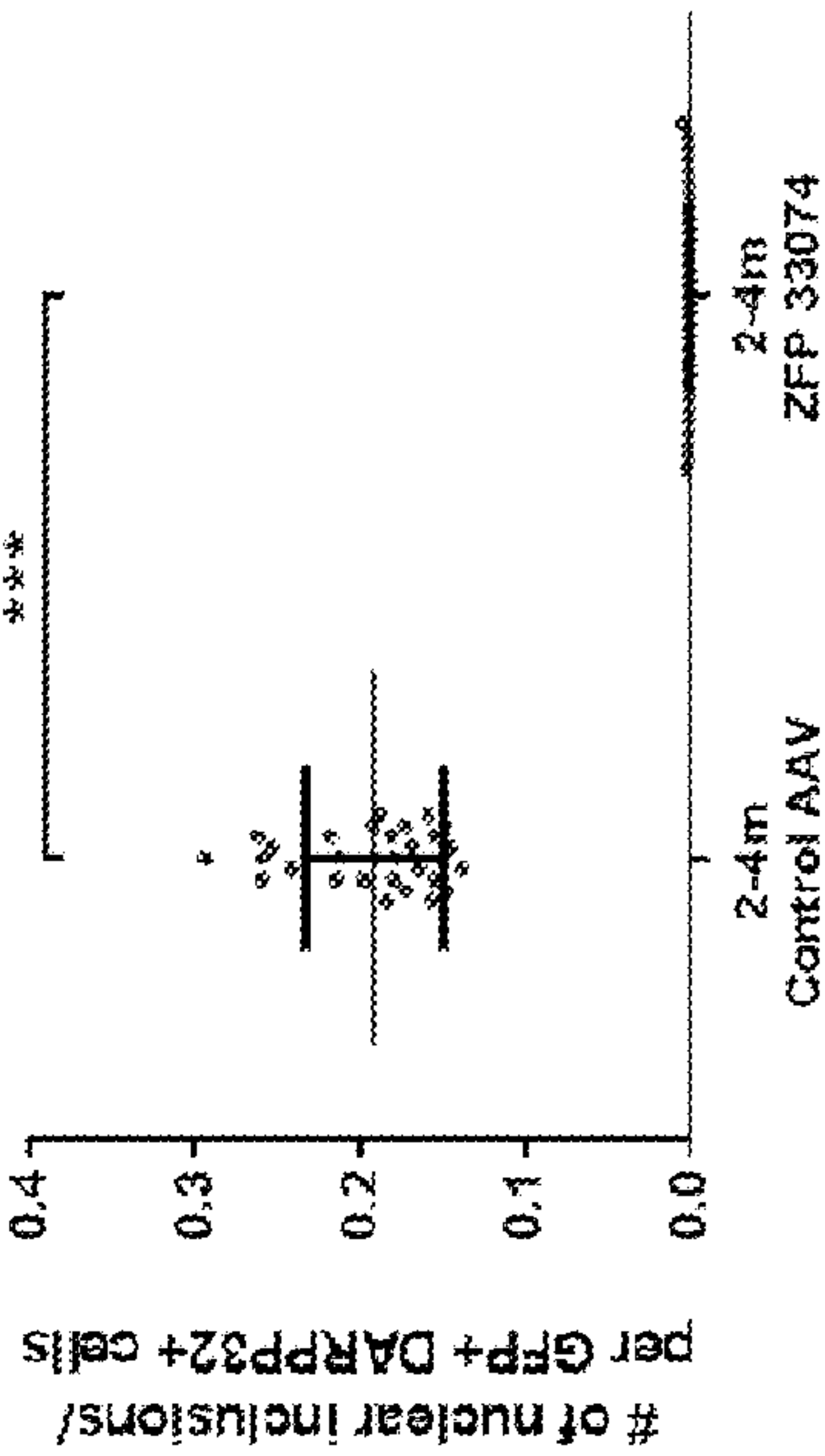


Figure 5C

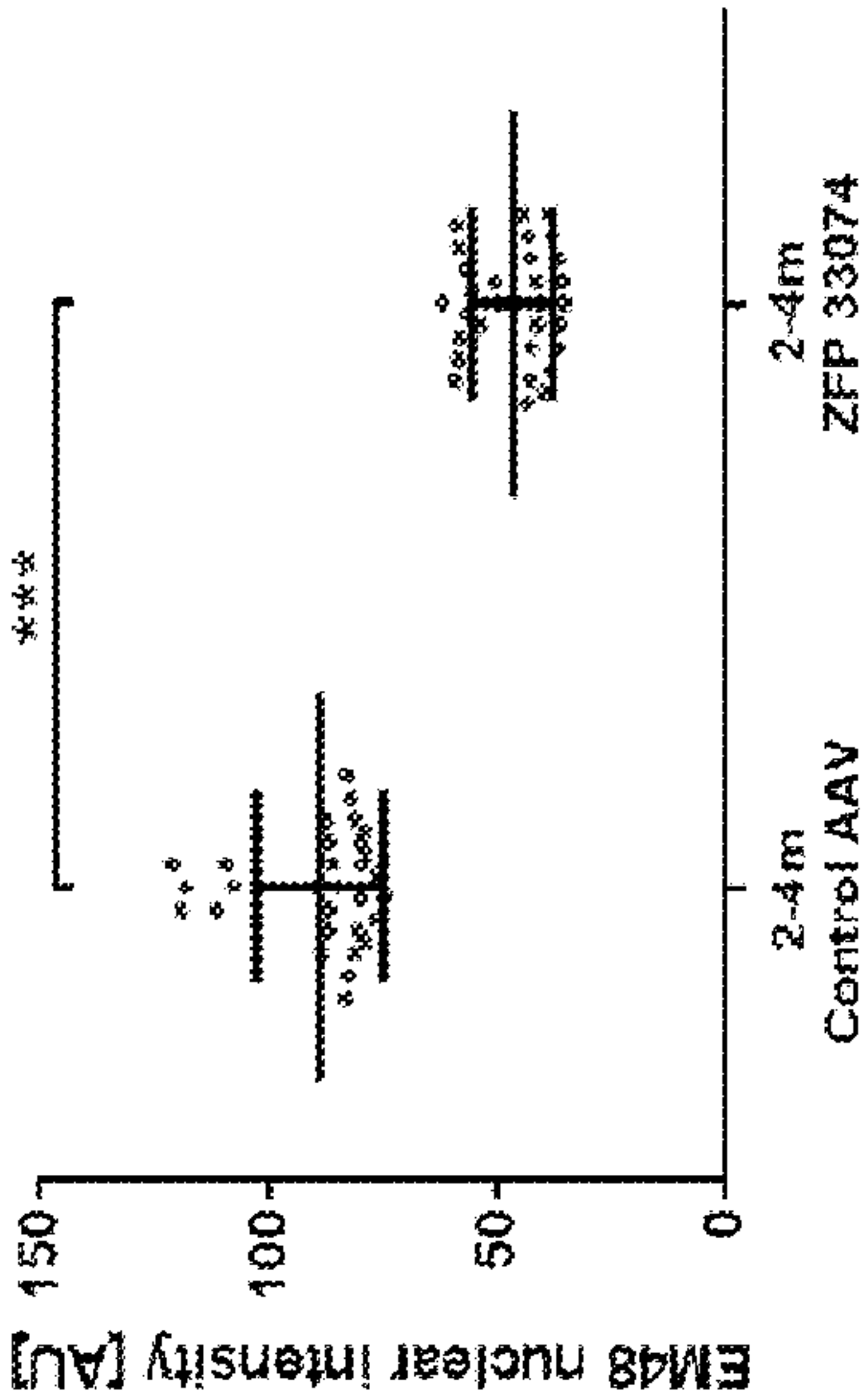


Figure 6A

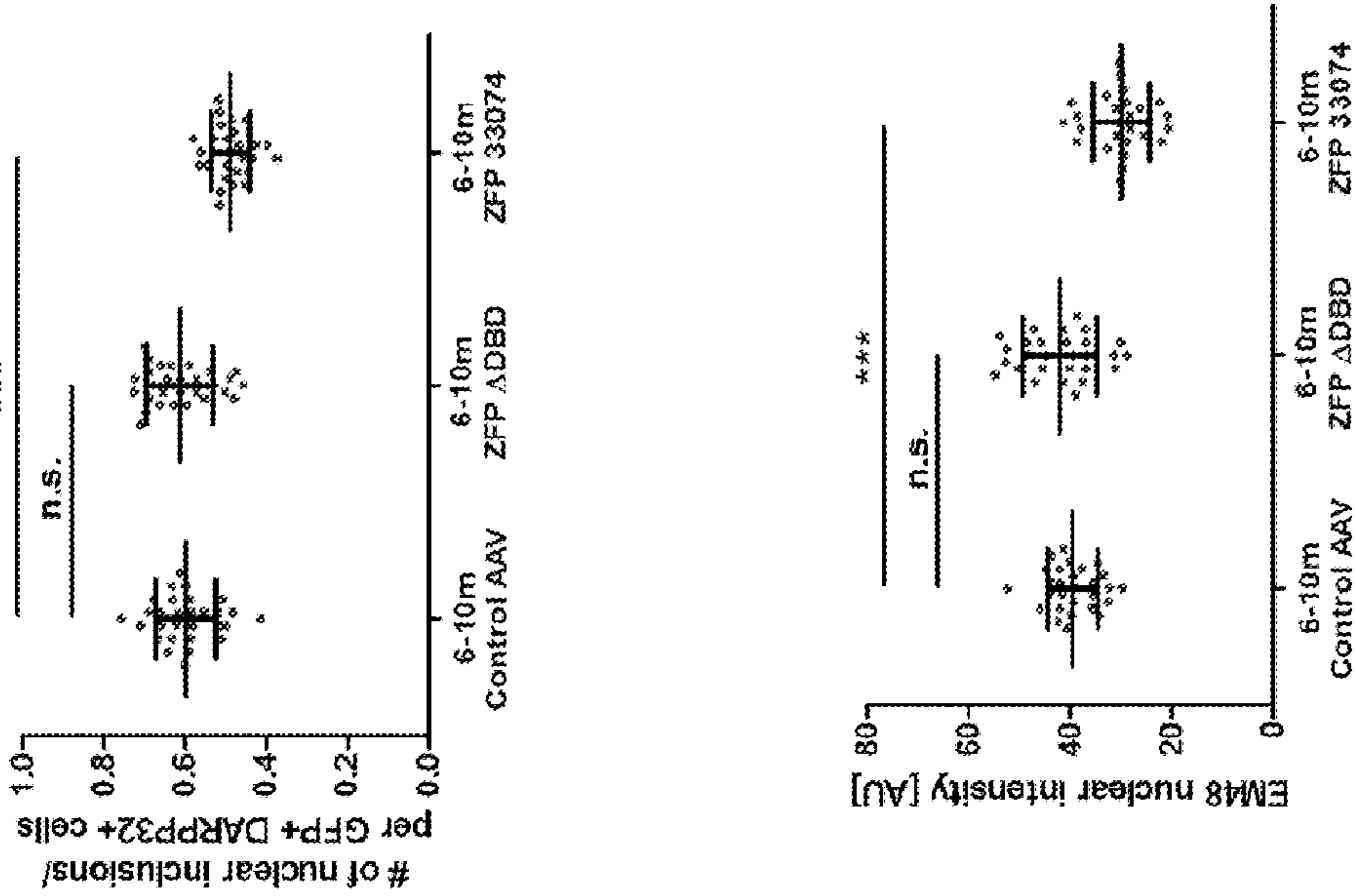


Figure 6B

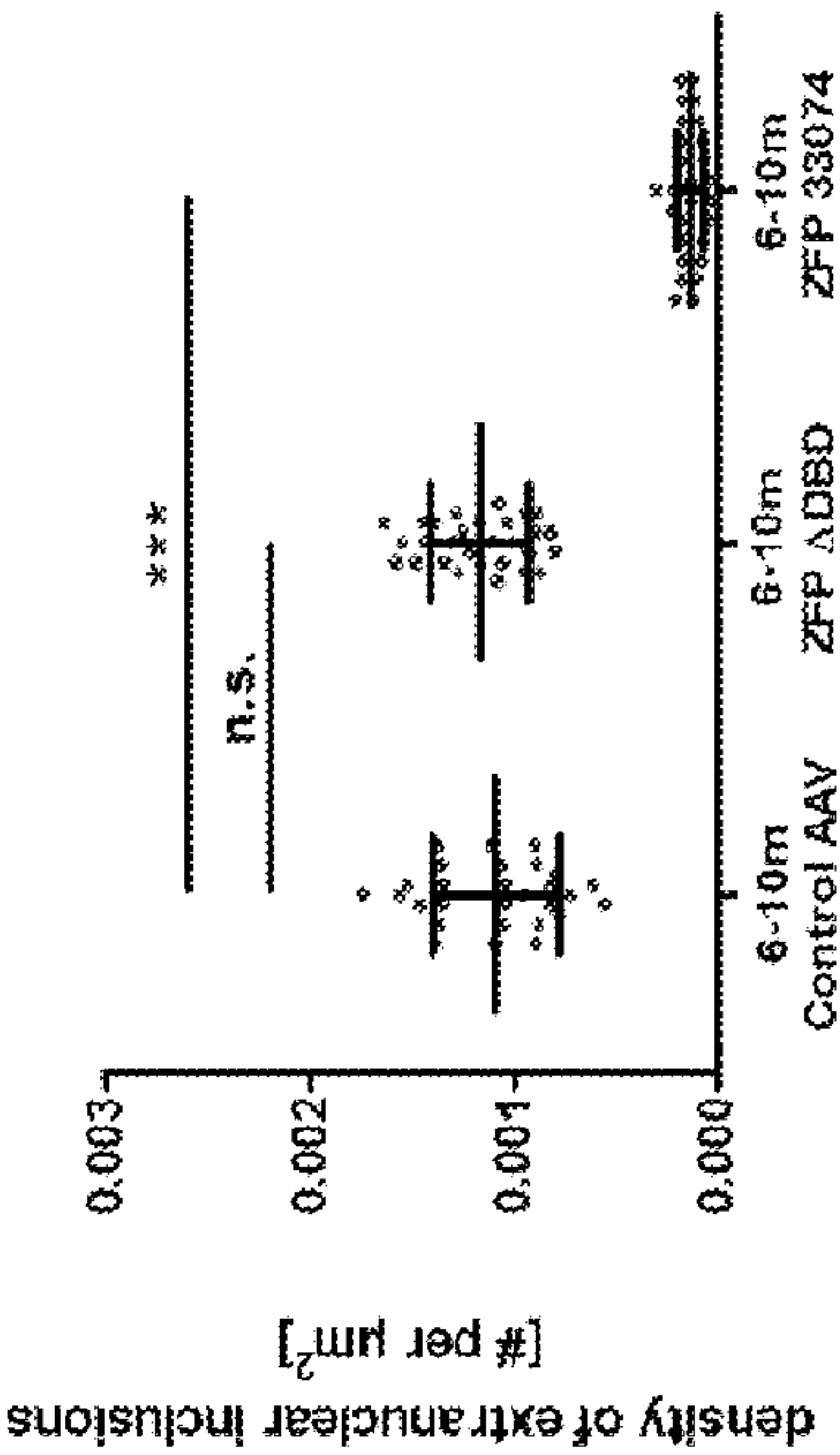
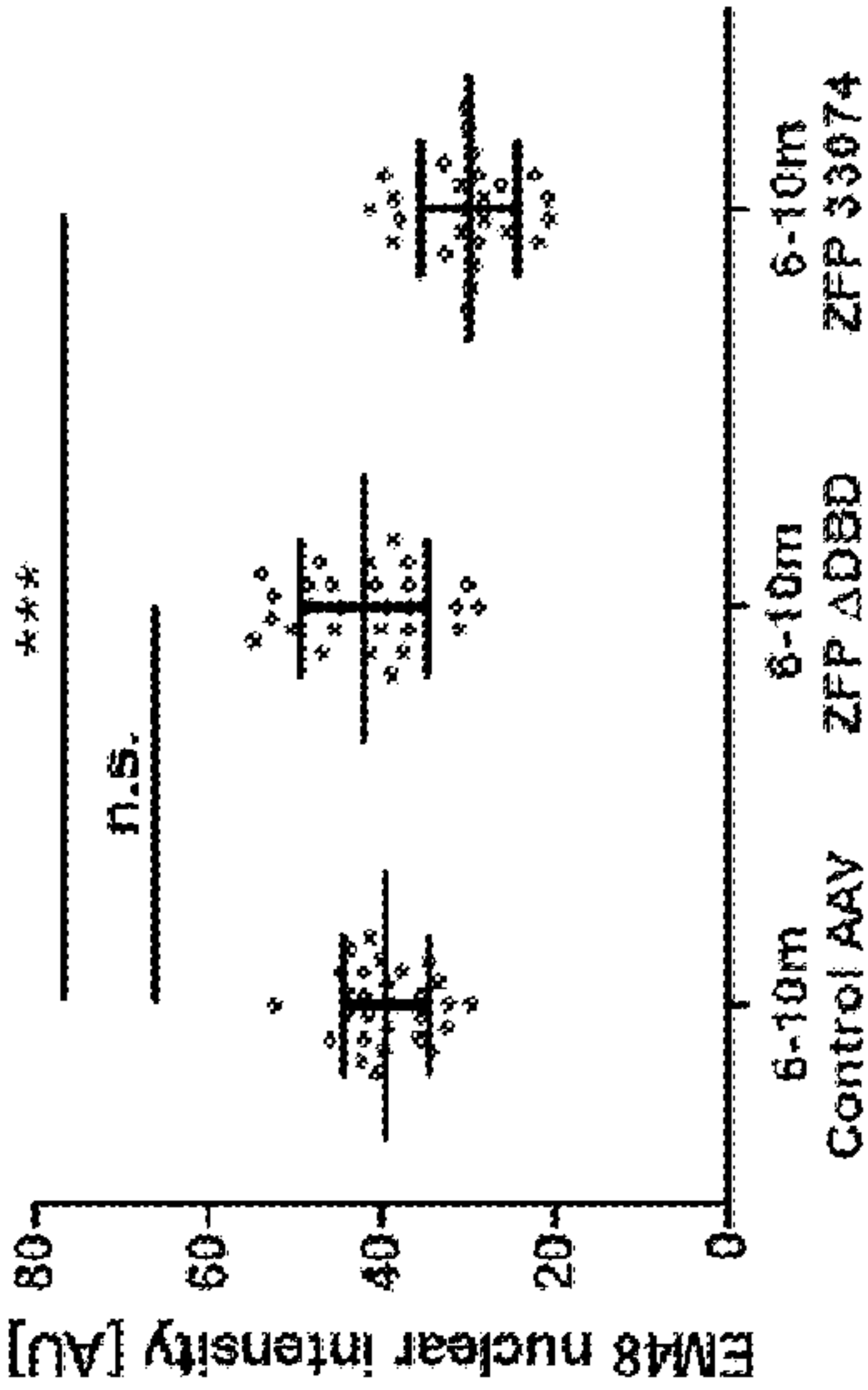


Figure 6C



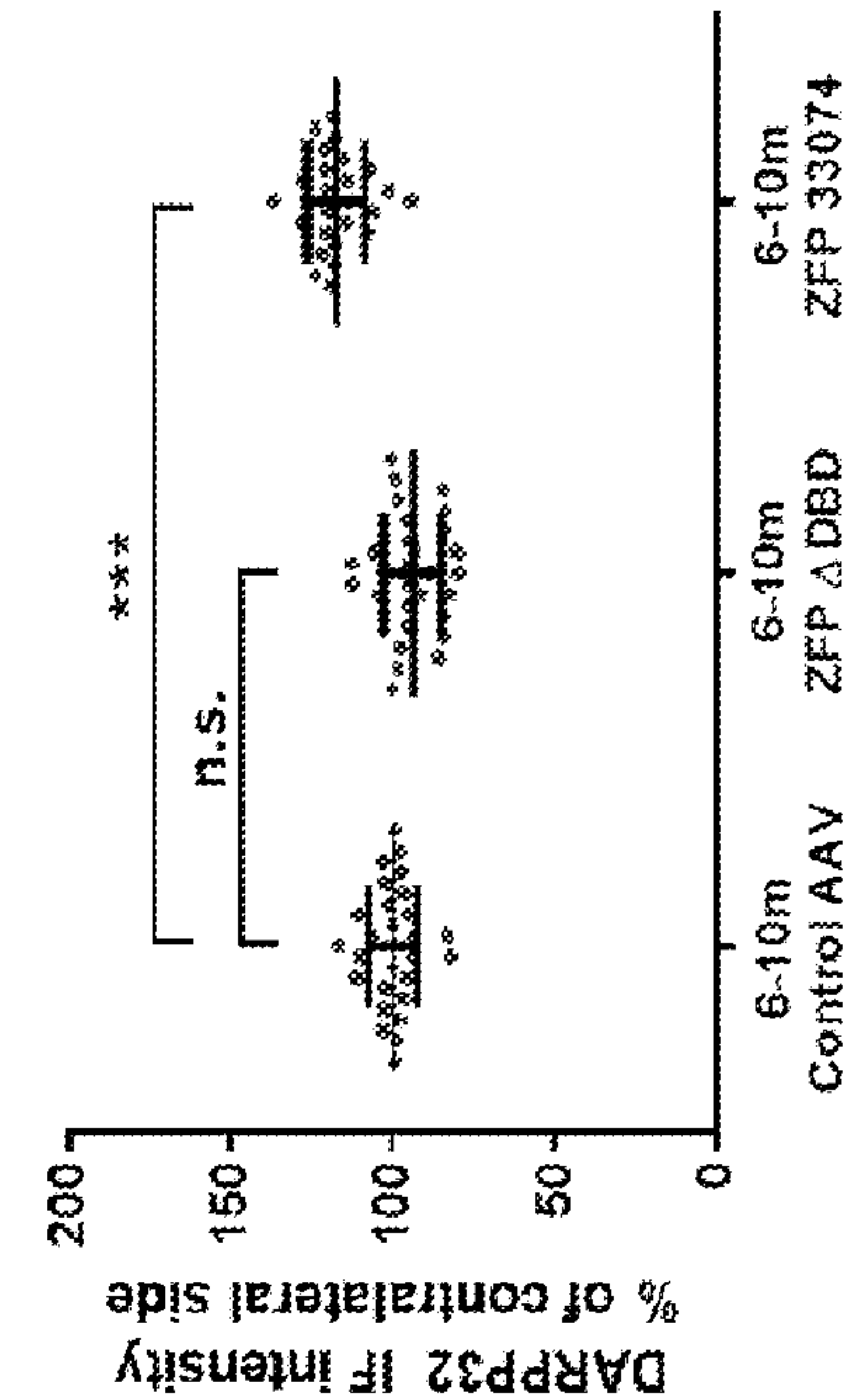


Figure 7B

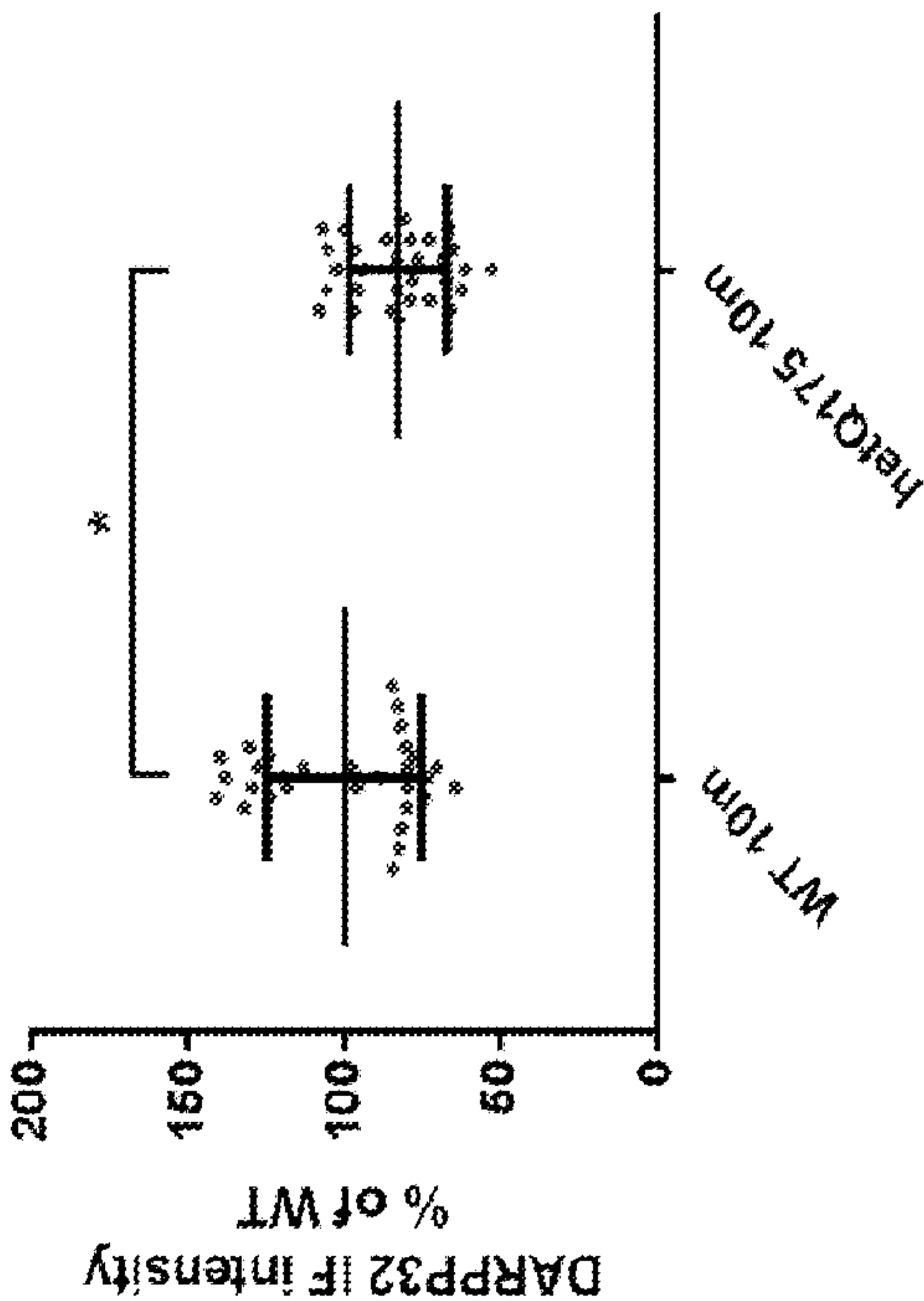


Figure 7A

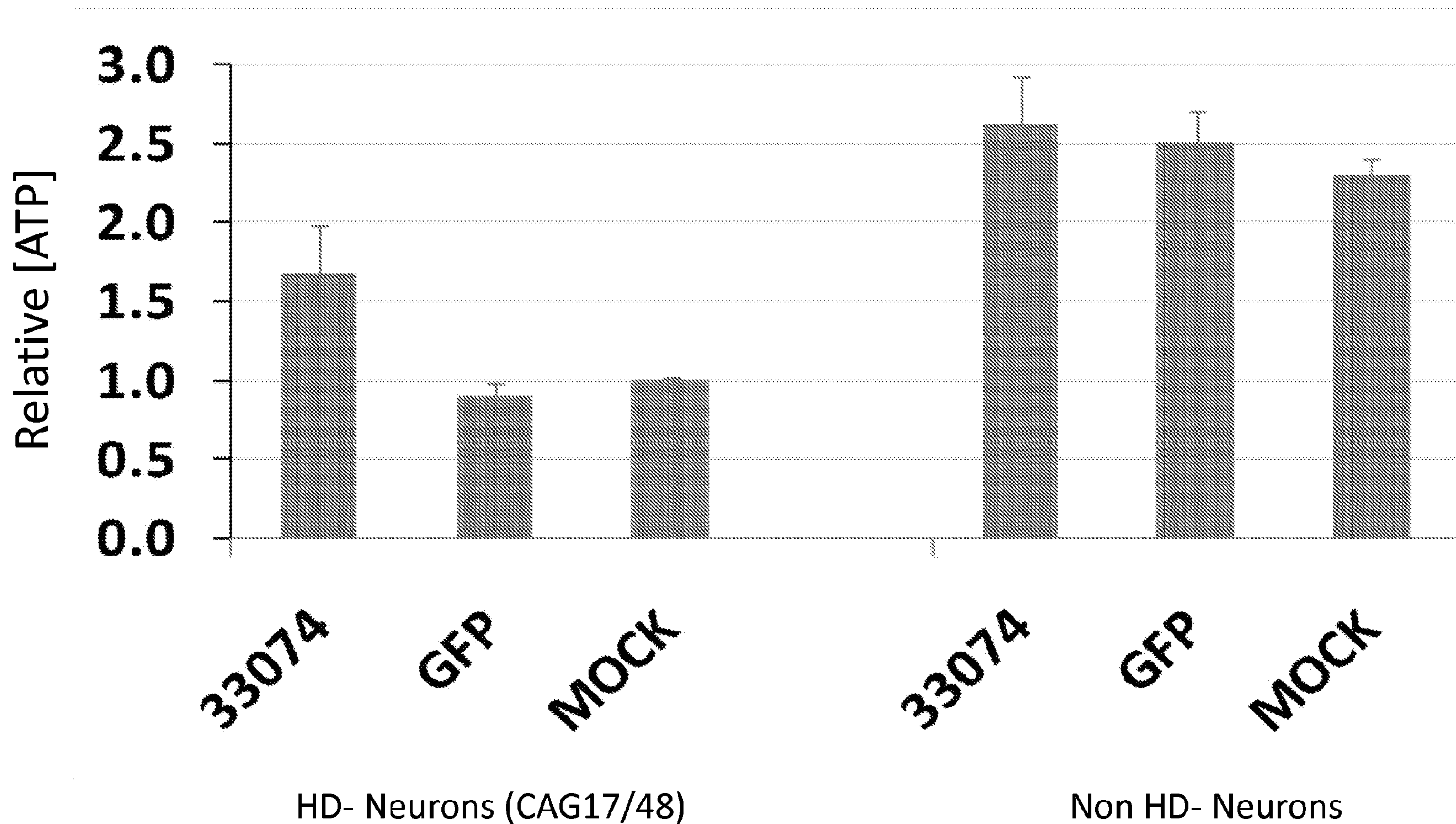


FIGURE 1