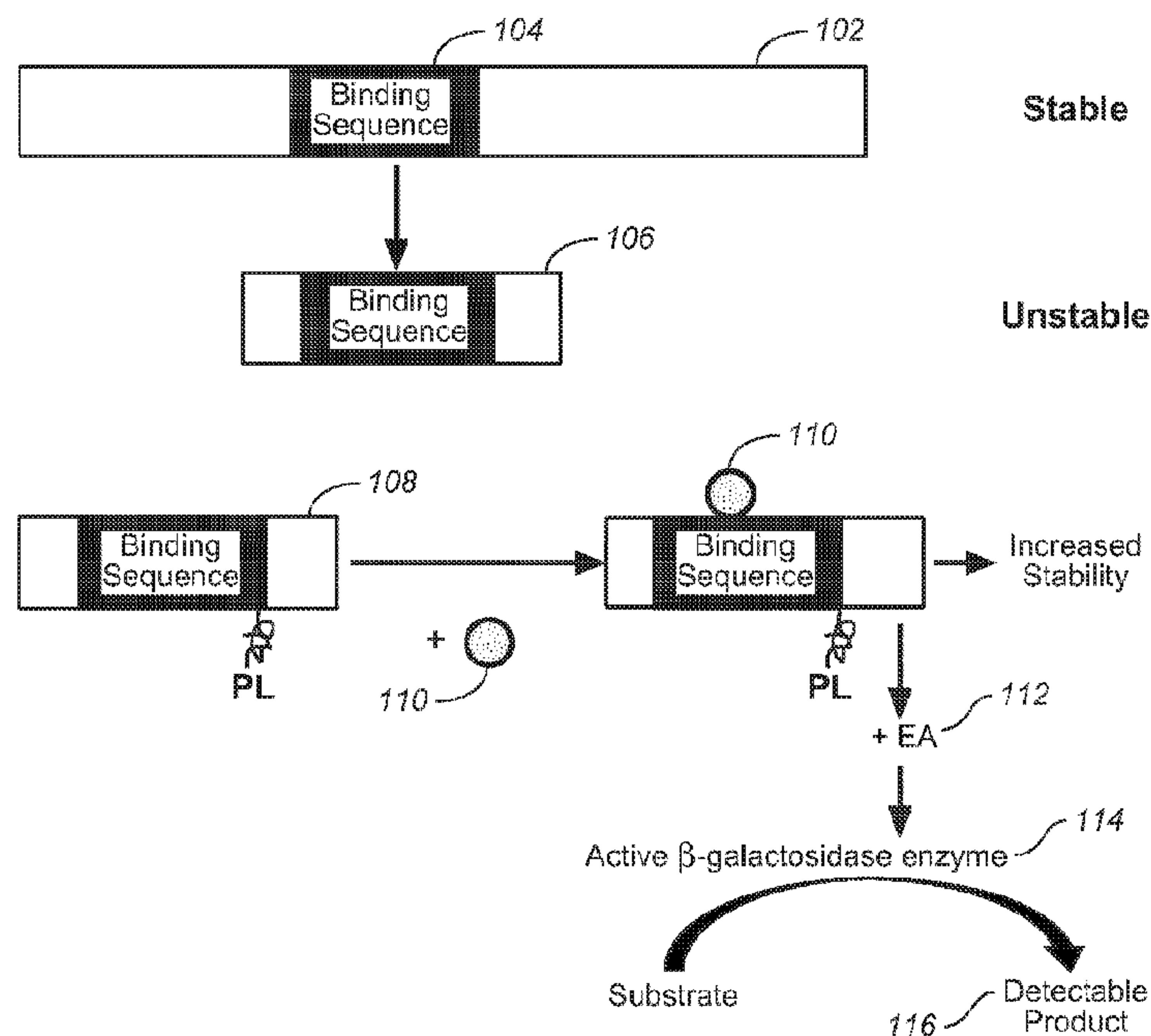




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(54) **Titre : DETECTION D'EVENEMENTS DE LIAISON INTRACELLULAIRE EN MESURANT L'ABONDANCE DE PROTEINES**
(54) **Title: DETECTION OF INTRACELLULAR BINDING EVENTS BY MEASURING PROTEIN ABUNDANCE**



(57) **Abrégé/Abstract:**

Methods and compositions are provided to measure the binding of a test compound to a target peptide by measuring the effect of the compound on the abundance of the target peptide inside a cell. The target peptide may bind the test compound at an active site or an allosteric site, and it has been found that such binding may stabilize the target peptide against cellular degradation. The target peptide will preferably comprise a destabilizing mutation which shortens the half life of the target peptide within the cell, typically a mammalian cell. Test compounds, including small molecules, have been found to stabilize target peptides. Also provided are systems and kits for use in practicing the methods.

**DETECTION OF INTRACELLULAR BINDING EVENTS BY MEASURING
PROTEIN ABUNDANCE**

ABSTRACT OF THE DISCLOSURE

5 Methods and compositions are provided to measure the binding of a test compound to
a target peptide by measuring the effect of the compound on the abundance of the target
peptide inside a cell. The target peptide may bind the test compound at an active site or an
allosteric site, and it has been found that such binding may stabilize the target peptide against
cellular degradation. The target peptide will preferably comprise a destabilizing mutation
10 which shortens the half life of the target peptide within the cell, typically a mammalian cell.
Test compounds, including small molecules, have been found to stabilize target peptides.
Also provided are systems and kits for use in practicing the methods.

DETECTION OF INTRACELLULAR BINDING EVENTS BY MEASURING PROTEIN ABUNDANCE

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BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

20 The present invention relates generally to methods which monitor binding of a compound to a target of interest inside a mammalian cell by increasing the stability of the target of interest and therefore its abundance, or number of molecules, in a cell. Further, the invention also relates to screening small molecules as inhibitors of target-compound binding in a cell.

25 **Related Art**

Presented below is background information on certain aspects of the present invention as they may relate to technical features referred to in the detailed description, but not necessarily described in detail. That is, individual parts or methods used in the present invention may be described in greater detail in the materials discussed below, which materials
5 may provide further guidance to those skilled in the art for making or using certain aspects of the present invention as claimed. The discussion below should not be construed as an admission as to the relevance of the information to any claims herein or the prior art effect of the material described.

Binding between and among various molecules such as proteins is central to
10 biological processes essential for normal cell functioning. Cellular pathways, such as signal transduction, apoptosis, cell and growth proliferation, gene regulation, require a series of interactions and bindings between and among specific proteins. Following transcription and translation, proteins assume their functional shape or confirmation through synchronized protein folding. The correct protein folding is essential for proteins to carry out their desired
15 functions and expression. Proteins which do not undergo folding or do not fold in the requisite manner will have a short half-life in a cell and will be discarded by the cell as the degradation system of the cell will recognize it as an improper protein. Properly folded proteins will have a longer half-life and participate in binding events or other required cellular functions. Thus, stability of proteins is essential for protein expression and
20 functioning in a cell, which is achieved through correct structure and participating in binding events leading to complex formation.

Protein binding occurs through special characteristic sequences or surfaces which are known as interacting interfaces. E.g. in case of protein-protein interactions these interfaces are known as ‘hotspots’ and constitute tight fitting regions which are generally characterized
25 by complementary pockets scattered through the central region of the interface and enriched in structurally conserved residues (Hubbard and Argos Cavities and packing at protein interfaces. Protein Sci 1994; 3: 2194-2206). These pockets are classified as “complementary” (Binkowski et al, Inferring functional relationships of proteins from local sequence and spatial surface patterns J. Mol Biol 2003; 332: 505-526) because there is a large
30 complementarity both in shape and in the juxtaposition of hydrophobic and hydrophilic hot

spots, with buried charged residues (Arkin and Wells Small molecule inhibitors of protein-protein interactions: progressing towards the dream. Nat Rev Drug Discov 2004; 3: 301-317). The “hotspots” are the essential amino acid sequences to participate in binding and to carry out physiological functions.

5 Other aspect of protein function is the allosteric modulation and has long been recognized as a general and widespread mechanism for the control of protein function. Modulators bind to regulatory sites distinct from the active site (hotspots) on the protein, resulting in conformational changes that may profoundly influence protein function and is a classical control mechanism of protein behavior. As described above, proteins are in native
10 state as they undergo allosteric modulation.

 Of particular importance (and exemplified below) are protein kinases, which participate in the process of phosphorylation, whereby they transfer phosphate groups from high-energy donor molecules, such as ATP to specific substrates. Protein phosphorylation is one of the most significant signal transduction mechanisms by which intercellular signals
15 regulate crucial intracellular processes such as ion transport, cellular proliferation, and hormone responses. Kinases are the key regulators of cell function that constitute one of the largest and most functionally diverse gene families. They direct the activity, localization and overall function of many proteins and almost all cellular processes. Protein kinases can be regulated by activator proteins, inhibitor proteins, ligand binding to regulatory subunits,
20 cofactors and phosphorylation by other proteins or by themselves (autophosphorylation). Kinases are prominent in signal transduction and co-ordination of complex functions such as the cell cycle. Thus, it makes kinases a potential target class for therapeutic interventions in many disease states such as cancer, diabetes, inflammation, and arthritis and represent as much as thirty percent of all protein targets under investigation by pharmaceutical companies.

25 A number of methods have been developed and used to study cellular binding events. Physical methods such as protein affinity chromatography, affinity blotting, immunoprecipitation and cross-linking however, either detect interactions that are so weak or else detect nearest neighbors which may not be in direct contact. Library-based methods such as protein probing and phage display also have certain intrinsic limitations. Two-hybrid
30 system is only limited to proteins that can be localized to the nucleus, which may prevent its

use with certain extracellular proteins. Translocation assays are very time consuming and expensive, as they require a confocal fluorescence system and are plagued by artifacts such as intrinsic fluorescence from combinatorial libraries and background fluorescence. However, none of the method is easy to perform, can be done in high throughput mode are amenable to
 5 studying disruption of constitutive biological complexes and identifying interaction interface.

Further, systems for protein stabilization and destabilization assays have also been developed. Studies by Stankunas et al (Stankunas K., Bayle H., Havranek JJ., Wandless TJ., Baker D., Crabtree GR., Gestwicki JE. Rescue of degradation-prone mutants of the FK506-Rapamycin binding (FRB) protein with chemical ligands; ChemBioChem, 2007; 8(10): 1162-
 10 1169) have shown the rescue of degradation prone mutants of FRB protein with chemical ligands. However, owing to the structure and half-life of luciferase in a cell it may interfere with the functioning of the target protein and also limits the availability of ligands to stabilize the fusion protein for the binding assays.

Earlier studies and assays have focused on large peptides and natural products as the
 15 primary compound classes capable of modulating cellular bindings. However a growing number of evidence has suggested that small molecules also modulate the interactions responsible for biological complexes (Toogood, Inhibition of protein-protein association by small molecules: approaches and progress. J Med Chem 2002, 45:1543-1558. Berg T, Modulation of protein-protein interactions with small organic molecules. Angew Chem Int
 20 Ed Engl 2003, 42:2462-2481). There are a number of advantages in using small molecules as inhibitors owing to higher metabolic stability, bioavailability, easier synthesis and great solubility among others.

The present invention is exemplified by use of enzyme fragment complementation. First shown in prokaryotes, enzyme fragment complementation (EFC) using beta-galactosidase (β -gal) is based on the complementation of enzyme fragments to form an active
 25 enzyme See, e.g., Ullman et al., *J. Mol. Biol.* 24:339-43 (1967); Ullman et al., *J. Mol. Biol* 32:1-13 (1968); Ullman et al., *J. Mol. Biol.* 12:918-23 (1965). These systems have important advantages including low level expression of the test proteins, generation of signal as a direct result of the interaction, and enzymatic amplification. As a result, they are highly

sensitive and physiologically relevant assays. See, e.g., Blakely et al., *Nat. Biotechnol.* 18:218-22 (2000).

SPECIFIC PATENTS AND PUBLICATIONS

Wandless et al. US 2010/0034777, published 2/11/2010, entitled “Method for
 5 Regulating Protein Function in Cells In Vivo Using Synthetic Small Molecules,” discloses a system for conditionally controlling protein stability. A genetic fusion of a destabilizing domain (DD) to a protein of interest (POI) results in degradation of the entire fusion protein. Exemplified destabilizing domains are derived from FKBP, and the stabilizing ligand is Shield 1.

10 US Patent Application US2005/0136488 “Cellular Membrane Protein Assay,” published 06/23/2005 and owned by the present assignee discloses various β -galactosidase enzyme donor or “ED” sequences for use in β -galactosidase enzyme fragment complementation.

US Patent Application US2005/0287522 “Detection of Protein Translocation by beta-
 15 galactosidase Reporter Fragment Complementation,” published 12/29/2005, discloses various methodologies for monitoring protein translocation using enzyme fragment complementation.

US Patent 7,479,377, entitled “Genetic Construct Intracellular Monitoring System”,
 dated 1/20/2009 and owned by the present assignee discloses system to monitor intracellular
 20 events using fusion protein which employ using genetic construct for introduction of fusion protein into a cell.

BRIEF SUMMARY OF THE INVENTION

The following brief summary is not intended to include all features and aspects of the present invention, nor does it imply that the invention must include all features and aspects discussed in this summary.

25 The present invention concerns an assay whereby a target peptide to be assayed is fused to a labeling peptide and expressed as a fusion protein in a eukaryotic cell, preferably a mammalian cell. As the target peptide binds a test compound it forms a complex and is

stabilized, thus changing the amount of fusion protein in a cell, i.e. the abundance of the fusion protein (and the target peptide component thereof) in the cell. The labeling peptide component can be a fragment of β galactosidase, for example an enzyme donor (ED), such as a proprietary ED termed a ProLabel (PL) peptide. In some embodiments, the labeling
 5 peptide/tag can be other than an ED.

In certain aspects, the present invention comprises a method to assess binding of a compound to a binding site on target peptide in a cell, comprising: (a) providing in the cell a fusion protein comprising (i) the target peptide and (ii) a labeling peptide, wherein the target peptide comprises a destabilizing mutation; (b) incubating a mixture of the cell and the
 10 compound for a period sufficient to allow binding of the compound to the binding site of the target peptide and to allow for stabilization of the fusion protein by the binding, then (c) combining the mixture from step (b) with a label that detects an amount of the labeling peptide remaining on the fusion protein after incubating, wherein a change in the amount of labeling peptide detected indicates binding to the target peptide.

15 The compound, which may be a test compound being evaluated for its binding effect, may be a small molecule, a peptide, or a full-length protein. The compound may be a pharmacological agent or it may be a native ligand for the target peptide. In this situation, one may add a test compound that binds to the native ligand and modulates its binding to the target peptide.

20 In certain aspects, the present invention comprises a method for measuring binding of a compound to a binding site on a target peptide, as stated above, and the binding site may be one of (a) an ATP binding site, (b) a bromodomain sequence, (c) a catalytically (enzymatic) active site or (d) an allosteric site.

25 In certain aspects, the present invention comprises a method wherein the labeling peptide is selected from the group consisting of (a) an enzyme donor fragment of β -galactosidase, (b) a peptide having a binding epitope for a secondary label.

In certain aspects, the present invention comprises a method wherein the labeling peptide is an ED having a sequence according to one of SEQ ID NO: 1, SEQ ID NO: 2, or SEQ ID NO: 3.

In certain aspects, the present invention comprises a method wherein the EA has a sequence according to is SEQ ID NO: 4.

In certain aspects, the present invention comprises the above-mentioned methods wherein the cell is a mammalian cell.

5 In certain aspects, the present invention comprises the above-mentioned methods further comprising the step of carrying out steps (a) through (c) in the absence of the compound to provide a control for determining the change in the amount of labeling peptide detected.

10 In certain aspects, the present invention comprises the above-mentioned methods wherein the target peptide comprises a mutation which is a truncation, said mutation being outside of the binding site. As described below, the target peptide has been selected so that it has a relatively short half- life unless it is stabilized by binding to a compound. The mutation may involve truncating the target peptide by removing a certain number of amino acids from either the amino terminus, the carboxy terminus or both termini. The number of amino acids
15 removed will depend on the target peptide being created. It may be for example, up to 5 -10 amino acids, 5-20 amino acids, 5-10 amino acids, etc., as long as the binding site is left in the target peptide. Amino acids may be removed from a central domain, such as a domain needed for proper folding. In certain aspects, the present invention comprises a method wherein said target peptide comprises a mutation which is a deletion of at least ten percent of
20 the sequence of the full length protein. In other words, in this embodiment if the native protein is 1000 amino acids long, at least 100 amino acids are removed.

In certain aspects, the present invention comprises a method to assess a small molecule as an inhibitor of binding to a binding site on target peptide in a cell, comprising:
(a) providing in said cell a fusion protein comprising (i) said target peptide and (ii) a labeling
25 peptide, wherein the target peptide comprises a destabilizing mutation; (b) adding to a sample well of said cell said compound; (c) incubating said cell and said compound of step (b) for a period sufficient to allow binding of the compound to the binding site of the target peptide and to allow for stabilization of the fusion protein by the binding of the compound, then (d) adding to a sample well of said cell said small molecule; (e) combining, in the

sample well, contents of the sample well from step (c) and (d) with a label that detects an amount of the labeling peptide remaining in the cell after said incubating, whereby a change in the amount of labeling peptide detected indicates inhibition of binding of the compound to the target peptide by the small molecule.

5 In certain aspects, the present invention comprises the above-mentioned methods wherein said compound is one of a small molecule, a peptide, and a full-length protein. In certain aspects, the present invention comprises the above-mentioned methods wherein said small molecule is one of a drug candidate, a peptide, and a full-length protein. In certain aspects, the present invention comprises a method wherein said binding site is one of (a) an
10 ATP binding site, (b) a bromodomain sequence, (c) a catalytic site or (d) an allosteric site.

In certain aspects, the present invention comprises the above-mentioned methods wherein the labeling peptide is (a) an ED or (b) a binding epitope for a labeling peptide. The ED may have according to one of SEQ ID NO: 1, SEQ ID NO:2, or SEQ ID NO:3.

In certain aspects, the present invention comprises a method wherein the assay is
15 carried out without adding a compound, in order to provide a control for said determining said change in the amount of labeling peptide.

In certain aspects, the present invention comprises kits for carrying out the above-mentioned methods. The kits will generally comprise an expression vector for inserting a target of interest and already containing a labeling peptide. In certain aspects, the present
20 invention comprises a kit to study the effect of introduction of compound into a cell comprising (a) a cell comprising: a fusion protein comprising the target and ED fragment of β -galactosidase fragment; (b) compound, (c) EA fragment of β -galactosidase; and (d) a β -galactosidase substrate. In certain aspects, the present invention comprises a kit to study the effect of compound on mediating cellular interactions comprising (a) a cell comprising: a
25 fusion protein comprising the target and ED fragment of β -galactosidase fragment; (b) compound, (c) EA fragment of β -galactosidase; and (d) a β -galactosidase substrate. In certain aspects, the present invention comprises a kit to study effect of small molecule inhibitors on cellular interactions comprising (a) a cell comprising: a fusion protein comprising the target and ED fragment of β -galactosidase fragment; (b) small molecule, (c) EA fragment of β -

galactosidase; and (d) a β -galactosidase substrate. In certain aspects, the present invention comprises a kit to monitor interacting interface comprising (a) a cell comprising: a fusion protein comprising the variant sequence lengths of target and ED fragment of β -galactosidase fragment; (b) EA fragment of β -galactosidase; and (c) a β -galactosidase substrate. In certain aspects, the present invention comprises a kit comprising an expression construct encoding a fusion protein comprising a target and ED fragment of β -galactosidase.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic representation of an embodiment of the present assay showing how a fragment of a stable protein is unstable, stabilized by binding of a compound to binding site, and detected with increased abundance.

Figure 2 is a plasmid map of RPS-BLK (241-490) for expressing a BLK construct of amino acids 241-490.

Figure 3 is a graph showing fusion constructs (BLK-kinase-Prolabel) with varying sequence lengths of tyrosine-protein kinase BLK ("BLK") participating in interactions with a small molecule, dasatinib.

Figure 4 is a graph showing the effect of various small molecules (dasatinib, PD173955 and XL-2880) on abundance of a BLK-PL fusion.

Figure 5 is a plasmid map of an RPS-BCL2 DNA construct.

Figure 6 is a plasmid map of an RPN-pBIM-PL DNA construct.

Figure 7A, 7B, and 7C is a series of three graphs showing the interaction of BCL-2 with fusion proteins; **Figure 7A** shows data from PL-Bax, **Figure 7B** shows data from PL-Bim, and **Figure 7C** shows data from PL-Bak.

Figure 8A is a graph showing the effect of kinase inhibitors (U0126 and PD0325901) on abundance of MEK-PL fusion interactions in HEK cells. **Figure 8B** is a graph as in Figure 8A, with CHO cells. **Figure 8C** is a graph as in **Figure 8A**, with U2OS cells.

Figure 9A is a graph showing the specificity of dasatinib, U0126 and PD035901 to MEK-PL. **Figure 9B** is a graph as in **Figure 9A**, with BLK-PL fusions.

Figure 10 is a graph showing change in luminescence in a histone methylase G9a fragment when treated with UN06038, a selective chemical probe for G9a/GLP methyltransferases.

Figure 11 is a graph showing fluorescence from a CYP 17 A –ED fusion, shows stabilization of that domain with Ketoconazole and Abiraterone.

DETAILED DESCRIPTION

OVERVIEW

As discussed above, truncation of a protein will affect its folding and unfolding, ultimately affecting its functionality. It has been now found that such instability, as well as other factors affecting protein stability within a cell, can be used to measure the effect of stabilization of such a protein. It is recognized that the unstable protein will be degraded by the cell until such time as it forms a complex and can be stabilized from further cellular processes. As binding of both natural compounds (e.g. proteins) and many test compounds occurs through specific binding sequences, certain truncated protein fragments containing the active or allosteric binding sequences can be stabilized through compound binding. Thus, a compound that binds at an active or allosteric site of a protein fragment will form a complex with the fragment and will change its half-life in a cell. This will lead to a greater number of protein molecules in the cell, or greater “protein abundance”.

Targeting native or naturally mutated human proteins with small molecule test compounds is an important part of drug development. Thus, monitoring the stability of truncated, destabilized proteins, compounds that bind to the truncated fragments, estimating the interaction interfaces and screening small molecules as inhibitors of cellular binding complexes will have potential applications in drug development against a number of human disorders and represent aspects of the present invention.

A number of small molecules act by binding to the ATP site of the active conformation of their target peptides (e.g. dasatinib, which noncovalently binds to BCR-Abl

kinases). By removing portions of the amino and/or carboxyl regions of a target peptide but leaving the ATP binding site, synthetic or natural ATP-competitive molecules can then be tested for binding by measuring the increased stability, and thus residence time in the cell, that such binding causes. An increased concentration of fusion protein bound to the target and
 5 carrying the PL will be measured by adding the EA, giving us an indication of the binding sequence which can further be characterized by known biophysical and biological approaches.

In summary, the present methods are carried out so as to measure the amount (e.g. concentration, or abundance) of a target peptide that remains in a cell after a predetermined
 10 time that is chosen to distinguish a target peptide, which is bound to an enzyme fragment for detection, that has bound a test compound and thus been stabilized against cellular turnover, from a target peptide that is not bound to the binding entity and is degraded by cellular machinery, such degradation also removing the enzyme fragment label.

Referring now to **Figure 1**, a full length protein 102 containing an amino acid
 15 sequence or protein domain 104, that participates in binding is generally stable in a cell and has a consistent, measurable half life. The binding sequence 104, e.g. a ligand binding site such as an ATP binding site, or a protein-protein interaction site such as an α 1 helix of BAX, may be anywhere within the primary sequence of the protein. It may be a contiguous sequence in primary structure or it may exist as amino acids in proximity in tertiary structure.
 20 The binding sequence will generally be on the surface of the protein. In the present assay, the protein 102 is truncated as shown at 106, where truncation may occur from the N terminus, the C terminus, or, as shown here, both termini. The binding sequence 104, however, is still present in the truncated target peptide. Because of these alterations, the cell will degrade the truncated protein (peptide) more rapidly. In the present assay, the truncated peptide 106 is
 25 fused with a small fragment of β -galactosidase (PL enzyme donor in this example) as shown at 108. Binding of a compound 110 to the truncated peptide 108 will increase the stability of the truncated fragment, an effect which can then be estimated by incubating the sample with a complementing β -galactosidase fragment, an enzyme acceptor or EA, shown at 112. The complementation of ED and EA results in an active enzyme (shown at 114) which will
 30 convert the substrate into a measurable product (shown at 116). The test compound 110 itself

may stabilize the truncated peptide, or, in certain embodiments, the test compound 110 mediates the binding of the truncated peptide to a cognate binding partner, and this binding to the binding partner stabilizes the truncated peptide. The compound may increase or decrease such binding and affect stability of the truncated peptide rather than directly stabilizing the truncated peptide. The ED label on the truncated peptide serves only for labeling and not for stabilization.

DEFINITIONS

Unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by those of ordinary skill in the art to which this invention belongs. Although any methods and materials similar or equivalent to those described herein can be used in the practice or testing of the present invention, the preferred methods and materials are described. Generally, nomenclatures utilized in connection with, and techniques of, cell and molecular biology and chemistry are those well known and commonly used in the art. Certain experimental techniques, not specifically defined, are generally performed according to conventional methods well known in the art and as described in various general and more specific references that are cited and discussed throughout the present specification.

In accordance with the present invention there may be employed conventional molecular biology, microbiology, and recombinant DNA techniques within the skill of the art. Such techniques are explained fully in the literature. See, e.g. Maniatis, Fritsch & Sambrook, "Molecular Cloning: A laboratory Manual (1982); "DNA Cloning: A Practical Approach, "Volumes I and II (D.N. Glover ed. 1985); "Oligonucleotide synthesis" (M.J. Gait ed. 1984); "Nucleic Acid Hybridization" (B.D. Hames & S.J. Higgins eds. (1985)); "Transcription and Translation" (B.D.Hames & S.J. Higgins eds. (1984)); "Animal Cell Culture" (R.I. Freshney, ed. (1986)); "Immobilized Cells and Enzymes" (IRL Press, (1986)); B.Perbal, "A Practical Guide to Molecular Cloning" (1984).

It is noted that, as used herein and in the appended claims, the singular forms "a", "an", and "the" include plural referents unless the context clearly dictates otherwise. It is further noted that the claims may be drafted to exclude any optional element. As such, this statement is intended to serve an antecedent basis for use of such exclusive terminology as

“solely” “only” and the like in connection with the recitation of claim elements, or use of a “negative” limitation.

As will be apparent to those of skill in the art upon reading this disclosure, each of the individual embodiments described and illustrated herein has discrete components and features which may be readily separated from or combined with the feature of any of the other several
 5 embodiments. Any recited method can be carried out in the order of events recited or in any other order which is logically possible.

For purposes of clarity, the following terms are defined below.

10 The term “peptide” as used herein refers to any polymer compound produced by amide formation between an α -carboxyl group of one amino acid and an α -amino group of another group.

The term “BCL2” is used in its scientifically accepted sense to refer to a family of proteins whose members contain at least one of the four conserved α -helical motifs known as
 15 the Bcl-2 homology (BH1-4) domains. The family is further classified into functional groups, the antiapoptotic and the pro-apoptotic members, as described in Szegezdi et al., “Bcl-2 family on guard at the ER.” *Am J Physiol Cell Physiol*, 2009; 296: C941 - C953.

Similarly, the terms BIM, BAK and BAX refer to members of the BCL2 family. Multidomain proapoptotic BAX and BAK are essential effectors. The activator BH3s,
 20 tBID/BIM/PUMA, attack and expose the α 1 helix of BAX, as described e.g. in Kim et al., “Stepwise Activation of BAX and BAK by tBID, BIM, and PUMA Initiates Mitochondrial Apoptosis,” *Molecular Cell* 36, 487–499, November 13, 2009

The term “BLK” is used in its scientifically accepted sense to refer to B-lymphocyte kinase, NCBI reference sequence NP_001706, also known as tyrosine-protein kinase Blk
 25 [Homo sapiens]. Variants of this sequence are found in the protein tyrosine kinase (PTK) family; Lck and Blk kinases; catalytic (c) domain. The PTKc family is part of a larger superfamily that includes the catalytic domains of other kinases such as protein serine/threonine kinases, RIO kinases, and phosphoinositide 3-kinase (PI3K).

The term “MEK” is used in its scientifically accepted sense to refer to a protein kinase that phosphorylates the ERK gene product. The MEK subfamily of protein kinases is part of a larger superfamily that includes the catalytic domains of other protein serine/threonine kinases, protein tyrosine kinases, RIO kinases, aminoglycoside phosphotransferase, choline kinase, and phosphoinositide 3-kinase. The mitogen-activated protein (MAP) kinase signaling pathways are important mediators of cellular responses to extracellular signals. The pathways involve a triple kinase core cascade comprising the MAP kinase (MAPK), which is phosphorylated and activated by a MAPK kinase (MAPKK or MKK), which itself is phosphorylated and activated by a MAPK kinase kinase (MAPKKK or MKKK). MEK1 and MEK2 are dual-specificity PKs that phosphorylate and activate the downstream targets, ERK(extracellular signal-regulated kinase) 1 and ERK2, on specific threonine and tyrosine residues.

The term “protein” as used herein refers to polypeptides of specific sequence of more than about 50 residues. While all proteins are peptides, the term “peptide” generally refers to a fragment of a protein; the term “fusion protein” is used to refer to both fusion proteins and fusions with peptides, such as a fusion with a labeling peptide, e.g. an ED.

The term “fusion protein” as used herein refers to a protein created through genetic engineering from two or more proteins/peptides. In general, this is achieved by creating a “fusion gene”, a nucleic acid that encodes the fusion protein. For example, a fusion gene that encodes a fusion protein may be made by removing the stop codon from a first DNA sequence encoding the first protein, then appending a DNA sequence encoding the second protein in frame. The resulting fusion gene sequence will then be expressed by a cell as a single fusion protein. Fusion proteins may include a linker (or “spacer”) sequence which can promote appropriate folding and activity of each domain of the fusion protein. Fusion proteins may also include epitope tags for identification (e.g., in western blots, immunofluorescence, etc.) and/or purification. Non-limiting examples of epitope tags in current use include: HA, myc, FLAG, and 6-HIS (SEQ ID NO: 19).

The term “amino acid” as used herein is intended to include not only the L-, D-and nonchiral forms of naturally occurring amino acids (alanine, arginine, asparagine, aspartic acid, cysteine, glutamine, glutamic acid, glycine, histidine, isoleucine, leucine, lysine,

methionine, phenylalanine, proline, serine, threonine, tryptophan, tyrosine, valine), but also modified amino acids, amino acid analogs, and other chemical compounds which can be incorporated in conventional oligopeptide synthesis, e.g., 4-nitrophenylalanine, isoglutamic acid, isoglutamine, ϵ -nicotinoyl-lysine, isonipecotic acid, tetrahydroisoquinoleic acid, α -aminoisobutyric acid, sarcosine, citrulline, cysteic acid, t-butylglycine, t-butylalanine, phenylglycine, cyclohexylalanine, β -alanine, 4-aminobutyric acid, and the like. The amino acid sequences are given in one-letter code (A: alanine; R: arginine; N: asparagine; D: aspartic acid; C: cysteine; Q: glutamine; E: glutamic acid; G: glycine; H: histidine; I: isoleucine; L: leucine; K: lysine; M: methionine; F: phenylalanine; P: proline; S: serine; T: threonine; W: tryptophan; Y: tyrosine; V: valine; X: any residue). NH_2 refers to the free amino group present at the amino terminus of a polypeptide. COOH refers to the free carboxy group present at the carboxy terminus of a polypeptide in keeping with standard polypeptide nomenclature, (*J Biol. Chem.* 243 (1969), 3352-59) is used.

The term “vector” as used herein refers to is a replicon, such a plasmid, phage or cosmid, to which another DNA segment may be attached so as to bring about the replication of the attached segment.

A cell has been “transformed” or “transfected” by exogenous or heterologous DNA when such DNA has been introduced inside the cell. The transforming DNA may or may not be integral (covalently linked) into the genome of the cell. In prokaryotes, yeast, and mammalian cells for example, the transforming DNA may be maintained on an episomal element such as a plasmid. With respect to eukaryotic cells, a stably transformed cell is one in which the transforming DNA has become integrated into a chromosome so that it is inherited by daughter cells through chromosome replication. This stability is demonstrated by the ability of the eukaryotic cell to establish cell lines or clones comprised of a population of cells derived from a single cell or common ancestor by mitosis. A “cell line” is a clone of a primary cell that is capable of stable growth *in vitro* for many generations.

As used herein, the term “expression system” refers to any suitable exogenous system for expressing the receptor components in the cell. For example, exogenous expression of receptor components by a cell as provided herein can result from the introduction of the nucleic acid sequences encoding the receptor component or a fusion protein comprising a

receptor component in an expression vector. As used herein, the term "fusion protein" refers to a reporter component that is fused to a heterologous protein or protein fragment using recombinant technology.

The term "target" as used herein refers to various macromolecules present in a cell such as DNA, RNA, lipids, proteins and carbohydrates or their constituent monomers. The term "target peptide" refers to a target peptide that has been modified by truncation or the like as described below, is labeled with a β -galactosidase fragment (preferably PL) and is being tested with a test compound, such as a small molecule, or another protein, or a combination of a small molecule and a protein partner. Exemplary target peptides include kinases, actins, chaperonins, hsp proteins, and polymerases, which have ATP binding sites, and G proteins and dynamin, which bind GTP.

The term "small molecule" is art-recognized and refers to a composition which has a molecular weight of less than 35 about 2000 amu, or less than about 1000 amu, and even less than about 500 amu. Small molecules may be, for example, nucleic acids, peptides, polypeptides, peptide nucleic acids, peptidomimetics, carbohydrates, lipids or other organic (carbon containing) or inorganic molecules. Many pharmaceutical companies have extensive libraries of chemical and/or biological mixtures, often fungal, bacterial, or algal extracts, which can be screened with any of the assays of the invention. The term "small organic molecule" refers to a synthetic or purified natural small molecule that is often identified as being an organic or medicinal compound, and does not include molecules that contain nucleic acids, peptides or polypeptides.

The term "binding" as used herein refers to the binding of small molecules, proteins or compound to the known proteins in a cell. The terms "binding partner" or "member of a binding pair" refer to molecules that specifically bind other molecules to form a binding complex such as antibody-antigen, lectin-carbohydrate, nucleic acid-nucleic acid, biotin-avidin, etc. In particularly preferred embodiments, the binding is predominantly mediated by non-covalent (e.g. ionic, hydrophobic, etc.) interactions and is between a small molecule and its target and/or two proteins that specifically bind to each other during a cellular process.

The term “protein abundance” is used as described herein, and in a commonly accepted sense, as described, e.g. in Ivanic J, Yu X, Wallqvist A, Reifman J (2009) “Influence of Protein Abundance on High-Throughput Protein-Protein Interaction Detection,” PLoS ONE 4(6): e5815. doi:10.1371/journal.pone.0005815. Protein abundance can be
 5 regarded as the number of protein or peptide molecules in a cell at a given time.

The term “destabilizing mutation” means a mutation in a peptide or protein sequence that causes an alteration in the stability of the peptide or protein in the cell, that is, the likelihood of its degradation or aggregation within a certain time period. Mutations may include amino acid deletions, additions or substitutions. The mutation generally will cause
 10 misfolding of the peptide or protein. The stability of the peptide or protein in a cell may also refer to the duration of time that the protein is present in the cell before being removed or degraded by cellular machinery. Protein or peptide stability can be measured in vivo (i.e. in a cell) by a number of methods, such as disclosed e.g. in Ghaemmaghami et al., “A quantitative, high-throughput screen for protein stability,” PNAS July 18, 2000 vol. 97 no. 15
 15 8296-8301 or Ignatova et al. “Monitoring protein stability and aggregation in vivo by real-time fluorescent labeling,” *PNAS January 13, 2004 vol. 101 no. 2* 523-528. Thus whether or not a mutation is a destabilizing mutation can be determined by comparing the mutated protein to the non-mutated protein and observing that the mutated protein has a half- life in the cell that is at least 10% or more shorter than that of the non-mutated protein. In some
 20 cases, the half- life may be at least 20% or more shorter than that of the non-mutated protein or 30% or more shorter than that of the non-mutated protein. In some cases, the destabilizing mutation will result in a peptide having a half-life of less than 3 hrs inside of a cell.

In certain aspects, the term “destabilizing mutation” refers to mutations which are truncations in which at least 5 amino acids are removed from either or both of the N terminal
 25 region or the C terminal region of a target peptide. Further, it may also refer to truncation from either or both of the N terminus or the C terminus which leads to the destabilization of the target peptide inside of a cell. As explained below, in the present method, the destabilizing mutation is not to the binding site of the target peptide.

The term “labeling peptide” means a peptide having essentially no secondary
 30 structure (i.e. random coil) and which functions as a label for detection of a protein or protein

fragment (e.g. target peptide) fused thereto and having essentially no effect on the stability of the target peptide to which it is fused. The labeling peptide will generally be less than 100 amino acids in length. It may itself function as a label, or it may provide an epitope for antibody recognition. As explained below, the labeling peptide is selected so as not to affect
 5 the stability or half life of a fusion partner of the labeling peptide.

The term “target peptide” refers to a protein or protein fragment which is the target of binding modulated by a test compound in the present assay. The target peptide will have a native site which provides a binding site for the test compound or that is a binding site for another cellular component wherein the test compound modulates. For example, the target
 10 peptide may have a catalytic site, a co-factor binding site, an allosteric regulatory site, etc. The binding site may also be a binding site for a native ligand. A native ligand is a cellular molecule that binds to the binding site of the target peptide as part of a cellular process. Examples are enzyme catalytic site-substrate, enzyme regulatory site-regulator, receptor-ligand, G-protein accessory proteins, etc.

15 The term “test compound” is used in a general sense to refer to a small molecule, macromolecule or other material that has a property of binding to a particular target peptide at a binding site. The test compound is generally not normally found in the cell where it is tested at the concentration being tested. The test compound may produce a positive test result of binding or a negative test result of not binding; binding may also be quantified, according
 20 to the present methods. More than one test compound may be used, in that a test compound may be used as a reference compound known to bind to a specific site, such as a catalytic site, and ATP binding site, etc. on a target peptide. The test compound will in some cases bind non-covalently to the binding site; in some cases it will bind covalently to the binding site.

The term “sample well” means any fluid container, and includes wells in a microtiter
 25 plate, various test tubes (e.g. Eppendorf tubes), chambers in a microfluidic device, etc.

The term “ED”, as is known in the art, means an enzyme donor fragment for use in a β galactosidase enzyme fragment complementation assay. Examples of EDs are given below.

The term “binding site” refers to a sequence or cluster of residues on a target where the target binds to another molecule. Binding sites on proteins are well known and

characterized. They are generally specific to a certain ligand or binding partner. They can be identified on a sequence basis by tools such as PPSearch, at EMBL-EBI. Exemplary binding sites are (a) nucleotide (e.g.ATP) binding site, (b) a bromodomain sequence, (c) a catalytic site or (d) an allosteric site.

5 GENERAL METHODS AND MATERIALS

Enzyme fragment complementation

In certain embodiments, the present presently disclosed methods and materials employ the wild-type *E.coli* β -galactosidase upon which the enzyme fragment complementation (EFC) system is based. The wild-type *E.coli* β -galactosidase is encoded by the *E.coli* lacZ gene.

The β -galactosidase enzymes and its fragments (See, U.S. Pat. No. 4,708,929) are required to have a number of characteristics. The fragments are substantially inactive individually, in that there is little, if any, background with only one fragment present in the presence of substrate. Secondly, the fragments have sufficient affinity for each other, that in the absence of other binding, e.g. by entities fused to the fragments, the fragments will combine to provide an active enzyme. The small fragment ("ED" or "PL") may be designed artificially and will not interfere with the biological activity of the gene or protein to which it is fused. The resulting fusion protein, as has been determined here, will fold properly and retain sites of activity, including enzyme activity, binding activity to other proteins, translocation capability, etc. ED will usually be at least about 37, usually at least about 40 amino acids, and usually not more than about 110, more usually not more than about 90.

In certain embodiments, the employed β -galactosidase complementation system is one that is made up of two or more β -galactosidase fragments or variants thereof. For example, in certain embodiments, the complementation system includes a first and second fragment of β -galactosidase (e.g., an α and ω fragment). In yet other embodiments, the complementation system may include more than two β -galactosidase fragments, such as a first, second and third β -galactosidase fragments (e.g., an α , β and ω fragment).

In a preferred aspect, small fragment of β -gal (also the signal producing peptide) will be referred to as the enzyme donor (ED). The signal producing peptide is one of a pair of

fragments of an enzyme that is reconstituted when the two fragments, the enzyme donor ("ED") and the enzyme acceptor ("EA") complex together. The ED will be a fragment of an enzyme that can be complemented with another fragment, the EA, to form an active enzyme. The ED fragment of the fusion protein will complex with the EA fragment as a result of the
 5 affinity of the fragments for each other.

In other embodiments, the complementing fragments are high affinity fragments. High affinity components are generally two fragments of an enzyme with the fragments having sufficiently high affinity such that they can spontaneously bind to each other and reform a fully functional enzyme or enzyme subunit. Typically, at least 5% of enzymatic
 10 activity of the native enzyme is achieved when mixed under appropriate conditions in solution, sometimes about 10, 20, 30, 40, 50, 60, 70, 80, 90, 95, 99, or 100% of the enzymatic activity of the native enzyme. Determination of such activity can be performed using routine methods with the concentration at which the complemented enzyme and parental enzyme are compared typically being the same with a range of, e.g., between 10^{-3} to 10^{-6} M. High
 15 affinity components permits monitoring of the presence, absence, or increase of the complementing fragments as they form a complex with the interacting partner. For example, if one complementing fragment is present in the fusion protein (fused to the target of interest) and forms a complex with the test compound then the incubation with the second fragment after lysis of the cell will result in detectable enzymatic activity, thus permitting the analysis
 20 of cellular interactions. Accordingly, if the amount of high affinity components increases in the assay system, then the amount of detectable enzymatic activity will increase proportionally. Typically, large increases in the amount of activity are detectable up to a 1:1 reporter component ratio. See e.g., the experimental section below, as well as U.S. patent 8,586,294 for a review of such a rational
 25 approach as employed with an initial high affinity .beta.-galactosidase complementation reporter system.

In some embodiments, the fusion protein comprises a truncated fragment of target of interest and high affinity ED fragment, wherein the target of interest is a protein kinase and the truncated fragment consists of the ATP-binding sequence. In some embodiments, the
 30 truncated protein fragment consists of non ATP binding sequence. The test compound can be

an ATP-competitive molecule, allosteric modulators or a kinase binding molecule. In some embodiments, the fusion protein comprises a truncated fragment of target of interest and low affinity ED fragment.

Various other indicator enzymes are also known to fulfill these criteria and additional enzymes may be developed in accordance with known technologies. Indicator enzymes that fit these criteria include split luciferase, GFP, ribonuclease A (See, U.S. Pat. No. 4,378,428), where the smaller fragment may come from the amino or carboxy terminus or internally, β -lactamase WO 00/71702 and 01/94617 and Wehrman, et al., Proc. Natl. Acad. Sci. 2002, 99, 3469-74, or enzymes that have small peptide cofactors, such as adenovirus proteases (See, U.S. Pat. No. 5,935,840).

In a specific embodiment, the α peptide employed is one that complements the ω peptide robustly in mammalian cells. The high affinity minimal α peptide permits sensitive, accurate analysis of cellular interaction events between various intracellular entities with only a minimum of interactions required for detection. Exemplary high affinity α peptides (enzyme donors) include

SEQ ID NO. 1 (Wild-type ED)

MGVITDSLAVVLQRRDWENPGVTQLNRLAAHPPFASWRNSEEARTDRPSQQL

SEQ ID NO. 2 (Prolabel, or "PL" ED)

NSLAVVLQRRDWENPGVTQLNRLAAHPPFASWRNSEEARTDR, and

SEQ ID NO. 3 (W34Y, a modified ED)

MGVITDSLAVVLQRRDWENPGVTQLNRLAAHPPFASYRNSEEARTDRPSQQL.

Another applicable ED is termed enhanced prolabeled, SEQ ID NO. 4 below:

NSLAVVLQRRDWENPGVTQLNRLAAHPPFASWRNSEEARTDR (SEQ ID NO. 4)

The enzyme fragments can be coupled to the peptide target of interest using any suitable method. Thus, the enzyme fragments and one or more targets of interest can be linked either directly or via a linker. Typically, the linker is covalent. For example, when the enzyme fragment and the target of interest are proteins, methods known in the art for linking

peptides can be employed. In one preferred embodiment, the enzyme fragment and the target of interest comprise a fusion protein that includes the enzyme fragment and the target being assayed.

Aspects of the methods include the use of a reduced-affinity enzyme
 5 complementation reporter system which is extensively described in the aforementioned references, U.S. Pat Appln. No. 20070275397, Pub. Date 11/29/2007 and U.S. Pat Appln. No. 20100285451, Pub. Date 11/11/2010 .

Embodiments of the reduced-affinity enzyme complementation reporter systems are
 10 characterized by providing a high signal-to-noise ratio.

Aspects of the method include the use of a first β -galactosidase fragment (also known as an enzyme donor or a fragment) that is a variant minimal N-terminal β -galactosidase peptide. By minimal N-terminal β -galactosidase peptide is meant that the peptide has an amino acid sequence that is found in the N-terminal region of a wild-type β -galactosidase
 15 protein, e.g., a sequence that starts within about 10 residues of the N-terminus, such as within about 5 residues of the N-terminus of a wild-type β -galactosidase protein. As the first β -galactosidase fragments of this embodiment are minimal, they are, in certain embodiments, about 60 amino acids or less in length, such as about 55 amino acids in length or less, including about 50 amino acids or less in length, e.g., 49 amino acids or less in length, 48
 20 amino acids or less in length, etc.

In certain embodiments, the second β -galactosidase fragment is a deletion mutant that is missing aa 11-41 of the wild type *E. coli* β -galactosidase protein (e.g., as described in Langley et al., Proc. Nat'l Acad. Sci. USA (1975) 72: 1254-1257), which fragment is known as the M15 acceptor or ω fragment. Other specific acceptors (i.e., co-fragments) of interest
 25 include, but are not limited to: the M112 dimer, a deletion of amino acids 23-31 within β -galactosidase (Lin, Villarejo and Zabin, 1970, Biochem. Biophys. Res. Commun. 40:249; Celeda and Zabin, 1979, Biochem. 18:404; Welphy, Fowler and Zabin, 1981, J. Biol. Chem. 256:6804; Langley et al., 1975, Proc. Natl. Acad. Sci. USA 72:1254).

One exemplary ω peptide sequence is set forth below (SEQ ID NO. 5)

MGVITDSLAVVARTDRPSQQLRSLNGEWRFAWFPAPEA VPESWLECDLPEADTVVV
 PSNWQMHGYDAPIYTNVTYPITVNPPFVPTENPTGCYSLTFNVDES WLQEGQTRIIFDGVNSA
 FHLWCNGRWVGYGQDSRLPSEFDLSAFLRAGENRLAVMVLRWSDGSYLEQDMWRMSGIF
 RDVSL LHKPTTQISDFHVATR FNDDFSRAVLEAEVQMC GELRDYLRVTVSLWQGETQVASG
 5 TAPFGGEIIDERGGYADRVTLRLNVENPKLWSAEIPNLYRAVVELHTADGTLIEAECDVGFRE
 VRIENGLLLLNGKPLLIRGVNRHEHHPLHGQVMDEQTMVQDILLMKQNNFNAVRC SHYPNH
 PLWYTLCDRYGLYVVDEANIETHGMVPMNRLTDDPRWLPAMSERVTRMVQRDRNHPSVII
 WSLGNESGHGANHDALYRWIKSVDPSPVQYEGGGADTTATDIICPMYARVDEDQPFPAVP
 KWSIKKWLSLPGETRPLILCEYAHAMGNSLGGFAKYWQAFRQYPR LQGGFVWDWVDQSLI
 10 KYDENNPWSAYGGDFGDTPNDRQFCMNGLVFADRTPHPALTEAKHQQQFFQFRLSGQTIEV
 TSEYLFRRHSDNELLHWMVALDGKPLASGEVPLDVAPQGKQLIELPELPQPESAGQLWLTVRV
 VQPNATAWSEAGHISAWQQWRLAENLSVTLPAAASHAIPHLTTSEMDFCIELGNKRWQFNRO
 SGFLSQMWIGDKKQLLTPLRDQFTRAPLDNDIGVSEATRDPNAWVERWKAAGHYQAEAAL
 LQCTADTLADAVLITTAHAWQHQQKTLFISRKTYRIDGSGQMAITVDVEVASDTPHPARIGL
 15 NCQLAQVAERVNWLGLGPQENYPDRLTAACFDRWDLPLSDMYTPYVFPSENGLRCGTREL
 NYGPHQWRGDFQFNISRYSSQQQLMETSHRHLLHAEEGTWLNIDGFHMGIGGDDSWSPSVSA
 EFQLSAGRYHYQLVWCQK

A range of methods are available to measure the enzyme activity of β -galactosidase
 which include live cell flow cytometry and histochemical staining with the chromogenic
 20 substrate 5-bromo-4-chloro-3-indolyl β -D-galactopyranoside (X-Gal). see e.g., Nolan et al.,
 Proc. Natl. Acad. Sci., USA, 85: 2603-2607 (1988); and Lojda, Z., Enzyme Histochemistry:
 A laboratory Manual, Springer, Berlin, (1979).

Assays of β -gal activity as described in Mohler and Blau, Proc.Natl.Acad.Sci., 93:
 12423-12427 (1996) may be used. In one embodiment, intracellular analyses may be
 25 conducted by fixing cells and staining with the indigogenic substrate X-gal. Fixed cells also
 can be analyzed by assaying for β -gal activity by fluorescence histochemistry using an azo
 dye in combination with either X-gal or 5-bromo-6-chloro-3-indolyl β -D-galactopyranoside
 (5-6-X-Gal). A combination of interest is the azo dye red violet LB (Sigma Chemicals, St.
 Louis, Mo.) and 5-6-X-Gal, referred to as Fluor-X-gal. For this combination, fluorescence
 30 micrographs can be obtained on a fluorescence dependent fluorescence to be visualized
 simultaneously with two or more other fluorescent signals.

Vital substrates for β -gal, which can be used in living cells, are also encompassed by the presently disclosed methods and materials. For example, a fluorogenic substrate, resorufin β -galactosidase bis-aminopropyl polyethylene glycol 1900 (RGPEG) has been described. Minden (1996) BioTechniques 20(1): 122-129. This compound can be delivered to cells by
5 microinjection, electroporation or a variety of bulk-loading techniques. Once inside a cell, the substrate is unable to escape through the plasma membrane or by gap junctions. Another vital substrate that can be used in the practice of the presently disclosed methods and materials is fluorescein di- β -D-galactopyranoside (FDG), which is especially well-suited for analyses for analysis by fluorescence-activated cell sorting (FACS) and flow cytometry. Nolan et al.,
10 Proc. Natl. Acad. Sci, USA, 85:2603-2607 (1988) and Rotman et al. (1963) Proc. Natl. Acad. Sci, USA 50: 1-6.

β -galactosidase may also be detected using a chemiluminescence assay. For example, cells containing β -galactosidase fusions are lysed (with or without contacting with a crosslinking agent) in a mixture of buffers containing Galacton Plus substrate from a
15 Galactolight Plus assay kit (Tropix, Bedford Mass.) Bronstein et al, J Biolumin. Chemilumin., 4:99-111 (1989). After addition of Light Emission Accelerator solution, luminescence is measured in a luminometer or a scintillation counter.

Representative substrates that are suitable for spectrophotometric or fluoremetric analysis include, but are not limited to: p-aminophenyl- β -D-galactopyranoside; 4-
20 methylumbel-liferyl- β -D-galactopyranoside; mapthyl-AS-B1- β -D-galactopyranoside; 1-naphthyl- β -D-galactopyranoside; 2-naphthyl- β -D-galactopyranoside monohydrate; O-nitrophenyl- β -D-galactopyranoside; and phenyl- β -D-galactopyranoside, 5-bromo-4-chloro-3-indolyl- β -D-galactopyranoside, resorufin β -D-galactopyranoside, 7-hydroxy-4-trifluoromethyl coumarin, Ω -notrostyryl- β -D-galactopyranoside and fluorescein- β -D-
25 galactopyranoside. See e.g., U.S. Patent No. 5,444,161 for exemplary substrates.

Association of components of the complementation systems disclosed herein will depend upon factors in solution, such as pH, ionic strength, concentration of components of the assay, and temperature. Assay solutions can be designed and developed for a particular system. The reporter systems disclosed herein can be used to conduct assays in solutions,
30 such as buffered cell free solutions, cell interiors, solutions of cells, solutions of cell lysates

and solutions of cell fractions, such as nuclear fractions, cytoplasmic fractions, mitochondrial fractions and membrane fractions. Methods for preparing assay solutions, such as enzyme assay solutions, cell extracts and cell suspensions, known in the art may be used. For example, physiologically compatible buffers such as phosphate buffered saline may be used.

5 See for example, the series, Methods in Enzymology, Academic Press, New York.

In some embodiments, the first and second reporter components are each fluorescent proteins and the detectable signal results from fluorescence resonance energy transfer (FRET). Luminescent proteins may also be employed. Thus, the first complementing component is a luminescent protein and the second complementing component is fluorescent
10 proteins and the detectable signal results from bioluminescence resonance energy transfer (BRET). Any suitable fluorescent protein can be used including, but not limited to green, red, cyan and yellow fluorescent proteins. In one example, the luminescent protein is a Renilla luciferase or a firefly luciferase.

In another aspect, provided herein is a nucleic acid sequence encoding SEQ ID NO: 1,
15 SEQ ID NO: 2, SEQ ID NO: 3, SEQ ID NO: 4 or SEQ ID NO: 5, a vector comprising the nucleic acid sequence, and a cell comprising the nucleic acid sequence or the vector. Also provided herein is a polypeptide encoded by the nucleic acid sequences provided herein. Specifically, provided herein is a polypeptide comprising the polypeptide encoded by SEQ ID NO: 1, SEQ ID NO: 2, SEQ ID NO: 3 SEQ ID NO: 4 or SEQ ID NO: 5.

20 Vectors

In certain embodiments, the fusion gene constructs of the invention are introduced into cells to assay for cellular interactions. The fusion gene constructs may also contain promoters and other transcriptional and/or translational regulatory sequences that are normally associated with the gene encoding the target of interest. The fusion gene construct
25 may be introduced into cells by any method of nucleic acid transfer known in the art, including, but not limited to, viral vectors, transformation, co-precipitation, electroporation, neutral or cationic liposome-mediated transfer, microinjection or gene gun. Viral vectors of interest include, but not limited to: retroviruses, poxviruses, herpesviruses, adenoviruses, and adeno-associated viruses. In certain embodiments, retroviral vectors are employed, which are

capable of stable integration into the genome of the host cell. For example, retroviral constructs encoding integration and packaging signals, drug resistance markers and one or more fusion genes of interest are useful in the practice of certain embodiments of the invention.

5 Different fusion gene constructs encoding unique fusion protein may be present on separate nucleic acid molecules or on the same nucleic acid molecule. The present fusion gene construct or fusion proteins may be introduced into cultured cells, animal cells in vivo, animal cells ex vivo, or any other type of cell in which it is desired to study cellular interactions.

10 Any suitable expression system can be used to express the reporter components in situ. Transformation may be achieved using viral vectors, calcium phosphate, DEAE-dextran, electroporation, cationic lipid reagents, or any other convenient technique known in the art. The manner of transformation useful in the present invention are conventional and are exemplified in Current Protocols in Molecular Biology (Ausubel, F. M., et al., eds. 2000).

15 Exogenous expression of the receptor components can be transient, stable, or some combination thereof. Exogenous expression can be enhanced or maximized by co-expression with one or more additional proteins, e.g., HIV rev. Exogenous expression can be achieved using constitutive promoters, e.g., SV40, CMV, and the like, and inducible promoters known in the art. Suitable promoters are those which will function in the cell of interest. In one
20 embodiment, the expression vector is a retroviral vector.

The expression construct is produced in accordance with conventional ways, as described in various laboratory manuals and by suppliers of vectors that are functional in numerous hosts. See, for example, Sambrook, Fritsch & Maniatis, "Molecular Cloning: A Laboratory Manual," Second Edition (1989) Cold Spring Harbor Laboratory Press, Cold
25 Spring Harbor, N.Y. (herein "Sambrook et al., 1989"); "DNA Cloning: A Practical Approach," Volumes I and II (D. N. Glover ed. 1985); "Oligonucleotide Synthesis" (M. J. Gait ed. 1984); "Nucleic Acid Hybridization" [B. D. Hames & S. J. Higgins eds. (1985)]; "Transcription And Translation" [B. D. Hames & S. J. Higgins, eds. (1984)]; "Animal Cell Culture" [R. I. Freshney, ed. (1986)]; "Immobilized Cells And Enzymes" [IRL Press,
30 (1986)]; B. Perbal, "A Practical Guide To Molecular Cloning" (1984).

It should be understood that the site of integration of the expression construct, if integrated into a host chromosome, would affect the efficiency of transcription and, therefore, expression of the fusion protein. One may optimize the efficiency of expression by selecting for cells having a high rate of transcription, one can modify the expression construct by
5 having the expression construct joined to a gene that can be amplified and coamplifies the expression construct, e.g. DHFR in the presence of methotrexate, or one may use homologous recombination to ensure that the site of integration provides for efficient transcription. By inserting an insertion element into the genome, such as Cre-Lox at a site of efficient transcription, one can direct the expression construct to the same site. In any event,
10 one will usually compare the enzyme activity from cells in a predetermined environment to cells in the environment being evaluated.

The gene encoding the fusion protein will be part of an expression construct. The gene is positioned to be under transcriptional and translational regulatory regions functional in the cellular host. In many instances, the regulatory regions may be the native regulatory
15 regions of the gene encoding the protein that forms the EC (expression construct), where the fusion protein may replace the native gene. The site of the gene in an extrachromosomal element or in the chromosome may vary as to transcription level. Therefore, in many instances, the transcriptional initiation region will be selected to be operative in the cellular host, but may be from a virus or other source that will not significantly compete with
20 the native transcriptional regulatory regions or may be associated with a different gene from the gene for the EC, which gene will not interfere significantly with the transcription of the fusion protein.

Vectors that may be used include viruses, plasmids, cosmids, phagemids, YAC, BAC and HAC. Other components of the vector may include origins of replication for one or more
25 hosts, expression constructs for selection, including antibiotic resistance, proteins providing for a signal, etc., integration sequences and enzymes providing for the integration, multiple cloning sites, expression regulatory sequences, expression construct for a protein of interest. Commercially available vectors have many or all of these capabilities and may be used to advantage.

By way of example, nucleotide sequence of the plasmid cloning vector pCMV-PL-C1 (SEQ ID NO. 6), having a CMV promoter, is shown below:

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1 TAGTTATTAA TAGTAATCAA TTACGGGGTC ATTAGTTCAT AGCCCATATA
5 51 TGGAGTTCCG CGTTACATAA CTTACGGTAA ATGGCCCGCC TGGCTGACCG
101 CCCAACGACC CCCGCCCAT T GACGTCAATA ATGACGTATG TTCCCATAGT
151 AACGCCAATA GGGACTTTCC ATTGACGTCA ATGGGTGGAG TATTTACGGT
201 AAAGTCCCCA CTTGGCAGTA CATCAAGTGT ATCATATGCC AAGTACGCCC
251 CCTATTGACG TCAATGACGG TAAATGGCCC GCCTGGCATT ATGCCCAGTA
301 CATGACCTTA TGGGACTTTC CTACTTGGCA GTACATCTAC GTATTAGTCA
10 351 TCGCTATTAC CATGGTGATG CGGTTTTTGGC AGTACATCAA TGGGCGTGGA
401 TAGCGGTTTG ACTCACGGGG ATTTCCAAGT CTCCACCCCA TTGACGTCAA
451 TGGGAGTTTG TTTTGGCACC AAAATCAACG GGACTTTCCA AAATGTCGTA
501 ACAACTCCGC CCCATTGACG CAAATGGGCG GTAGGCGTGT ACGGTGGGAG
551 GTCTATATAA GCAGAGCTGG TTTAGTGAAC CGTCAGATCC GCTAGCGCTA
15 601 CCGGACTCAG ATCTCGAGCT CAAGCTTCGA ATTCTGCAGT CGACGGTACC
651 GCGGGCCCGG GATCCACCGG CCGGTCGCCA CCATGAGCTC CAATTCACTG
701 GCCGTCGTTT TACAACGTCG TGACTGGGAA AACCTGGCG TTACCCAACT
751 TAATCGCCTT GCAGCACATC CCCCTTTCGC CAGCTGGCGT AATAGCGAAG
801 AGGCCCCGAC CGATCGCCCT TCCCAACAGT TGCAGCAGCT GAATGGCGAA
20 851 TAGGCGGCCG CGACTCTAGA TCATAATCAG CCATACCACA TTTGTAGAGG
901 TTTTACTTGC TTTAAAAAAC CTCCCACACC TCCCCCTGAA CCTGAAACAT
951 AAAATGAATG CAATTGTTGT TGTTAACTTG TTTATTGCAG CTTATAATGG
1001 TTACAAATAA AGCAATAGCA TCACAAATTT CACAAATAAA GCATTTTTTTT
1051 CACTGCATTC TAGTTGTGGT TTGTCCAAAC TCATCAATGT ATCTTAAGGC
25 1101 GTAAATTGTA AGCGTTAATA TTTTGTAAA ATTCGCGTTA AATTTTTGTT
1151 AAATCAGCTC ATTTTTTAAC CAATAGGCCG AAATCGGCAA AATCCCTTAT
1201 AAATCAAAAG AATAGACCGA GATAGGGTTG AGTGTGTTC CAGTTTGGAA
1251 CAAGAGTCCA CTATTAAAGA ACGTGGACTC CAACGTCAA GGGCGAAAAA
1301 CCGTCTATCA GGGCGATGGC CCACTACGTG AACCATCACC CTAATCAAGT
30 1351 TTTTGGGGT CGAGGTGCCG TAAAGCACTA AATCGGAACC CTAAAGGGAG
1401 CCCCCGATTT AGAGCTTGAC GGGGAAAGCC GCGGAACGTG GCGAGAAAGG
1451 AAGGGAAGAA AGCGAAAGGA GCGGGCGCTA GGGCGCTGGC AAGTGTAGCG
1501 GTCACGCTGC GCGTAACCAC CACACCCGCC GCGCTTAATG CGCCGCTACA
1551 GGGCGCGTCA GGTGGCACTT TTCGGGGAAA TGTGCGCGGA ACCCCTATTT
35 1601 GTTTATTTTT CTAAATACAT TCAAATATGT ATCCGCTCAT GAGACAATAA
1651 CCCTGATAAA TGCTTCAATA ATATTGAAA AGGAAGAGTC CTGAGGCGGA
1701 AAGAACCAGC TGTGGAATGT GTGTCAAGTA GGGTGTGGAA AGTCCCCAGG
1751 CTCCCCAGCA GGCAGAAGTA TGCAAAGCAT GCATCTCAAT TAGTCAGCAA
1801 CCAGGTGTGG AAAGTCCCCA GGCTCCCCAG CAGGCAGAAG TATGCAAAGC
40 1851 ATGCATCTCA ATTAGTCAGC AACCATAGTC CCGCCCCTAA CTCCGCCCAT
1901 CCCGCCCTA ACTCCGCCCA GTTCCGCCCA TTCTCCGCC CATGGCTGAC
1951 TAATTTTTTT TATTTATGCA GAGGCCGAGG CCGCCTCGGC CTCTGAGCTA
2001 TTCCAGAAGT AGTGAGGAGG CTTTTTTGGA GGCCTAGGCT TTTGCAAAGA
2051 TCGATCAAGA GACAGGATGA GGATCGTTTC GCATGATTGA ACAAGATGGA
45 2101 TTGCACGCAG GTTCTCCGGC CGCTTGGGTG GAGAGGCTAT TCGGCTATGA
2151 CTGGGCACAA CAGACAATCG GCTGCTCTGA TGCCGCCGTG TTCCGGCTGT
2201 CAGCGCAGGG GCGCCCGGTT CTTTTTGTCA AGACCGACCT GTCCGGTGCC
2251 CTGAATGAAC TGCAAGACGA GGCAGCGCGG CTATCGTGGC TGGCCACGAC
2301 GGGCGTTCCT TGCGCAGCTG TGCTCGACGT TGCTACTGAA GCGGGAAGGG

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2351 ACTGGCTGCT ATTGGGCGAA GTGCCGGGGC AGGATCTCCT GTCATCTCAC
 2401 CTTGCTCCTG CCGAGAAAGT ATCCATCATG GCTGATGCAA TGCGGCGGCT
 2451 GCATACGCTT GATCCGGCTA CCTGCCCATT CGACCACCAA GCGAAACATC
 2501 GCATCGAGCG AGCACGTACT CGGATGGAAG CCGGTCTTGT CGATCAGGAT
 5 2551 GATCTGGACG AAGAGCATCA GGGGCTCGCG CCAGCCGAAC TGTTCGCCAG
 2601 GCTCAAGGCG AGCATGCCCCG ACGGCGAGGA TCTCGTCGTG ACCCATGGCG
 2651 ATGCCTGCTT GCCGAATATC ATGGTGGAAA ATGGCCGCTT TTCTGGATTC
 2701 ATCGACTGTG GCCGGCTGGG TGTGGCGGAC CGCTATCAGG ACATAGCGTT
 2751 GGCTACCCGT GATATTGCTG AAGAGCTTGG CGGCGAATGG GCTGACCGCT
 10 2801 TCCTCGTGCT TTACGGTATC GCCGCTCCCG ATTCGCAGCG CATCGCCTTC
 2851 TATCGCCTTC TTGACGAGTT CTTCTGAGCG GGACTCTGGG GTTCGAAATG
 2901 ACCGACCAAG CGACGCCCAA CCTGCCATCA CGAGATTTCG ATTCCACCGC
 2951 CGCCTTCTAT GAAAGGTTGG GCTTCGGAAT CGTTTTCCGG GACGCCGGCT
 3001 GGATGATCCT CCAGCGCGGG GATCTCATGC TGGAGTTCTT CGCCCACCCT
 15 3051 AGGGGGAGGC TAACTGAAAC ACGGAAGGAG ACAATACCGG AAGGAACCCG
 3101 CGCTATGACG GCAATAAAAA GACAGAATAA AACGCACGGT GTTGGGTCGT
 3151 TTGTTTATAA ACGCGGGGTT CGGTCCCAGG GCTGGCACTC TGTCGATACC
 3201 CCACCGAGAC CCCATTGGGG CCAATACGCC CGCGTTTCTT CCTTTTCCCC
 3251 ACCCCACCCC CCAAGTTCGG GTGAAGGCC AGGGCTCGCA GCCAACGTCG
 20 3301 GGGCGGCAGG CCCTGCCATA GCCTCAGGTT ACTCATATAT ACTTTAGATT
 3351 GATTTAAAC TTCATTTTTA ATTTAAAAGG ATCTAGGTGA AGATCCTTTT
 3401 TGATAATCTC ATGACCAAAA TCCCTTAACG TGAGTTTTCG TTCCACTGAG
 3451 CGTCAGACCC CGTAGAAAAG ATCAAAGGAT CTTCTTGAGA TCCTTTTTTT
 3501 CTGCGCGTAA TCTGCTGCTT GCAAACAAA AAACCACCGC TACCAGCGGT
 25 3551 GGTTTGTGTT CCGGATCAAG AGCTACCAAC TCTTTTTCCG AAGGTAACG
 3601 GCTTCAGCAG AGCGCAGATA CCAATACTG TCCTTCTAGT GTAGCCGTAG
 3651 TTAGGCCACC ACTTCAAGAA CTCTGTAGCA CCGCCTACAT ACCTCGCTCT
 3701 GCTAATCCTG TTACCAGTGG CTGCTGCCAG TGGCGATAAG TCGTGTCTTA
 3751 CCGGGTTGGA CTCAAGACGA TAGTTACCGG ATAAGGCGCA GCGGTCGGGC
 30 3801 TGAACGGGGG GTTCGTGCAC ACAGCCCAGC TTGGAGCGAA CGACCTACAC
 3851 CGAACTGAGA TACCTACAGC GTGAGCTATG AGAAAGCGCC ACGCTTCCCG
 3901 AAGGGAGAAA GGCAGACAGG TATCCGGTAA GCGGCAGGGT CGGAACAGGA
 3951 GAGCGCACGA GGGAGCTTCC AGGGGGAAAC GCCTGGTATC TTTATAGTCC
 4001 TGTCGGGTTT CGCCACCTCT GACTTGAGCG TCGATTTTGT TGATGCTCGT
 35 4051 CAGGGGGGCG GAGCCTATGG AAAAACGCCA GCAACGCGGC CTTTTACGG
 4101 TTCCTGGCCT TTTGCTGGCC TTTTGCTCAC ATGTTCTTTC CTGCGTTATC
 4151 CCCTGATTCT GTGGATAACC GTATTACCGC CATGCAT

The DNA or RNA vectors may be introduced into a cell where the expression of the
 fusion protein can occur. The host may be a primary cell, a cell line, a unicellular
 40 microorganism, or the like, where the cell may be modified having an expression construct
 integrated or transiently present in the cell expressing a secretable form of EA, expressing or
 over-expressing a protein that the cell does not normally express under the conditions of the
 assay, not expressing a protein that the cell normally expresses as a result of a knockout,
 transcription or translation inhibitor, or the like.

The vector will include the fusion gene under the transcriptional and translational control of a promoter, usually a promoter/enhancer region, optionally a replication initiation region to be replication competent, a marker for selection, and may include additional features, such as restriction sites, PCR initiation sites, an expression construct providing
 5 constitutive or inducible expression of EA, or the like. As described above, there are numerous vectors available providing for numerous different approaches for the expression of the fusion protein in a host.

The vector may be introduced into the host cells by any convenient and efficient means, such as transfection, electroporation, lipofection, fusion, transformation, calcium
 10 precipitated DNA, etc. The manner in which the vector is introduced into the host cells will be one of efficiency and convenience in light of the nature of the host cell and the vector and the literature has numerous directions for the introduction of a vector into a host cell and the selection of the host cells that have effectively received the vector. By employing expression constructs that allow for selection, e.g. antibiotics, the cells may be grown in a selective
 15 medium, where only the cells comprising the vector will survive.

Labeling peptides

In addition, the detection of the levels of the target could be obtained through a variety of antibody based methods such as Alpha Screen®, FRET, TR-FRET and the like. Alpha Screen® Technology is commercially available from BioTek Instruments, Inc.
 20 AlphaScreen, used mostly in high throughput screening, is a homogenous assay technology similar to TR-FRET, to some extent, which allows detection of molecular events such as binding. Coated "Donor" and "Acceptor" beads are the basis of the AlphaScreen assay technology. AlphaScreen, a bead based assay, works through the interaction of the beads coming close to each other, resulting in a cascade of chemical reactions that act to produce a
 25 greatly amplified signal. FRET and TR FRET are described, e.g. in US 2012/02191, "Detection method based on time resolved real time fluorescent energy ..." Other labeling peptides that could be used in place of the ED include affinity tags, such as an affinity tag, e.g. a tag derived from hemagglutinin (HA-tag; polyhistidine tag (His5-10 (SEQ ID NO: 20), preferably His6 (SEQ ID NO: 19); also referred to as His-tag), FLAG-tag), or a Myc-tag.
 30 These tags are further described, e.g. at EP2487183, "Ubiquitin-isopeptide probes."

Another possibility is horse radish peroxidase (HRP), as described in e.g. Grigorenko et al. "A Genetically Engineered Fusion Protein with Horseradish Peroxidase as a Marker Enzyme for Use in Competitive Immunoassays," Anal. Chem. 73:1134-1139 (2001). A labeling peptide may also be a peptide having a binding epitope for an antibody, a peptide
 5 binding biotin, a peptide for attachment of FITC, etc.

Assay Applications

The assay procedure employed is to use the intact cells, either viable or non-viable. Non-viability can be achieved by heat, antibiotics, toxins, etc., which induce mortality while leaving the cells intact. The cells are grown in culture in an appropriate culture medium
 10 suitable for the cells and may be grown to confluence or subconfluence, e.g. 80%. The fusion protein expression construct and other constructs, as appropriate, may be present in the cell, integrated into the genome or may be added transiently by the various methods for introducing DNA into a cell for functional translation. These methods are amply exemplified in the literature, as previously described. By employing a marker with the protein reagent for
 15 selection of cells comprising the construct, such as antibiotic resistance, development of a detectable signal, etc., cells in culture comprising the fusion protein can be separated from cells in which the construct is absent. Once the fusion protein is being expressed, the environment of the cells may be modified, as appropriate.

Embodiments of the invention can be used in a broad range of studies for monitoring
 20 various cellular/molecular binding events. In what follows, non-limiting examples of different applications of the methods of the invention are provided. The presently disclosed systems and methods can be used to detect various interactions in a cell.

It has been shown that compounds that bind to known proteins can result in their stabilization and an increase in protein half-life intracellularly and extracellularly. E.g. a
 25 fusion protein comprising the target of interest and ED is introduced into the cell and a known compound is applied to the cells. If the compound promotes the target peptide-test compound complex formation, there will an increase in the concentration of fusion protein in cell. Lysing the cell and incubating it with EA will result in an active enzyme formation. The

enzyme will act on the substrate and produce a detectable product which will indicate complex formation when compared to cells where the compound is not applied to the cells.

In certain embodiments, the methods and assays disclosed in the present application can be employed to determine the interacting interfaces through which proteins interact. The point of contacts through which proteins interacts have specific characteristics and are known as “hotspots”. A fusion protein comprising target protein of different sequence lengths and ED is introduced into the cell. A particular sequence length target comprising the interacting sequences will form a complex with its interacting counterpart whereas the sequence length target which does not comprise the interacting sequence will not be able to form a complex with its interacting counterpart. As a result the fusion protein forming a complex will be stabilized whereas the fusion protein which does not form a complex will be degraded in cell. An increase in the concentration of stabilized fusion protein will be detected through complementation assay and thus will help in identifying the interacting sequences.

In certain embodiments, the methods disclosed can be used to screen small molecules that may act as inhibitors of known binding complexes. Small molecule inhibitors are an emerging choice for drug discovery studies. E.g. a fusion protein comprising a known target and ED is introduced into the cell. The target peptide interacts with the test compound and forms a complex through protein-protein interactions. Treating the cells with small molecules will result in the destabilization of fusion protein and hence will be degraded which will result in a decrease in concentration of fusion protein which will then be detected using complementation assay.

Target peptides

A wide variety of cellular proteins having specific binding sites may be adapted for use in the present assay. The binding sites may exist in the wild type protein for binding to cell signaling molecules, natural enzymatic substrates, accessory proteins, nucleotides, polynucleotides, etc.

As one example, transcription factors are known to regulate specific gene expression patterns in response to developmental and environmental stimuli. They form specialized multi-protein complexes to regulate gene expression and thus regulating cellular responses.

Thus, directly inhibiting or activating the function of a transcription factor requires specific disruption or recruitment or protein-protein or protein-DNA interactions. Therefore, the methods disclosed in the present application can be used to screen small molecules that modulate these interactions and thus will have implications in various human cancers and to develop probes for understanding the role of transcription factors in various cancers. Various transcription factors such as NF κ B, JNK, STAT1, STAT2, FOXO, Sox2, SP1, RXR, RAR, Myc, Max, MAPK, HNF4, VDR among others and their interactions can be studied with the disclosed methodology.

Signaling pathways are a rich source of therapeutic targets comprised of association and dissociation of protein complexes. Signal transduction therapy has become an important area of drug research. Signaling disorders represent a major cause for various known pathological states. A number of recently identified validated target peptides of drug research are signal transduction related macromolecules. The presently disclosed methodology can be utilized to study inhibitors of known signaling complexes.

Heat shock protein –Hsp90 is one of the most abundant proteins in eukaryotic cell, comprising 1-2% of total proteins under non-stress conditions. Hsp90 interacts with and stabilizes various kinases such as ErbB2, Src, Abl, Met tyrosine kinases, cyclin dependent serine kinases among others which are key members of malignant transformation. Further, Hsp90 is also necessary for the maturation of several transcription factors, like the nuclear hormone receptors and the hypoxia-inducible factor-1. Thus, assays of Hsp90 inhibitor causing the release of the complex partner and subsequent degradation can be done using the presently disclosed methodology.

Apoptosis, or programmed cell death, is a normal component of the development and health of multicellular organisms. Cells die in response to a variety of stimuli and during apoptosis they do so in a controlled, regulated fashion. This makes apoptosis distinct from another form of cell death called necrosis in which uncontrolled cell death leads to lysis of cells, inflammatory responses and, potentially, to serious health problems. Direct initiation of apoptotic mechanisms in mammals have been suggested through TNF-induced path and the Fas induced path. Following TNF-R1 and Fas activation in mammalian cells a balance between pro-apoptotic (BAX, BID, BAK, or BAD) and anti-apoptotic (Bcl-Xl and Bcl-2)

members of the Bcl-2 family is established. The presently disclosed methodology can be exploited to study various interactions leading to apoptosis.

Kinases are of great significance, such as tyrosine kinases, the MAP kinases, the cyclin dependent kinases, GTP kinases, ser/thr kinases, Chk1 and 2, etc and can be studied
5 with the presently disclosed methodology.

Further, the methodology can be extended to neuronal proteins, such as β -amyloid, TNF, prion, APP, transporters, e.g. dopamine transporter, receptors, such as NMDA receptors, AMDA receptors, dopamine receptors, channels, etc.

In some instances, housekeeping proteins will be of interest, such as the proteins
10 involved in the tricarboxylic acid cycle, the Krebs cycle, glycogenesis, etc.

The present methods and materials can be used to study diseases known to be caused by the degradation/destabilization of mutated proteins. For example, in lysosomal storage disorder (LSD), genetic mutations may cause a lysosomal enzyme to be misfolded [Brooks, D.A. Nat. Chem. Biol. 3, 84-85 (2007)] thus rendering it unstable and unable to move within
15 the cell and function. [Römisch, K. Traffic. 5, 815-820 (2004).

Using the present assay, one can study the mechanism of LSD by the introduction of fusion protein (comprising the misfolded protein and labeling peptide) and then analyzing the effects of known/unknown small molecule drugs on the stabilization of fusion protein. Thus, the assay finds utility in diseases resulting from the mutated proteins like SOD1 (associated
20 with ALS), p53 (associated with cancer). Alanine glyoxylate aminotransferase (associated with primary hyperoxaluria type 1), SMN1 (associated with spinal muscular atrophy) and can be an important tool to elucidate mechanism of action and to screening assay for small molecule drug candidates.

The present assay also finds utility in determining the half-life of mutated target
25 peptide. Mutated peptide can be fused to a labeling peptide and a time-dependent activity can be detected in the presence and absence of binding partner to determine the half-life. Methods for measuring protein half lives can be derived using the present methods, or other, different methods known in the art. See, e.g. Yewdell et al., "Out with the old, in with the new? Comparing methods for measuring protein degradation," Cell Biol Int 35:457 (2011)

The composition, methods and assays disclosed also find utility to study proteins with tandem repeats in the sequence. Proteins with tandem repeats have a variety of binding properties and are known to be involved in protein-protein interactions and thus the studies will have great implications in elucidating the nature of known and unknown interactions, sequences involved in the interactions, compounds specific for tandem repeat structures.

Binding sites

From the above discussion of possible target peptides, it is clear that various binding sites may be used in the present assay. Examples are (a) an ATP (nucleotide) binding site, (b) a bromodomain sequence, (c) a catalytic site or (d) an allosteric site.

The ATP-binding motif, also called the Walker motif, is a structural protein motif that is frequently found in proteins that bind ATP or GTP. It can usually be identified from just the primary structure of a protein using a fingerprint sequence that characterizes proteins as ATP or GTP-binding (see GTP-Binding Proteins). Walker et al. (1) identified two regions of sequence conservation: the A region has a stretch of small hydrophobic residues followed by [Gly/Ala]—X—X—Gly—X—Gly —Lys—Thr/Ser, where X is any residue. The second region of sequence conservation also has a stretch of small hydrophobic residues, this time ending in a conserved aspartate residue. In the three-dimensional structures of proteins having the ATP-binding motif, such as adenylate kinase, the hydrophobic residues of the A-region form a buried b-strand, and the glycine-rich region forms a loop, called the P-loop, that interacts with the phosphate of the bound nucleotide. The second conserved region codes for another hydrophobic b-strand, and the conserved aspartate is required for binding the magnesium ion that usually accompanies nucleotides bound to proteins.

As discussed above, transcription factors (including zinc finger proteins) bind to nucleotide sequences through binding sites on those molecules.

An allosteric binding site is generally defined as a site other than the protein's active site. Allosteric modulation is the regulation of proteins or enzymes by the binding of an effector molecule at the allosteric site (a site other than the proteins active site). Here, a fusion protein is constructed with a mutated peptide having an amino acid sequence other

than or in addition to the active binding site (i.e. an allosteric site) and introduced into the cell. Treating the cells with various molecules who participate in binding will help in identifying the allosteric modulators of known protein as they will bind to the proteins at the non-active site and will stabilize the proteins. Allosteric sites can be drug targets, such as in the case of GPCRs. exemplified below is allosteric binding to MEKK. Allosteric JNK inhibitors are also known. Methods for identifying allosteric sites for inclusion in the present assay are described further in Patent Application WO/2003/087051, "Methods for Identifying allosteric sites".

Bromodomain sequences are described in detail in the examples below. The bromodomain (BRD), which is the conserved structural module in chromatin-associated proteins and histone acetyltransferases, is the sole protein domain known to recognize acetyl-lysine residues on proteins. These sequences are known in the literature, and, e.g described in US 7,589,167 entitled "ZA loops of bromodomains."

The catalytic site of an enzyme, also referred to as the "active site", is the portion of the enzyme where the substrate is acted upon. For example, protein kinases are known to have a consensus pattern of about 10 amino acids in the catalytic site, as described in Prosite documentation PDOC 00100 ([http \(colon slash slash\) prosite.expasy.org/PDOC00100](http://prosite.expasy.org/PDOC00100)). As another example, a catalytic triad refers to the three amino acid residues found inside the active site of certain protease enzymes: serine (S), aspartate (D), and histidine (H). Further descriptions of catalytic sites on enzymes may be found at [http \(colon slash slash\)www \(dot\)ebi.ac.uk/thornton-srv/databases/CSA/](http://www.ebi.ac.uk/thornton-srv/databases/CSA/), the EMBL catalytic site atlas.

The catalytic site of an enzyme is often found in a separate subunit. The catalytic subunits of protein kinases are highly conserved, and several structures have been solved.

Kits

Also provided by the subject invention are kits for use in practicing one or more of the above described applications. In certain embodiments, kits at least include a cell that expresses, either constitutively or inducibly, fusion protein that include a target protein and a β -galactosidase fragment, as reviewed above. In certain embodiments, kits include elements

for making such cells, e.g., nucleic acids encoding fusion protein present on vectors and/or nucleic acids encoding β -galactosidase fragment to which proteins of interest can be fused using standard molecular biology techniques, as reviewed above. The kits may further include one or more additional components which find use in practicing certain embodiments
5 of the invention, including but not limited to enzyme substrate, cell growth media, etc.

In certain embodiments, the present kits include (a) a cell comprising: a first fusion protein comprising the target protein and ED fragment of β -galactosidase, (b) EA fragment of β -galactosidase and (c) β -galactosidase substrate.

In certain embodiments, the kit may include (a) a cell comprising: a fusion protein
10 comprising the target and ED fragment of β -galactosidase fragment; (b) EA fragment of β -galactosidase; and (c) a β -galactosidase substrate.

Also provided are kits that include (a) a cell comprising: a fusion protein comprising the target and ED fragment of β -galactosidase fragment; compound, (b) EA fragment of β -galactosidase; and (c) a β -galactosidase substrate.

Also provided are kits that include (a) a cell comprising: a fusion protein comprising
15 the target and ED fragment of β -galactosidase fragment; small molecule, (b) EA fragment of β -galactosidase; and (c) a β -galactosidase substrate.

Also provided are kits that include (a) a cell comprising: a fusion protein comprising the variant sequence lengths of target and ED fragment of β -galactosidase fragment; (b) EA
20 fragment of β -galactosidase; and (c) a β -galactosidase substrate.

Also provided herein are kits comprising an expression construct encoding a fusion protein comprising a target peptide fused to an ED fragment of β -galactosidase.

In certain embodiments, the vector comprises a restriction site positioned on a vector such that when a protein coding sequence is inserted into the vector using the restriction site,
25 the vector encodes a fusion protein of the target and the β -galactosidase fragment. In certain embodiments, the kit further comprises a mammalian cell.

In addition to the above components, the subject kits may further include instructions for practicing the subject methods. These instructions may be present in the subject kit in a

variety of forms, one or more of which may be present in the kit. One form in which these instructions may be present is as printed information on a suitable medium or substrate, e.g., a piece or pieces of paper on which the information is printed, in the packaging of the kit, in a package insert etc. Yet another means would be a computer readable medium, e.g., diskette, CD, etc., on which the information has been recorded. Yet another means that may be present is a website address which may be used via the internet to access the information at a removed site. Any convenient means may be present in the kits.

Experimental

The following examples are intended to illustrate but not limit the invention.

10 Example 1: Use of binding assay to monitor interaction interfaces

Kinases bind ATP and catalyze the transfer of phosphate to target proteins. A general method of inhibiting kinase function is to apply a small molecule that blocks ATP binding to the target kinase. In this manner the compound is termed ATP-competitive.

To carry out the studies, fusions were made between the BLK and ProLabel.

15 The BLK (241-490)-PL amino acid sequence is shown below (SEQ ID NO. 7). The amino acid numbers 241-490 of the BLK (full length being 505 amino acids at GenBank Locus NP_001706) are shown within the sequence. The PL sequence is underlined, and the nucleotide binding sequence is bolded. The kinase domain is included in the sequence.

20 M-(241)LRLVRK**LGSGQFG**EVWMGYKNNMKVAIKTLKEGTMSPEAFLGEANVMKALQ
HERLRLYAVVTKEPIYIVTEYMARGCLLDFLKTDEGSRLSLPRLIDMSAQIAEGMAYIERMN
SIHRDLRAANILVSEALCCKIADFGLARIIDSEYTAQEGAKFPIKWTAPEAIHFGVFTIKADVW
SFGVLLMEVVITYGRVPYPGMSNPEVIRNLERGYRMPRPDTCPELYRGVIAECWRSRPEERP
TFFFLQSVL(490)-SSFELLESSNSLAVVLQRRDWENPGVTQLNRLAAHPPFASWRNSEE
ARTDR (SEQ ID NO. 7).

25 A number of fusions were constructed that included varying amounts of the protein sequence centered around the kinase active site as defined by homology to other kinases. E.g. fusion containing protein BLK amino acid numbers 241-494, 246-494, 251-494, 256-494, 261-494 and 266-494 were made.

The expression construct containing the fusion protein was used to transduce the HEK cells. The cells were then incubated in the presence of dasatinib for 3 hours.

BLK-PL fusions were then quantified by adding lysis buffer, EA and chemiluminescent substrate. It was found that a fusion with the 241-494 amino acid residues showed the highest affinity with dasatinib. Dasatinib, *N*-(2-chloro-6-methylphenyl)-2-[[6-[4-(2-hydroxyethyl)-1-piperazinyl]-2-methyl-4-pyrimidinyl]amino]-5-thiazole carboxamide monohydrate, is an oral multi- BCR/ABL and Src family tyrosine kinase inhibitor approved for use in patients with chronic myelogenous leukemia (CML).

Results showing the binding of dasatinib to BLK containing amino acid sequence 241-494 are depicted in **Figure 3**. The expression plasmids (e.g. 241-494) indicated in the legend are named to show the amino acid locations of the start and stop of the BLK sequence used. The plasmids were used to transduce parental U2OS cells. The cells were then treated with dasatinib for 3 hrs and the BLK-PL fusions were quantified by adding lysis buffer, EA and chemiluminescent substrate. As can be seen, the 241-494 construct showed the most robust response.

Example 2: Use of binding assay to monitor small molecules as inhibitors of kinase interactions

PDL173955 is a small molecule known to complex with the C-Abl kinase domain. Foretinib (GSK1363089, XL880) is a small molecule MET and VEGFR2/KDR kinases inhibitor. Cells expressing the BLK-PL fusion were treated with the indicated ATP-competitive molecules for 6 hours. The cells were then lysed in the presence of EA and substrate; luminescence was measured 30 minutes later.

To carry out the binding assay to screen small molecules, fusions were made between the BLK and ProLabel, BLK-PL (SEQ ID NO. 7). The expression constructs were used to transduce HEK cells. The U2OS cell pools expressing the indicated BLK-PL fusion were shown to detect different affinity compounds (dasatinib, PD173955, XL-2880) by changes in efficacy and potency (**Figure 4**).

Example 3: Use of binding assay to monitor interaction of fusion protein with known compound and inhibition by small molecules

B-cell lymphoma-2 (BCL2) and BCL-X_L are anti-apoptotic proteins whose function is regulated by the binding of anti- or pro-apoptotic factors such as BAK (Bcl-2 homologous antagonist/killer).

As described in further detail in US 2008/0306127 entitled “Inhibiting the interaction of Bcl Proteins with binding partners,” the Bcl-2 family of proteins include both anti-apoptotic molecules, such as Bcl-2 and Bcl-XL, and pro-apoptotic molecules, such as Bax, Bak, Bid and Bad. Bcl-2 contributes to cancer cell progression by preventing normal cell turnover caused by physiological cell-death mechanisms. Members of the BCL-2 family of proteins represent key regulators of apoptosis, with pro-apoptotic (e.g., Bax, Bak, Bid, Bim, Noxa, Puma) and anti-apoptotic function (e.g., Bcl-2, Bcl-xL, Mcl-1). Selective and competitive dimerization between pro-and anti-apoptotic members of the family determines the fate of a cell given pro-apoptotic stimulus.

As is described below, truncating BCL2 will affect the stability of the protein. Various truncated BCL2 fragments can be synthesized containing varying amino acids or deletions, but containing the binding site of interest, which ordinarily will be a binding site where a small molecule, e.g. a drug candidate, will bind (see **Figure 1**). For example, Bcl-2 has separate binding sites that are responsible for homodimer and heterodimer formation. See, PNAS March 10, 2009 vol. 106 no. 10 3935-3940.

Interaction of BCL-2 with a peptide test compound (Bim, Bak, and Bax) was studied. Truncated peptides from Bim (SEQ ID NO. 8), Bak (SEQ ID NO. 9), and Bax (SEQ ID NO. 10) were fused to ProLabel (PL).

The amino acid sequence of the BIM fragment (SEQ ID NO. 8) (full length bim beta 5, 36 amino acids is at GenBank: AAT34900.1) is shown below:

MRPEIWIAQELRRIGDEFNA (SEQ ID NO. 8)

The amino acid sequence of the BAK fragment (SEQ ID NO. 9) is shown below:

GQVGRQLAIIGDDINR (SEQ ID NO. 9) full length Bak at GenBank: AAI10338.1, 153 amino acids)

The amino acid sequence of the BAX fragment (SEQ ID NO. 10) is shown below:

QDASTKKLSECLKRIGDELDS (SEQ ID NO. 10)(compare to full length Bax
5 epsilon at GenBank: AAD22706.1, 164 amino acids)

The BIM-PL fusion sequence is shown below (SEQ ID NO. 11):

MRPEIWIAQELRRIGDEFNASSFELLESSLAVVLQRRDWENPGVTQLNRLAAHPPF
AS WRNSEEARTDR (SEQ ID NO. 11)

The native BCL-2 was co-expressed with each of the ProLabel fusions in U2OS cells.
10 Small molecules that are reported to disrupt BCL-2 interactions were then applied to the cells and incubated overnight.

Addition of the compounds resulted in a significant loss-of-signal in all cases, but is most pronounced with the BCL-2-Bim interaction which incidentally is the highest affinity reaction (**Figure 7A-C**). Cells were transduced with the indicated target PL-fusion and the
15 untagged protein Bcl-2. The cells were treated with the indicated compounds overnight and the remaining target-PL fusion was detected by lysing the cells in the presence of EA and substrate. Luminescence was measured 30 minutes later. The following tables relate to the **Figures 7A-C**:

20 7A: Compound [M]

	ABT-263	ABT-737
Best-fit values		
Bottom	5900	6973
Top	31800	31292
LogEC50	-8.329	-8.423
HillSlope	-1.216	-1.485
EC50	4.683e-009	3.779e-009

S/B = 14.0

5.5

7B Compound [M]

	ABT-263	ABT-737
Best-fit values		
Bottom	6740	7774
Top	136900	139290
LogEC50	-8.221	-8.363
HillSlope	-1.635	-1.898
EC50	6.011e-009	4.335e-009

S/B = 66.5 26.1

5

7:

7C Compound [M]

	ABT-263	ABT-737
Best-fit values		
Bottom	-14342	5446
Top	11081	11602
LogEC50	-4.378	-7.191
HillSlope	-0.4082	-0.5348
EC50	4.192e-005	6.437e-008

S/B = 5.1 2.1

10

Figure 7B shows that addition of ABT263 (small molecule dual Bcl-2/Bcl-xL inhibitor designed to restore apoptosis) and ABT 737 (small molecule mimicking Bcl-2 antagonist BH3) prevented the stabilizing effect of Bim on BCL-2. These compounds had a somewhat similar effect on BCL-2 stabilization of Bax (**Figure 7B**). These compounds had
15 little effect on BCL-2 binding to and stabilization of Bak (**Figure 7C**).

These experiments are run for a predetermined time sufficient to allow for the degradation of the PL-labeled binding peptide. This will vary with the peptide being studied,

but 3 to 6 hrs. or 6 to 8 hrs was found in many cases to be optimum. Generally, a 24 hr. or less incubation period will be sufficient to observe protein stabilization according to the present methods. In cases where the binding partner (e.g. Bcl-2) and the PL-target are already bound together in the cell, sufficient time must be allowed for the small molecule to replace the peptide. The method also contemplates measuring responses at different concentrations of test compound and measurements with controls.

Example 4: Use of binding assay to detect allosteric modulators

MEK kinases (MEKKs) comprise a family of related serine-threonine protein kinases that regulate mitogen-activated protein kinase (MAPK) signalling pathways leading to c-Jun NH2-terminal kinase (JNK) and p38 activation, induced by cellular stress (e.g., UV and gamma irradiation, osmotic stress, heat shock, protein synthesis inhibitors), inflammatory cytokines (e.g., tumor necrosis factor alpha, TNF alpha, and interleukin-1, IL1) and G protein-coupled receptor agonists (e.g., thrombin). These stress-activated kinases have been implicated in apoptosis, oncogenic transformation, and inflammatory responses in various cell types.

Interactions of kinase inhibitor small molecule compounds (U0126 and PD0325901) with the MEK-PL fusion construct were studied using the presently disclosed assay. U0126 is a highly selective inhibitor of both MEK1 and MEK2, a type of MAPK/ERK kinase. U0126, (2Z,3Z)-2,3-bis(amino(2-aminophenylthio)methylene)succinonitrile, is known to be an allosteric inhibitor, binding outside binding outside the ATP- and ERK1 /2- binding sites on MEK1 /2.

PD0325901((R)-N-(2,3-dihydroxypropoxy)-3,4-difluoro-2-(2-fluoro-4-iodophenylamino)benzamide) is a selective and non ATP-competitive mitogen activated protein kinase kinase (MEK or MAPKK) MEK inhibitor.

Truncated MEK peptide containing amino acids 58-371 (see NCBI Ref SEQ NP_002746.1) was fused with the PL (SEQ ID 12). The MEK (58-371)-PL sequence is shown in (SEQ ID NO. 12). This contains the catalytic domain. The PL portion is underlined.

MQKVGELKDDDFEKISELGAGNGGVVFKVSHKPSGLVMARKLIHLEIKPAIRNQIIRE
 LQVLHECNSPYIVGFYGAFYSDGEISICMEHMDGGSLDQVLKKAGRIPEQILGKVSIAVIKG
 LTYLREKHKIMHRDVKPSNILVNSRGEIKLCDFGVSGQLIDSMANSFVGTRSYMSPERLQ
 GTHYSVQSDIWSMGLSLVEMAVGRYPPIPPDAKELELMFGCQVEGDAAETPPRPRTPGRPLS
 5 SYGMDSRPPMAIFELLDYIVNEPPPKLPSGVFSLEFQDFVNKCLIKNPAERADLKQLMVHAFI
 KRSDAEEVDFSSFELLESLAVVLQRRDWENPGVTQLNRLAAHPPFASWRNSEEARTDR
 (SEQ ID NO. 12)

The constructs were then expressed in various cell types including HEK (**Figure 8A**),
 CHO (**Figure 8B**) and U2OS (**Figure 8C**) cells. Kinase inhibitors U0126 and PD0325901
 10 were then applied to the cells.

Binding of the compound resulted in a significant increase in the active β -
 galactosidase enzyme formation, giving us an indication that the compounds (known as
 kinase inhibitors) bound to the allosteric site rather than the active site (**Figure 8A-C**).

Example 5: Use of binding assay to monitor the specificity of binding compounds

15 Dasatinib (a known ATP-competitive molecule) and U0126 and PD0325901 (known
 kinase inhibitors) were used to determine their specificity for ATP binding and non-ATP
 binding sites respectively.

Truncated MEK peptide containing amino acids from 58-371 and BLK peptide
 containing amino acids from 241-494 were fused with the PL. Expression construct
 20 containing MEK fusions were used to transduce CHO cells and incubated with dasatinib,
 U0126 and PD035901. A gain in signal was observed with U0126 and PD035901 as
 compared to the cells incubated with dasatinib over a period of time (**Figure 9A**).

In the second part of the experiment, expression constructs containing BLK fusions
 were used to transduce U2OS cells and incubated with dasatinib, U0126 and PD035901. A
 25 gain in signal was observed with dasatinib compared to the cells incubated with U0126 and
 PD035901 over a period of time (**Figure 9B**).

As observed, dasatinib was specific for binding to the BLK fusion containing the ATP
 binding site and U0126 and PD035901 (kinase inhibitors) were specific for binding to the
 allosteric sites regulating the protein function.

Example 6: Use of binding assay to study bromodomains

Bromodomain proteins are known as epigenetic reader proteins and play an important role in the targeting of chromatin-modifying enzymes to specific sites. BRD4, for example, contains two bromodomains, a conserved sequence motif which may be involved in chromatin targeting.

To study the effect of compound binding, fusion proteins were prepared using fragments of BRD4 (1) (Accession No. NM_058243), BRD2 (1) (Accession No. NM_005104) and BRDT (1) (Accession No. NM_001242806) (SEQ ID NO. 13, 14 and 15 respectively) and prolabel (PL). The expression construct containing the fusion proteins were used to transducer the HEK cells. Cells were plated in a 384 well-plate and incubated overnight at 37°C/5% CO₂ to allow the cells to attach and gro. These sequences are listed as follows:

BRD4(1) (SEQ ID NO. 13), ED portion underlined for clarity

MKVSEQLKCCSGILKEMFAKKHAAYA WPFYKPVDVEALGLHDYCDIIKHPMDMSTI
KSKLEAREYRDAQEFGADVRLMFSNCYKYNPPDHEVVAMARKLQDVFEMRFAKMPSSFEL
LESS NSLAVVLQRRDWENPGVTQLNRLAAHPPFASWRNSEEARTDR

BRD2(1) (SEQ ID NO. 14) ED portion underlined for clarity

MRVTNQLQYLHKVVMKALWKHQFA WPFQRPVDAVKLGLPDYHKIIKQPMDMGTI
KRRLENNYYWAASECMQDFNTMFTNCYIYNKPTDDIVLMAQTLEKIFLQKVASMPQEEQEL
VSSFELLESSLAVVLQRRDWENPGVTQLNRLAAHPPFASWRNSEEARTDR

BRDT(1) (SEQ ID NO. 15) ED portion underlined for clarity

MLTNQLQYLQKVVLKDLWKHSFSWPFQRPVDAVKLQLPDYYTIKNPMDLNTIKKR
LENKYYAKASECIEDFNTMFSNCYLYNKPGDDIVLMAQALEKLFMQKLSSFELLESSLAV
VLQRRDWENPGVTQLNRLAAHPPFASWRNSEEARTDR

The cells were then exposed to a control compound (JQ1) and incubated for 6 hrs at 37°C. the fusion proteins were then quantified by adding lysis buffer, EA and detection substrate and an increase in stability of fusion protein was observed following compound binding.

5 Further, the assay can also be applied to proteins which consist of bromodomains as tandem domains (BRD-BRD, PHD-BRD or BRD-PHD) which are tightly associated with each other in sequence. To carry out the binding assays-fusions were prepared between BRDT (tandem) and BRD (3) (tandem, SEQ ID NO. 16) with -PL.

BRD3(1-403)-PL (SEQ ID NO. 16)

10 MSTATTVAPAGIPATPGPVNPPPPEVSNPSKPGRKTNQLQYMQNVVVKTLWKHQFA
WPFYQPVDAIKLNLDPDYHKIKNPMDMGTIKKRLENNYYWSASECMQDFNTMFTNCYIYNK
PTDDIVLMAQALEKIFLQKVAQMPQEEVELLPAPKGKGRKPAAGAQSAGTQQVAAVSSVS
PATPFQSVPPTVSQTPVIAATPVPTITANVTSPVPPAAAPPPPATPIVPVVPPTPPVVKKKGVK
RKADTTTPTTSAITASRSESPPPLSDPKQAKVVARRESGGRPIKPPKKDLEDGEVPQHAGKKG
15 KLSEHLRYCDSILREMLSKKHAAYA WPFYKPVDAAEALHDYHDIKHPMDLSTVKKRMDG
REYPDAQGFAADVRLMFSNCYKYNPPDHEVVAMARKSNCCISFELLESSLAVVLQRRDW
ENPGVTQLNRLAAHPPFASWRNSEEARTDR

Following the above mentioned experimental conditions and control compound (JQ1) fusion proteins were quantified for the stability and an increase in the half-life (stability) was
20 observed in tandem repeat domains following compound binding.

Example 7: Use of binding assay to study the effect of compound binding on half-life of a transferase enzyme in a cell

Methyltransferases are a group of transferases enzymes involved in DNA methylation. G9a methyltransferase methylates lysine 9 of histone H3 and is present in
25 humans. For the present assay, the catalytic domain of G9A methyltransferase (a.a. 918-1193, accession no. NM_006709) was fused at its C-terminus to PL tag (detection peptide, underlined below) (SEQ ID NO. 17).

G9A(918-1198)-PL (SEQ ID NO. 17), PL underlined for clarity

MTEKIICRDVARGYENVPIPCVNGVDGEPCPEDYKYISENCETSTMNIDRNITHLQHCTCVDD
 CSSSNCLCGQLSIRCWYDKDGRLLQEFNKIEPPLIFECNQACSCWRNCKNRVVQSGIKVRLQL
 YRTAKMGWGVRALQTIPQGTFIGEYVGELISDAEADVREDDSYLFDLDNKGDEVYCIDARY
 5 YGNISRFINHLCDPNIIPVRVFMLHQDLRFPRIAFFSSRDIRTGEELGFDYGDREWDIKSKYFTC
 QCGSEKCKHSAE AIALEQSRLARLDLSFELLESSLAVVLQRRDWENPGVTQLNRLAAHPP
FASWRNSEEARTDR

The enzyme donor PL fused to the catalytic domain of G9A was expressed in A549 cells, which were plated in a 384-well plate and incubated overnight at 37°C/5% CO₂ to allow
 10 the cells to attach and grow. Cells expressing fusion protein were divided into 2 batches, one serving as control and other treated with binding compound (UNC0638) for 6 hrs at 37°C. Both the batches were then treated with cycloheximide to prevent further protein production and the half-life of the fusion protein in both the batches were calculated as shown in **Figure 10**. As can be seen, after 100 minutes the percent change in luminescence of the UNC0638
 15 treated cells was minimal, while the cells treated with only cycloheximide had dropped approximately 50%. UNC0638 is commercially available and is an inhibitor of G9a/GLP methyltransferases. See, e.g. [http \(colon slash slash\) apps.thesgc.org/chemical_probes/UNC0638/#overview](http://apps.thesgc.org/chemical_probes/UNC0638/#overview), SGC product literature.

As also can be seen from the graph in **Figure 10**, the half-life of fusion-protein with
 20 binding partner (UNC 0638) is greater as compared to fusion protein not exposed to the binding partner, indicating that the truncated fragment having amino acids 918-1198 was destabilized.

Example 8: Use of binding assay to study Cytochrome P₄₅₀

Cytochrome P450 (CYPs) are a major class of enzymes participating in drug
 25 metabolism and thus also act as a marker in drug designing/discovery studies.

Catalytic domain of each CYP (CYP19A accession no. NM_000103; SEQ ID NO. 18 and CYP 17A, accession no. NM_000102; SEQ ID NO. 19) was fused at its C-terminus to the PL tag. HEK cells were transduced with fusion protein expression construct. The cells were then treated with different compounds for 3-6 hrs at 37°C. the fusion proteins were then
 30 quantified to analyze the effect of different compounds on the stabilization of fusion proteins.

The following best-fit values were obtained, and the data for CYP 17 A is shown in **Figure 11**, which shows stabilization of that domain with Ketoconazole and Abiraterone, with the following best fit data:

	Ketoconazole	Abiraterone
Best-fit values		
Bottom	1.230e+006	1.231e+006
Top	2.348e+006	2.516e+006
LogEC50	-7.988	-9.598
HillSlope	1.083	1.152
EC50	1.028e-008	2.522e-010

S/B = 1.9 2.0

5 CYP17 localizes to the endoplasmic reticulum. It has both 17 α -hydroxylase and 17,20-lyase activities and is a key enzyme in the steroidogenic pathway that produces progestins, mineralocorticoids, glucocorticoids, androgens, and estrogens. Ketoconazole is an imidazole medicine used to treat fungal infections. It binds to the fungal p450 enzymes, and is shown here to bind to CYP17a. Abiraterone, CAS 154229-19-3, is known to be a potent
10 CYP17 inhibitor

 Using CYP 19A amino acids 1-503, it was also found that anastrozole and YM511 stabilized that fusion peptide (data not shown). Arimidex ® anastrozole is available from AstraZeneca and is known to bind to aromatase. YM511 (chemical Name: 4-[[[4-Bromophenyl)methyl]-4H-1,2,4-triazol-4-ylamino]benzonitrile) is also an aromatase
15 inhibitor. CYP19 is also known as aromatase.

CYP17A (SEQ ID NO. 18), with ED underlined for clarity:

 MWELVALLLLTLAYLFWPKRRCPGAKYPKSLLSLPLVGSLPFLPRHGHMHNNFFKL
 QKKYGPIYSVRMGTKTTVIVGHHQLAKEVLIKKGKDFSGRPQMATLDIASNNRKGIAFADSG
 AHWQLHRRLAMATFALFKDGDQKLEKIICQEISTLCDMLATHNGQSIDISFPVFVAVTNVISLI
20 CFNTSYKNGDPELNVIQNYNEGIIDNLSKDSLVDLVPWLKIFPNKTLEKLKSHVKIRNDLLNKI
 LENYKEKFRSDSITNMLDTLMQAKMNSDNGNAGPDQDSELSDNHILTTIGDIFGAGVETTTTS
 VVKWTLAFLHNPQVKKKLYEEIDQNVGFSRTPTISDRNRLLLLEATIREVLRLRPVAPMLIP
 HKANVDSSIGFAVDKGTVEIINLWALHHNEKEWHQPDQFMPERFLNPAGTQLISPSVSYLPF

GAGPRSCIGEILARQEELFLIMAWLLQRFDLVPDDGQLPSLEGIPKVVFLIDSFKVKIKVRQAW
REAQAEGSTSSFELLESSLAVVLQRRDWENPGVTQLNRLAAHPPFASWRNSEEARTDR

CONCLUSION

5 The above specific description is meant to exemplify and illustrate the invention and
should not be seen as limiting the scope of the invention, which is defined by the literal and
equivalent scope of the appended claims. The citation of any publication is for its
disclosure prior to the filing date and should not be construed as an admission that the present
invention is not entitled to antedate such publication by virtue of prior invention. Further, the
dates of publication provided may be different from actual publication dates which may need
10 to be independently confirmed.

15

What is claimed is:

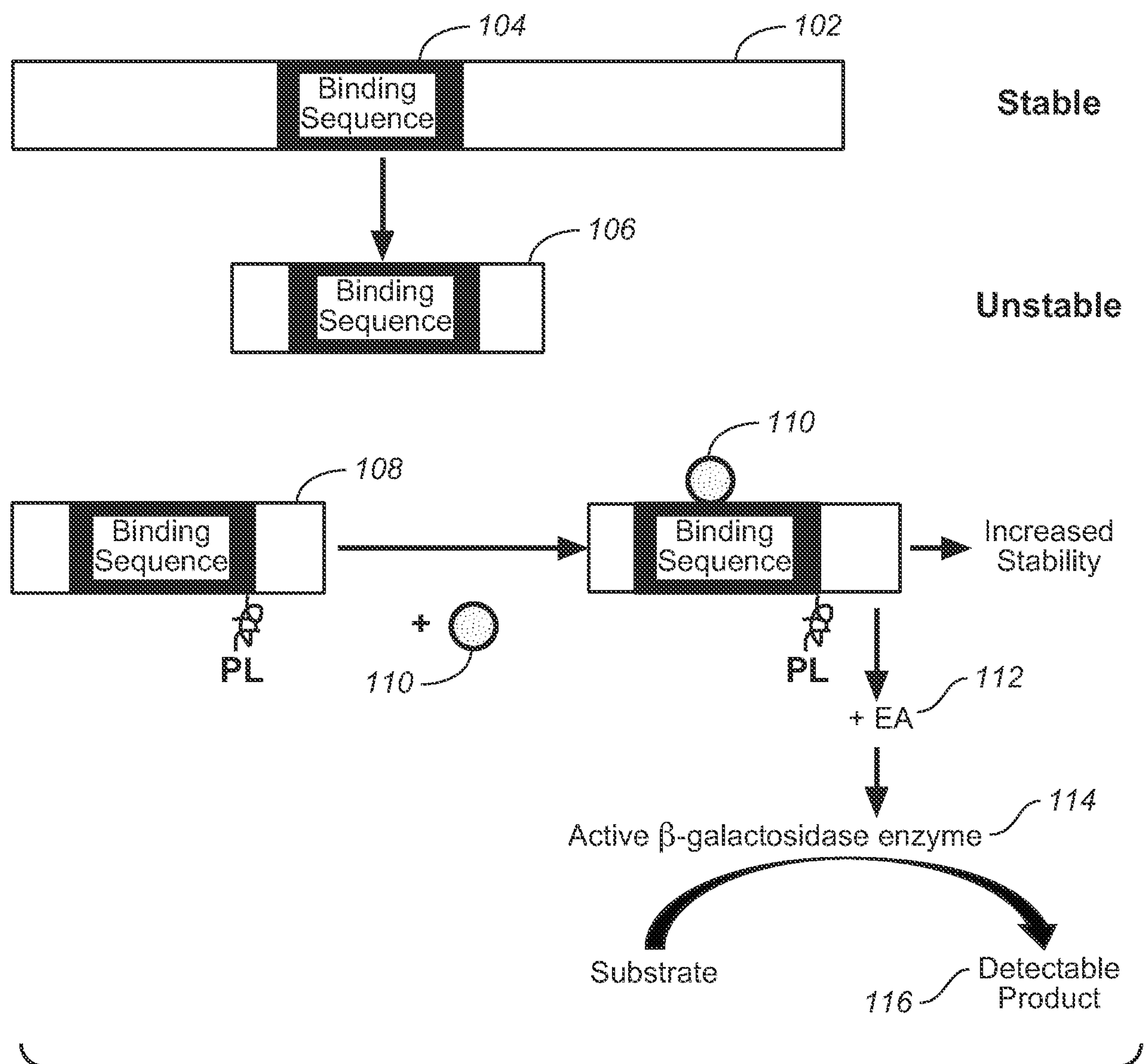
1. A method to assess binding of a compound to a binding site of a target peptide in a cell, comprising:
 - (a) providing in the cell a fusion protein comprising (i) a target peptide having a destabilizing mutation and (ii) a labeling peptide;
 - (b) incubating a mixture of the cell of (a) and the compound for a period sufficient to allow binding of the compound to the binding site of the target peptide and to allow for stabilization of the fusion protein by the binding, then
 - (c) combining the mixture from step (b) with a label that detects an amount of the labeling peptide remaining after incubating,

wherein a change in the amount of labeling peptide detected indicates binding of the compound to the target peptide.
2. The method of claim 1 wherein the compound is one of a small molecule, a peptide, or a full-length protein.
3. The method of claim 1 wherein the compound inhibits binding of the target peptide to a native ligand for the target peptide.
4. The method of claim 1 wherein the binding site is one of (a) an ATP binding site, (b) a bromodomain sequence, (c) a catalytic site or (d) an allosteric site.
5. The method of claim 1 wherein the labeling peptide is (a) an enzyme donor fragment of β -galactosidase, or (b) a peptide having a binding epitope for a secondary label.
6. The method of claim 5 wherein the labeling peptide is an enzyme donor ("ED") having a sequence according to one of SEQ ID NO: 1, SEQ ID NO: 2, SEQ ID NO: 3, or SEQ ID NO: 4.
7. The method of claim 6 wherein the labeling peptide is detected by an enzyme acceptor ("EA") that has a sequence according to SEQ ID NO: 5.
8. The method of claim 1 wherein the cell is a mammalian cell.

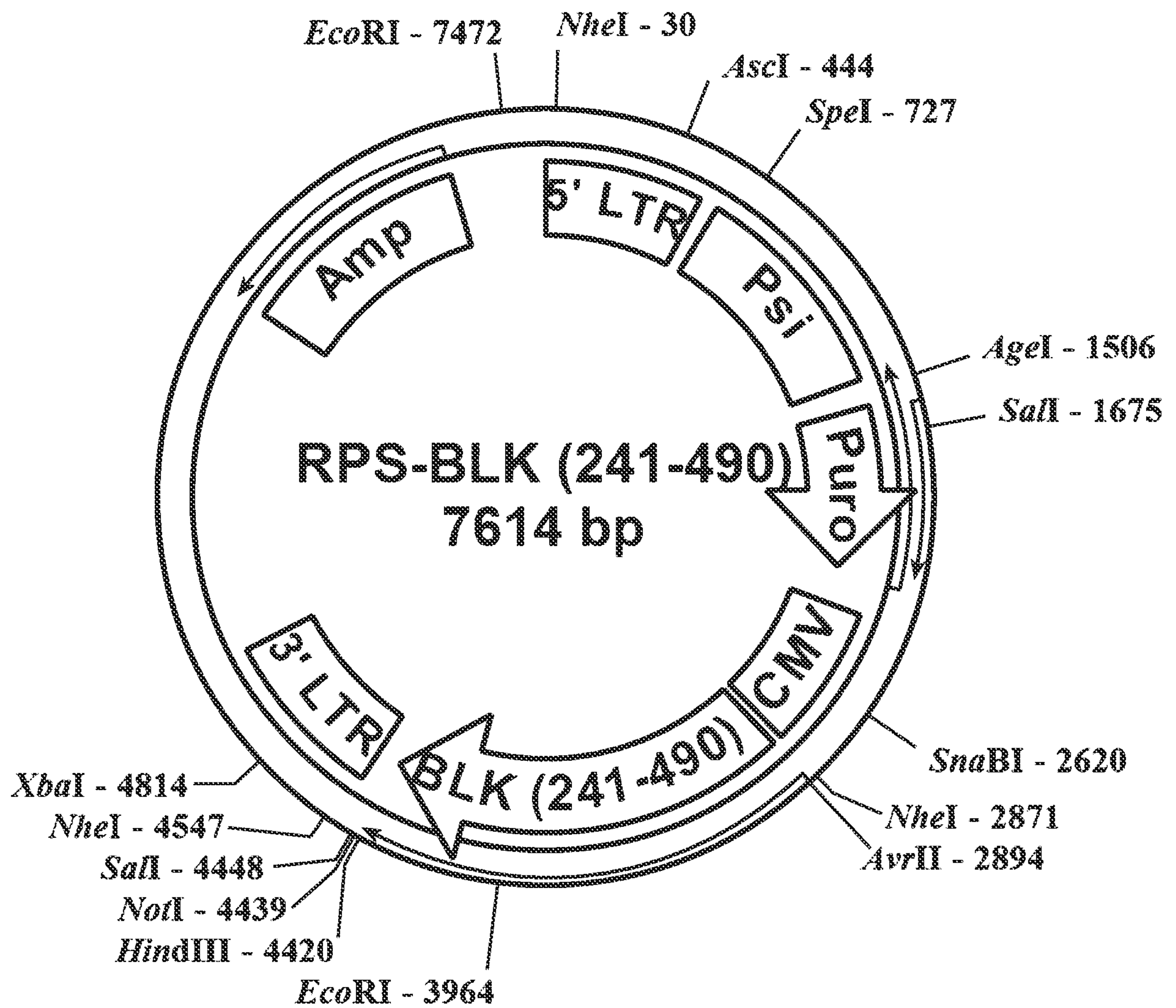
9. The method of claim 1 further comprising the step of carrying out steps (a) through (c) in the absence of the compound to provide a control for determining the change in the amount of labeling peptide detected.
10. The method of claim 1 wherein said target peptide comprises a mutation which is a truncation, said mutation being outside of the binding site.
11. The method of claim 1 wherein said target peptide comprises a mutation which is a deletion of at least ten percent of the sequence of the full length protein.
12. A method to assess a compound as binding to a binding site on target peptide in a cell, comprising:
 - (a) providing cells expressing a fusion protein comprising (i) said target peptide , having therein a destabilizing mutation, and (ii) a labeling peptide ;
 - (b) incubating a first number of cells from step (a) with said compound and a second number of cells from step (a) without said compound for a period sufficient to allow binding of the compound to the binding site of the target peptide and to allow for stabilization of the fusion protein by the binding of the compound, then
 - (c) adding to samples incubated in step (b) a label that detects an amount of the labeling peptide remaining in the cell after said incubating, whereby
 a difference in the amount of labeling peptide between the first number of cells and the second number of cells indicates binding of the compound to the target peptide.
13. The method of claim 12 wherein said compound is one of a small molecule, a peptide, or a full-length protein.
14. The method of claim 12 further comprising the step of adding a second compound that competes for binding with the compound of step (b).
15. The method of claim 12 wherein said binding site is one of (a) an ATP binding site, (b) a bromodomain sequence, (c) a catalytic site or (d) an allosteric site.

16. The method of claim 12 wherein said labeling peptide is (a) an ED or (b) a binding epitope for a labeling peptide.
17. The method of claim 16 wherein said labeling peptide is an ED having a sequence which is SEQ ID NO: 1, SEQ ID NO: 2, SEQ ID NO: 3, or SEQ ID NO: 4.
18. The method of claim 12 wherein said cell is a mammalian cell.
19. The method of claim 12 wherein said target peptide comprises a mutation which is a truncation, said mutation being outside of the binding site.
20. The method of claim 12 wherein said target peptide comprises a mutation which is a deletion, said mutation being outside of the binding site.
21. The method of claim 14 wherein said second compound is one of a small molecule, a peptide, or a full-length protein.

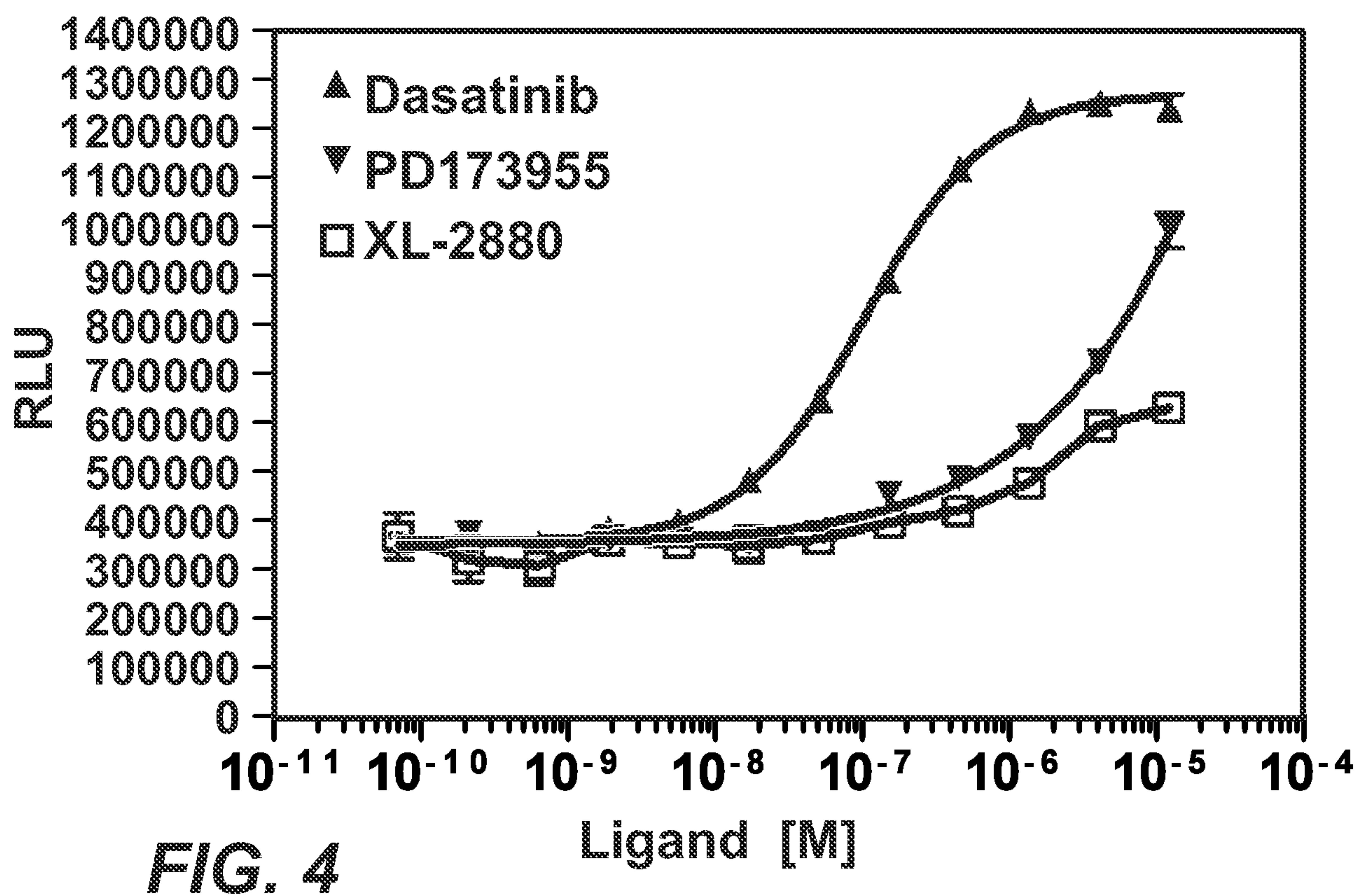
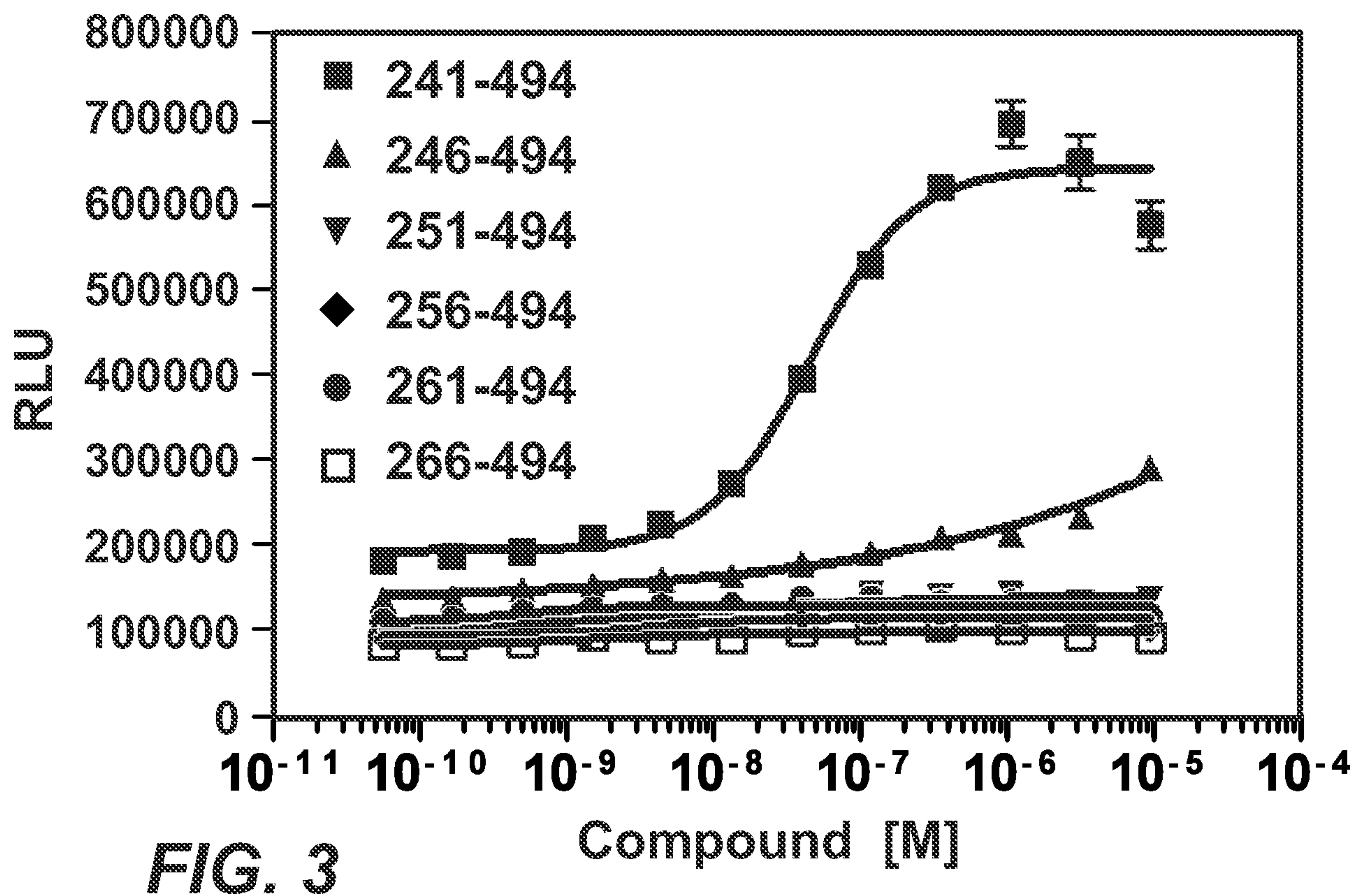
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**FIG. 1**

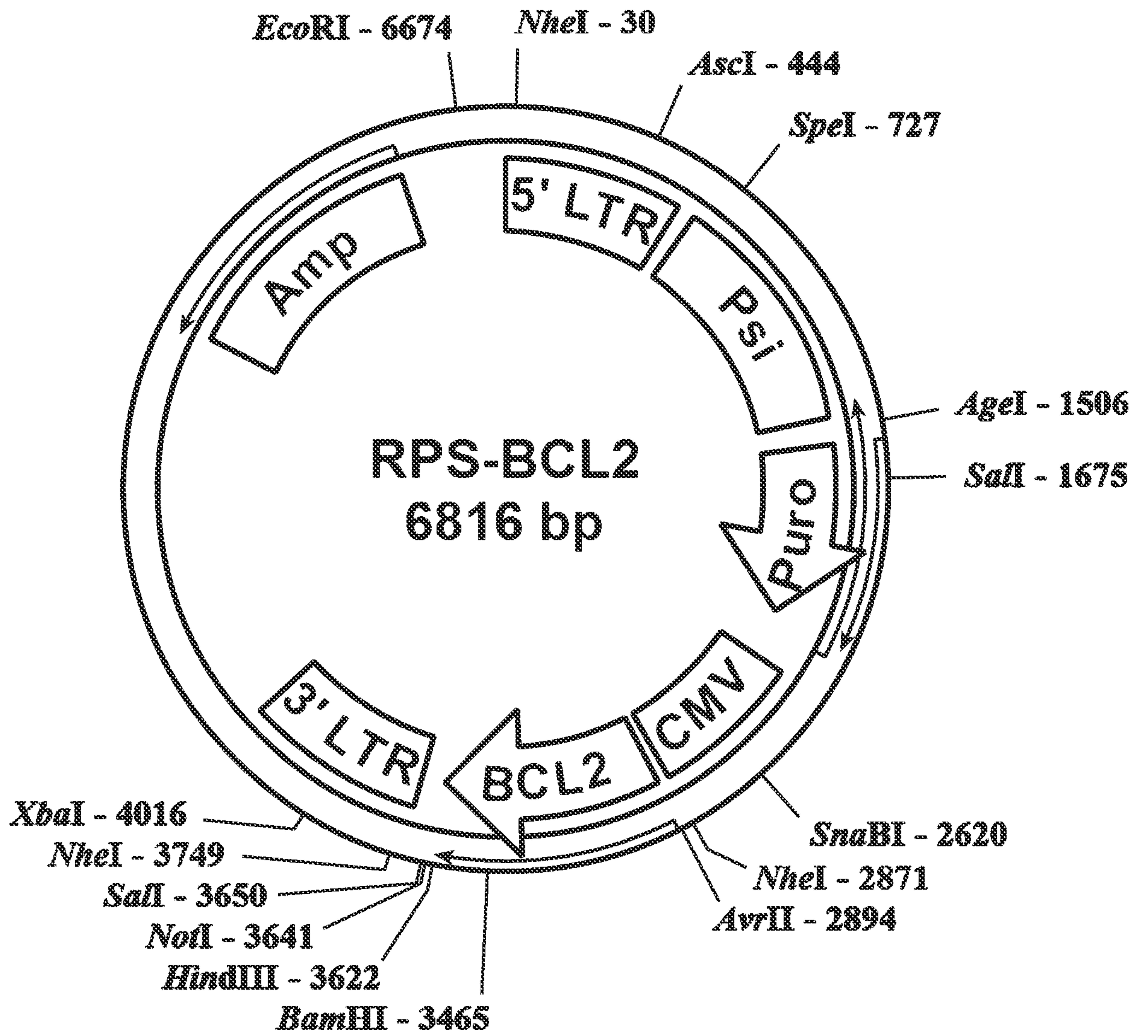
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**FIG. 2**

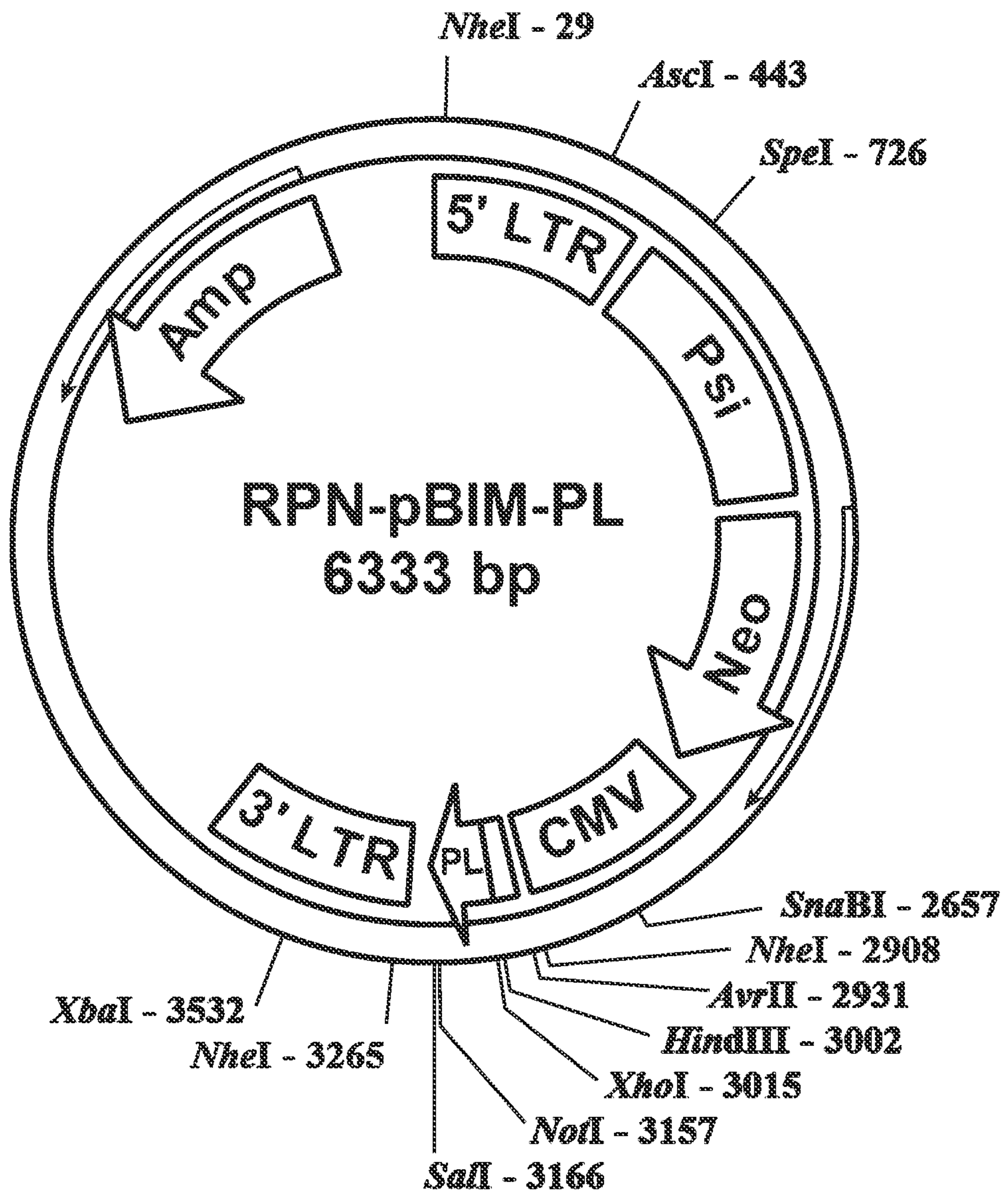
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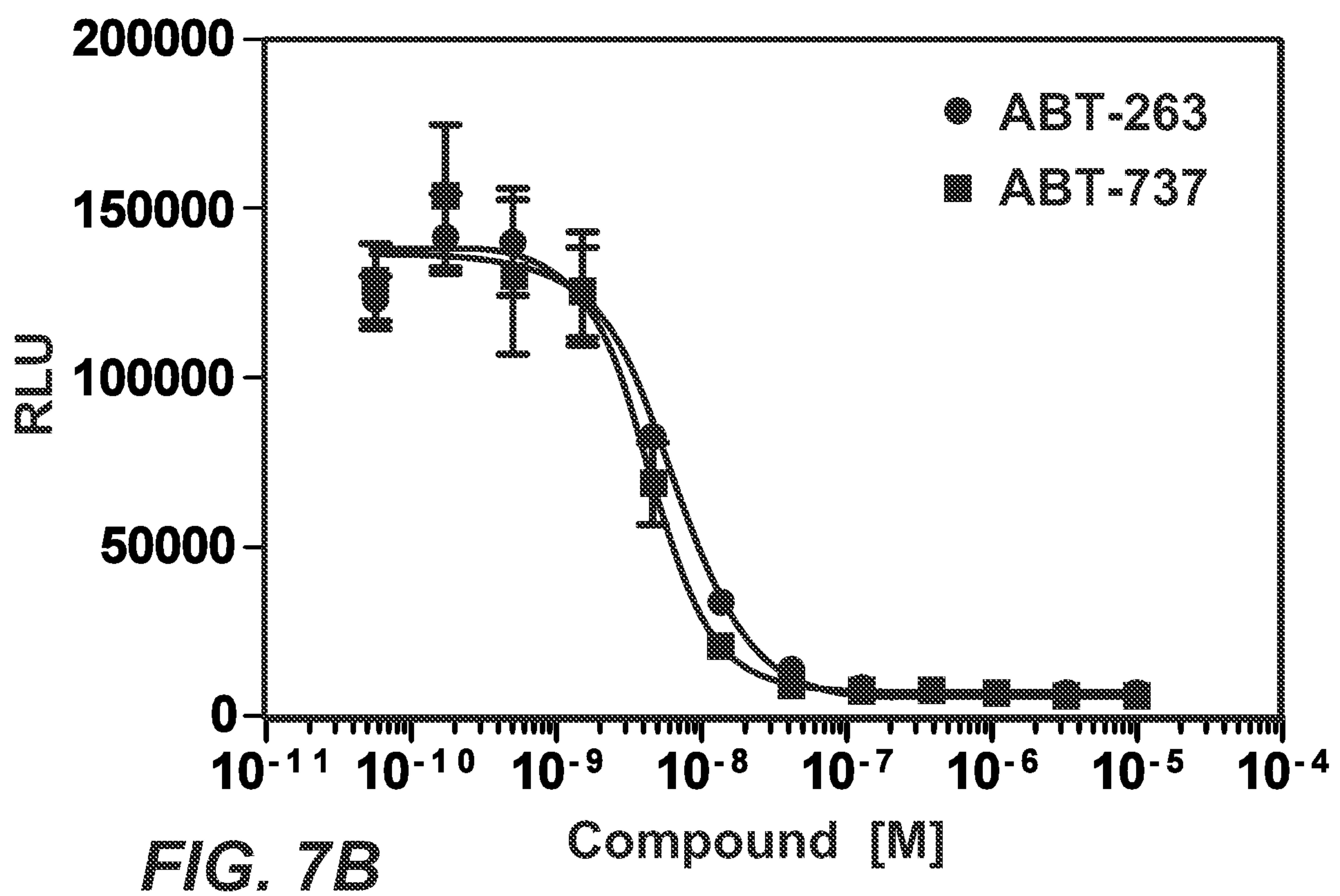
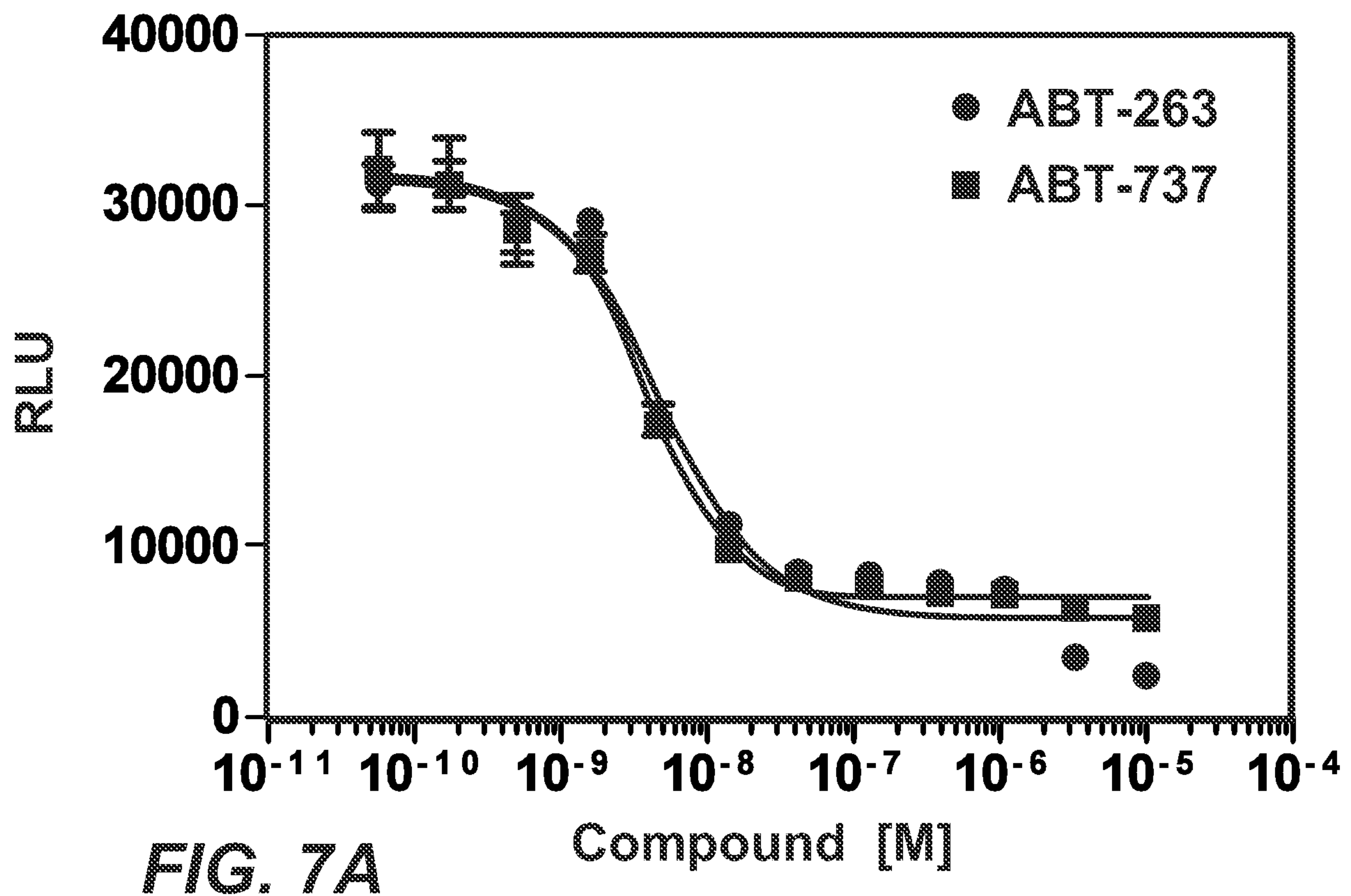
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**FIG. 5**

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**FIG. 6**

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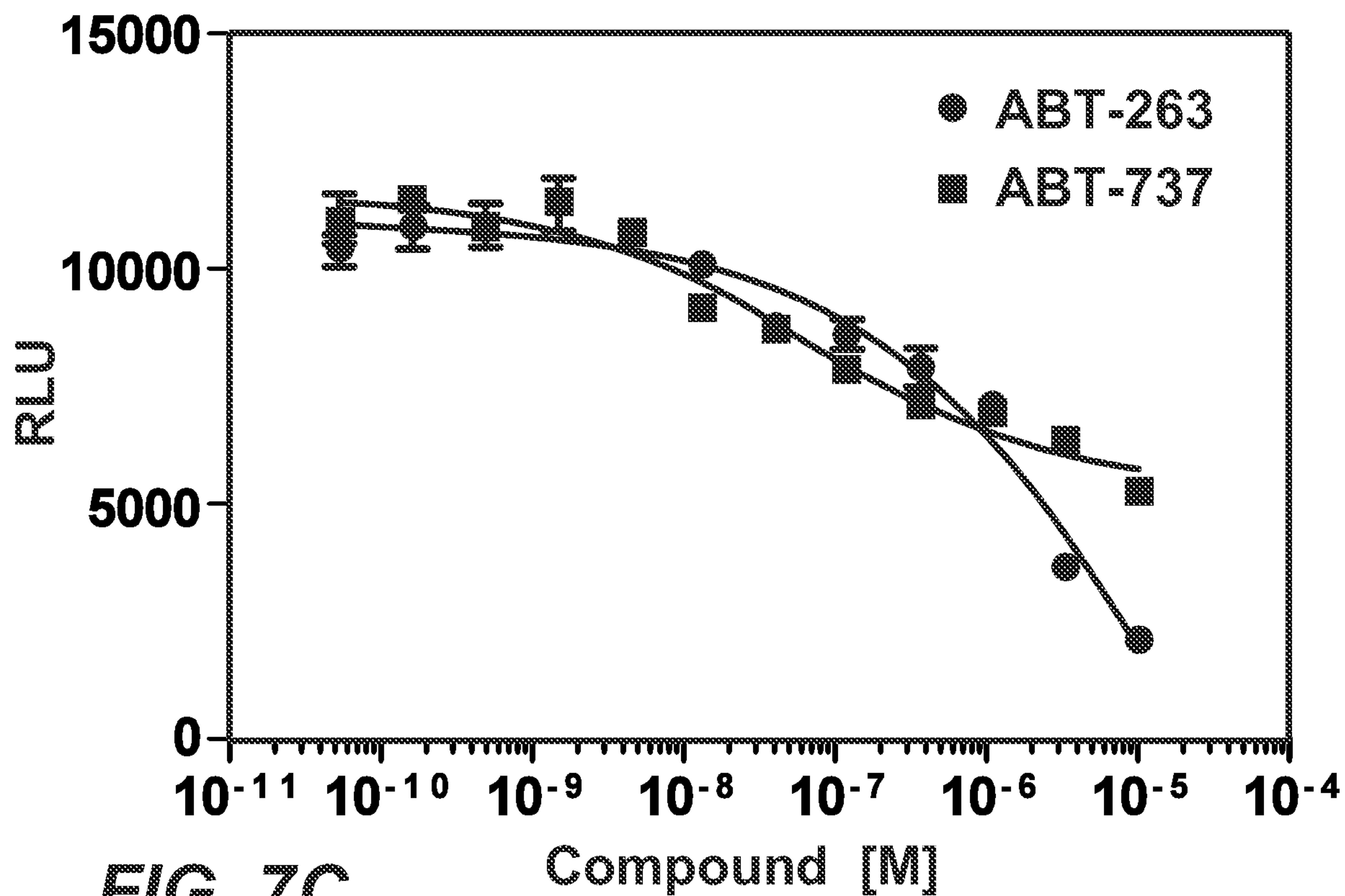


FIG. 7C

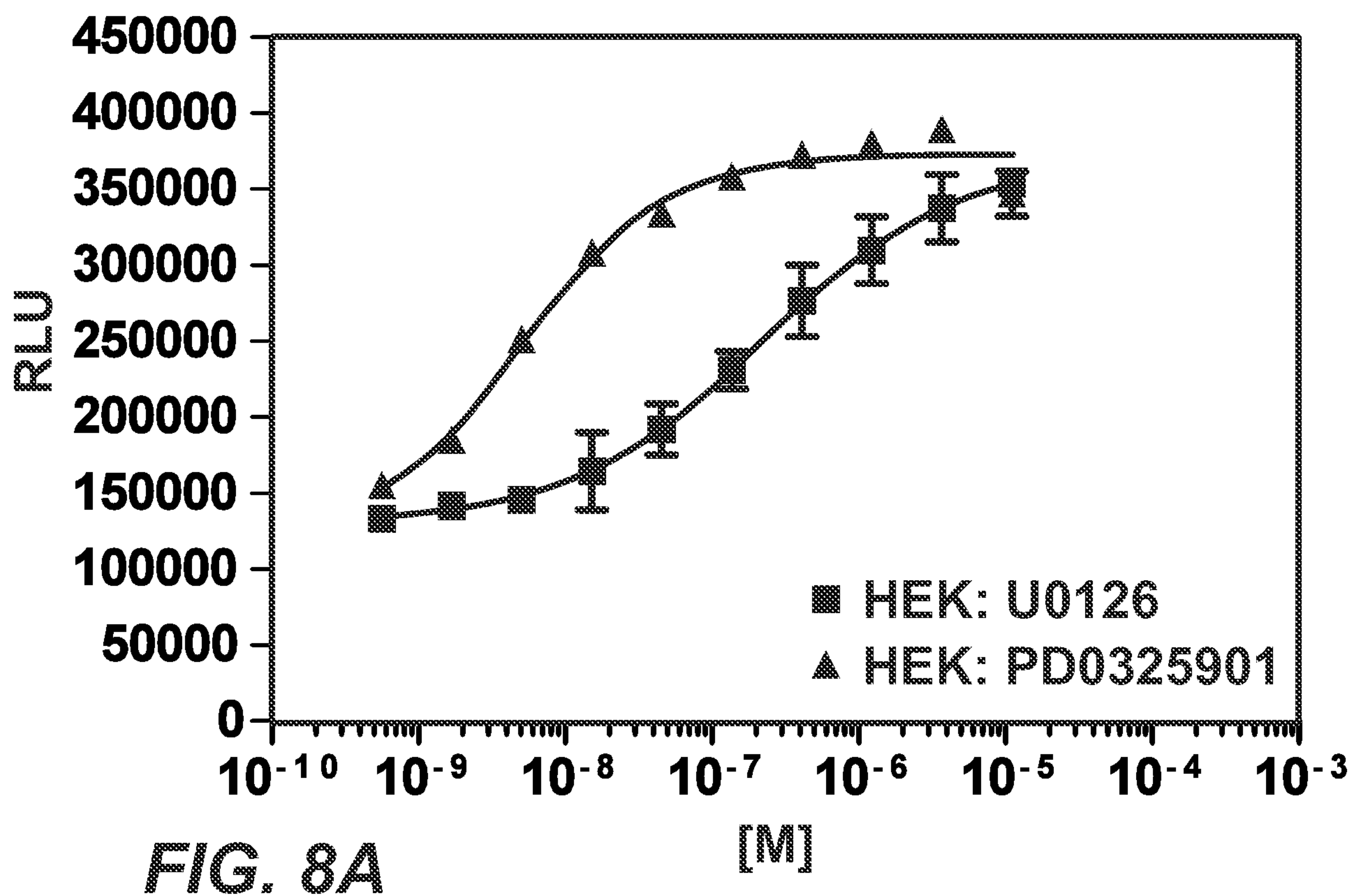
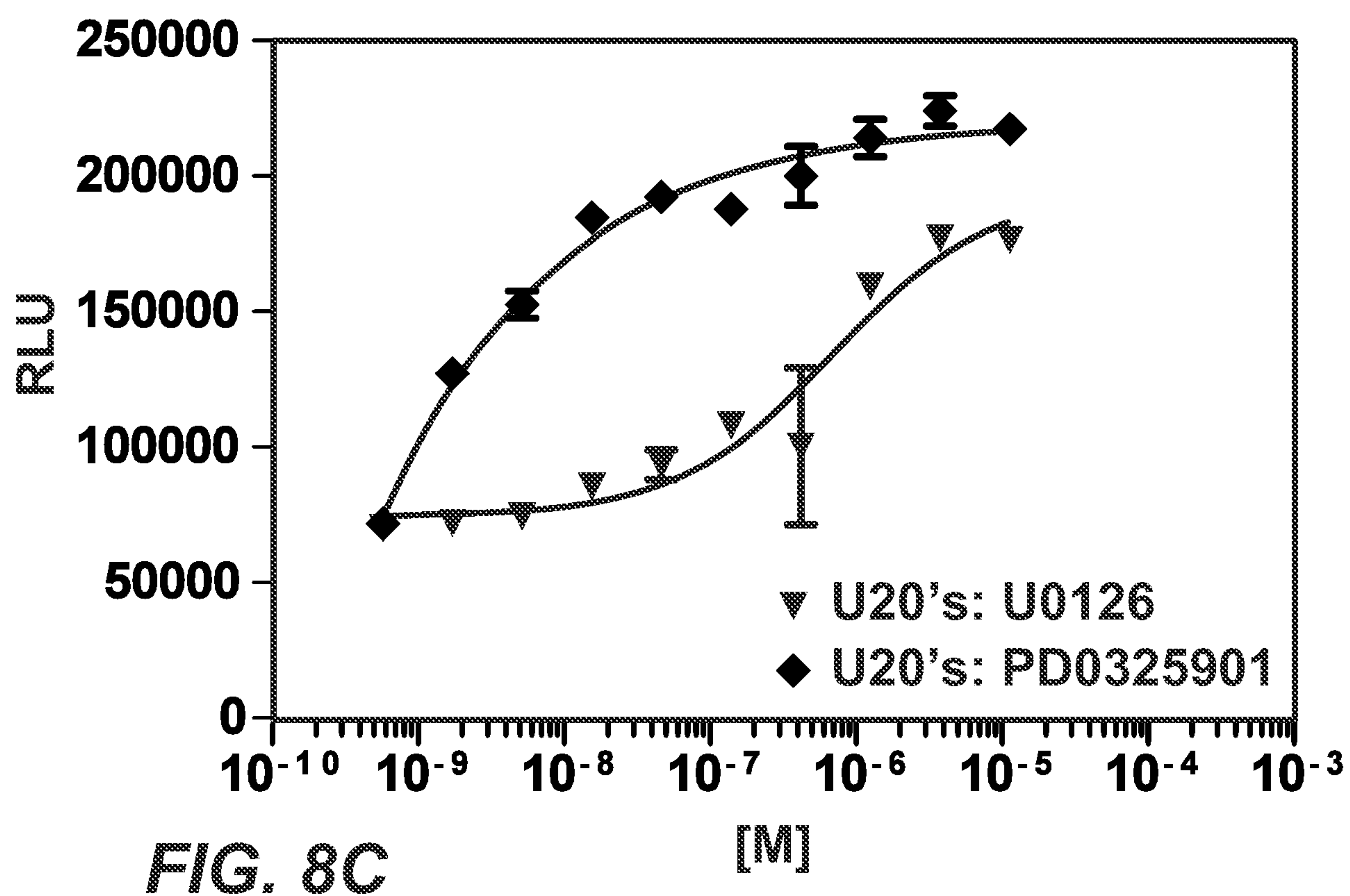
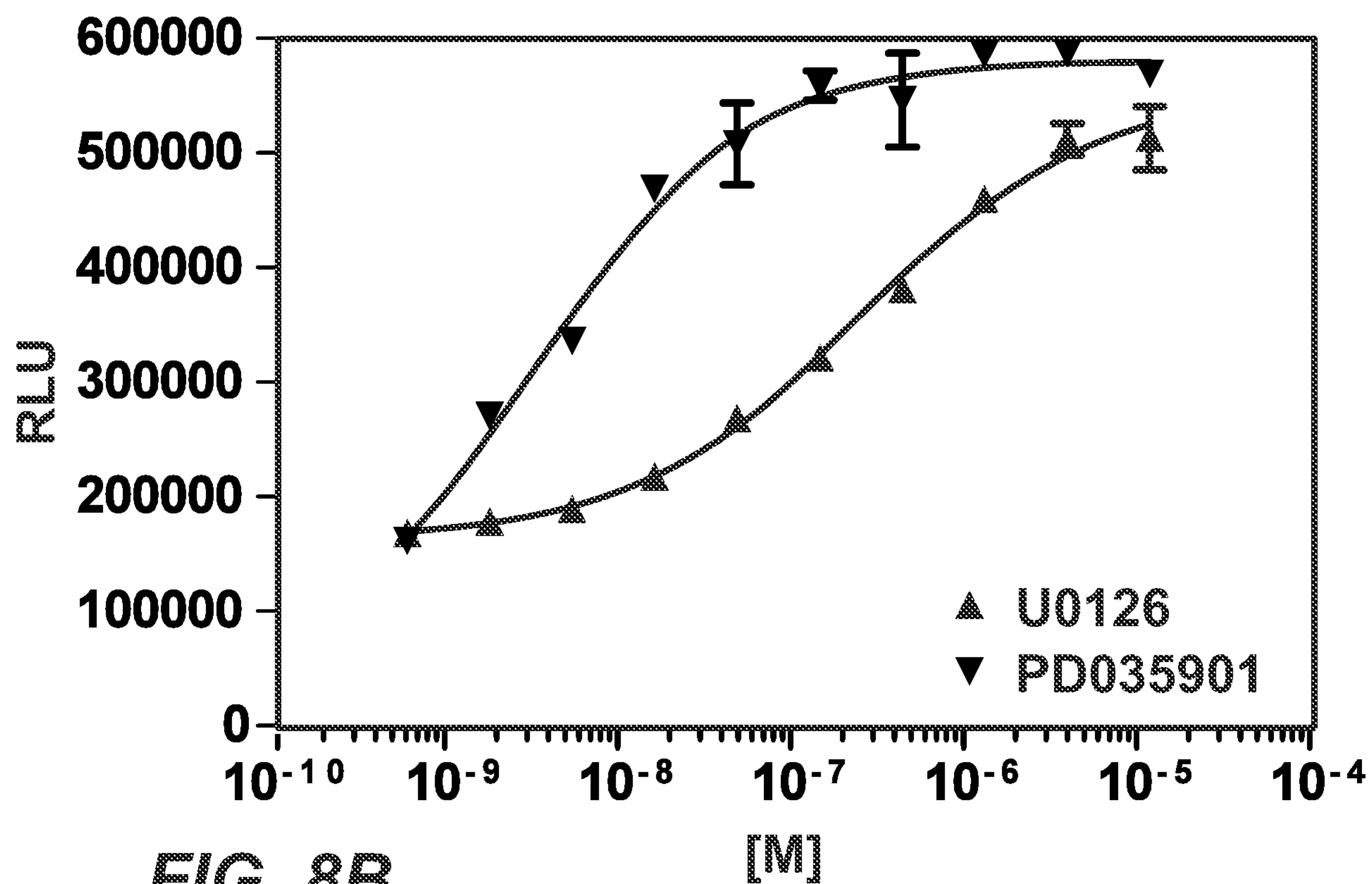
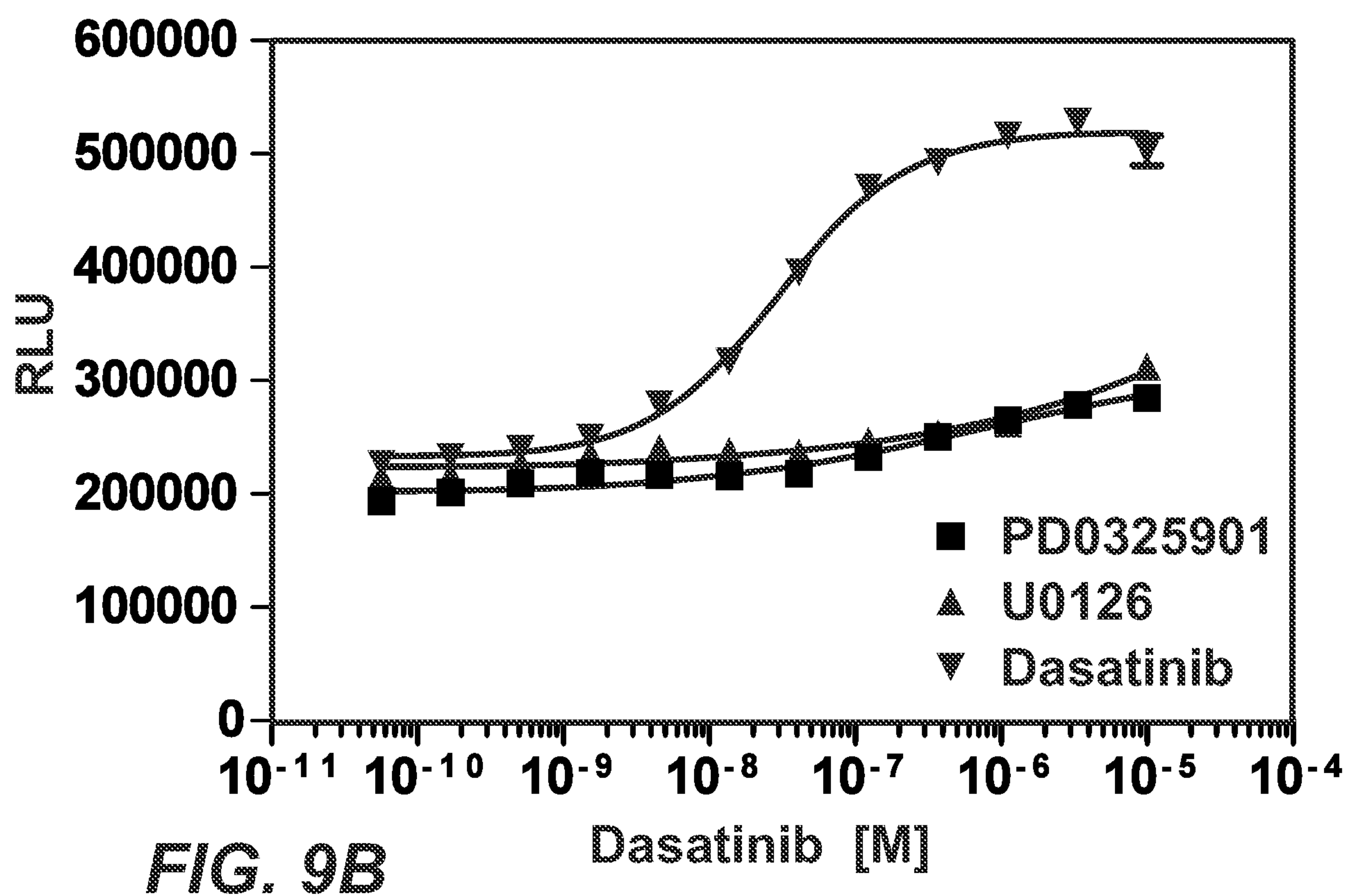
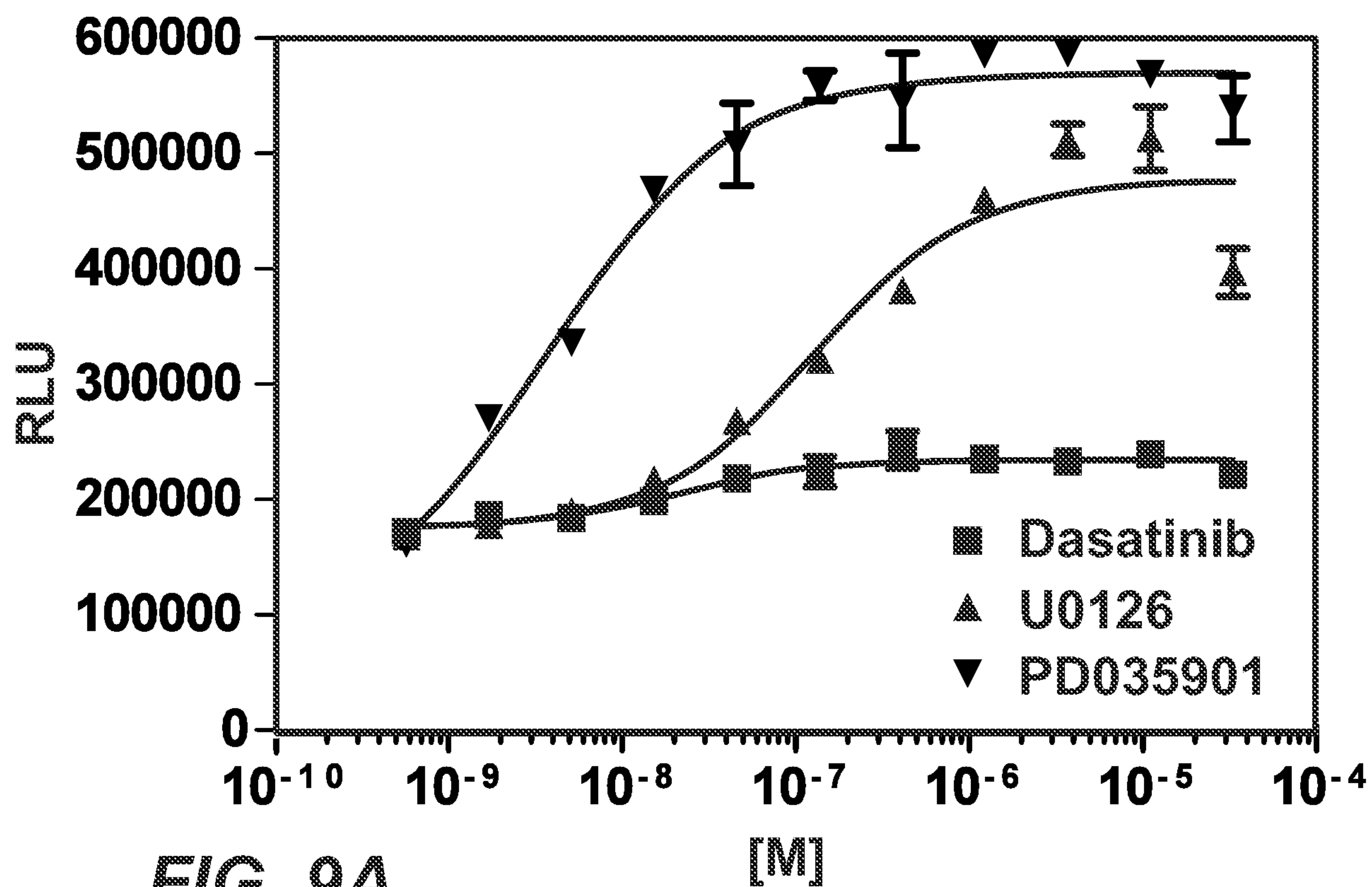


FIG. 8A

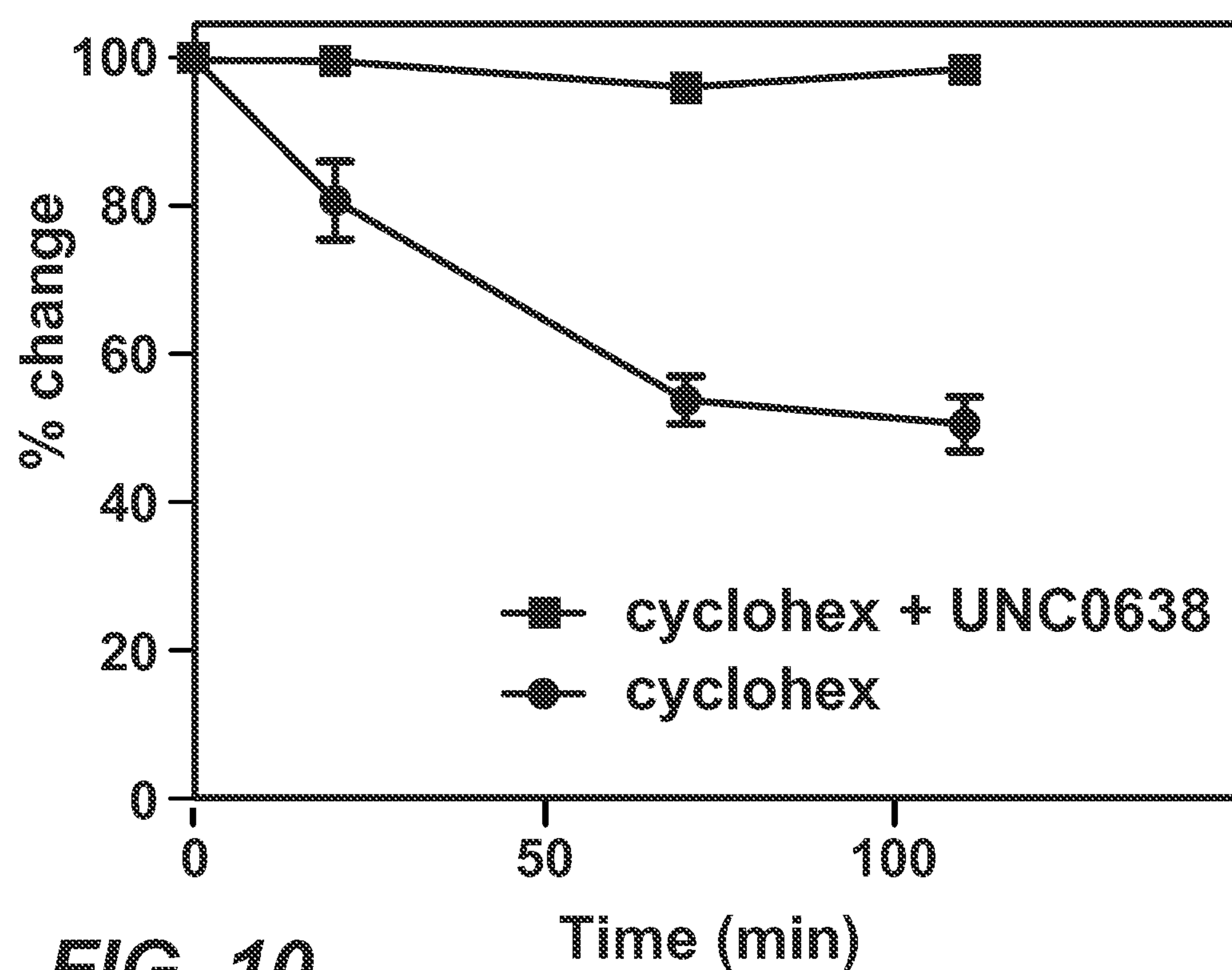
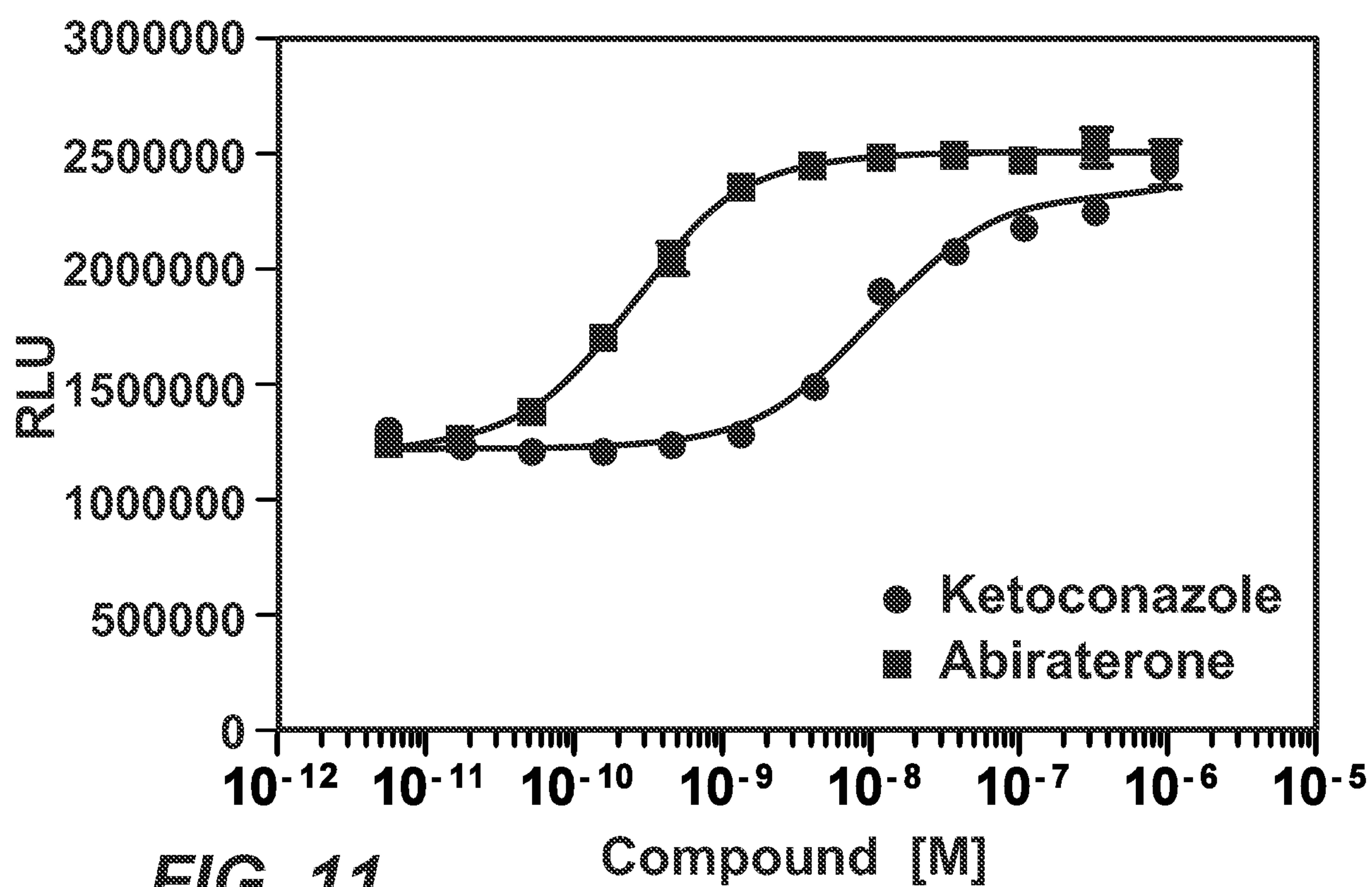
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**FIG. 10****FIG. 11**

